Is Growing Livestock Inventories a Sustainable Initiative Given Phosphorus Crop Removal Regulations?

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Abstract

As environmental regulations continue to tighten and shift from nitrogen to phosphorus-based application standards for manure, phosphorus removal will become increasingly important for any state considering a livestock growth initiative. A framework was developed that can determine a state's phosphorus removal capacity based upon production of livestock and crops and varying phosphorus removal standards. The state level results indicate that Indiana, along with Arizona, Illinois, Iowa, Kansas, and Texas, are well positioned to undertake a livestock growth initiative given that each state has excess phosphorous removal capacity.

Introduction

Divisive and intensive debate surrounds the decisions concerning the location and siting of livestock production facilities in the United States (U.S.). Many state economic development groups, livestock farmers, and producer groups argue that growing a state's livestock production sector will generate both business opportunities and spur economic development. Indiana is a prime example of a state that is attempting to grow its livestock industry through public and political initiatives and proposals to stimulate private investment. Other states, which are discussing growth initiatives include: Wisconsin (GWDT, 2009), Illinois (IGNN, 2005), and North Carolina (Dairy Advantage, 2008). These livestock growth initiatives have obstacles however, in the form of environmental groups and rural residents that express strong opposition to the environmental problems that can be attributed to confined animal feeding operations (CAFO).

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Acknowledgements

The authors expresses thanks to the USDA Cooperative State Research, Education, and Extension Service (CSREES) for support of this research. The authors also wish to thank Dr. Ken Paxton and Dr. Jeffery Gillespie both with the Louisian State University Agricultural Center's Department of Agricultural Economics and Agribusiness, for their constructive comments and feedback.

Historically, the geographic location of livestock production was determined primarily by access to feed supplies, and as a complement to grain farming, with respect to both diversification and full use of the farmer's labor supply. However, the determinants of livestock production are more complex today, specifically with respect to environmental regulations. A major question that must be answered is whether a state will have the necessary land base to assimilate the manure nutrients from a livestock growth initiative. Consequently, environmental regulations will play a major role in the sustainability of livestock inventory growth in the U.S.

Animal nutrient production and crop nutrient removal capacity will likely be key limiting factors in terms of future growth in the livestock industry, as phosphorus (P)-based manure land applications are phased in across the U.S. Shifting from a nitrogen-based to a P-based land application standard reduces the crop nutrient removal capacity of agricultural fields by approximately 66 percent since crops can remove nitrogen (N) at about three times the rate of P. The result is that some livestock operations will be required to find additional land in order to apply manure nutrients at a P rate. As states consider enacting a livestock growth initiative, understanding whether livestock growth can occur with or without additional acreage is crucial in land planning efforts of the state.

The purpose of this research is to present a framework to determine if a sustainable competitive advantage exists for a locale to increase livestock production given regulations regarding manure utilization and P crop removal capacity. A universal framework is provided that can be used by policy makers, livestock producers, non-government organizations (NGOs), and other interested stakeholders to determine whether livestock growth opportunities exist first on a state level and eventually on a county level. First, a comparison is made for selected states in terms of P production and crop nutrient removal capacity. For example, if a state has excess P removal capacity, how does this excess capacity compare to other states, and what other factors would be crucial in determining if a sustainable competitive advantage exists. Once it has been determined a state has excess P removal capacity, stakeholders must turn their attention to feed availability and cost, population and animal densities, spatial issues, and processing capacities, all of which are factors that will influence the location of new livestock production. The framework may also be applied on a regional and/ or county level for a state to determine what areas within the state have the necessary attributes to accommodate sustainable livestock growth, given the restrictions on P assimilation (Mark, 2006). To illustrate the use of the framework, it is used to assess the potential of growing the livestock industry in the state of Indiana. Such analysis is not only important to policy makers who want to encourage expansion of the livestock sector in a particular locale, but also to livestock production farms as they make strategic decisions concerning the location and expansion of their livestock operation. The framework can be used by any state as the initial screening for evaluating the feasibility of increasing livestock inventories for the whole state or in specific areas of the state. Mark (2006) provides a detailed analysis of applying this framework on a regional (NASS crop production regions) and county level for the state of Indiana and the additional information garnered from doing a finer level of analysis.

The Indiana Context

Since the early 1980's, the production of several species of livestock has been in decline in Indiana. The majority of the decline has taken place in beef cattle, dairy cattle, and swine inventories. Since 1980, beef animal inventories have fallen by 56 percent and dairy by 23 percent, while hogs have fallen by 32 percent (USDA [a], 2005). This rapid decline has sparked proposals from the Indiana state government to try to reverse these trends in livestock inventories (ISDA 2005). Doubling the swine industry in the state is at the center of this initiative.

