THE GROWTH POTENTIAL FOR

THE INDIANA LIVESTOCK

INDUSTRIES

by

Michael Boehlje, Allan Gray, and Tyler
Mark

Staff Paper #06-06

April 2006

Dept. of Agricultural Economics

Purdue University

*Funding for this study was provided through the Indiana Pork Producers Association from a Value Added Grant awarded by the Indiana Office of the Commissioner of Agriculture.

THE GROWTH POTENTIAL FOR THE INDIANA LIVESTOCK INDUSTRIES

by
Michael Boehlje, Allan Gray, and Tyler Mark
Dept. of Agricultural Economics, Purdue University
West Lafayette, Indiana 47907-2056
boehljem@purdue.edu, gray@purdue.edu, tmark@purdue.edu

Staff Paper #06-06
April 2006

Abstract

Feed, processing capacity, population density versus animal density, and environmental capacities are the four different dimensions of livestock location and growth potential analyzed for Indiana. These four dimensions provide livestock producers, government officials, and livestock associations a valuable perspective on the constraints that could limit Indiana's livestock growth potential. Comparisons among 21 states on these dimensions indicated that Indiana is a second choice of states for livestock growth; Kansas and Iowa are the only first choices. Indiana's strength in the state comparison is its ability to assimilate the phosphorus produced by livestock and commercial phosphorus. As environmental regulations continue to tighten and shift from nitrogen to phosphorus based application standards for manure, the ability to assimilate phosphorus will continue to be one of Indiana's strengths, along with its abundance of feed and swine processing capacity. Population density is the key dimension that is a disadvantage for Indiana. Within the state of Indiana, the West Central district has key advantages compared to other districts of the state. This district has an abundance of feed, the second lowest population density in the state, and excess phosphorus assimilation capacity. This district does not have processing capacity for any species, but the adjoining districts do have adequate processing capacity. Overall, the results show that Indiana has the potential to grow the livestock sector. However, there will be constraints such as population density that require more in-depth study to determine how to address this potential limitation on growth.

Keywords: Livestock Growth, Animal Waste, Feed Capacity, Livestock Processing Capacity, Animal Density, Population Density

Table of Contents

List of Tables

List of Figures

Figure | Page

*Color figures are on CD attached to back cover.

THE GROWTH POTENTIAL FOR THE INDIANA LIVESTOCK INDUSTRIES

by

Michael Boehlje, Allan Gray, and Tyler Mark

Introduction

Livestock production is a significant portion of Indiana's agricultural economy, and Indiana is an important producer of livestock in the United States. Currently Indiana ranks 23rd in the United States in livestock production, but sales have declined slightly in recent years. In 2003, of the over $5.16 billion in total agricultural receipts for Indiana, 35% or $1.79 billion came from just livestock and livestock products (IASS (2004)). However, as seen in Figure 1 the proportion of agricultural receipts that livestock and livestock products accounts for has been trending downward since the late 1980's. This widening gap between all commodity receipts and livestock receipts shows that the livestock industry is not as significant to the states' agricultural economy as it once was.

The dominant species of livestock production in Indiana are poultry (layers and pullets) and swine. Indiana ranks 5th in the nation in both poultry and swine inventories accounting for 6.4% and 5.2% of the nation's inventories, respectively (IASS (2004)). The major production of livestock based products comes from the production of egg-type chickens hatched and ice-cream which account for 13.9% and 8.5% of the nation's production, respectively (IASS (2004)). In addition, Indiana is ranked in the top ten for eggs produced, turkeys raised, and pig crop farrowed.

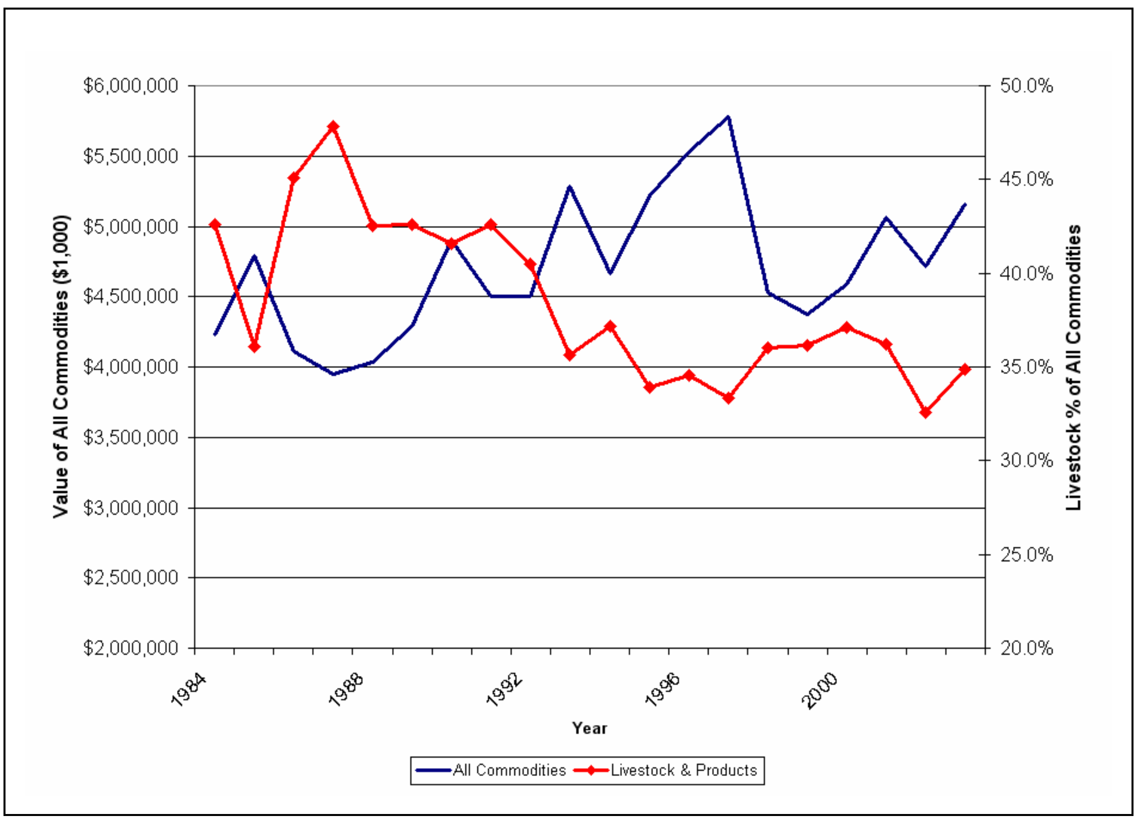

Figure 1: Cash Receipts for All Ag Commodities vs. Livestock & Livestock Products as a Percentage of All Ag Commodities[1]

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%, and dairy by 23%, while hogs have fallen by 32% in Indiana (USDA [a] (2005)). These same trends are also present for the United States as a whole, but Indiana has witnessed a more rapid decline. This has sparked proposals from the Indiana state government to try to reverse these trends and begin to grow livestock inventories (ISDA (2005)). Doubling the swine industry is at the center of this initiative. An initiative of this magnitude raises many questions, but two are the focus of this study. First, is Indiana a location that has the attributes to enable livestock growth compared to other states in the nation? Second, where within the boarders of Indiana are locales that have the attributes to accommodate growth?

To understand Indiana's competitive position as a locale for the livestock industries, it is critical to understand the fundamental determinants of the location and structure of the livestock sector. 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. The critical determinants used in this study are; can Indiana feed current livestock inventories plus new animal inventories, will Indiana have the capacity to process these animals, is human population a limitation, and does Indiana have the manure assimilation capacity according to environmental regulations. It is important to recognize that these are not the only criteria that can affect the competitive nature of a locale. Determinants such as weather, zoning regulations, and numerous other considerations are important, but the determinants used in this study are shown throughout the literature as significant drivers of locale competitiveness.

The main sources of feed for Indiana livestock are corn and soybeans. In 2002, Indiana livestock consumed an estimated 134,174,812 bushels of corn and 43,868,505 bushels of soybeans. This translates into 17% and 17%, respectively of the total amount of corn and soybeans produced in the state on average from 2000 to 2004. What would the effect be on corn and soybean use if livestock production increases?

Another major area of concern for the state is environmental regulations. As farms continue to become more concentrated and animal numbers increase, will Indiana have the land base to assimilate the increase in manure nutrients according to regulations? Environmental concerns about runoff have led to increased regulation on when and where manure can be applied. In addition, the Environmental Protection Agency (EPA) has plans for regulations that mandate manure be applied on a phosphorus standard instead of the traditional nitrogen standard. Some states like Wisconsin have already implemented this regulation for manure application (Clark (2005)). Applying manure on a phosphorus standard requires three to four times more land than when applied on a nitrogen basis (Boland, et. al. (1998)).

In addition to environmental problems, Indiana only has a limited number of processing facilities. Currently, there are only seven federally inspected slaughter plants in the state as of January 2005, with the majority of the federally inspected plants in the swine industry (USDA

[b] (2005)). Indiana also has no federally inspected plant for cattle slaughtering; therefore the majority of cattle have to be shipped out of state for slaughter.

Thus, there may be real impediments to increasing animal agriculture in Indiana over the next 10 years. Indiana's livestock industry as a whole has been in decline for the past decade, the exceptions being poultry and recently dairy. Environmental regulations, harvesting capacity, feed capacity, and population could be limiting factors on Indiana's ability to grow livestock inventories. The government officials, livestock producers, environmental regulators, and livestock associations need to be aware of what constraints the livestock industry is facing presently and what the potential growth locales in the state are for livestock.

The Study Framework and Methods

Purpose and Objectives

The fundamental purpose of this study is to complete an assessment of the future potential of the Indiana livestock industry focusing on: 1) the relative strengths and weaknesses of the Indiana industry compared to other states/locals, and 2) what public sector and private sector initiatives might be taken to improve the competitive position of the Indiana livestock sector. Information from the analysis will provide government officials, livestock producers, environmental regulators, and livestock associations with an analysis of key concerns that may need to be addressed to facilitate the growth of Indiana livestock industries.

The objectives are:

1. To assess Indiana's competitiveness compared to 20 other states on the criteria of feed production, feed price, processing capacity, population density, animal density, and environmental capacity based on 2004 production.

2. To assess all Indiana counties on the dimensions of feed usage/price, processing capacity/location, population density, animal density, and environmental capacity based on the 2002 Census of Agriculture livestock inventories and 2000 to 2004 average crop production.

3. To assess the potential of Indiana to increase livestock inventories in the future based on the criteria of processing and environmental capacity constraints.

The Framework

Figure 2 summarizes the overall framework used in the analysis. The major determinants of the growth of the livestock industry were identified as feed availability, feed price, processing capacity, population density, animal density, and environmental capacity shape Indiana's livestock industry.

For the state comparison each determinant is evaluated at the state level only. The states used for the state comparisons either border Indiana or are in the top two fastest growth states in terms of absolute inventories from 2000-2005. There are a total of 20 other states that will be evaluated in addition to Indiana.

The Indiana specific portion of this study provides an avenue to compare counties across the state to help with the planning of new livestock operations within the state. In addition, binding constraints for each county are determined so that methods to meet these constraints can be determined. For the Indiana specific portion, the above stated determinants are evaluated at the county level.

There are two significant differences between the state comparison and the Indiana specific comparison. The state comparison uses 2004 production levels, whereas, the Indiana specific portion uses the 2002 Census of Agriculture livestock inventories and 2000 to 2004 average crop production. The second difference is that in the Indiana specific portion, feed consumption will take the place of feed production.

There has been an abundance of literature devoted to the analysis of the impacts of the availability/mobility of grain, shifts in the nation's processing capacity over the past decade, community issues relative to large-scale livestock production, livestock industry structure as it relates to phosphorus assimilation capacity, and alternative technologies/uses for manure on the livestock industries. Appendix A summarizes the literature used in this study. However, none of these studies have combined this literature to try to determine how the various determinants shape the growth potential of the livestock industries.

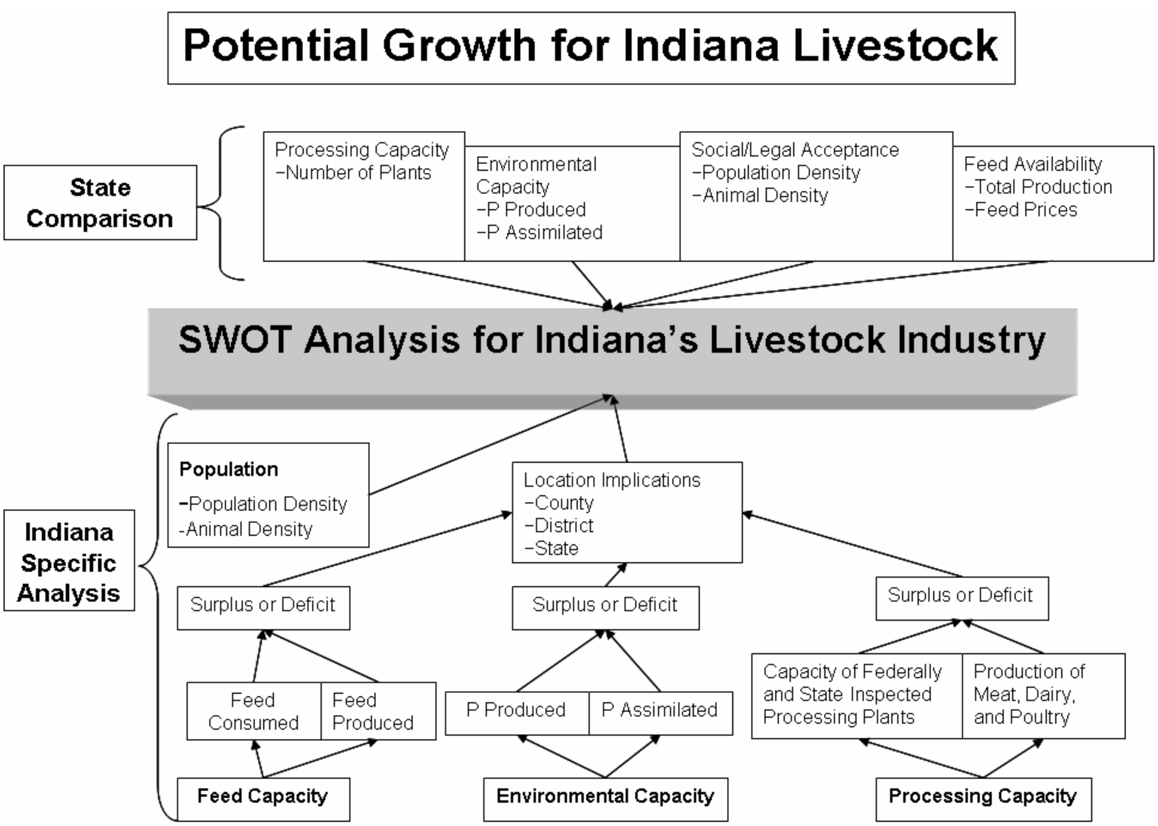

Figure 2: Analytical Framework

Appendix B contains the sources of data and the methods used to gather the information needed for completion of the analysis summarized in Figure 2. This appendix summarizes: 1) the general outline of the state comparison methodology, 2) the general outline of the Indiana specific methodology, 3) the categorization of livestock segments for estimation, 4) an example of disaggregating method used for county level data, 5) a typical ration formulations, 6) animal nutrient production calculations, and 7) crop nutrient assimilation calculations.

State Comparisons

Four main dimensions of location and growth of the livestock industries are evaluated at the state level: feed availability, processing capacity, population and animal densities, and environmental capacity. The focus of this discussion is the Corn Belt and in particular, how Indiana compares to the rest of nation on these dimensions in 2004.

Feed Production & Price

Feed production and feed price are not the significant drivers of livestock location they once were. Although feed comprises 60-70% of total cost for livestock operations (Farm Foundation), technological improvements in grain transportation have weakened regional competitive advantages. Nevertheless, availability and relative price still have some influence on livestock growth potential. The two major sources of feed at the state level that this study focuses on are corn and soybeans.[1]

Corn is a significant feed input for all livestock industries. Figure 3 shows the distribution of corn production for the 21 states. In 2004, the United States produced 11.8 billion bushels of corn and 63% of the production took place in the Eastern and Western Corn Belts[2]. The four largest producers of corn for 2004 were Iowa (19%), Illinois (18%), Minnesota (9%), and Indiana (8%) of the nation's corn production.

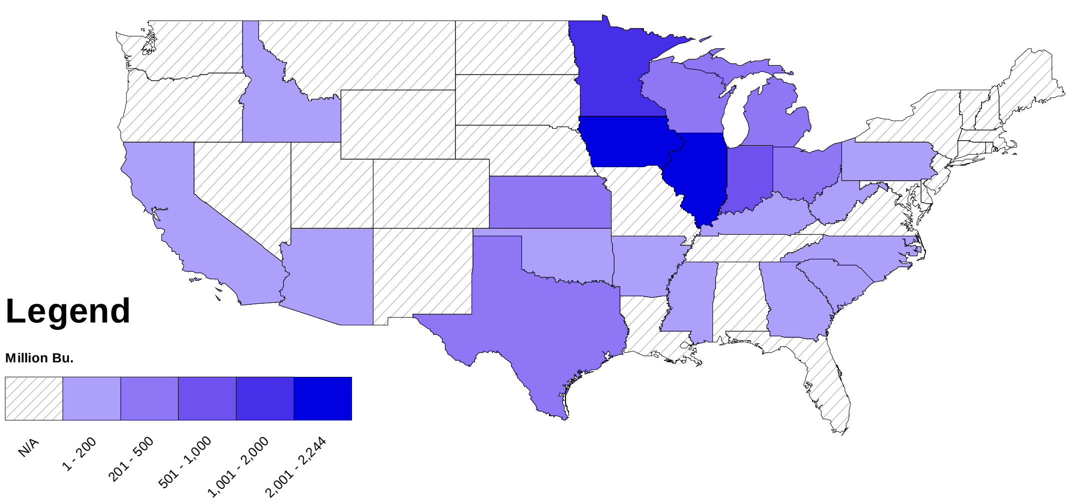

Figure 3: Distribution of Corn Production[3]

[1] Corn is only corn for grain and does not include silage
[2] Eastern Corn Belt – IL, IN, MI, OH, WI. Western Corn Belt – IA, MN
[3] Source: NASS

Another important factor to consider along with the location of corn production is the price of corn in different locales. The price of corn depends on a number of different factors like demand, proximity to a processing plant, and weather just to name a few. Therefore, to try to examine the price of corn for each of these states in our comparison, an estimated long-term corn basis is computed.[4] Figure 4 shows the estimated basis for each county of the 21 states.