There may be impediments to increasing animal agriculture in Indiana, especially with respect to P regulations. Indiana environmental regulations prevent additional P applications on a field if soil levels reach 200 parts per million (ppm) (USDA [c] 2007). The application of excess soil nutrients increases the potential for nutrient movement to ground and surface water, decreasing water quality (Sharpley, 1995; Sims, et al., 2000; Ribaudo, et al., 2003; Shepard, 2005; Kleinman, 2005; Norwood and Chvosta, 2005). Government officials, livestock producers, environmental regulators, and livestock associations need to be aware of the environmental constraints the livestock industry is facing presently to accurately assess potential locations for livestock growth. Acknowledgement of these current and future environmental regulations is crucial to understanding if livestock inventory growth is sustainable and if it is, where this growth should occur.

The Analytical Framework

State Selection for Comparison

States were initially included in the comparative analysis because of geographic proximity to Indiana (Illinois, Kentucky, Michigan, Ohio, and Wisconsin). Figure 1, is a map of the United States, segmented according to USDA's farm production regions. A state was also included if it was one of the top two, fastest growth states in terms of absolute inventory numbers from 2000-2005, for one of the following livestock sectors: beef cow inventory (Oklahoma and Mississippi), steer inventory (Texas and Arizona), dairy cow inventory (California and Idaho), all hog inventory (Iowa and Minnesota), breeding hogs inventory (North Carolina and Oklahoma), and market hogs inventory (Iowa and Minnesota). Lack of data meant the top two growth states for each poultry type (broilers, ducks, layers, pullets, and turkeys) could not be determined. Consequently, for poultry the states added were the top poultry producing states (Arkansas, Georgia, Ohio, Pennsylvania, South Carolina, and West Virginia). In addition, any state that was ranked in the top six in more than half of the non-poultry inventories was also included in the competitive analysis. Kansas was the only additional state included based on the previous criteria as it ranked sixth or higher in the following four categories: beef cow inventory (third), dairy cow inventory (sixth), all hog inventory (fourth), and market hogs inventory (fourth). This selection criterion generated 20 states (Table 1) in addition to Indiana. The state comparison uses 2004 production levels from NASS. While this study focuses on those states whose livestock inventories have exhibited the most growth, i.e., those states that have livestock growth initiatives, it does not imply that those states that traditionally produce large quantities of livestock (Colorado and Nebraska) are immune to nutrient management issues.

Data

The basic data needed to calculate P production and crop nutrient removal capacities are livestock inventories, P production from animals, commercial/inorganic P sales and crop production. The data for 2004 livestock inventories and crop production were obtained from a variety of reports published by the United States Department of Agriculture (USDA) and industry professionals, shown in Table 1. For some states, select livestock inventories are not disclosed due to concentration within the industry or the lack of that species of livestock or crops in the state. Industry professionals in those states were contacted to determine whether concentration or no production was the case. If concentration within the industry was a reason for missing data, then industry professionals provided an estimate of 2004 production.

National Agricultural Statistical Service (NASS) categorization of the livestock segments was used. However, they were further disaggregated because different nutrient excretion values exist for animals given their life cycle stage (Table 2). To ensure accurate measurement of P produced, eleven additional sub-categories were added to the initial NASS categories. This categorization of provides a more accurate measure of P by accounting for the differing rations fed to the livestock sub-categorizations.

One category in the beef segment is disaggregated, "Calves under 500 Pounds." The subcategories for "Calves under 500 Pounds" are beef calves and veal calves. The assumption is the distribution of beef and veal calves follows the distribution of beef and dairy cows.

For the dairy segments, dairy cows are disaggregated into lactating and dry dairy cows. The average dairy cow will lactate for 305 days and have a 60-day dry period during a given year (Schutz, 2005). During these two cycles, they will consume different rations, resulting in different ratios of nutrients being excreted. The ratio of lactation to dry days was used to allocate the dairy NASS dairy inventory to separate segments.

There are five additional categories defined for hogs and pigs, because the census combines both sows and boars in their definition of breeding stock. To disaggregate, the assumption is made that 85 percent of the swine industry uses Artificial Insemination (AI) (one boar per 100 sows) and 15 percent uses conventional methods (one boar per 15 sows) (Richert, 2005).

To determine the number of gestating and lactating sows, the ratio of days in each cycle over the total days to complete the cycle is used. An average sow is in the lactation phase for 20 days, the gestation phase for 114 days, and rest for 6 days for a total of a 140 (Richert 2005). Market hogs were separated into nursery pigs and grow-finish pigs. Nursery pigs are pigs weighing less than 60 pounds, and grow-finish pigs are between 60 pounds to market weight. The "Quarterly Hogs and Pigs" report compiled by the NASS provides the number of head in each.