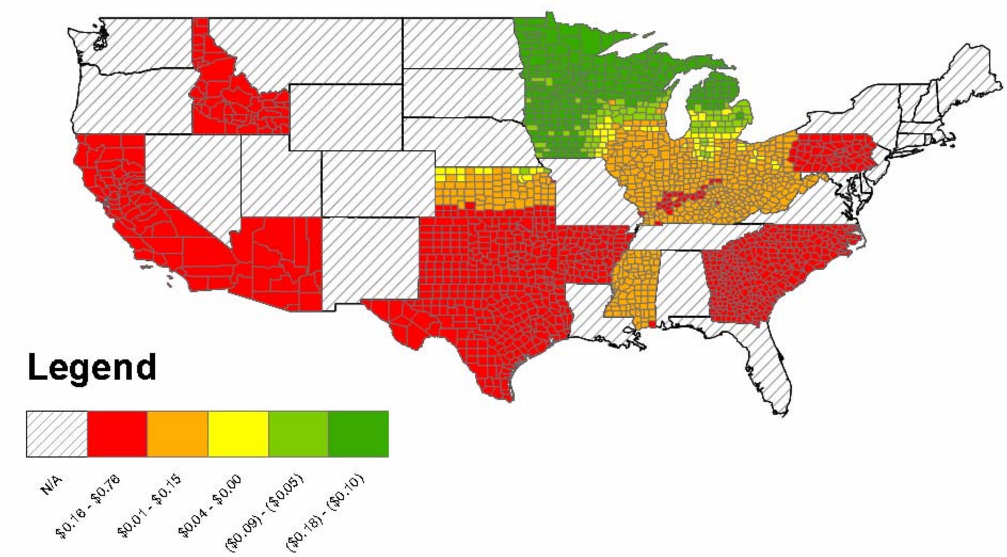

Figure 4: Estimated Long-Term Corn Basis[5]

It is evident from Figure 4 that the lowest corn prices in the nation are in the Corn Belt with the Western Corn Belt exhibiting lower prices than the Eastern Corn Belt. Minnesota had the lowest average corn basis at ($0.13) followed closely by Iowa at ($0.09) below the national average. Indiana's average basis is $0.06 above the national average. The price of corn also varies by county across the state as indicated in Figure 4. For example, in Indiana the corn basis is higher next to the Ohio River compared to the Northern part of the state. Traditionally, river markets have a higher basis because of the decreased transportation costs to the export markets. Overall, Indiana is a significant producer of corn in the United States but has slightly higher prices than the Western states in the Corn Belt.

The second major input for livestock feed is soybean meal. Soybeans are different from corn in that they are processed into soybean meal before they are fed. The distribution of

[4] Corn Basis – difference between county or state loan rates and the national loan rate of $1.95

[5] Source: Farm Service Agency

soybean production across the 21 states in our comparison can be seen in Figure 5. In 2004, the United States produced 3.14 billion bushels of soybeans of which the Corn Belt produced 60%. The top four soybean producing states in this comparison are Illinois (16%), Iowa (16%), Indiana (9%), and Minnesota (8%) of the nation's total soybean production.

The price of soybeans can also play a role in shaping the location of livestock but the price of soybeans may not be as important as the price of soybean meal. Therefore, in this study we look at the price of soybean meal rather than the price of soybeans. Figure 6 shows the distribution of soybean meal price across the nation. Again, the Corn Belt generally has lower prices for soybean meal. On average, the soybean meal price in the Corn Belt is 4% lower than the average United States price for 2004.

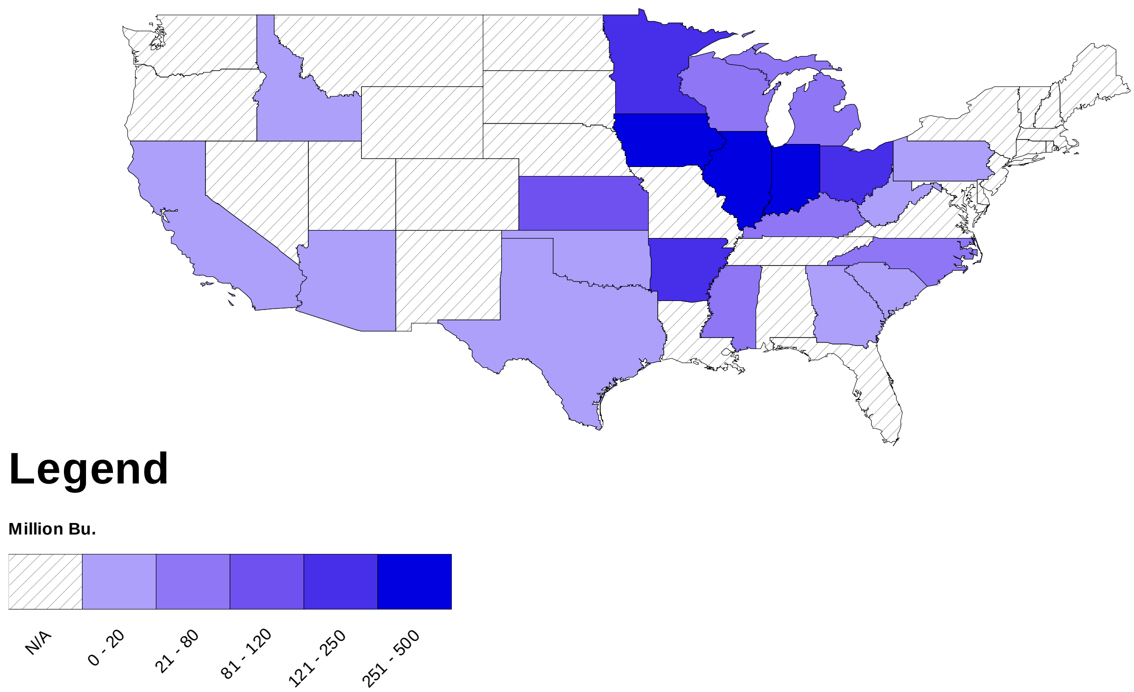

Figure 5: Distribution of Soybean Production[6]

[6] Source: NASS

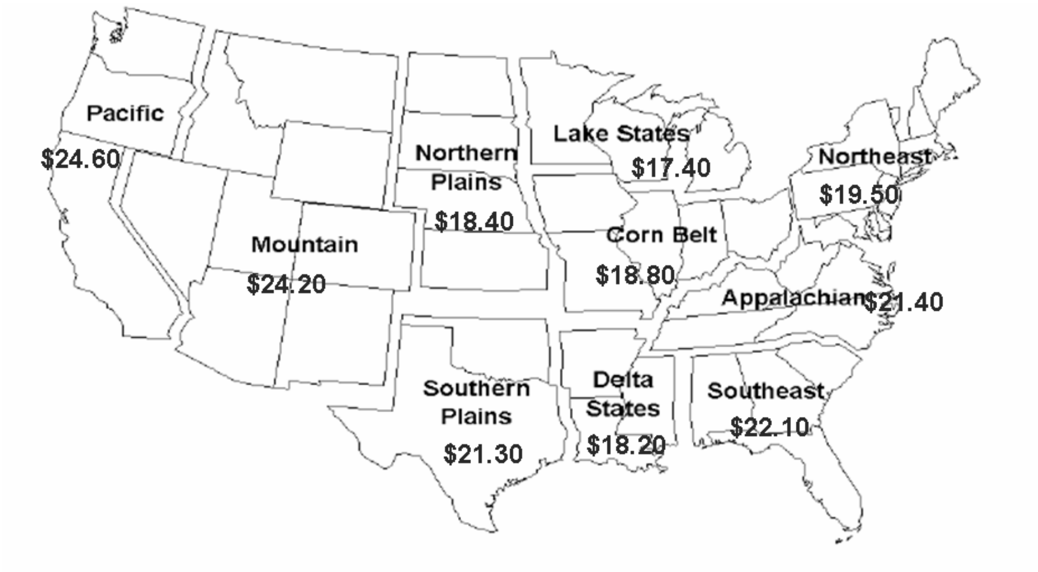

Figure 6: Distribution of Soybean Meal Prices[7]

Overall, feed production and price may not be the most important drivers of the livestock industries location and growth potential compared to the past. Improvements in transportation technology as found by Abdalla, et. al. (1995) have weakened the relative competitive advantage historically exhibited by some regions of the country. However, the Corn Belt still does maintain a small advantage over other regions because of the abundance of corn and soybeans produced in the region. In addition, the Corn Belt also has lower feed prices relative to other regions of the United States. Within the Corn Belt, the Western states have a slight advantage over the Eastern states in both production and price.

Processing or Harvest Capacity

Processing or harvest capacity is another key factor that can influence location and growth potential of the livestock industry. The literature on processing capacity indicates that processing plants are consolidating to achieve economic coordination and economies of scale according to Purvis (1998).

Swine

In 2004, the United States slaughtered 102.4 million head of swine in federally inspected plants with 56% of the swine slaughtered in the Corn Belt. Figure 7 shows the percentage of all swine slaughtered in federally inspected plants in the United States for each of the 21 states. The top four states in swine processing are Iowa (29%), North Carolina (11%), Minnesota and Illinois (9%), and Indiana (7%) of the nation's total swine slaughtered.

The Corn Belt contains 122 of the 664 federally inspected swine slaughtering plants in the nation. These plants on average slaughtered 462,528 head per plant in 2004 compared to the

[7] Source: NASS – "Agricultural Prices"

national average of 153,172 head per plant. The Corn Belt has a definite advantage over the rest of the nation with respect to swine processing capacity.

Indiana slaughtered 7% of the nations total swine slaughtered in its eight federally inspected swine processing plants in 2004. The average plant size for Indiana was 882,710 head slaughtered per plant per year, which is almost six times larger than the national average. The average plant size ranks Indiana second in the Corn Belt and the nation, behind only Iowa with an average plant size of 1,347,900 head per plant per year. Overall, Indiana has a highly concentrated swine processing industry and a significant proportion of the United States swine industry.

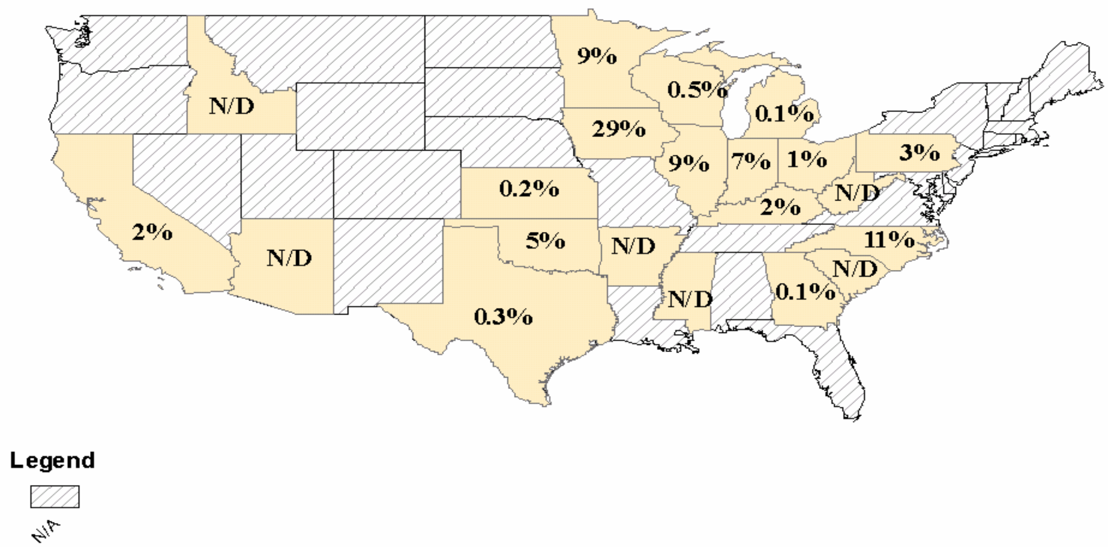

Figure 7: Percentage of Swine Slaughtered by State (Federally Inspected Plants Only)[8]

Beef

In 2004, the United States slaughtered 32.2 million head of cattle with 41% slaughtered in two states - - Kansas and Texas. Figure 8 shows the percentage of all cattle slaughtered in the United States for the each of the 21 states. The top five states for cattle slaughtering in this study are Kansas (22%), Texas (19%), Wisconsin (4%) and California (4%), and Pennsylvania (3%) of the nation's total cattle slaughtered. The Corn Belt only accounted for 7% of all the cattle slaughtered in the United States with Iowa, Illinois, and Indiana having no federally inspected cattle slaughtering facilities.

---

[8] Source: NASS – "Livestock Slaughter 2004 Summary"
N/D = concentration in the slaughter industry does not allow for reporting in the state even though they may have slaughter capacity

In 2004, the Corn Belt contained only 10% of the nation's total cattle slaughtering plants. The average plant size in 2004 for the United States was 46,470 head per plant compared to the Corn Belt's average of 35,090 head per plant. This is no surprise because in 2004 the Corn Belt only contained 14% of the slaughter heifer and steer inventories in the United States, compared to Texas and Kansas that controlled 31% of the nation's slaughter heifers and steers. Overall, the Corn Belt has a relative small cattle slaughtering industry compared to other regions in the nation.

Indiana has no federally inspected beef processing capacity within the state. The closest states with beef processing capacity are Kentucky, Michigan, and Ohio. Indiana produced less than 1% of the slaughter heifers and steers in the United States in 2004. Overall, Indiana has a weak position in the cattle slaughtering industry.

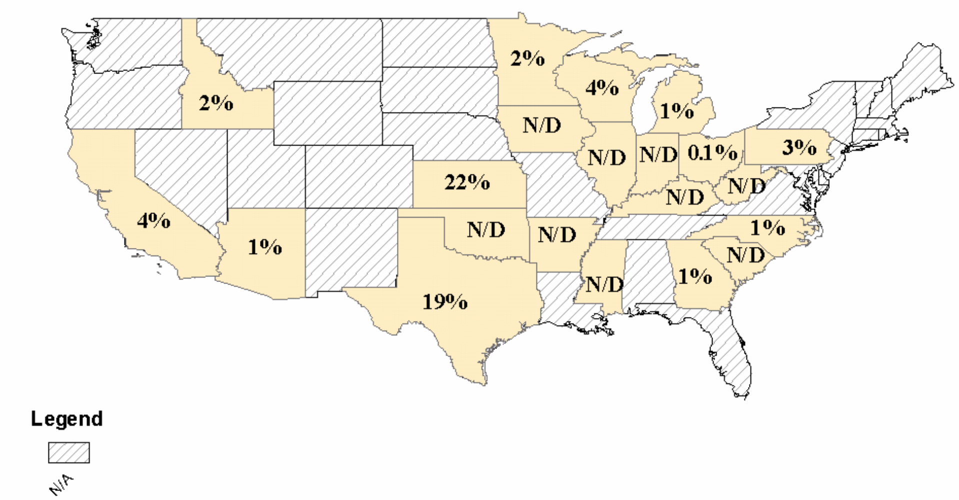

Figure 8: Percentage of Cattle Slaughtered by State (Federally Inspected Plants Only)[9]

Dairy

In 2004, the United States produced 170.8 billion pounds of milk with 29% of production coming from the Corn Belt. The United States has 1,096 plants that process one or more dairy products of which 35% are located in the Corn Belt. Figure 9 shows the distribution of dairy plants that are processing one or more products. The dairy industry is substantially different than the meat processing industry in that milk can be shipped into different milk marketing orders, (shown in Figure 10), of the United States, especially the Southeastern and Eastern seaboards, and receive a premium. A city within each of the milk marketing orders in Figure 10 is used as a

[9] Source: NASS – "Livestock Slaughter 2004 Summary"
N/D = concentration in the slaughter industry does not allow for reporting in the state even though they may have slaughter capacity

pricing point. Tampa, Florida has the highest pricing point of all milk market orders at $4.00 per gallon and is followed by Boston $3.25, Charlotte and Atlanta $3.10. This is in comparison to the Mideast order, which most of Indiana is in, where it is $2.00. Indiana's proximity to these higher prices is an advantage (USDA [l]).

The Corn Belt contained 30% of the nation's dairy cows in 2004. Wisconsin had the largest inventory of dairy cows with 1.2 million head producing 44% of the milk in the Corn Belt. Indiana ranked sixth out of the seven states in the Corn Belt in dairy cow inventories and milk production. Indiana had the third most productive dairy cows in the Corn Belt with 19,747 pounds of milk produced per cow. In 2004, Indiana accounted for only 2% of the nation's dairy cows and produced 2% of the nation's total milk production.

Location is a factor for Indiana dairy industry because of the Milk Marketing Order structure. If a line extending out 600 miles is drawn around Indiana, this is a conservative measure of the distance someone might drive in a day with a tanker load of milk. Within this radius of 600 miles, Indiana has access to approximately 50% of the processing plants in the entire United States and access to the Southeast and Eastern seaboards where milk prices are the highest in the nation.

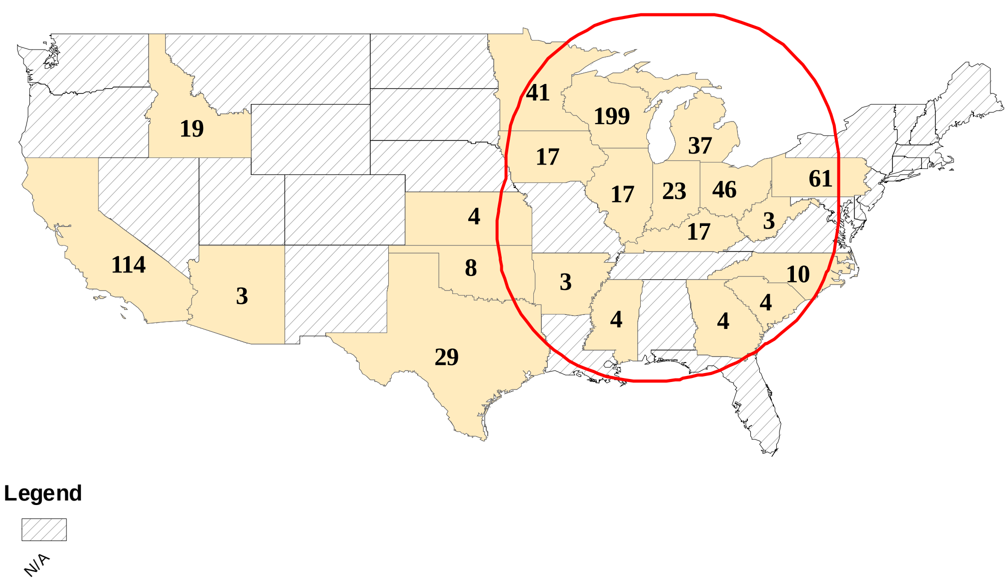

Figure 9: Number of Dairy Plants Processing One or More Products[10]

[10] Source: NASS – "Dairy Products 2004 Summary"

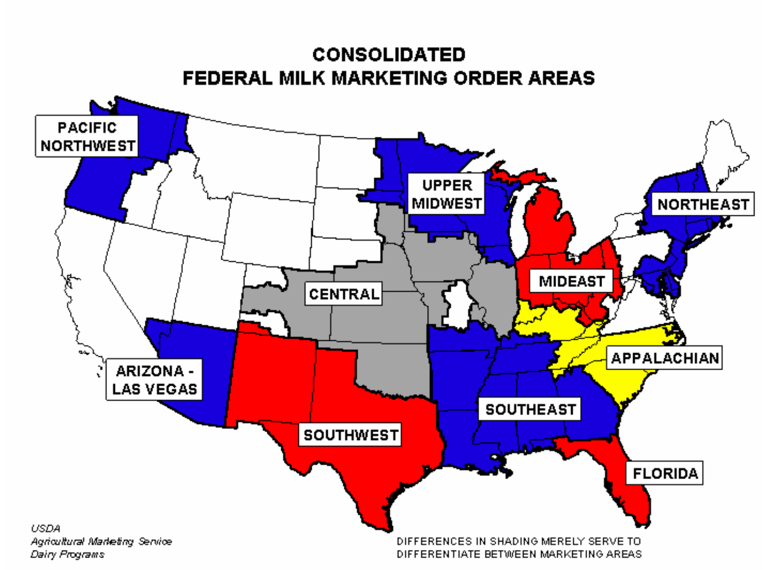

Figure 10: United States Milk Marketing Orders[11]

Poultry

The poultry industry is the last species that this study examines. Due to the vertical integration within the industry, disaggregated location data is difficult to find. In general, the poultry industry is dispersed throughout the country in clusters dependent upon the species. The majority of US egg production takes place in Iowa, Indiana, Ohio, and Pennsylvania and is affectionately known as the Egg Belt. The Broiler Belt stretches from Delaware down around the Atlantic and Gulf Coasts to Arkansas and Texas. For turkeys, there are two main clusters with one being in Minnesota and the other in North Carolina. The majority of the US poultry processing capacity is located in close proximity to these production clusters.