For poultry, two additional categories are defined. Male and female turkeys are separated via a ratio devised by Applegate (2005).

Animal Nutrient Production

Nutrient excretion for animals used for meat production is in pounds excreted per finished animal. The values for average daily excretion found in Table 2 are from the American Society of Agricultural Engineers Standards (ASAE, 2005). Pullets are the exception because they become layers once reaching 20 weeks of age. For all livestock used for breeding, excretion values are on a pounds-per-head-per-day basis. Two additional livestock groups were added to the ASAE standards – bulls and pullets. Excretion from bulls is estimated as the average amounts for beef cows and a growing calf. The reason for this computation is that when NASS reports bulls, it includes both herd or mature bulls and replacement bulls. For pullets, the nutrient excretion is 0.07 pounds of P per pullet (Applegate, 2005). The pullet industry provides new layers. Not accounting for pullet P excretion understates livestock nutrient production.

The number of turns or days per cycle for each species is also found in Table 2. For pullets, the number of turns per year is 2.6. To obtain the number of turns for turkeys, an average of the male and female turns is used, resulting in turkeys turning over 3.1 times per year.

The next step is to find the average annual excretion of manure for each of the livestock categories by state. The annual P production for each category of animal species (Table 1) is calculated as the animal inventory times the appropriate daily excretion factor from Table 2 adjusted for the number of days of production and/or turns per year for each category. The following step is to sum the P production of animal species in a state to arrive at estimated P production.

Crop Removal

Crop removal capacities were estimated using fifteen different crops in the state comparison (Table 3). While some crops are excluded from the analysis, the crops chosen represent the primary crops grown in the states analyzed in this research. Additional crops, much like additional types of livestock could be incorporated relatively easily into the analytical framework used in this study if the crop is grown on a significant amount of acreage in a state.

The P crop removal capacity per unit of output for all crops is also shown in Table 3 (MSU 2004). Nutrient removal may vary by soil type, weather conditions, and the hybrid planted, which will have a direct impact on an individual farm's ability to assimilate P (J.R. Heckman, et al., 2001). Since published capacities are in terms of P_2O_5, a conversion to P is accomplished by dividing pounds of P_2O_5 by 2.29 (Peters, 2005).

The acres planted, yield, and production of crops were obtained from "Crop Production 2004 Summary" (USDA [d], 2005). While pasture is not a crop, it is used to provide vegetation for grazing of livestock. Consequently, P is applied to pasture land to stimulate growth of vegetation on pastureland. Acres of pastureland are obtained from the 2002 Census of Agriculture, the most recent census at the time of the study. Moreover, average production per acre of pasture is not documented; it is assumed that the pasture acreage in each state will mirror the average production of all hay. Since there are two types of pasture grazing, intensive and extensive pasture grazing, this research uses the average of their P crop removal capacity (MSU 2004).

The amount of P assimilated by crop type is estimated by multiplying the yield of the crop in a state by its specific P removal factor. The next step is to sum the P assimilation of each crop in a state to arrive at a state's estimated P assimilation. The nationally estimated assimilation of P is the summation of all of the states estimated P assimilation.

The difference between the amount of livestock P produced and the amount removed, is the surplus/deficit in P for a state; state comparisons are made on these results. Next, the sale of inorganic P by state is added to livestock produced P and the surplus/deficit are recalculated. State comparisons are then made based on the percentage of P removal capacity that is presently being used by both livestock production and commercial fertilizer usage. Fertilizer sales by state are summarized in National Fertilizer Institute (2005) and the Office of Indiana State Chemist (OISC, 2002). It was assumed that fertilizer was applied to land in the area where it was sold.

Results and Discussion

Four scenarios are examined in the state comparison. Scenarios 1 and 2 examine crop nutrient removal capacity for livestock production of P at both the 1.0 and 1.5 times crop nutrient removal capacity. Scenarios 3 and 4 examine crop nutrient removal capacity for both livestock production of P and commercial fertilizer application of P at both the 1.0 and 1.5 times crop nutrient removal capacity. Although environmental regulations and manure application regulations differ by state depending on how the state has modified the Natural Resource Conservation Service (NRCS) 590 standard (Osmond et al., 2006; Srinivasan et al., 2006), for purposes of this analysis, the most common regulations are implemented to create a uniform policy for all states. The assumption of a uniform policy rule is made with the recognition that some states might have less strict environmental regulations regarding P removal; however, it is expected that P standards for manure application will take the place of N standards in upcoming years. Wisconsin is already undergoing these changes and it is likely that those states with more lax restrictions will begin to adopt stricter restrictions, similar to the one used in this analysis. One of the key determinates of whether growing livestock inventories in a state is a sustainable initiative will be whether the land in a state has the ability to assimilate P. Additionally, the manure application rate prescribed in these environmental regulations is the single most important manure management factor influencing the water quality (Mulla, et al., 1999).