Population and Animal Density

Population Density

The interaction between people and animals has long been a topic of debate when looking at expanding the livestock industry. Within the literature, no specified threshold has been identified as to if population and animal density reach a specified level, then concerns arise about conflicts between people and animals. In this study, locations that have a higher density in human and animal populations are identified. In 2004, there were 293.7 million people living in the United States with an average population density of 83 per square mile. Figure 11 shows the distribution of population density for each of the 21 states. The most densely populated states in this study are Ohio (280/mi^2), Pennsylvania (277/mi^2), and California (230/mi^2).

In 2004, the Corn Belt contained 18% of the United States total population and had an average population density of 143 people per square mile. Even within the Corn Belt there is a large difference between the Eastern and Western states. The Eastern Corn Belt in 2004 had a

[11] Source: Agricultural Marketing Service

population density of 189 people per square mile compared to the Western at 59 people per square mile. Purvis (1998) and Martin and Norris (1998) indicate that processing plants and livestock production are moving to areas that are sparsely populated. Therefore, the Western Corn Belt has an advantage over the Eastern Corn Belt in terms of a lower average population density. Indiana in 2004 was the fourth most populated state in the Corn Belt with 6.2 million people and an average population density of 174 people per square mile.

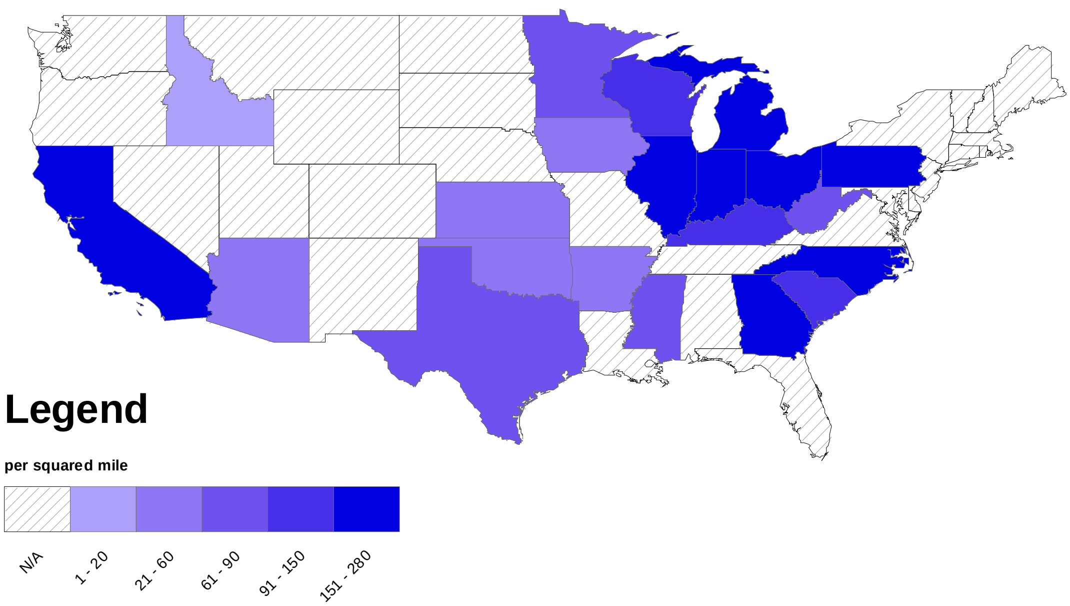

Figure 11: Population Density[12]

Animal Density

Animal density is the second dimension of the interaction between people and animals. There were 86.9 million phosphorus producing animal units[13] in the United States in 2004 with an average animal density of 25 animals per square mile. Figure 12 shows the distribution of animal units across the 21 states. The most densely populated states with phosphorus producing animal units are Iowa (80/mi^2), Arkansas (60/mi^2), and North Carolina (58/mi^2).

In 2004, the Corn Belt contained 17% of the total phosphorus producing animal units and had an average animal density of 39 animals per square mile. Again, there is a distinct difference between the Eastern and Western Corn Belt; the animal density in the Western Corn Belt was 53 animals per square mile compared to the Eastern Corn Belt at 31 animals per square

[12] Source: Economic Research Service
[13] Phosphorus Producing Animal Units – based on the phosphorus excretion of 1 beef cow for a total year

mile. Indiana in 2004 had the third highest animal density within the Corn Belt at 37 animals per square mile and contained 9% of all the phosphorus producing animal units in the Corn Belt.

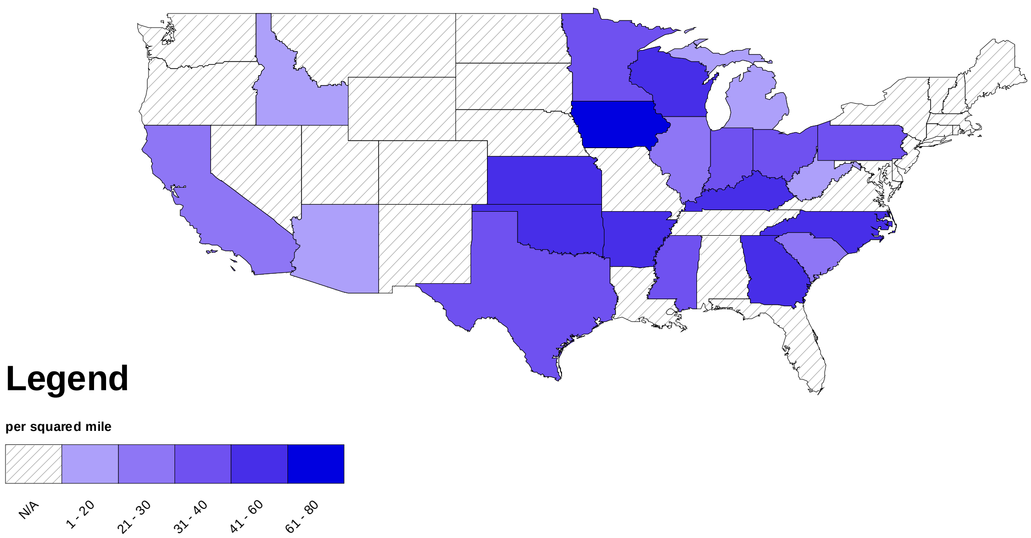

Figure 12: Animal Density

The population and animal density maps clearly indicate that livestock production is more prevalent in areas where population densities are lower. A good example of this is the Corn Belt: in the Eastern Corn Belt population densities are higher than the Western Corn Belt, but animal densities are lower in the Eastern than the Western Corn Belt. The movement of livestock to sparsely populated areas is also supported by the literature and is evident when looking at shifts in state livestock inventories. For example, Oklahoma has witnessed a 583% increase in swine inventories since 1980, and has one of the lowest population densities - - 51 people per square mile - - of the states included in this study. Expansion of the dairy industry in Idaho is an additional example of this phenomenon.

<u>Animal Nutrient Production and Assimilation</u>

Animal nutrient production and assimilation capacity could be one of the most limiting factors in the future in terms of growth in the livestock industry, depending on EPA’s decisions concerning phosphorus based application policy for manure. Currently the phosphorus standard can vary by state with some states, like Wisconsin, already mandating that manure be applied at a phosphorus rate, while other states still use a nitrogen rate of application. There is a significant difference between the two types of standards. Shifting from a nitrogen standard to a phosphorus standard reduces the nutrient assimilation capacity by approximately 66% since nitrogen can be assimilated at about three times the rate of phosphorus. The result is that some livestock operations will be required to find additional land in order to apply manure nutrients at a phosphorus rate.

Two scenarios are examined at the state level: 1) the nutrient balance with just livestock production of nutrients, and 2) both livestock nutrients and commercial fertilizer. The focus will be on phosphorus since environmental rules appear to be moving to that standard.

In 2004, livestock in the United States produced an estimated 1.6 million tons of phosphorus and used an estimated 38% of the nation's total assimilation capacity. The largest phosphorus producers of the 21 analyzed states in this study were Texas (185,150 tons), California (88,850 tons), and Iowa (79,420 tons). Figure 13 shows the percentage of each states assimilation capacity that is being used by livestock production only - - note that there are five states that have excess phosphorus production. Just because a state has excess amounts of phosphorus does not necessarily mean that the livestock industry cannot continue to grow there. To expand and site new livestock operations is a localized issue, which these state level maps are not able to depict. In addition, issues like soil types and transporting manure out of the state have not been taken into account. Only three states have 0-25% of their assimilation capacity being used by livestock production.

In the Corn Belt, only Wisconsin is above 50% in use of assimilation capacity by livestock production. Ribaudo, et. al. (2003) provide three reasons for this pattern of the Corn Belt using less of their total assimilation capacity than other regions of the United States. 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, is that allowable nutrient levels are higher in the Corn Belt because the crops grown in that region use large amounts of nitrogen/phosphorus and crop yields in this region tend to be higher.

Indiana uses only 18% of its total assimilation capacity. Arizona (11%) and Illinois (9%) are the only two states out of the 21 that are using a lower percentage of their assimilation capacity. Overall, when comparing Indiana to the other 20 states, Indiana has an advantage in that they still have a significant portion of their assimilation potential that is unused.

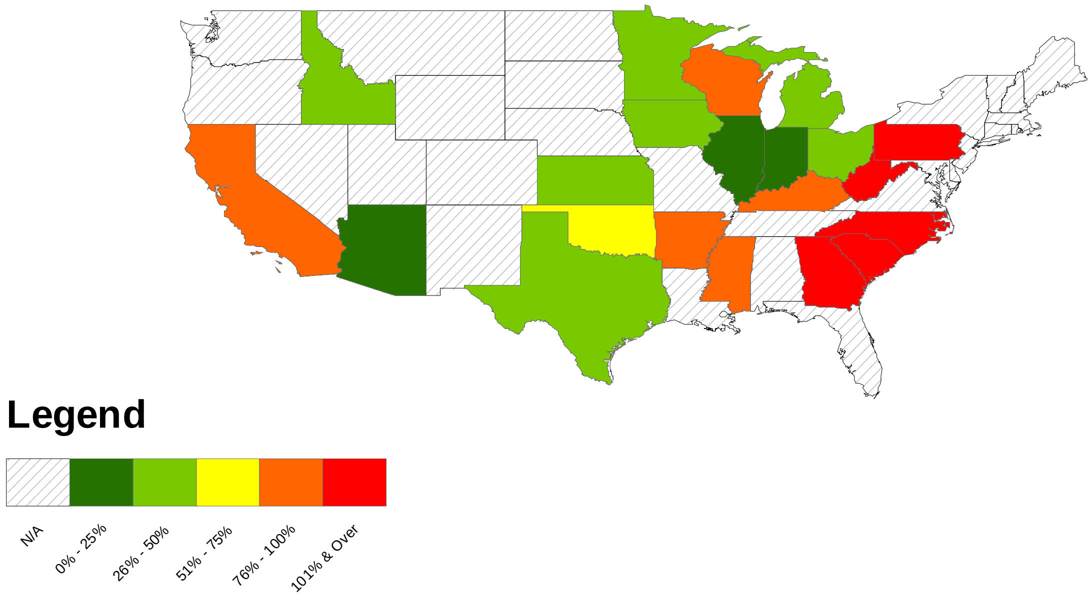

Figure 13: Estimated State Level Assimilation Capacity at Strict Phosphorus Standard (Livestock Phosphorus Production Only)

Figure 14 shows the state's total assimilation capacity that is being used by both livestock production and commercial phosphorus. From July 1, 2003 to June 30, 2004, the United States used 2.1 million tons of commercial phosphorus. This is 0.5 million tons more than what was produced by livestock in 2004. The largest users of commercial phosphorus in 2004 were Iowa (165,063 tons), Minnesota (141,994 tons), and Illinois (140,445). The largest commercial phosphorus user outside of the Corn Belt is California (132,217 tons). With the addition of commercial phosphorus, the United States used 3.7 million tons of phosphorus and approximately 87% of its total assimilation capacity. When commercial phosphorus is included, 15 states have excess phosphorus applied.

The Corn Belt used 33% of all the commercial phosphorus sold for the 2004 crop. Only Iowa, Illinois, and Indiana do not have excess phosphorus application once commercial phosphorus is added. Wisconsin used the least amount of commercial phosphorus of the seven states in the Corn Belt, but also had the highest level of assimilation capacity used in both scenarios. Overall, the Corn Belt uses a significant amount of commercial phosphorus that could instead be supplied from livestock manure.

Indiana in 2004 used 88,957 tons of commercial phosphorus. If commercial phosphorus is included in the analysis, Indiana increased its assimilation capacity used from 18% to 82%. Although, Indiana did not have an excess phosphorus problem in 2004, assimilation capacity was high because Indiana experienced some of the highest crop production totals in years.

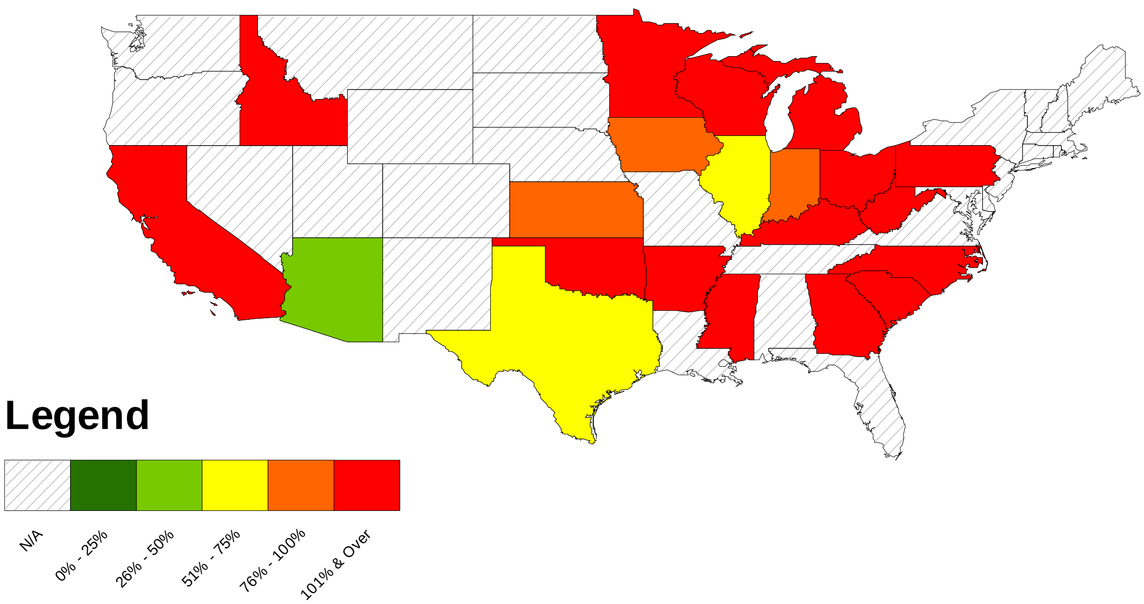

Figure 14: Estimated State Level Assimilation Capacity at Strict Phosphorus Standard (Livestock & Commercial Fertilizer)

The amount of farmland in each state actually receiving manure nutrients is useful in evaluating phosphorus production and assimilation capacity. According to the 2002 Census of Agriculture manure does not appear to be a widely used source of fertilizer. Table 1 summarizes the percentage of land and farms that applied manure in 2002 for the states in this study. Pennsylvania and Wisconsin have the highest percentage of farms and the largest percentage of land in the state that is receiving manure nutrients. There are several reasons why manure is not being used for fertilizer (Kellogg, et. al. (2000)). First, manure is not a uniform product compared to the commercial fertilizer that can be bought at the fertilizer dealer. The second reason is the issue of soil compaction when heavy equipment travels over the field to apply the manure. The last reason is the issue of the transportation cost to haul manure. If the EPA continues to trend toward phosphorus application standards, these issues will have to be resolved to apply animal nutrients to the land.

Table 1: State Percentage of Land and Farms That Applied Manure in 2002[14]

State	% Farms	% Acres
Arizona	10%	0%
Arkansas	15%	4%
California	9%	3%
Georgia	13%	4%
Idaho	16%	2%
Illinois	18%	3%
Indiana	24%	5%
Iowa	29%	7%
Kansas	9%	1%
Kentucky	12%	3%
Michigan	22%	7%
Minnesota	28%	7%
Mississippi	7%	2%
North Carolina	17%	5%
Ohio	28%	6%
Oklahoma	5%	1%
Pennsylvania	40%	17%
South Carolina	11%	4%
Texas	4%	1%
West Virginia	20%	4%
Wisconsin	40%	15%

Summary

In this state comparison, the key dimensions discussed are feed availability and feed price, processing plants, population density, animal density, and assimilation capacity. Figure 15 summarizes the results of the state analysis; x's indicate that the state has a competitive advantage on this dimension. The first dimension is feed price. Corn price and soybean meal price are the two components of the feed price dimension. To be assigned an (x) for corn price the state must have an estimated corn price that is less than $0.10 above the estimated national average corn price of $1.95. An (x) for soybean meal means that the state had an average soybean meal price that is less than $19.60, the average national price for soybean meal. States that exhibit these characteristics of lower feed prices have a competitive advantage in livestock production.

To be assigned an (x) for the population density dimension, the state had to have an average population density lower than the national average of 83 people per square mile to have an advantage. Assimilation capacity, the third dimension, has two components measuring first the capacity consumed by livestock only, and second the capacity used by both livestock and commercial phosphorus at a strict phosphorus standard. An (x) for the first component means that the state's livestock consume less than 50% of the state's total assimilation capacity, - - thus giving them an advantage. To get an (x) for the second component of assimilation capacity, the state had to use less than 100% of their total assimilation capacity.