In 2004, livestock in the United States produced an estimated 1.6 million tons of P. Furthermore, the U.S. used an estimated 38 percent of the nation's total crop removal capacity. The largest P producers in 2004, of the 21 analyzed states in this study, were Texas (185,150 tons), California (88,850 tons), and Iowa (79,420 tons). Figure 2 shows the percentage of each state's crop removal capacity satisfied by livestock P production. Five of the 21 states have excess P from only livestock P production. Excess P removal capacity is the first hurdle for expanding livestock operations; however, livestock expansion also faces additional localized issues, which are beyond the scope of this paper. Furthermore, alternative manure utilization and the transportation of manure out of the state have not been taken into account. Of the twenty-one states evaluated, only Arizona, Illinois, and Indiana use less than 25 percent of available crop nutrient removal capacity when only livestock P production is considered. In the Corn Belt (Ohio, Illinois, Indiana, Iowa, Missouri, and Ohio) and Lake States (Michigan, Minnesota, and Wisconsin) regions, only Wisconsin uses more than 50 percent of its crop nutrient removal capacity when considering only livestock P production. This result should not be surprising given that the states located in the Corn Belt region have several advantages in terms of P removal capacity relative to other states located outside this region (Ribaudo, et al. 2003). First, livestock operations, especially swine, tend to be more integrated with cropland in the Corn Belt than in other regions of the United States. The second reason is the availability of land for manure application due to grain production. Third, the per acre crop removal capacity is higher in the Corn Belt because the crops grown in that region use large amounts of crop nutrients (P and N) and crop yields in this region tend to be higher. For example, Indiana uses only 18 percent of its total crop removal capacity, and Illinois uses only 9 percent of its capacity.

Figure 3 shows the state's total crop removal capacity that is being used when accounting for both livestock production and commercial fertilizer P. From July 1, 2003 to June 30, 2004, the United States used 2.1 million tons of commercial P fertilizer. This is approximately 0.5 million tons more than what was produced by livestock in 2004. The largest users of commercial P fertilizer in 2004 were Iowa (165,063 tons), Minnesota (141,994 tons), and Illinois (140,445). The largest commercial P fertilizer user outside of the Corn Belt is California (132,217 tons). With the addition of commercial P fertilizer, the United States used 3.7 million tons of P and approximately 87 percent of its total crop removal capacity. When commercial P is included, 15 of the 21 states in this study have excess P applied.

The Corn Belt states of Ohio, Indiana, Illinois, Iowa, and Missouri used 33 percent of all the commercial P fertilizer sold for the 2004 crop (National Fertilizer Institute, 2004). In the Corn Belt only Iowa, Illinois, and Indiana have excess crop removal capacity when accounting for both livestock production and commercial fertilizer P. Wisconsin used the least commercial P fertilizer of the eight states in both the Corn Belt and Lake States regions, but had the highest level of crop nutrient removal capacity used in both scenarios. Overall, the Corn Belt uses a significant amount of commercial P fertilizer that theoretically could be supplied from livestock manure. Outside of the Corn Belt three other states that have excess crop nutrient removal capacity, Arizona, Kansas, and Texas.

The amount of farmland in each state actually receiving manure nutrients is useful in evaluating P production and crop nutrient removal capacity. According to the 2002 Census of Agriculture, manure does not appear to be a widely used fertilizer source. Pennsylvania and Wisconsin have the highest percentage of farms and the largest percentage of acres receiving manure nutrients. Kellogg, et al. (2000), note several reasons why manure is not being used for fertilizer: 1.) Manure is not a uniform product compared to the commercial fertilizer that can be bought at the fertilizer dealer; 2.) Fear of soil compaction when heavy equipment travels over the field to apply the manure; and 3.)The high transportation cost of hauling manure. While, we note that each of these issues must be addressed at a local level to determine the applicability and financial feasibility of applying animal nutrients to the land, the analysis of these issues are beyond the scope of this study. What this study does do, however, is inform interested stakeholders in whether these additional factors even need to be examined, i.e., this additional analysis only needs to be undertaken if a state has excess crop nutrient removal capacity when accounting for both livestock production and commercial fertilizer P.

While the goal of this paper is not to provide a strategic management plan for states with excess P removal capacity, it is crucial that a brief overview of potential strategies be provided so that stakeholders understand that excess P removal capacity is just the first hurdle in a successful livestock growth initiative. Stakeholders in the livestock growth initiative should promote the value of manure nutrients as a substitution for commercial fertilizer, and/or find ways to blend livestock manure with commercial fertilizers. In most states, livestock alone do not produce enough P to meet the state's demand for P, but the livestock industry is a significant supplier. Stakeholders in the livestock growth initiative should begin discussions with the commercial fertilizer industry to identify blending of organic and inorganic P and other strategies that will benefit both livestock producers and commercial fertilizer dealers. Current data indicate that manure is not as widely used as a source of fertilizer as it could be (USDA [b], 2002). In addition, education and extension programming will need to be provided to livestock producers on how alterations in their livestock feed rations changes the N and P ratios in the manure produced by their animals. More states will likely need to find alternative methods to handle the excess P in animal manure. According to Maguire, et al. (2007), the use of phytase can increase the digestibility of P, and significantly decrease excreted P from 25 to 50 percent depending on animal species. Stakeholders will also want to educate crop producers on how to implement cropping practices and rotations that will more fully utilize animal nutrients. According to Ribaudo, et al. (2003), there are cropping patterns that could be implemented to increase the nutrient uptake. Stakeholders will also need to consider investing in technology that does real-time testing of manure nutrients; real-time testing would allow farmers to use site-specific management for manure application.

Based on the above analysis, it could be argued, Indiana along with other states that have excess crop removal capacity including Arizona, Kansas, and Texas, have a competitive advantage for growing the livestock sector. In an average crop production year, Indiana can assimilate all of the livestock and commercial P produced and used under current regulations. Of the six states with excess crop removal capacity when accounting for both livestock production and commercial fertilizer P, Indiana performed well in nutrient crop removal capacity, using only 82 percent of its total crop removal capacity under a 1-time crop removal P-based application standard. If regulations were tightened to a strict P application standard, Indiana would still be able to assimilate all of the nutrients at 2002 livestock inventories. Consequently, excess assimilation capacity even at strict standards indicates that the livestock growth initiative in Indiana is sustainable.

Furthermore, Indiana offers additional attributes besides its competitive advantage in P removal capacity that makes it advantageous for increasing the livestock produced in the state (Boehlje, et al., 2006). It should be noted that these other advantages would be moot if the state did not have excess phosphorous removal capacity. Boehlje, et al. (2006) research found that when comparing Indiana to other states based on feed availability and cost, processing capacity, population and animal densities, and environmental capacity, only Iowa and Kansas were better suited for livestock growth. Indiana has a relative advantage in feed price and processing capacity for swine. Even though Indiana does not have the lowest feed corn and soybean meal prices, its Eastern Corn Belt location means large quantities of these products are grown in the state relative to non-Western Corn Belt states, creating an ample supply of feed grains. A significant portion of the nation's swine processing capacity is located in Indiana, and currently excess capacity exists relative to the state's current swine production. To meet this excess slaughter capacity hogs are imported from other states. Indiana also supplies 65 percent of the swine processed in Swift's Louisville, Kentucky plant (Hurt, 2005).

Even though Indiana has a competitive advantage in P removal, population density is a major constraint for Indiana when it comes to increasing the amount of livestock in the state. Of the six states with excess P removal capacity, Indiana's population density of 169.5 people per square mile is only lower than Illinois (223.4 people per square mile) (U.S. Census Bureau, 2009). As population continues to increase, it will be increasingly important that land planners understand the relationships between people and animals. Another hurdle for Indiana is the lack of federally inspected slaughter facilities for beef. Federally inspected facilities were responsible for 98 percent of commercial cattle slaughter in the nation for 2004 (USDA [f], 2005).

Summary and Conclusion

Overall, the results show that Indiana is well suited for a growing livestock sector. While six of the twenty-one states in this study are able to assimilate the P produced and used at a 1.0 time crop removal P standard, Indiana's P removal capacity is better than the other twenty states included in this study. Consequently, as environmental regulations continue to tighten and shift from nitrogen to P-based application standards for manure, the ability to assimilate P will continue to be one of Indiana's strengths. This competitive advantage in terms of P removal provides an indication that the livestock growth initiative in Indiana is a sustainable policy initiative.

While P removal capacity is a limiting factor in the ability of a state and areas within a state to grow its livestock sector, additional factors also influence livestock growth once it has been determined that excess P removal capacity exists. Research shows that to understand not only Indiana's but any other state with the excess P removal capacity (Arizona, Illinois, Iowa, Kansas, and Texas) total competitive position as a locale for the livestock industries, it is critical to understand whether it has the capacity to feed current livestock inventories plus new animal inventories, whether it will have the capacity to process these animals, and whether there are population limitations. Boehlje et al. (2006) found that when the aforementioned factors are included in a competitive analysis, Indiana is the third best option behind Iowa and Kansas of the twenty-one states studied, both of which have excess P removal capacity like Indiana. Both of these states have lower population densities and more livestock slaughter capacity relative to Indiana (Boehlje, et al., 2006).