[14] Source: 2002 Census of Agriculture

The fourth dimension analyzed is harvesting capacity where the federally inspected processing industries within each state are listed. All states have some dairy processing so it was omitted from the figure. An assessment scale was used to summarize this information as indicated in the legend of the figure. This scale attempts to provide an overall summary of the relative attractiveness of the different geographic locales when all dimensions or drivers are combined. The scale is qualitative in nature and does not recognize that some of the drivers may be more or less important compared to others in determining the location of the livestock industry.

State	Feed Price		Population Density***	Assimilation Capacity**** (Livestock)	Assimilation Capacity**** (Livestock and Fertilizer)	Harvesting Capacity
	Corn*	Soybean Meal**	<83	<50%	<100%	Species
Arizona			X	X	X	Cattle
Arkansas		X	X			Cattle
California						Cattle, Swine
Georgia						Cattle, Swine
Idaho			X	X		Cattle
Illinois	X	X		X	X	Swine
Indiana	X	X		X	X	Swine
Iowa	X	X	X	X	X	Swine
Kansas	X	X	X	X	X	Cattle, Swine
Kentucky						Cattle, Swine
Michigan	X	X		X		Cattle, Swine
Minnesota	X	X	X	X		Cattle, Swine
Mississippi		X	X			
North Carolina						Cattle, Swine
Ohio	X	X		X		Cattle, Swine
Oklahoma			X			Cattle, Swine
Pennsylvania		X				Cattle, Swine
South Carolina						
Texas				X	X	Cattle, Swine
West Virginia			X			Cattle, Swine
Wisconsin	X	X				Cattle, Swine

* < $0.10 above estimated long term basis, ** < the national average of $19.60, *** 83 people/mi2 is population density for United States, **** Capacity Used at strict Phosphorus Standard

LEGEND: X in All 6 (green) | X in 4-6 (yellow) | X in < 4 (red)

Figure 15: State Comparison Results

Feed availability may not be as significant a driver of the location and growth of the livestock industry as it once was due to improved transportation technologies. But feed availability still has some influence on the industry as it impacts prices. The Corn Belt produces over 60% of the corn and soybeans in the United States. In addition, the Corn Belt has relatively lower prices for both corn and soybean meal compared to other regions of the nation. Location within the Corn Belt is also important, as prices are lower in the Western states versus the Eastern states.

The capacity to process livestock is dispersed in pockets throughout the United States, with concentrations in key regions depending on the type of livestock. For swine, the key region is the Corn Belt with 56% of swine slaughtered in the nation occurring in seven states. Indiana has a large and highly concentrated swine processing industry. Cattle slaughter is concentrated in Kansas and Texas – these two states account for 41% of the all cattle slaughtered in the United States. The Corn Belt only accounts for 7% of the cattle slaughtered. Indiana has no federally inspected cattle slaughter plants.

As to the dairy industry, California is the largest producer of milk in the nation. However, the seven states in the Corn Belt account for 29% of milk production and 35% of the milk processing plants in the United States. In addition, Indiana's location in the Corn Belt provides it access to the Southeastern and Eastern seaboards of the United States, which are milk deficient regions. Vertical integration of the poultry industries does not allow for easy access to data. In general, the poultry industry is located in clusters around the United States depending on the species. Broiler production is concentrated in the Southeastern proportions of the United States. Egg production is concentrated across the Midwest in the Egg Belt. Turkey production is concentrated in the Upper Midwest and Southeastern states.

Human and animal interaction was the next dimension concerning location of the livestock industry. The Corn Belt was home to 18% of the US population in 2004, and Indiana was the fourth most populated state in the Corn Belt. Ohio is the most densely populated state in this study. In 2004, the US had an average animal density of 25 animals per square mile; Iowa had the highest animal density. The Eastern Corn Belt states have a higher human population density and the western states have a higher animal density.

Phosphorus production and assimilation is the last dimension of the state level analysis. A significant change is taking place in the amount of manure that can be land applied as the EPA changes from a nitrogen application standard to a phosphorus application standard. This change will reduce the land assimilation capacity by 66%. Of the 21 states in the study, five have excess phosphorus due to just the production of livestock in the state. All of the states in the Corn Belt except for Wisconsin use less than 50% of their total phosphorus assimilation potential from livestock production. In Indiana, livestock production only uses 18% of its total assimilation potential. If the use of commercial phosphorus is included, the number of states with excess phosphorus applied increases from 5 to 15. All Corn Belt states except Iowa, Illinois, and Indiana will have excess phosphorus concerns if strict phosphorus application standards are enforced. In Indiana, assimilation capacity used increases from 18% to 82% once commercial phosphorus is included. With the increased need for land in the case of the strict phosphorus application standard, land available to apply manure could become a limiting constraint on livestock expansion.

Indiana Locales

The analysis will now turn from an assessment of Indiana's competitive position for growth in the livestock industries compared to other states to the region or locations within the state that have the most potential for expansion of the livestock industries. Four main determinants of location and growth of the livestock industries are evaluated at the state and county level: feed usage and price, number of processing plants/capacity, population verses animal density, and environmental capacity. The focus of this discussion is Indiana - - in particular how Indiana counties compare to each other on these dimensions according to the 2002 Census of Agriculture livestock inventories, 2000 to 2004 average crop production, and relevant 2004 production where it applies.

Feed Usage & Price

Feed availability and feed price historically were significant drivers of livestock location, but advances in transportation technologies have eroded regional advantages. Although eroded, they still have an impact on the distribution of livestock throughout the state. There are two different components of feed analyzed on the county level: 1) feed usage and 2) county estimated price of corn.

Corn

The production of corn for grain in Indiana is a significant revenue producer for the agricultural sector and feed source for Indiana livestock producers. On average, Indiana produces 808.5 million bushels of corn. Since 2000, the 2002 corn crop was the lowest yielding crop to date for Indiana. It was approximately 30% smaller than the corn crops grown in 2001 and 2003. Furthermore, it was 35% smaller than the average crop grown from 2000-2004 of 808.5 million bushels of corn, but it still provided the estimated 134.2 million bushels of corn needed to feed Indiana livestock. Indiana livestock consumed approximately 17% of the corn for grain grown, with the residual going into food, energy production (e.g. ethanol), and exports. The swine industry is the largest of the livestock consumers of corn for grain in Indiana. The distribution for the number of bushels consumed by each species and the percentage of the total bushels fed to livestock in 2002 is provided in Table 2.

Table 2: Bushels and Percentage of Corn for Grain Consumed by Species

Species	Bushels of Corn	Percentage of Corn for Grain
Beef	19,205,223	14.31%
Dairy	664,378	0.50%
Swine	73,126,942	54.50%
Poultry	41,178,269	30.69%

Only 2 of the 92 counties in Indiana were able to consume all of the corn produced in that county using the typical rations in Appendix E. Figure 16 shows what percentage of corn grown in a county is consumed by livestock in that county. Those counties able to consume more corn than is grown in the county are home to a significant proportion of the poultry industry in the state. Martin and Dubois counties are the only two counties in Indiana who's 2002 livestock inventories consumed all of the corn grown in the county. The counties in the southern part of the state stretching from Greene and Monroe down to Spencer and Harrison are responsible for the majority of the state's turkey and broiler production for which corn constitutes over 60% of their food intake (Applegate (2005)). The top three corn-for-grain consuming counties for Indiana in 2002 were Randolph, Dubois, and Jay respectively.

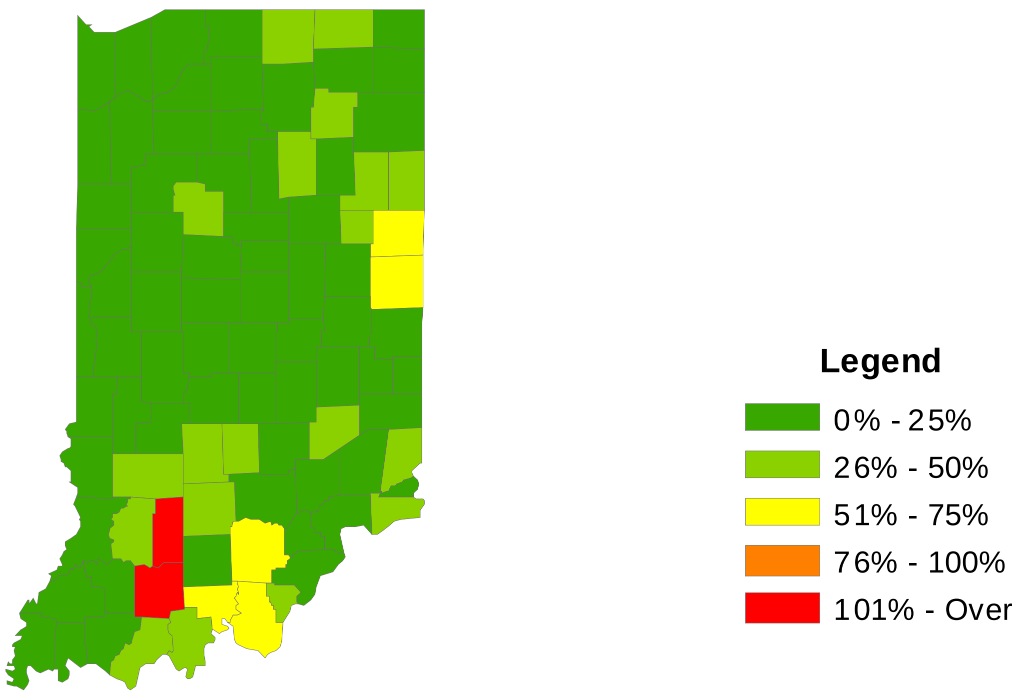

Figure 16: Percentage of County Corn Production Needed for Feed

The availability of feed is not the only factor that can influence location of livestock. Price is also important when determining whether to build or expand livestock production facilities in the state. Figure 17 summarizes the estimated long term corn basis differential for Indiana with Huntington County as the base county. The lowest corn prices in the state are in the northeast corner of the state. Prices continue to increase to the south with the highest prices for corn being in counties that are along the Ohio River. One exception to this trend is that the counties that surround Lake Michigan also have higher prices. Factors that can influence the price of corn in a county are the demand for corn for the milling, energy production, and export industries. In addition to the price of corn, Figure 17 shows the location of milling and energy production facilities (operational and under construction) in the state. Currently Indiana has the ability to process approximately 224.4 million bushels per year in the 11 different facilities that are operational.[15] There are additional processing plants for ethanol production that will be coming on line in the future, but their impact on the corn basis has yet to be determined. The export facilities are not displayed, but there are approximately 40 export facilities located throughout the state and 11 barge stations located along Lake Michigan and the Ohio River (Nedham (2005)).

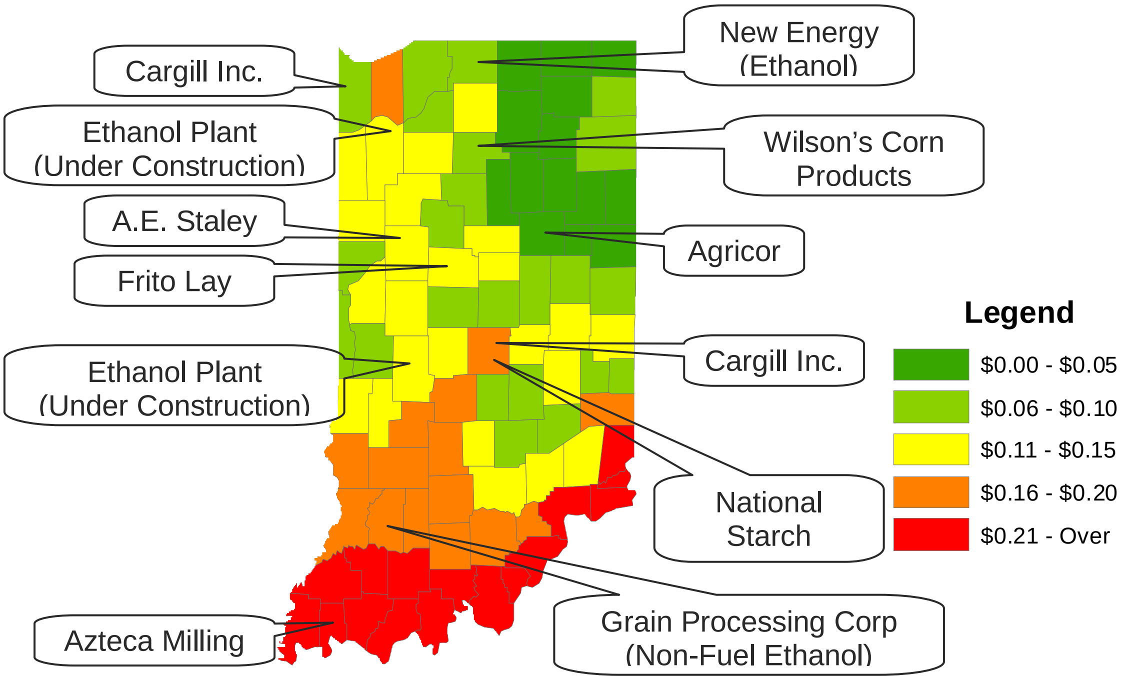

Figure 17: Estimated Long Term Corn Basis Differential (Huntington County is base county)[16]

The region stretching from the western border of the state east to Jay County and from Lake Michigan down to Morgan County currently exhibits excess corn supply. This region is home to 8 of the top 10 corn producing counties in 2004 (IASS (2004)). The increase in transportation technologies allows excess corn to be moved efficiently to deficit regions in the state. As for counties with an advantage in corn price, the northeast corner of Indiana has the lowest prices. The western part of the state below Lake County and down to Vermillion County also has lower corn prices compared to the river markets.

Soybeans

On average, Indiana produced 251.3 million bushels of soybeans annually during the 2000 to 2004 period. Indiana's livestock industry consumed 17% of the crop or an estimated 43.9 million bushels of soybeans were turned into soybean meal. The largest consumer of soybean meal for 2002 was the poultry industry, consuming 16.9 million bushels or 39% of all soybeans used for feed production. The consumption for each species is provided in Table 3.

---

[15] A.E. Staley has two plants in Lafayette, Indiana.
[16] Source: Farm Service Agency (County Loan Rates)

Table 3: Bushels and Percentage of Soybeans Consumed by Species

Species	Bushels of Soybeans	Percentage of Soybeans
Beef	2,897,388	7%
Dairy	7,407,478	17%
Swine	16,657,450	38%
Poultry	16,906,188	39%

Indiana only had two counties - - Dubois and Martin - - that consumed more soybeans than were grown in the county. The counties that consume the most soybeans are Dubois, Randolph, and Elkhart, respectively. These are all large poultry producing counties in Indiana and soybean meal is the second largest ingredient in poultry rations. Figure 18 shows the percentage of the soybeans grown in each county needed to feed the livestock in the county. In addition, it shows where the soybean processing facilities are located in the state.

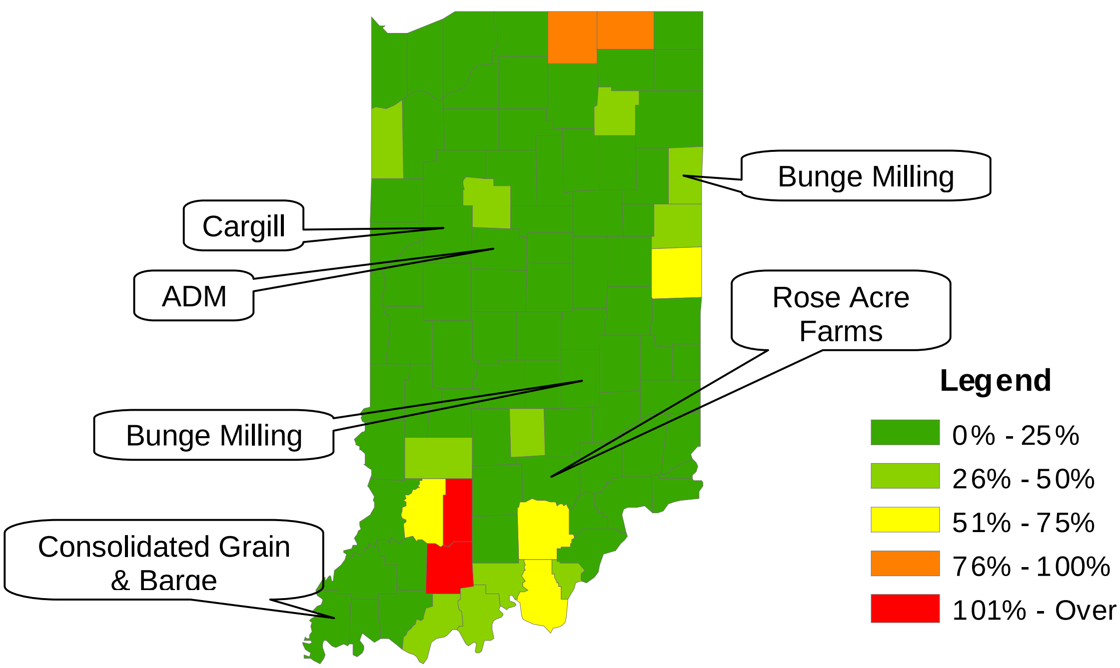

Figure 18: Percentage of County Soybean Production Needed for Feed

The counties with advantages in soybean production are the entire region north of Brown County. Elkhart and Lagrange counties are exceptions to this because they consume over 75% of the soybeans in the county. Overall, this region has all ten of the top producing soybean counties in the state for 2004 (IASS (2004)). In general, increases in transportation technologies have enabled counties consuming all locally produced soybeans the opportunity to meet their demand efficiently.

Silage

On average, Indiana produces 2.5 million tons of silage annually during the 2000 to 2004 period. The only two users of silage in this study are the beef and dairy industries. In total, these two industries consumed an estimated 76% of the silage Indiana produced.[17] Dairy, the largest user of silage for the two industries, consumed an estimated 82% or 1.6 million tons of the silage.

On average, 28 counties used over 100% of the silage grown in the county based on 2002 livestock inventories. Figure 19 shows the percentage of silage grown that is used by livestock in that county. The top three silage-consuming counties are Elkhart, Newton, and Lagrange respectively. Elkhart County is the only county of the three that does not use all of the silage produced in the county. In addition, these are also the top three counties in terms of dairy cow inventories with 30% of the state's total inventories located in these three counties.

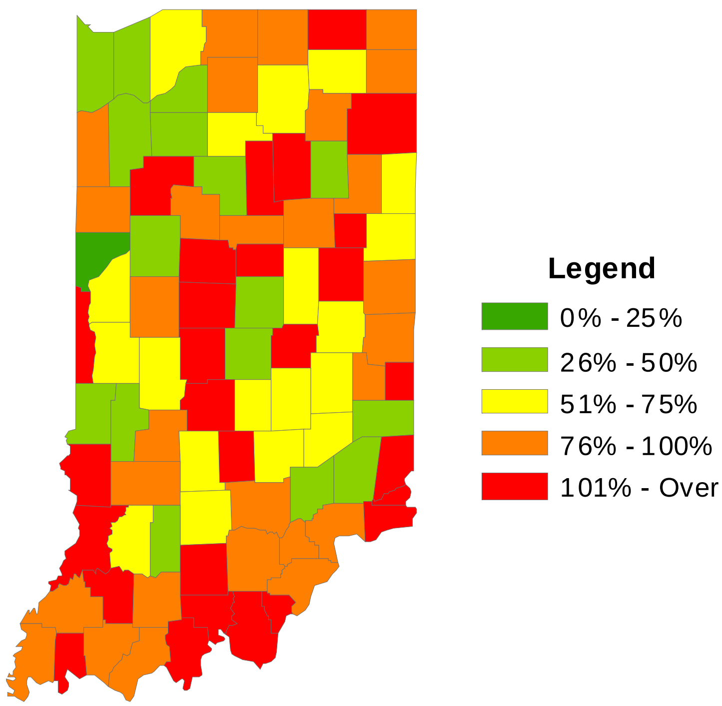

Figure 19: Percentage of County Silage Production Needed for Feed

There are no real advantages to growing excess silage because of spoilage, and silage is not a feed that livestock producers will transport over a long distance. Therefore, it would be expected that Indiana uses all of the silage that it produces each year, and that it is produced, in general, near where it is used.