Having excess P removal capacity can be viewed as the first hurdle for a sustainable livestock growth initiative. Mark (2006) applies this framework to specific counties and NASS production regions in Indiana in an effort to provide a finer screen of where livestock expansion should occur within a state. For example hauling of manure outside of a county is likely to be cost prohibitive, making a intra-state analysis using this framework very valuable, i.e., to see if crop production and livestock production are occurring in close proximity to each other. Regional and county level analysis by state would provide a more complete understanding of the spatial issues at play. The final hurdle would be to understand how factors such as population density and slaughtering capacity affect the locales' competitive advantage.

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Figure 1. USDA farm production regions

Figure 2. Estimated state level crop removal capacity at one-time crop removal phosphorus standard: Only livestock P production is considered

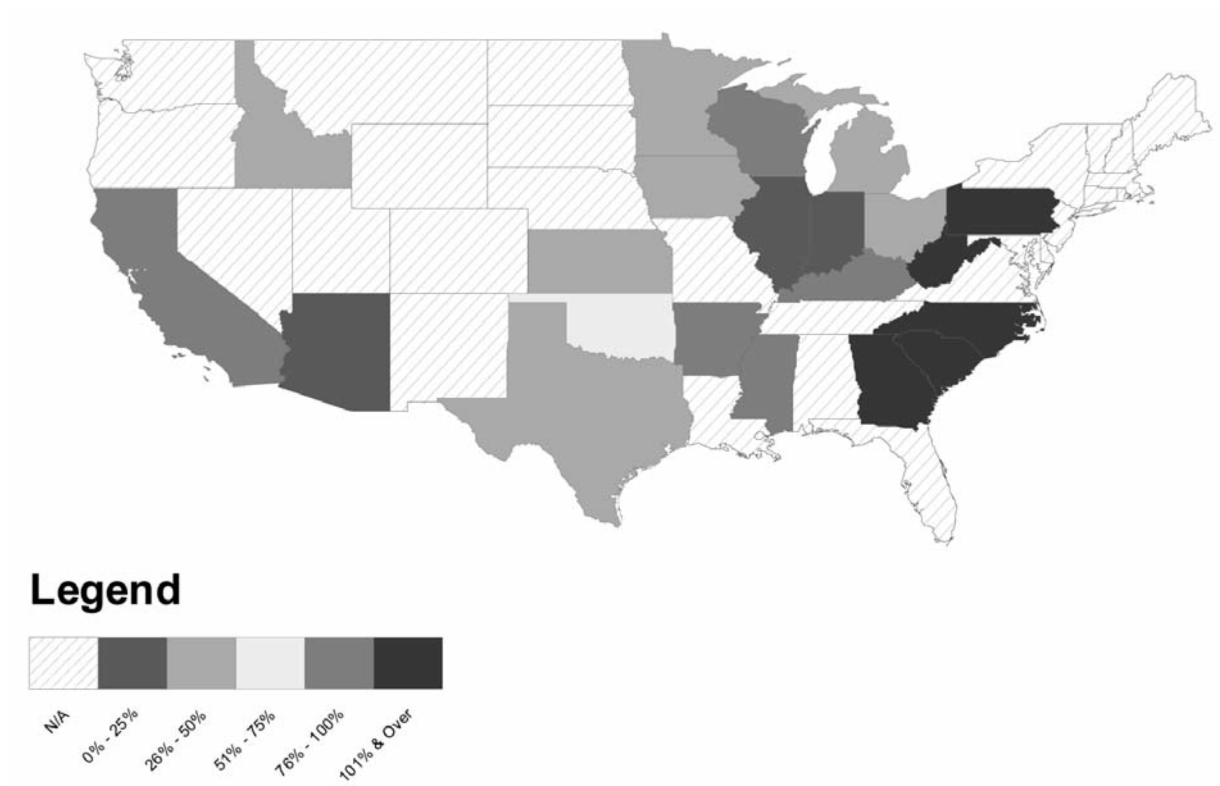

Figure 3. Estimated state level crop removal capacity at one-time crop removal phophorus standard: Both livestock P production and commercial P fertilizer application are considered