[17] The assumption was that all dairy cows where consuming silage. There was no way to differentiate between the dairy cows in the state that are on a grazing ration verses those that are consuming silage, therefore all were grouped together resulting in consumption of more silage than is actually produced.

Forage

On average, Indiana produces an estimated 5.7 million tons of forage of which only an estimated 43% was consumed by 2002 livestock inventories.[18] The major user of forage is the beef industry, consuming an estimated 78% of the estimated 2.5 million tons of forage consumed. Only Newton and Jasper counties used all of the forage grown in the county in 2002. Two other counties in the state used over 75% of the forage grown in the county; the percentage used for the remainder of the counties is shown in Figure 20. The largest forage consuming counties are Elkhart, Washington, and Lawrence respectively. Washington and Lawrence counties are the top two in terms of beef cow inventories, while Elkhart County has the largest dairy cow inventory.

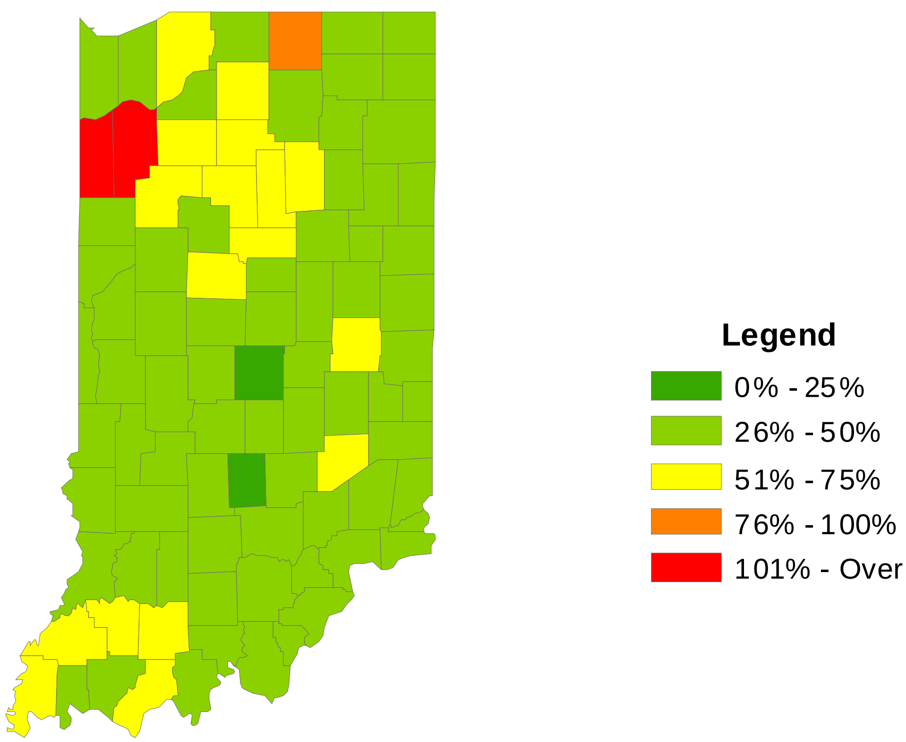

Figure 20: Percentage of County Forage (All Hay & Pasture) Production Needed for Feed

In terms of excess county forage, there are no relative advantages in any region of the state. Only three counties in the entire state use more than 75% of their forage, and only two of those counties use all of their forage.

---

[18] Forage includes all hay irrespective of type and includes pasture under the assumption that each acre of pasture produces 2.77 tons.

Processing Capacity

The processing industry is the next dimension of the Indiana specific analysis. Processing capacity for all species of livestock exists in Indiana. Indiana has no federally inspected beef processing facilities, but there are state inspected processing facilities.[19]

Beef

The beef processing industry in Indiana is limited to only state inspected processing facilities scattered throughout the state. As of January 1, 2005 there were 58 facilities registered that slaughtered red meat. The size of these facilities is unknown but in 2004, 98% of all commercial cattle slaughtered in the United States were slaughtered in federally inspected plants (USDA [b] (2005)). Therefore, it is not likely that Indiana has the beef slaughtering capacity in the state to slaughter a significant proportion of the state's beef.

Dairy

The dairy processing industry in Indiana spans from the processing of raw milk to the production of whey. In 2004, Indiana had 23 different plants that were manufacturing one or more dairy products. For the purpose of this study we have specifically focused on the nine plants that process fluid milk in Indiana. Although the processing capacity of each plant is confidential, we do know their locations, which are shown in Table 4. In addition, we know that in 2004 Indiana produced 2,962 million pounds of milk of which 98% went into fluid milk production (USDA [m] (2005)). Indiana's geographic location in the United States gives it a competitive advantage over some other states with respect to transportation to the markets as discussed in the state comparison section.

Table 4: Indiana Fluid Milk Processors[20]

Plant	City
Crossroads Dairy (Kroger)	Indianapolis
Deans Foods	Rochester
Prairie Farms	Anderson
Prairie Farms	Holland
Prairie Farms	Ft. Wayne
Trader's Point	Zionsville
Smith Dairy	Richmond
Schenkel's Dairy	Huntington
Pleasant View Dairy	Gary

[19] The difference between state and federally inspected facilities is that state inspected plants can only sell and transport the meat within the state it is slaughtered.
[20] Source: Dr. Mike Schutz, Department of Animal Science at Purdue University

Swine

The swine processing industry in Indiana is concentrated with Tyson (IBP) and Indiana Packers Corporation (IPC) controlling the majority of swine slaughter capacity in Indiana. There are six other federally inspected plants in the state, but they only account for 4% of the swine slaughtered in the state. Between the two major plants, they have the capacity to slaughter approximately 27,000 head a day as of fall 2004 (National Pork Board). Annually, these two plants can currently slaughter an estimated 6.8 million head of hogs. In 2002, Indiana produced approximately 6.1 million head of hogs and had the ability to process approximately 6.5 million head. This gave Indiana excess slaughter capacity of slightly over 400,000 head in 2002. This excess capacity was filled with 1.3 million head of inshipments from other states.[21] In the next couple of years, the IPC plant will be increasing its size by 35%, which will increase the daily slaughter capacity to 31,375 and the annual capacity to approximately 7.8 million head.

In addition to the swine slaughtered in Indiana, the state also ships hogs to a processing plant in Louisville, Kentucky. The Swift plant, located just across the river from Indiana, processes 10,000 head per day, or about 2.5 million head annually (National Pork Board). Of this 2.5 million head, Indiana supplies about 65% or 1.6 million head annually to this plant (Hurt (2005)). Overall, Indiana is currently not producing enough swine to fill its own processing capacity, but the processing industry is expanding. This increasing capacity for swine slaughter will either be met with increased inshipments as Indiana has seen since the early 1990's, or swine inventories in Indiana will increase.

Poultry

The poultry processing industry is geographically concentrated much like the swine industry. Within each of the poultry segments (duck, broilers, turkeys, and layers), there are a limited number of firms. Due to this concentration, the processing capacity of each firm is confidential, but we do know the location of the plants. Table 5 summarizes the firm names, the county in which they are located, and the segment within the poultry industry in which they are affiliated. In addition to the location of the plants, the Indiana State Poultry Association has provided us with estimates as to the size of each segment (Brennan (2005)).

[21] Inshipments includes both feeders and breeding stock. There is no metric to separate these into swine that came in to be fed out or is breeding stock so the number is reported together.

Table 5: Poultry Firms, Locations, and Industries[22]

Plant	County	Industry
Maple Leaf Farms	Kosciusko	Duck
Culver Corporation	Elkhart	Duck
Pine Manor	Steuben	Broiler
Tyson	Harrison	Broiler
Perdue Farms	Daviess	Turkey
Farbest Farms	Dubois	Turkey
Rose Acres	Pulaski	Layer
Rose Acres	Newton	Layer
Rose Acres	White	Layer
Rose Acres	Clinton	Layer
Rose Acres	Jackson	Layer
Rose Acres	Jennings	Layer
Wabash Valley	Dubois	Layer
Berne-HiWay	Adams	Layer
Midwest Poultry Service	Wabash	Layer
Creighton Brothers	Kosciusko	Layer

In 2004, Indiana processed approximately 10.7 million ducks between the two firms in the state, making Indiana the largest duck production and processing state in the nation. The broiler industry is also dominated by two firms that processed over 40 million birds in 2004. As to the turkey industry, Indiana ranked 7th in the nation in 2004 with two firms processing over 11 million birds. The last poultry segment is the layer industry in which Indiana ranked 4th in the nation for total egg production. This industry is supported by the 3rd largest flock of layers in the nation with 21.9 million birds.

Population and Animal Densities

Human versus animal densities is the next dimension of the Indiana state specific analysis. This is the most difficult dimension to document because it encompasses so many different facets. Our approach is to compare the population density of humans' versus the population density of animals. Phosphorus-producing animal units are used to measure the animal densities because one of the key concerns is the environmental dimension of the animal versus human interaction. The most recent county population data is 2002, so both the population densities and animal densities will be based on 2002 data.

In 2002, Indiana was home to 6.2 million people with an average county population density of 172 people per square mile. Population densities ranged from 2,178 people per square mile in Marion County to 23 people per square mile in Benton County. The 10 most populated counties in Table 6 accounted for 48% of the total population and contained cities like Indianapolis, Fort Wayne, Evansville, Gary, and Lafayette.

[22] Source: Paul Brennan, Indiana State Poultry Association

Table 6: Ten Most Populated Counties and Their Population Density[23]

Counties	2002 Population	Population Density
Marion	862,499	2178
Lake	485,851	978
Allen	337,310	513
St. Joseph	266,378	583
Hamilton	206,270	518
Elkhart	185,972	401
Vanderburgh	171,763	731
Tippecanoe	152,288	305
Porter	150,535	360
Madison	131,884	292

In 2002, Indiana was home to 1.4 million phosphorus producing animal units with an average animal density for the state of 40 animal units per square mile.[24] Animal densities range from a high of 214 per square mile in Randolph County to a low of two per square mile in Marion County. The 10 most animal populated counties are listed in Table 7 and accounted for 36% of all the animal units in the state.

Table 7: Ten Most Animal Populated and Their Animal Density

County	Animal Units	Animal Density
Randolph	97,059	214
Dubois	76,341	178
Elkhart	58,228	125
Martin	42,061	125
Jay	47,773	124
Spencer	40,458	119
Adams	38,447	113
Whitley	33,130	99
Lagrange	36,923	97
Daviess	40,182	93

As reflected in the data of Table 6, Table 7, and Figure 21, it is clear that counties that are highly populated tend to have lower animal numbers. The one exception to this is Elkhart County that is the 6th most populated county with people and the 3rd most populated county with animals. Overall, 7 out of 10 of the most highly animal populated counties have human populations that rank them in the bottom 50% of Indiana counties. There are a couple of exceptions to this pattern of high human population density and low animal population density.

[23] Source: Economic Research Service

[24] Phosphorus producing animal units is based on phosphorus produce of the animal over the course of a year verses the typical animal unit based on 1,000 lbs. Refer to methodology to see the differential between the two.

One example is Benton County that ranks 89 out of 92 for total human population and has the lowest human population density in the state. One would expect that they would have a large number of animals in the county, but in terms of animal units they rank 88 out of 92.

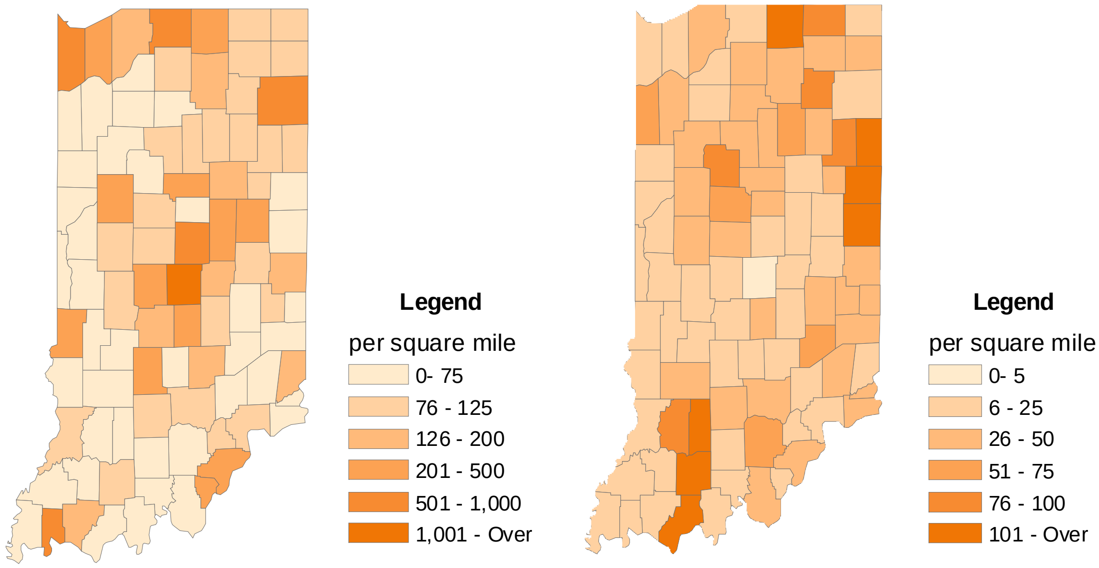

Figure 21: Population (left) vs. Animal Density (right) for 2002[25]

The counties with the lowest human population density are located along the western border of the state - - the counties stretching from Newton and Jasper counties down to Parke and Vermillion counties. This region has an average human population density of 42 people per square mile, which is 130 people less per square mile than the state average. There are some other counties scattered across the state that have low human population densities, but this area is the largest contiguous region with a low human population.

Animal Nutrient Production and Assimilation

The last dimension of the Indiana state specific analysis, which in the future could become one of the most limiting factors to the potential growth of the livestock industry in Indiana, is animal nutrient production and assimilation. As noted earlier, over the past two decades, there has been a gradual movement from a nitrogen standard to a phosphorus application standard for animal manure. A shift from a nitrogen standard to a phosphorus standard would result in a 66% loss in assimilation capacity which could have profound impacts on Indiana's livestock industry. Currently, Indiana's regulations incorporate a combination of both nitrogen and phosphorus standards as summarized in Table 8. The current system is based on soil test values, so as soils build up phosphorus, the amount of phosphorus that can be applied is decreased. Once soil test levels reach 200 parts per million (ppm) of phosphorus, that field is not eligible for any phosphorus application until test levels decrease.

[25] Source: US Census Bureau

Table 8: Indiana's Current Manure Application Policy[26]

P < 50 ppm = 3 times P crop removal rate (Nitrogen Standard)
50 < P < 100 ppm = 1.5 times P crop removal
100 < P < 200 ppm = 1.0 time P crop removal
P > 200 ppm = NO APPLICATION

Analyzing phosphorus production and assimilation based on animal production is a two-step process. First, the amount of phosphorus produced by each species is determined. In 2002, Indiana livestock produced an estimated 25,343 tons of phosphorus; Figure 22 shows the distribution of phosphorus production in Indiana by species. Poultry was the largest producer of phosphorus with the beef and swine industries close behind. Within each one of the species there was one dominate segment that produced the majority of the phosphorus. Layers accounted for 62% of the phosphorus produced within the poultry industry. The grow-finish segment accounted for 76% of phosphorus produced by swine. Lactating dairy cows lead the dairy industry producing 82% of the phosphorus. The beef cow segment accounted for 59% of the phosphorus produced by the beef industry.

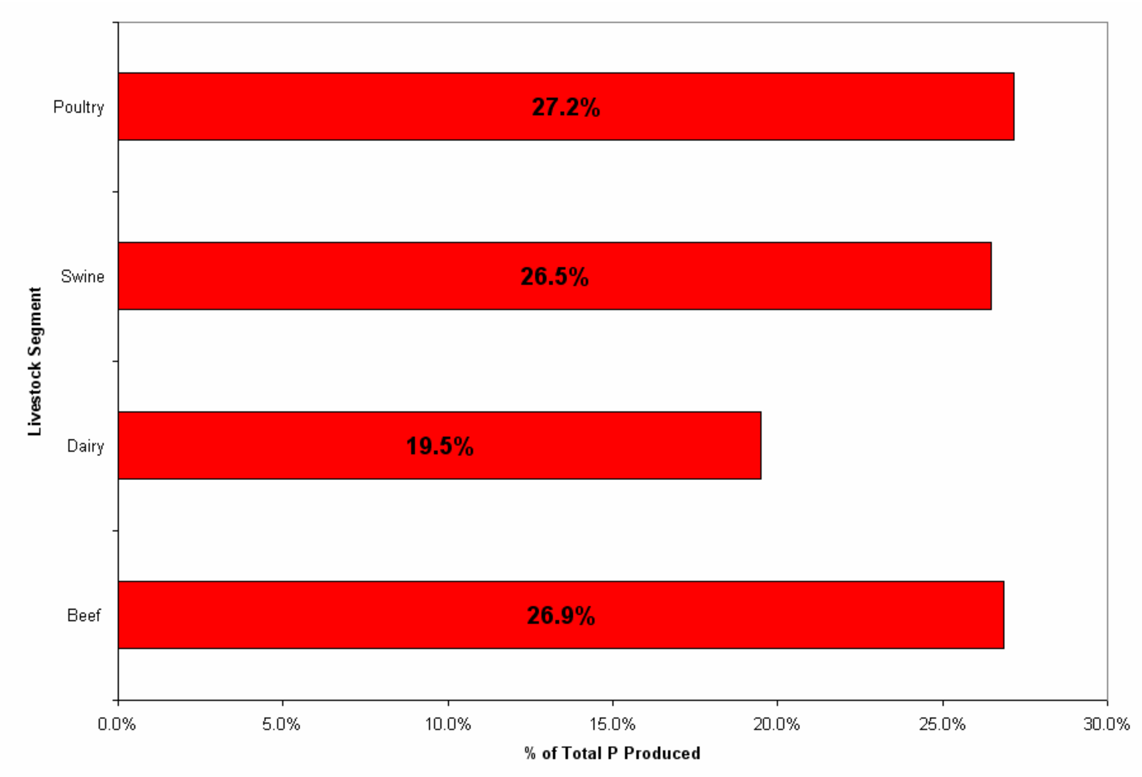

Figure 22: Phosphorus Production by Species for 2002

[26] Source: Dr. Brad Joern, Department of Agronomy at Purdue University

The second step is to determine what percentage of Indiana's assimilation capacity is being used at the state level and then the county level. Two different scenarios were analyzed in this step. The first is a manure application standard where manure can be applied at 1.5 times the phosphorus assimilation potential of the crop that is going to be produced in that field. For example, corn can assimilate 0.16 pounds of phosphorus per bushel but at the 1.5 level of application level, 0.24 pounds of phosphorus could be applied. This application level in reality builds up soil phosphorus levels with the excess 0.08 pounds of phosphorus that is being applied. The 1.5 level of application is a proxy for the regulations that are currently in place. Over time it is expected that a strict phosphorus application standard will be implemented, resulting in regulations that will only allow phosphorus to be applied in a 1 to 1 ratio with the crop that is using the phosphorus (USDA [c] (1999)). Using the average crop production levels for the 2000 to 2004 period, the state and county levels of phosphorus assimilation capacity used is estimated. In addition to the phosphorus produced by livestock, commercial phosphorus that can be applied is also included in the analysis. Additional factors such as soil types, phosphorus banking, and alternative technologies that might impact assimilation capacity or phosphorus production have not been taken into consideration in this analysis.