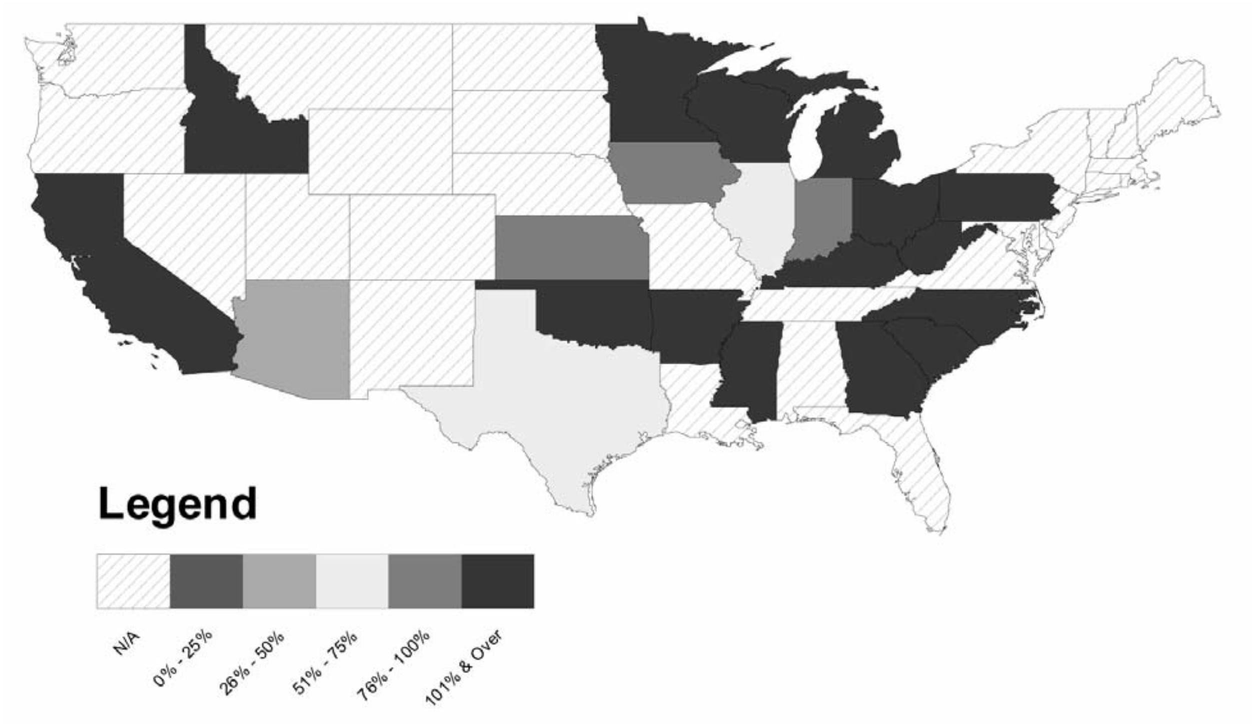

Table 1. Primary categorization of livestock segments and 2004 inventories

	Cattle & Calves				Hogs & Pigs		Poultry			
State	Cows & Heifers Calved	Heifers 500 lbs& Over	Steers & Bulls	Calves Under 500 lbs	Breeding Stock	Market Hogs	Layers	Broilers	Pullets	Turkeys
AZ	330,000	90,000	282,000	158,000	16,000	120,000	-	-	-	-
CA	2,420,000	1,025,000	705,000	1,050,000	20,000	120,000	20,337,000	250,000,000	4,208,000	17,300,000
ID	900,000	480,000	375,000	245,000	3,000	18,000	853,000	-	375,000	-
IL	540,000	245,000	295,000	230,000	420,000	3,580,000	4,004,000	-	569,000	2,900,000
IN	370,000	158,000	132,000	170,000	290,000	2,860,000	23,532,000	47,800,000	7,094,000	12,800,000
IA	1,180,000	810,000	1,010,000	450,000	1,070,000	15,030,000	43,569,000	10,000,000	10,877,000	8,500,000
KS	1,660,000	1,960,000	2,275,000	755,000	155,000	1,565,000	3,000,000	-	-	1,024,650
MN	860,000	570,000	485,000	485,000	600,000	5,900,000	10,873,000	46,300,000	3,090,000	45,000,000
MS	570,000	132,000	103,000	230,000	35,000	280,000	6,923,000	827,800,000	3,659,000	-
NC	460,000	120,000	70,000	230,000	1,020,000	8,780,000	10,877,000	720,200,000	5,619,000	42,500,000
OH	520,000	260,000	210,000	240,000	155,000	1,295,000	27,938,000	41,600,000	8,110,000	5,800,000
OK	2,050,000	920,000	1,210,000	920,000	360,000	2,040,000	4,076,000	243,800,000	1,174,000	100,000
PA	720,000	370,000	190,000	360,000	115,000	965,000	23,893,000	133,500,000	4,532,000	9,500,000
SC	235,000	54,000	34,000	107,000	30,000	270,000	5,243,000	204,500,000	1,613,000	12,000,000
TX	5,800,000	2,480,000	3,120,000	2,500,000	100,000	880,000	18,406,000	620,700,000	5,563,000	8,000,000
WV	200,000	65,000	50,000	65,000	2,000	8,000	1,259,000	86,400,000	816,000	4,300,000
AR	1,010,000	275,000	195,000	420,000	85,000	245,000	15,598,000	1,241,500,000	7,303,000	28,500,000
GA	700,000	141,000	79,000	330,000	42,000	233,000	20,323,000	1,298,900,000	8,018,000	-
MI	385,000	211,000	234,000	200,000	110,000	830,000	7,493,000	-	1,615,000	5,000,000
KY	1,240,000	310,000	270,000	500,000	40,000	310,000	4,982,000	290,800,000	1,775,000	-
WI	1,490,000	820,000	380,000	660,000	50,000	380,000	4,534,000	33,800,000	1,320,000	7,000,000
US	41,850,800	19,344,500	18,483,200	15,209,500	5,969,000	54,531,000	342,279,000	8,740,650,000	101,624,000	264,207,000