At the 1.5 level, or current regulations, Indiana livestock use 14% of the state's estimated assimilation capacity. With the addition of the average commercial phosphorus sold from 2000 to 2004, the state used 61% of its estimated total assimilation capacity. Therefore, with the current regulations, Indiana has the ability to assimilate all of the phosphorus used and produced in the state. However, this assumes that animal nutrients and commercial fertilizers can be applied over all cropland where it can be assimilated in the state, which is not necessarily true. Several constraints like transportation costs and consistency can limit the mobility of animal nutrients in particular.

To determine the potential locales that have excess phosphorus, the data is disaggregated to the county level. The estimated assimilation capacity that is used in each county for livestock (left) and livestock plus commercial fertilizer (right) is shown in Figure 23. Using 2002 livestock inventories, only Martin County had excess phosphorus from livestock production at the 1.5 level standard. After adding commercial fertilizer, the number of counties with excess phosphorus increases to 8. The majority of the counties with excess phosphorus are located in the southern part of the state with several counties dotting the eastern border. The region of the state stretching from Lake County east to St. Joseph County down to Hamilton County and over to Vermillion County has only two counties that are using over 75% of their estimated assimilation capacity. This region of the state has a definite competitive advantage over other regions in the state with respect to unused assimilation capacity. Therefore, under current regulations this would be a desirable region for livestock expansion based on this dimension of the analysis.

What happens if the regulations tighten to a strict phosphorus standard? Using the 2002 livestock inventories, new assimilation capacities were estimated. At a strict phosphorus standard, Indiana's livestock used 21% of the states' estimated assimilation capacity. When commercial fertilizer is added to livestock phosphorus, the state uses 91% of its estimated assimilation capacity. On average, Indiana crops are able to assimilate the phosphorus produced by 2002 livestock inventories at a strict phosphorus standard.

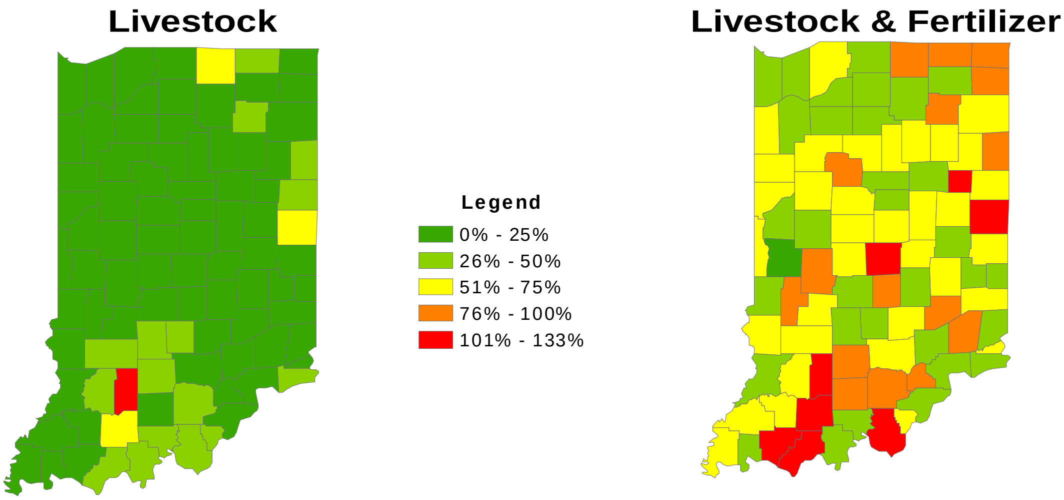

Figure 23: Estimated County Level Assimilation Capacity at 1.5 times the Phosphorus Standard

When this data is disaggregated to the county level, the results are reflected in Figure 24 with livestock phosphorus production (left) and livestock plus commercial phosphorus (right). With the strict phosphorus application standard, the number of counties with excess phosphorus increases to five from just livestock production. With the addition of commercial phosphorus, the number of counties with excess phosphorus increases to 28 - - 30% of the counties in Indiana. The same region as discussed above continues to have a competitive advantage over other regions in the state. This dimension could be a limiting factor to the growth of the livestock industry in the future if a phosphorus standard is implemented and livestock and crop producers are not prepared to make appropriate changes to meet this standard. Substitution of manure for commercial fertilizer, transportation of manure over larger distances, decreased livestock inventories, different crop rotations, different feed rations, and adoption of alternative manure management strategies are just a few of the changes that might have to be made with a change in application standard for counties that have excess phosphorus.

Sensitivity Analysis of Animal Nutrient Production and Assimilation

In the earlier state comparison discussion based on 2004 production, Indiana had excess phosphorus assimilation capacity compared to 2002 when Indiana had excess phosphorus production. There were no significant changes between the two years in livestock inventories, but there was a significant change in the crop production. In 2002, Indiana experienced decreases from the previous year in corn for grain, wheat, hay, and soybean production. All levels of production for corn for grain, silage, soybeans, wheat, and hay were below average for the period 2000-2004 compared to 2004 when all of these crops were above average in production except for wheat. To determine how fluctuations in livestock inventories, crop production, and fertilizer usage impacts the results, ten different cases were analyzed to assess how assimilation capacity was affected.

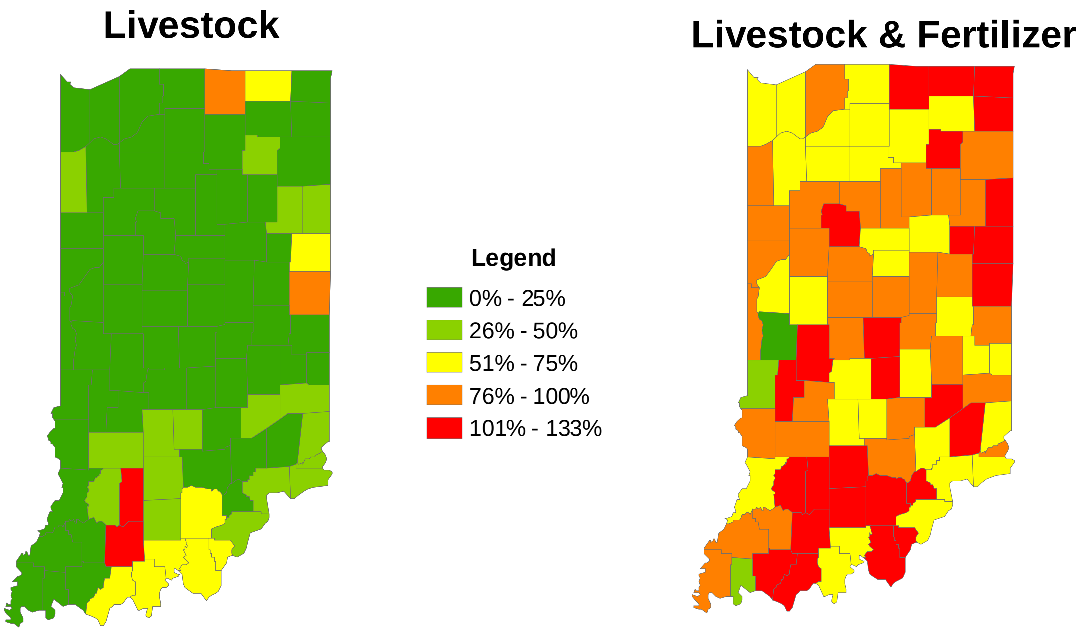

Figure 24: Estimated County Level Assimilation Capacity at Strict Phosphorus Standard

Within the 10 different cases, there were four different variations of crops, three different variation of livestock inventories, and six different variations of fertilizer usage used in this analysis. The base case (Case 1) for this analysis is that all three variables are at levels equivalent to their average from 2000-2004. An average year should consist of livestock using 21% of the states assimilation capacity. The addition of commercial fertilizer increases assimilation capacity used to 93%, as shown in Table 9. However, a change in the crop mix as in Case 8 would allow for more growth in livestock inventories than the base case with all other variables held constant.

The goals of doubling swine inventories and using less than 100% of assimilation capacity are achieved in Cases 7 and 9. In Case 7, there is an increase in crop production for all crops and a decrease in fertilizer usage. Case 9 also involves a change in crop production but it is a change in the acres of soybeans and corn with all other crops held constant at their average and a decrease in fertilizer. Cases 2, 5, and 6 do not allow for the doubling swine inventories, under a strict phosphorus standard. Another case that would allow for the doubling of swine inventories as well as the inventories of all livestock is Case 4. Crop production in this case is maintained at its average level, but the amount of commercial phosphorus is decreased by 40% from its average level. In Cases 8-10 there is a change in crop mix indicated by (60%C, 40%B). This change in crop mix represents an increase in acres of continuous corn grown, fewer soybeans, and all other crops held at their average acreage.

In general in most cases Indiana is able to assimilate all of the phosphorus produced and used in the state at a strict phosphorus standard. This gives Indiana an advantage over other states in the nation that may not even be able to assimilate the phosphorus that livestock produce in the state. From Table 9 it is evident that small changes in fertilizer consumption and crop mixes can influence livestock growth potential.

Table 9: Assimilation Capacity Fluctuations

Case	Crop Variable	Livestock Variable	Fertilizer Variable	Capacity used Livestock	Capacity used Live & Fert
1	Avg	Avg	Avg	21%	93%
2	Avg	D-Swine	Avg	36%	107%
3	Avg	D-All	Avg	53%	125%
4	Avg	D-All	Dec. 40%	53%	96%
5	Avg	D-Swine	Inc. 3%	36%	109%
6	Dec. 10%	D-Swine	Inc. 3%	40%	121%
7	Inc. 10%	D-Swine	Dec. 20%	32%	84%
8	60%C, 40%B	Avg	Avg	20%	89%
9	60%C, 40%B	D-Swine	Dec. 10%	34%	96%
10	60%C, 40%B	D-All	Dec. 20%	51%	113%
Avg = Average; Inc. = Increase; Dec. = Decrease; C = Corn; B = Soybeans; D = Double; All = All Species;					

Summary

Figure 25 summarizes the results of the analysis by crop reporting districts for the state of Indiana for each of the four dimensions – feed price, population density, phosphorus assimilation capacity, and harvesting capacity. The first dimension is feed availability as proxied by corn price; the estimated average corn price for the state is $2.01 so any district that had an average corn price below this level has a competitive advantage. The next dimension is population density; districts that had a lower density than 172 people per square mile or the state average had an advantage. Third is phosphorus assimilation capacity; any district that used below 100% of its assimilation capacity is assumed to have an advantage. Lastly, is processing or harvesting capacity -- the type of processing capacity located in the last column of Figure 25 is recorded. Using these four dimensions an assessment scale is summarized in Figure 25 was used to help determine which region(s) might be best suited for livestock growth. As in the case of the previous synopsis of the state comparisons, this scale is qualitative in nature and does not recognize that some of the drivers may be more or less important compared to others in determining the location of the livestock industry within the state.

	Feed Price*	Population Density**	Assimilation Capacity***	Harvesting Capacity
District	Corn	<172	<100%	Species
NW	X		X	Dairy, Layer
NC	X		X	Swine, Dairy, Layer, Duck
NE	X			Dairy, Layer
WC	X	X	X	
C	X		X	Dairy, Layer
EC	X	X		Dairy
SW		X		Dairy, Turkey, Layer
SC		X		Broiler, Layer
SE		X	X	Layer

*Price < Indian's long term average price of $2.01 bu

** 172 people/mi² is population density for Indiana

*** Capacity Used under strict Phosphorus Standard

Legend

≥ 3 + Pop & Assimilation

< 3

≥ 3 + Pop or Assimilation

Figure 25: Indiana Specific Summarization

NW-Lake, Porter, LaPorte, Newton, Jasper, Starke, Pulaski, White, Benton; NC-St. Joseph, Elkhart, Marshall, Kosciusko, Fulton, Carroll, Cass, Miami, Wabash; NE-Lagrange, Steuben, Noble, Dekalb, Whitley, Allen, Huntington, Wells, Adams; WC-Warren, Tippecanoe, Vermillion, Fountain, Montgomery, Parke, Putnam, Vigo, Clay, Owen; C-Clinton, Howard, Grant, Tipton, Boone, Hamilton, Madison, Hendricks, Marion, Hancock, Morgan, Johnson, Shelby, Rush, Bartholomew, Decatur; EC-Blackford, Jay Delaware, Randolph, Henry, Wayne, Fayette, Union; SW-Sullivan, Greene, Knox, Daviess, martin, Gibson, Pike, Dubois, Posey, Vanderburgh, Warrick, Spencer; SC-Monroe, Brown, Lawrence, Jackson, Orange, Washington, Crawford, Perry, Harrison, Floyd; SE-Franklin, Jennings, Ripley, Dearborn, Ohio, Switzerland, Jefferson, Scott, Clark.

Within Indiana, there are generally no significant locales with feed shortages. The livestock industry only uses 17% of the corn for grain, 17% of the soybeans, 43% of the forage (hay and pasture), and 76% of the silage produced in the state. At the county level, some counties consume more of these feeds than can be produced in the county, but the mobility of feed allows for grain produced outside the county to be shipped in. As to price, higher corn prices occur along the Ohio River and Lake Michigan. The lowest corn prices are in the Northeast corner of the state. In Figure 25, the only districts that do not meet the requirement of $2.01 or lower are along the Ohio River.

Processing capacity and location for each species is the next dimension. The beef industry is the only industry that does not have a federally inspected plant in Indiana, but beef producers do have access to state inspected plants. However, in 2004, federally inspected plants were responsible for 98% of all commercial cattle slaughtered in the United States. Indiana's dairy industry has 23 facilities that process one or more milk products. Specifically, nine facilities process fluid milk, which accounts for 98% of the milk produced in 2004. In addition, Indiana's location relative to the Southern and Eastern seaboards of the United States allows milk to be transported into those milk deficit regions.

Indiana's swine slaughter industry is highly concentrated and dominated by two firms that process 6.8 million head of swine annually, which is more animals than Indiana produced in 2002. This surplus harvesting capacity allows for the inshipment of swine from other states to fill this excess slaughter capacity. Indiana also supplies 65% of the swine slaughtered at the Swift plant in Louisville, Kentucky. The poultry processing industry within Indiana is also highly concentrated. Maple Leaf Farms and Culver Corporation dominate duck production, and Indiana is the largest duck producing state in the nation with over 10 million birds produced in 2004. Two firms that processed over 40 million birds in 2004 do the processing of broilers in Indiana. Purdue Farms and Farbest Farms dominated the turkey industry and processed over 11 million birds in 2004, ranking Indiana 7th in the nation. The layer industry is controlled by five firms, has the 3rd largest laying flock in the nation, and produces enough eggs to rank Indiana 4th in the nation.

In Figure 25, all of the districts within the state except for one - the WC - have some form of processing capacity. Close proximity of production to processing capacity decreases transportation costs, and as the livestock production industries continue to consolidate, the pattern has been to do so in clusters close to processing plants.

The human versus animal interaction is the next dimension. Overall, it appears that counties with higher population densities like Marion County tend to have lower animal densities. However, some counties are exceptions to this pattern - - Benton County for example has among the lowest densities in both categories. As shown in Figure 25, only three districts meet the criteria of human population densities below the state population average. The least populated district in the state is the Southeast (SE) with 100 people per square mile.

Animal nutrient production of Indiana livestock and its assimilation capacity is the next dimension. A gradual shift is occurring from the historically nitrogen based application standard for manure to a phosphorus based application. Once this shift is complete, it will effectively reduce the assimilation capacity of the state by 66%, increasing the need for land to apply manure. Currently Indiana livestock producers are faced with manure application standards that are a mix of both nitrogen and phosphorus based application, determined by the soil test levels of the field on which the manure is to be applied. To represent the current manure application regulations, an application standard of 1.5 times the phosphorus the crop can assimilate was used. At the state level under this regulation, livestock consumed an estimated 14% of the states' total assimilation capacity. The use of commercial phosphorus was then added to the phosphorus produced by livestock, which resulted in 61% of the states' total assimilation capacity being used. At the county level, only one county had phosphorus production in excess of assimilation capacity due to livestock production. But once commercial fertilizer was added, 8 counties exceeded 100% of their assimilation capacity.

To reflect the increasing environmental constraints, the phosphorus application standard was reduced to a 1 to 1 ratio; i.e. phosphorus can be applied only up to a 1 to 1 ratio with the expected utilization of that phosphorus by the crop. Under this more restrictive regulation, the livestock industry produced enough phosphorus to utilize 21% of the states' total assimilation capacity. With the addition of commercial phosphorus, Indiana was using 91% of its total assimilation capacity. At the county level, there were two counties that had excess phosphorus from livestock production only. When commercial phosphorus is added, the number of counties with excess phosphorus increased to 28; 30% of the counties in the state have excess phosphorus. As reflected in Figure 25, only three districts in the state were able to meet the criteria of using less than 100% of their assimilation capacity. The district that used the least amount of its assimilation capacity was the NW district, which consumed 76% of its total capacity.

As summarized in Figure 25, the WC and SE districts have the most potential for growth of the livestock industry based on the criteria noted. The WC district has an abundance of feed, relatively lower corn prices, the third lowest district population density, and excess phosphorus assimilation capacity. The WC district meets three of the four criteria for expansion and the only one that it is missing is processing capacity. However, the district has access to processing capacity for all species in the surrounding regions. The SE district also has an abundance of feed, excess assimilation capacity, forth lowest population density and processing capacity. However it does not have a competitive advantage in corn price do to its location on the Ohio River.

The sensitivity analysis does not fundamentally change the conclusions. On average, Indiana can assimilate all of the phosphorus produced and used in the state. Doubling swine populations and doubling all livestock inventories in the state is also a possibility if Indiana only had to meet the criteria of to be able to assimilate all of the phosphorus.

Conclusions

The qualitative analysis summarized earlier indicates that Indiana does have the potential for growth of the livestock industries. However, some of the constraints on growth may need to be assessed and/or augmented through improved technology or policy to accomplish this goal.