Source: United States Department of Agriculture (USDA) [a], National Agricultural Statistics Service. 1980-2005. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp. Accessed June 2005

Table 2. Average daily nutrient excretion values for livestock and number of turns or days

Meat-producing livestock and poultry

		lb / finished animal					
Animal Type	Production Grouping	Nitrogen	P	K	Total Manure	Turns	Moisture (%w.b.)*
Beef	Finishing Cattle	55.100	7.280	37.700	7440.000	1.5	92.0
Poultry	Broiler	0.117	0.035	0.068	10.800	7.7	74.0
Poultry	Turkey (male)	1.220	0.355	0.567	78.300	2.7	74.0
Poultry	Turkey (female)	0.057	0.163	0.249	32.900	3.5	74.0
Poultry	Duck	0.136	0.048	0.068	14.300	9.4	74.0
Swine	Nursery Pig	0.911	0.150	0.353	87.300	7.3	90
Swine	Grow-Finish	10.500	1.670	4.410	981.000	3	90
Poultry	Pullets	-	0.073	-	-	2.6	-
Poultry	Turkeys	0.639	0.259	0.408	55.600	3.1	74.0

Production Livestock

		lb / day-animal					
Animal Type	Production Grouping	Nitrogen	P	K	Total Manure	Days	Moisture (%w.b.)*
Beef	Cow (confinement)	0.419	0.097	0.300	110.000	365	88.0
Beef	Growing Calf (confinement)	0.287	0.055	0.187	40.300	365	88.0
Beef	Bulls	0.353	0.076	0.244	75.150	365	88.0
Dairy	Lactating Cow	0.977	0.172	0.227	151.000	305	87.0
Dairy	Dry Cow	0.503	0.066	0.326	82.900	60	87.0
Dairy	Heifer	0.258	0.044	-	48.400	365	83
Dairy	Veal	0.033	0.010	0.044	7.790	365	96
Layer	Layer	0.004	0.001	0.001	0.194	365	75.0
Swine	Gestating sow 440-lb	0.071	0.020	0.049	9.000	120	90.0
Swine	Lactating sow 423-lb	0.187	0.055	0.117	19.800	20	90.0
Swine	Boar -440lb	0.061	0.021	0.039	8.290	365	90.0

Source: American Society of Agricultural Engineers Standard (ASAE). 2005. "Manure Production and Characteristics." Pub# D384.1
*As-excreted manure moisture contents range from 75 to 90 percent. At these moisture levels, as-excreted manure has a density nearly equal to that of water, and a specific gravity of 1.0 was assumed in calculation of manure volume.

Table 3. Crop removal capacity for each of the selected crops

Crop	Unit	P_2O_5/Unit	P/Unit
Barley	Bu	0.3800	0.1659
Canola	Bu	0.9100	0.3974
Corn Grain	Bu	0.3700	0.1616
Corn Silage	Ton	3.3000	1.4410
Cotton	bale (500 lbs)	12.5000	5.4585
Hay	Ton	11.0000	4.8035
Oats for grain	Bu	0.2500	0.1092
Pasture	Ton	6.2500	2.7293
Potato	Cwt	0.1300	0.0568
Rice	Bu	0.2900	0.1266
Rye for grain	Bu	0.2050	0.0895
Sorghum for grain	Bu	0.3900	0.1703
Soybeans	Bu	0.8000	0.3493
Tobacco	Lb	0.0076	0.0033
Wheat	Bu	0.6300	0.2751

Source: The Ohio State University, "Tri-State Fertilizer Recommendations." Extension Bulletin E-2567, http://ohioline.osu.edu/e2567/index.html. Accessed Nov. 2005
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