Four dimensions of location and growth potential were analyzed earlier - - feed availability and cost, processing capacity, population and animal densities, and environmental capacity. This analysis compared Indiana to 20 other top livestock producing states on these dimensions. The results indicate that Indiana is a second choice for potential livestock growth along with six other states. Iowa and Kansas were the only two states who have location advantages compared to Indiana. Population density is a major constraint for Indiana; Indiana has a population density of 174 people per square mile, which is 91 people per square mile higher than the national average. Indiana preformed the strongest in nutrient assimilation capacity, only using 82% of its total assimilation capacity under a strict phosphorus based application standard.

Indiana has a relative advantage in feed price and processing capacity for swine. Indiana does not have the lowest prices for corn and soybean meal, but large quantities of these products are grown in the state. The swine processing industry in Indiana is a significant proportion of the nation's swine processing capacity and has excess capacity compared to in state hog production.

Population density will be a key hurdle in the future if Indiana wants to continue growth of the livestock sector. As population continues to increase, it is going to be ever more important to understand the relationships between people and animals.

The same four dimensions of location and growth potential were used to assess county competitiveness within the state, and determine districts in Indiana desirable for livestock growth. For an average crop production year, Indiana as a state can assimilate all of the livestock phosphorus and commercial phosphorus produced and used under current regulation. Furthermore, if the regulations were tightened to a strict phosphorus application standard, Indiana can still assimilate all of the nutrients at 2002 livestock inventories.

At the county level, livestock inventories would use all of the feed grown in the county, but with the increased mobility of feed, this is not a major constraint. A higher corn price for the counties along the Ohio River and around Lake Michigan was the only location disadvantage in the feed dimension.

With the exception of beef, the processing capacity provides Indiana livestock producers with adequate outlets for their livestock. However, Indiana has no federally inspected slaughter facilities for beef, only state inspected facilities. Federally inspected facilities are responsible for

98% of commercial cattle slaughter in the nation for 2004. The swine processing industry has excess slaughter capacity filled by inshipments from other states. Indiana also supplies 65% of the swine that are processed in the Kentucky based Swift plant. The dairy industry has nine fluid milk processing plants in the state, and Indiana's location relative to the eastern and southern seaboards provides opportunities for higher prices in these milk markets. Indiana's poultry industries are very concentrated and the duck, turkey, and layers industries in Indiana are among the highest producers in the nation.

Human population versus animal density comparisons indicates that livestock populations tend to be higher in counties with lower human population. However, it is still unknown what levels of human population density relative to livestock population densities are sufficient to restrict growth.

Analysis of animal nutrient production and assimilation capacity at the county level indicates that under current regulations, only 8 counties in Indiana have excess phosphorus considering both animal phosphorus and commercial phosphorus. If regulations were tightened as is projected to occur in the future, an estimated 28 counties would have excess phosphorus when livestock phosphorus and commercial phosphorus are combined.

When the county level data on constraints is aggregated to a district level, the WC and SE districts of Indiana are the strongest candidates as locations to increase livestock production. The WC district has an abundance of feed, the third lowest population density, and excess nutrient assimilation capacity. This district does not have any processing capacity, but processing capacity for all species is available in the adjoining districts. The SE district has an abundance of feed, the forth lowest population density, and processing capacity. However this district does have higher corn prices because of its location on the Ohio River.

Strategy Recommendations

Based on the analysis previously summarized, several strategies could be employed to stimulate or continue the growth of Indiana livestock industries.

1. Work with processing plants and determine the possibilities of locating new processing plants or expanding existing facilities. Indiana has a competitive advantage in swine processing, but it does not have any federally inspected beef processing facilities. This is a limiting factor to the growth of the cattle industry in Indiana since in 2004, 98% of all cattle slaughtered in the United States were slaughtered in federally inspected plants.

2. Work with community leaders and policy makers to education them about the livestock industry, and enable community leaders to educate the livestock industry on their concerns about the livestock industry. As the human population of Indiana continues to increase, it is going to become evermore important to understand the relationship between people and livestock. Several states that have witnessed significant increases in livestock population have relative low population densities.

3. Promote the value of manure nutrients and encourage the substitution of manure for commercial fertilizer, or find ways to blend manure with commercial fertilizers. Indiana livestock alone does not produce enough phosphorus to meet the states demand for phosphorus, but the livestock industry is a significant supplier. In addition, work with the commercial fertilizer industry to identify strategies that will benefit both livestock producers and commercial fertilize dealers. Data indicates that manure is not as widely used as a source of fertilizer as it could be.

4. Work with researchers to find ways to change the nitrogen and phosphorus ratios in the manure. If environmental regulations are tightened to a 1 to 1 ratio, than even more states and Indiana counties will find that they are going to have to find alternative methods to handle the excess phosphorus.

5. Work with researchers to find methods to do real time testing of manure nutrients. Real time testing would allow farmers to use site specific management for manure application.

6. Work with researchers to find new technologies for manure management. Furthermore, determine if current manure management technologies are financially feasible.

Limitations of Study and Further Research

As with any study, the analysis could be improved. First, data problems were encountered. Reporting errors at the county level can be a problem when using the Census of Agriculture. The general reporting procedure is that livestock and crops are reported where the headquarters of the operation is located (Wilson (2005)). This may or may not be the same county where production took place. Commercial fertilizer sales from the Office of Indiana State chemist have the same limitation (Hancock (2005)). However, it was necessary to disaggregate to the county level so that counties that have potential excess phosphorus could be identified.

Another limitation is that not all of the livestock species and crops were used to estimate assimilation capacities. This leads to an under-estimation of livestock phosphorus production and assimilation capacity of crops. For Indiana it is believed that these are not major issues because all major crops produced in the state that typically receive manure have been included, and all major livestock groups in the state have been included as well. The horse industry is the only industry that may have a significant impact on livestock phosphorus production. As for other states, crop and livestock combinations differ by state and may be a source of error. Lack of information is the major constraint on being able to account for all livestock and crop production.

An additional limitation is that this study does not take into account specific county ordinances or Environmental Protection Agency regulations that may affect the growth of the livestock industry in a specific location. Counties have the opportunity to zone specific areas of the county for livestock production. In addition, they may have regulations on odor levels, size, and manure handling practices. Waterways that are on the 303D list specified by the EPA can also have an impact on a county's flexibility to zone an area for livestock production.

Further research should be conducted to determine the effect of new ethanol plants on livestock production. How will the construction of an ethanol plant affect the corn basis in the counties surrounding the plant and thus feed costs? Where are these new ethanol plants going to market their by-product? Limited research has been done in this area and it is still unclear which livestock industry is going to be able to use the by-product efficiently. Can these ethanol plants produce a by-product that is consistent, because without consistency the efficiency of a precise ration could be lost? Current research shows that ethanol by-products have elevated levels of phosphorus, and for livestock producers who already might have a phosphorus problem, this could only add to it. Can ethanol plants find a way to reduce the phosphorus levels in their by-products?

The human versus animal interaction as a constraint on expansion of livestock production also needs further analysis. Numerous studies have been completed on the effects of confined animal feeding operations on land prices and other issues that neighbors to these operations feel are important. Further analysis is needed to determine at what point human or animal populations become sufficiently high to create conflicts between livestock producers and neighbors.

Further research could be conducted on how to change the ratio of nitrogen to phosphorus in livestock manure and find methods to make it a more consistent product. Products such as phytase will help some livestock species more efficiently use phosphorus, but other additives and technologies need development and analysis. The issue of consistent manure has plagued the livestock industry for years. Without a consistent product, the cost of manure application is increased due to the need for increased testing and labor. Further research should also be conducted on the feasibility of using alternative manure handling methods.

Case studies at the farm level could also be done to examine how a change in environmental regulations, increase in human population, rising feed prices, and rising fertilizer costs affect the individual farm. A farm level analysis would be the preferred method to analysis the United States livestock industry, but lack of data makes this difficult if not impossible. However, in farm level case studies, the impact of individual determinants on different size farms could be analyzed.

Finally, this study analyzed nutrient assimilation capacity in 21 states. Further study should examine all 50 states. Such a study should include animal nutrients as well as the usage of commercial fertilizers to accurately assess phosphorus use and assimilation capacity.

List of References

Abdalla, C. W., L.E. Lanyon, and M.C. Hallberg. "What We Know about Historical Trends in Firm Location Decisions and Regional Shifts: Policy Issues for the Industrializing Animal Agriculture Sector." American Journal of Agriculture Economics. 77(December 1995):37-52.

American Society of Agricultural Engineers Standard (ASAE). "Manure Production and Characteristics." Pub# D384.1. 2005.

Applegate, Todd. Purdue Animal Scientist. Personal Interview. August 2005.

Besanko, David, David Danove, and Mark Shanley. "Economics of Strategy." 2nd ed. *John Wiley & Sons, Inc.* 2000.

Brennan, Paul. Executive V.P. Indiana State Poultry Association. December 2005.

Bock, B. "Fertilizer Nutrient Value of Broiler Litter Ash. From Appendix B of Economic and Technical Feasibility of Energy Production from Poultry Litter and Nutrient Filter Biomass on the Lower Delmarva Peninsula." *Northeast Regional Biomass Program.* 1999. http://www.nrbp.org/pdfs/pub20b.pdf. Accessed November 2005.

Boland, Michael A., Paul V. Preckel, and Kenneth A. Foster. "Economic Analysis of Phosphorus-Reducing Technologies in Pork Production." *Journal of Agricultural and Resource Economics* 23(December 1998): 468-482.

Brown, Dennis and Eileen Stommes. "Rural Transportation: Infrastructure." *Economic Research Service.* 2003. http://www.ers.usda.gov/Briefing/Transport/transinfra.htm , accessed October 2005.

Clark, Edward. "New Regs Demand Manure Application Changes." *The Digest.* November 1, 2005. http://cornandsoybeandigest.com/mag/soybean_new_regs_demand/ , accessed December 2005.

Davis, G., Jr. "Feeding Broiler Litter to Beef Cattle." *University of Arkansas, Division of Agriculture, Cooperative Extension Service.* 1999.

Drabenstott, Mark, Mark Henery, and Kristin Mitchell. "Where have all the Packing Plants Gone? The New Meat Geography in Rural America." *Economic Review.* 3rd Qrt. 1999.

EREN/DOE. "Technologies – Gasification." *Biopower, Energy Efficiency and Renewable Energy Network, U.S. Department of Energy*. 2000.

Flora, Cornelia B., Wynne Wright, et. al. "Technical Work Paper on Social and Community Impacts." 2001. http://www.eqb.state.mn.us/geis/TWP_Social.pdf accessed December 2005.

Hancock, Michael. Office of the Indiana State Chemist. Personal Interview. September 2005.

Herath, Deepananda P., Alfons J. Weersink, and Chantal L. Carpentier. "Spatial and Temporal Changes in the U.S. Hog, Dairy, and Fed-Cattle Sectors, 1975-2000. *Review of Agriculture Economics.* Vol. 27, No. 1, 49-69.

Hurt, Chris. Purdue Agricultural Economist. Personal Interview. November 2005.

Indiana Agricultural Statistics (IASS) 2003-2004. Compiled by Indiana Agricultural Statistics Service. West Lafayette, Indiana: Purdue University, 2005.

Indiana State Department of Agriculture (ISDA). "Possibilities Unbound: The Plan for 2025". 2005. http://www.in.gov/isda/strategic_plan/In_strategic_plan_final.pdf , accessed November 2005.

Johnson, K.D. Purdue University Agronomist. Personal Interview. October 2005.

Joern, Brad. Purdue University Agronomist. Personal Interview. May. 2005.

Kellogg, Robert L., Charles H. Lander, David C. Moffitt, Noel Gollehon. "Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States." *U.S. Department of Agriculture, Natural Resource Conservation Service.* 2000. www.nhq.nrcs.usda.gov/land/index/publication.html. Accessed May 2005.

Lemenager, Ron. Purdue University Animal Scientist. Personal Interview. August 2005.

Linn, James. G. et.al. "Feeding the Dairy Herd." *University of Minnesota Extension Service."* publication 346. 2002. http://www.extension.umn.edu/distribution/livestocksystems/DI0469.html. Accessed June 2005.

Martin, L.L., and P.E. Norris. "Environmental Quality, Environmental Regulation and the Structure of Animal Agriculture." *Feedstuffs* 70, No.18(1998):29-34.

Michigan State University. "Nutrient Recommendations for Field Crops in Michigan." *MSU Extension Bulletin E2904.* May 2004.

National Fertilizer Institute. "Commercial Fertilizers 2004." 2005.

National Pork Board. “Estimated Daily U.S. Slaughter Capacity.” http://www.pork.org/NewsAndInformation/QuickFacts/porkFactPDFS/pg77.pdf. Accessed May 2005.

Nedham, Joe. Personal Interview. November 2005.

Office of Indiana State Chemist (OSIC). “Total Fertilizer and Nutrients by County.” 2002. http://www.isco.purdue.edu/. Assessed June 2005.

Peters, John. “Fertilizer Grade and Calculations.” 2005. http://www.soils.wisc.edu/extension/teachingmaterials/Peters/Fertilizer%20Grade%20Slides%202005.ppt#263,1,Fertilizer Grade and Calculations. Accessed December 2005.

Prince Edward Island. “Guidelines for Manure Management for Prince Edward Island.” 2000. http://www.gov.pe.ca/af/agweb/index.php3?number=70588. Accessed September 2005.

Purvis, A. “An industrializing Animal Agriculture: Challenges and Opportunities Associated with Clustering.” In S. Wolf, ed. *Privatization of Information and Agricultural Industrialization.* Boca Raton, FL: CRC Press, 1998, 117-150.

Richert, Brian. Purdue Animal Scientist. Personal Interview. August 2005.

Ribaudo, Marc, et. al. “Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land.” *U.S. Department of Agriculture, Economic Research Service.* No. 824. 2003.

Roe, Brian, Elena G. Irwin, and Jeff S. Sharp. “Pigs in Space: Modeling the Spatial Structure of Hog Production in Traditional and Nontraditional Production Regions.” *American Journal of Agriculture Economics.* 84(May 2002). 259-278.

Schutz, Mike. Purdue Animal Scientist. Personal Interview. May 2005.

Thünen, Johann von. “Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie” 3rd ed. 1875.

Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa. Michigan State University Extension. Pub# E-2567. 1996.

University of Nebraska, Lincoln (UNL). “Composting Manure and Other Organic Residues.” 1998. http://ianrpubs.unl.edu/wastemgt/g1315.htm. Accessed September 2005.

U.S. Department of Agriculture [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.

U.S. Department of Agriculture [b], National Agricultural Statistics Service. *Livestock Slaughter 2004 Summary*. March 2005.

U.S. Department of Agriculture [c], Environmental Protection Agency. “Unified National Strategy for Animal Feeding Operations. 1999.

U.S. Department of Agriculture [d], Economic Research Service. “State Fact Sheets.” http://www.ers.usda.gov/StateFacts/. Accessed July 2005.

U.S. Department of Agriculture [e], Nature Resources Conservation Service. “Definition of Animal Units.” http://techreg.sc.egov.usda.gov/NTE/TSPNTE2/AnimalUnits.html. Accessed August 2005.

U.S. Department of Agriculture [f], National Agricultural Statistics Services. “Cattle.” January 2005.

U.S. Department of Agriculture [g], National Agricultural Statistics Services. “Quarterly Hogs and Pigs.” December 2004.

U.S. Department of Agriculture [h], National Agricultural Statistics Services. “Turkeys Raised.” January 2005.

U.S. Department of Agriculture [i], National Agricultural Statistics Services. “Poultry-Production and Value 2004 Summary.” April 2005.

U.S. Department of Agriculture [j], National Agricultural Statistics Services. “Chickens and Eggs 2004 Summary.” February 2005.

U.S. Department of Agriculture [k], National Agricultural Statistics Services. “Crop Production 2004 Summary.” January 2005.

U.S. Department of Agriculture [l], Agriculture Marketing Service. “Federal Milk Order Principal Pricing Points, with Class I Differentials.” http://www.ams.usda.gov/dyfmos/mib/prin_prc_pt_dff.pdf. Accessed October 2005.

U.S. Department of Agriculture [m], National Agricultural Statistics Service. “Milk Production, Disposition, and Income 2004 Summary.” April 2005.

U.S. Department of Agriculture, Farm Service Agency. “National Loan Rates.” http://www.fsa.usda.gov/dafp/psd/LoanRate.htm. Accessed June 2005.

U.S. Department of Agriculture, National Agricultural Statistics Services. “Agricultural Prices.” April 2005.

U.S. Department of Agriculture, National Agricultural Statistics Services. “Dairy Products 2004 Summary.” April 2005.

USPEA. “Environmental Framework and Implementation Strategy for Poultry Operations: A Voluntary Program Developed and Adopted by the Poultry Industry.” *Meeting of the Poultry Industry Environmental Dialogue.* U.S. Poultry and Egg Association. 1998.

Weber, Alfred. “Theory of the Location of Industries.” translated 1929.

Wilson, Steve. Indiana Agriculture Statistics Service. Personal Interview. September 2005.

2002 Census of Agriculture. National Agricultural Statistical Service (NASS). 2002.

Appendix A: Literature Review

Theoretical Framework

A Five-Forces Analysis is used in both the state comparison and the Indiana specific portions of this study. The five forces, as seen in Figure 26, include: internal rivalry, entry, substitute and complementary products, supplier power, and buyer power. This framework provides a simple and efficient qualitative method to determine the threats to the growth of Indiana's livestock industries.

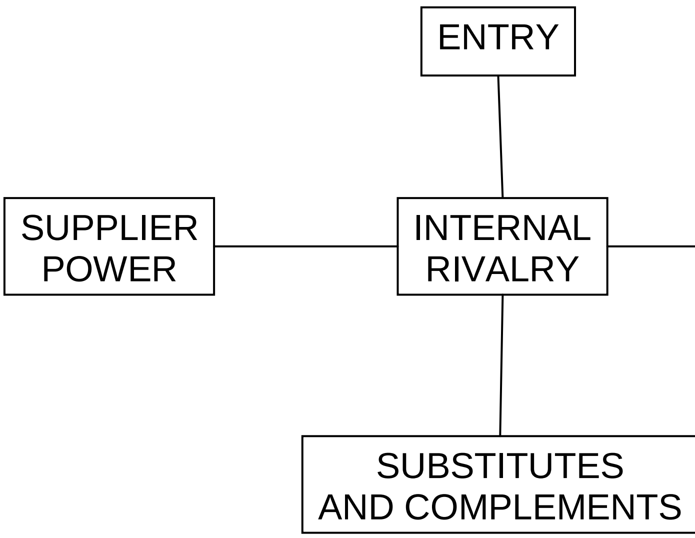

Figure 26: The Five-Forces Framework for Industry Evaluation

According to Besanko, et. al. (2000) the five forces framework provides a tool to systematically assess the status and the potential evolution of an industry. Internal rivalry deals with the positioning of firms to gain market share. Factors influencing internal rivalry are number of sellers in the market, cost structure of firms, firm production capacity, and strong exit barriers. Entry refers to the ease with which firms can move in and out of an industry. This is affected by brand loyalty, access to key inputs, experience, government regulations, network externalities, and economies of scale. Substitutes and complements examine the affect that products outside the industry can have on the industry under evaluation. Factors influencing this are availability of close substitutes or complements and price elasticity of industry demand. Supplier and buyer power refers to upstream and downstream firms' impact on the industry. This is influenced by concentration of industry, availability of substitute inputs, relationship with suppliers/buyers, threat of integration, and ability of suppliers to price discriminate.

This basic qualitative framework for five-forces analysis is adapted as seen in Figure 2 to help in the evaluation of Indiana's potential for livestock growth. The new framework allows for a systematic analysis of five key forces that shape the livestock industry in Indiana and the United States.

Location theory is the second theoretical framework that is used in both the state comparison and the Indiana specific portions. The goal of location theory is to understand the drivers and determinants of industry and firm location. Location theory can be used to determine other constraints on an industry as this study does.

Transportation costs are a key variable in location theory according to Thünen. He found that the most one could pay for land rent is the price of the product at the market place minus the transportation costs as shown in Figure 27. Economic activity will locate itself around cities according to its ability to pay for land. This idea is still evident today as we see in general retail, residential, manufacturing, and agriculture forming rings around cities.

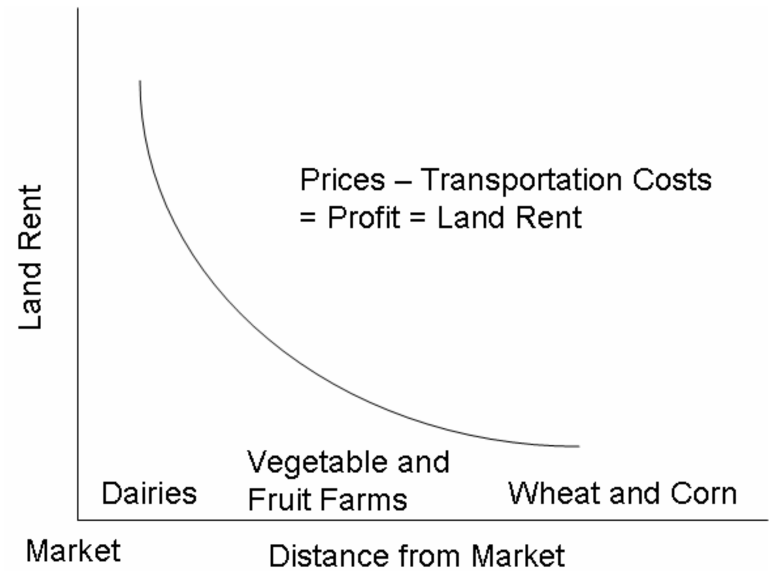

Figure 27: Thünen's Rent Curve for Land

Alfred Weber added to Thünen's theory by recognizing that location can be affected depending on whether the process is weight gaining, losing, or neutral. A weight gaining process would be distillers grains from the production of ethanol and as such this industry would want to be located as close to the livestock industry as possible to minimize shipping costs of a heavier product. In weight losing industries like the livestock processing industry, locating close to livestock production as possible to decrease shrinkage and transportation costs is desirable. In a weight neutral industry inbound and outbound transportation costs should be the same, therefore making location not as important.

Availability/Mobility of Feed Grains

The United States is a world leader in corn and soybean production. In 2004, the United States produced over 11 billion bushels of corn for grain and 3 billion bushels of soybeans (USDA [a]). To move these large quantities of grain the United States has developed an infrastructure of roads, railroads, waterways, and airports that allow for an efficient mode of transportation for these bulk commodities according to the Economic Research Service (Brown (2005)). This infrastructure allows the United States to move grain around the United States and the World to be processed or used as feed.

The quantity of grain as well as numerous factors (transportation cost, location, production, processing, and etc.) impact the price of grain in a locale. Using county loan rates from the Farm Service Agency (FSA), which should account for all of these factors, a map of the United States can be developed that shows the variation in prices (mainly corn) across the nation. From this, inferences about regions or locales of the United States that have lower feed prices can be developed. In addition, at the state level rations for each of the species can be developed allowing for estimates of feed consumption in each county to be calculated.

Shifts in Meat Production and Processing

Drabenstott, et. al. (1999) analyze the changes that have taken place in the meat production and packing industry over the last three decades as well as the change that might occur in the future. Traditionally, meatpacking plants were found in Midwestern urban centers like Chicago, but packing plants have left urban centers for new homes in rural towns. Poultry processing has moved to the Southeast, beef packing to the Great Plains, and pork still has a focus in the Midwest with minimal shifts to the Southeast and Great Plains.

The meat packing industry has followed the production of livestock to areas of the United States that provide the opportunity to expand operations and achieve economies of scale. Slaughter companies continue to consolidate the number of firms and build larger plants. The meatpacking industry is roughly ten times more concentrated geographically than it was in the early 1960's (Drabenstott, et. al. (1999)). Some of the reasons for this shift in meatpacking are population pressure in urban areas as well as the need for more open space to accommodate the manure nutrients produced by large-scale livestock operations.

This exodus from urban centers to rural America has provided substantial economic development opportunities for those communities that are able to attract new processing plants. However, these new plants do not come without debates concerning social impacts and the environmental issues that surround locating a packing plant in a community.

Herath, et. al. (2005) analyzed shifts that have taken place in the hog, dairy, and fed cattle sectors in the United States from 1975 to 2000. They found that inventories of hog and dairy are increasing in nontraditional states. For example, from 1990-2000 the Rocky Mountain region[27] experienced a 183% increase in hog inventories (USDA [a]). Reasons they proposed for these shifts are public policy in accordance with environmental regulations and subsidies farmers may or may not receive for producing livestock in that region. They found that hog and dairy sectors exhibited a pattern of decreasing regional concentration due to the entrance of non-traditional states. For the fed-cattle sector regional concentration increased as traditional regions played a larger role.

Abdalla, et. al. (1995) found that constraints such as climate, land availability, and feed availability have been weakening as determinants of the location of livestock production and processing due to technological advances. This in turn has weakened the competitive advantages that some regions of the United States historically have had in livestock production. Roe, et. al. (2002) found that processing plants are significant drivers of livestock location. As processing

[27] Rocky Mountain region includes Colorado, Idaho, Montana, Utah, and Wyoming

continues to consolidate and increase in size to achieve economies of scale, clusters or pockets of livestock production are created around those plants. Reasons for this clustering according to Purvis (1998) are cost reductions from economic coordination, economies of size for both production and processing, and savings in transportation costs. Purvis (1998) and Martin and Norris (1998) also found that new production facilities are likely to be sited in places where populations are sparse, land prices relatively low, and regulatory pressures are low.

Drabenstott, et. al. (1999) find that the future of the meat animal industries in the United States is not clear. As environmental regulations in some states continue to tighten, there has been discussion of animal production and processing moving out of the United States. Some countries that have been mentioned as possible locations are Canada, Mexico, and Brazil. Overall, it seems that livestock production will continue to concentrate in locations that will allow them to continue to expand and the packing plants will follow.

Community Issues Relative to Livestock Production

Community perception of the livestock industry and even of individual producers can have significant effects on the ability to expand or start a new livestock operation. Numerous factors such as decreased land values, number of spills, odor, increased traffic, and a change in community population dynamics can influence the publics' opinion of livestock operations.

Flora, et. al. (2001) found conflicts between producers that want to construct or expand large-scale operations and the neighbors that surround the proposed operation. They also found that there can be sources of conflict between two livestock producers. In one case they found livestock producers saw that the industrialization of livestock positively affected their farming operation and increased their quality of life. Meanwhile, other livestock producers in the county were against the idea of the industrialization of agriculture because they saw it as a threat to their way of life. Flora, et. al. (2001) found from the interview surveys of livestock producers and community leaders in Minnesota five common themes, which characterize the conflict - - - changes in animal agriculture, quality of life impacts, community interaction, future of animal agriculture, and changes in population dynamics.

Livestock Industry Structure Relative to Phosphorus Assimilation Capacity

Kellogg, et. al. (2000) access two dimensions of the livestock industry; the first being trends in livestock operations, and the second manure production and assimilation potential of cropland. They found that in the past two decades, the livestock industry in the United States has been going through significant changes with respect to concentration and location. From 1982 to 1997 the number of livestock operations in the nation decreased by 24% with the majority of the decrease coming from livestock operations with less than 50 total animal units. Meanwhile, the number of animal units[28] in the United States remained constant. The only areas of the nation that experienced growth in the number of livestock operations are eastern Texas, Oklahoma, and the Mountain States.

---

[28] The basis for Animal Units (AU) is 1,000 lbs

The increase in livestock concentration has lead to the concentration of manure nutrients prompting a heightened awareness of environmental concerns. Excess levels of both nitrogen and phosphorus in the soil can lead to leaching of these nutrients into the ground water. Kellogg, et. al. (2000) provided a farm level and county level analysis for the entire United States. Poultry operations have experienced the largest growth in the production of manure nutrients due to growth of the industry combined with the fact that poultry manure contains two to four times the nutrients compared to other species. They found that in 1997, 73 counties had excess nitrogen and 160 counties had excess phosphorus in the US. This was an increase from the 36 counties with excess nitrogen and 102 counties with excess phosphorus in 1982. The utilization of animal nutrients is becoming ever more important as the livestock industry continues to trend toward larger and fewer operations.

In a related study, Ribaudo, et. al. (2003) assessed the cost for different regions in the United States to comply with a switch from nitrogen to a phosphorus based manure application standard. In a farm level analysis of swine and dairy CAFOs, they found that production costs could double if manure application standards are changed from nitrogen to phosphorus based. This results from the increased need of land for phosphorus application because manure contains higher concentrations of phosphorus relative to nitrogen. The increase in production cost also depends on whether or not banking[29] of phosphorus in the soil is permitted.

Species and region[30] can also have an impact on the increase in production costs related to animal nutrient disposal. They found that production cost increases could be the lowest (and in some cases zero) in the Corn Belt due to crop production that can absorb the nutrients and lower livestock concentrations. Costs would be the highest in the Mid-Atlantic where livestock densities are higher and cropland is not readily available. The main problem with areas that have higher livestock concentrations is the availability of land for the application of manure, which is still the predominate method for the disposal of manure (USDA [c] (1999)). Another problem that Ribaudo, et. al. (2003) cite is the willingness of farms to accept or apply manure to their land. Some key concerns about applying manure are its uniformity, soil compaction from application equipment, and odor. They found that across all levels of willingness to apply manure that the Corn Belt had the lowest net production costs.[31] There are three reasons for this. 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, is that allowable nutrient levels are higher in the Corn Belt because the crops grown in the region use large amounts of nitrogen and crop yields in this region tend to be higher.

All of these issues are shaping the future of the livestock industry in the United States. In regions that could experience significant increases in production costs (specifically manure management), farmers and stakeholders are experimenting with alternative methods to handle

[29] Banking – permitted to apply more phosphorus than the crop being grown in the field can assimilate

[30] Regions – Eastern Corn Belt includes IL, IN, MI, OH, WI. Western Corn Belt includes IA, KS, MN, MO, NE, SD. Mid-Atlantic includes NC, SC, VA. South includes AL, AR, GA, KY, TN. West includes CO, OK, UT

[31] Willingness to apply manure is a scale ranging from 0-100%. They use this scale to examine what happens to production costs as the number of farmers willing to apply manure moves from zero to all farmers willing to apply manure.

manure. Ribaudo, et. al. (2003) found that this might be a result of increasing cost of transporting manure further from the operation so that it can be applied at a phosphorus standard. In the future, they suggest that constraints on land available for manure application and increasing manure management costs may lead to livestock operations moving to regions with more land and lower costs.

In this study, an updated version of the Kellogg, et. al. (2000) is completed but several different techniques are used. First, the Kellogg study uses farm level data, which the public does not have access to and some farms had to be omitted do to confidentiality. Here we use the 2002 Census of Agriculture, because it is publicly available, disaggregated to county level, and has information on both crop and livestock production. Second, the Kellogg, et. al. (2000) study uses animal units[32] to aggregate over species, but their particular definition of animal units does not contain some important disaggregations of the different species. For example, in the Kellogg, et. al. (2000) analysis, milk cows are treated as one category, but in reality, there is a large difference in the nutrient excretion of a lactating dairy cow versus a dry dairy cow. Table 10 provides an example of the different calculation methods used in the Kellogg, et. al. (2000) study and this study. Third, Kellogg, et. al. (2000) do not account for any commercial fertilizer usage in their study; this analysis includes both animal manure and commercial fertilizer as sources of nutrients.

Table 10: Phosphorus Production Comparison[33]

Study	Tons of Manure per Animal per year as excreted	Pounds of Phosphorus per Ton of Manure
Kellogg et.al., 2000	15.24	1.92
This study	37.3	2.23

Alternative Technologies/Uses for Manure

As the livestock industry continues to become more concentrated in different regions of the country, new and improved technologies for handling manure nutrients are also being used to relax some of the environmental constraints that might be faced. In "Alternative Technologies/Uses for Manure *Draft*" by the Environmental Protection Agency (EPA) they classify alternative manure handling technologies into the three basic groups: 1) treatment technologies, 2) conversion to value-added products, and 3) conversion to energy source.

A study by Prince Edward Island (2000) indicated that treatment processes fall into three categories: physical, chemical, and biological. All of these treatment processes have the purpose of stabilizing the manure to help solve odor issues, recover nutrients, kill pathogens, kill weed seeds, increase value, decrease volume, and prepare manure for transportation. Physical treatment involves the separation of liquids from solids by using equipment such as a centrifuge. Chemical treatment involves using coagulants to bring manure solids together so that they settle

[32] Animal Units – the basis for this is 1000 lbs of live animal weight
[33] Source: ASAE Standards provides the excretion values for this study

faster. Biological treatment involves the use of naturally occurring microorganisms and this can be done with biodrying, anaerobic digestion, anaerobic lagoons, and aerobic lagoons.

The second group of methods is the conversion of manure to value-added products. Composting is one such value-added method; through composting an odorless, low-moisture-content, fine textured product is created and it can be sold as bulk or bagged fertilizer (UNL (1998)). Another value-added process is pelletizing also known as extrusion. The processing of pelletizing converts manure into a dry, pathogen-free, easy to handle, finished product that has numerous uses (USPEA (1998)). Livestock feed additives is another value-added conversion: for example, broiler litter is a good source of protein and energy for ruminant animals and is currently an accepted practice (Davis (1999)).

The third group of methods is the conversion and use of manure as an energy source. Gasification is one such method. Several different gasification processes can be used. The gas produced from this process can be used in wide range of power systems (EREN/DOE (2000)). In addition, the by-product or ashes produced are high in phosphorus concentrations and can be transported more economically because of their condensed form (Bock (1999)). Another energy use for manure is cofiring. Cofiring involves the simultaneous combustion of a supplementary fuel, such as manure, with wood or coal. The by-product of cofiring is an ash that is both rich in potash and phosphate, which is an environmentally friendly fertilizer. Anaerobic digestion is a third energy conversion method. Biogas is formed during the process and captured so that it can be used to generate electricity used in the facility or sold back to the local grid. This method also involves treatments to create an end product that is uniform and is a high-quality fertilizer. The last energy method is the production of methanol or in this case biomethanol when using manure. Biomethanol production is very expensive and as of 1995, was not commonly produced in the United States.

In addition, these three major categories, innovative technologies such as algae production, aquaculture, building materials, and flowerpot ornaments are being adopted as nutrient management strategies. Many of these technologies are still in the early stages of their adoption and still need further research.

<u>Summary</u>

The two theoretical frameworks used to analyze the determinants are discussed in this appendix. In addition, the relevant literature used to determine what the major determinants would be is discussed. While many studies have examined each of these determinants independently, this study focuses on the combination and interaction of the four major determinants of livestock industry location.

Appendix B: Data and Methodology

State Comparison Methodology

There are four dimensions used to analyze the location and growth potential in the state comparison portion of this study - - feed, harvesting capacity, population and animal densities, and environmental capacities. The states listed in Figure 28 are used for the Five-Forces competitive analysis. These states were chosen based on the criteria that they are the fastest growing states in absolute livestock inventories from 2000-2005. The top six states for each of the different livestock species are shown in Figure 29 but to limit the scope, only the top two states for each species were used. Because of incomplete information, the top six fastest growing states for each poultry type could not be determined; consequently for the poultry industry five additional states were added. These states may not be the fastest growing states in poultry numbers, but are some of the top poultry producing states in the nation. The added states are Arkansas, Georgia, Ohio, Pennsylvania, South Carolina, and West Virginia. In addition, Illinois, Kentucky, and Wisconsin were added to the analysis because of their location relative to Indiana and the fact that traditionally they have been significant livestock producers in the United States.

Arizona	Minnesota
Arkansas	Mississippi
California	North Carolina
Georgia	Ohio
Idaho	Oklahoma
Illinois	Pennsylvania
Indiana	South Carolina
Iowa	Texas
Kansas	West Virginia
Kentucky	Wisconsin
Michigan	

Figure 28: States for Comparison

Beef Cow Inventory (Absolute Change)			Steer Inventory (Absolute Change)			Dairy Cow Inventory (Absolute Change)		
Rank	State	Head	Rank	State	Head	Rank	State	Head
1	Oklahoma	157,000	1	Texas	170,000	1	California	250,000
2	Mississippi	99,000	2	Arizona	120,000	2	Idaho	103,000
3	Kansas	58,000	3	Wisconsin	50,000	3	New Mexico	82,000
4	Arkansas	56,000	4	Oklahoma	40,000	4	Arizona	30,000
5	Virginia	54,000	5	Arkansas	20,000	5	Oregon	30,000
6	Tennessee	44,000	6	Mississippi	15,000	6	Kansas	22,000
All Hog Inventories (Absolute Change)			**Breeding Hogs (Absolute Change)**			**Market Hogs (Absolute Change)**		
Rank	State	Head	Rank	State	Head	Rank	State	Head
1	Iowa	1,200,000	1	North Carolina	20,000	1	Iowa	1,250,000
2	Minnesota	700,000	2	Oklahoma	20,000	2	Minnesota	700,000
3	North Carolina	600,000	3	Texas	15,000	3	North Carolina	580,000
4	Kansas	190,000	4	Arizona	14,000	4	Kansas	195,000
5	Utah	140,000	5	Utah	12,000	5	Utah	128,000
6	Arizona	127,000	6	Mississippi	7,000	6	Arizona	113,000

Figure 29: State Rankings for Absolute Change from 2000-2005[34]

[34] Source: NASS

Feed Availability and Prices

For the state comparison, this dimension analyzes the distribution of corn and soybean production and it examines the differences in the price of corn and soybean meal by state. The distribution of corn and soybean production is determined for each state using the "Crop Production 2004 Summary" report. States included in this study accounted for 68% of both corn and soybeans produced in the nation. Iowa was the largest producer of corn, while Illinois was the largest producer of soybeans for 2004.

Corn prices for each state are estimated using the 2004 loan rates published by the Farm Service Agency (FSA). The estimated corn prices can then be compared to the national loan rate of $1.95 to compute the estimated corn basis differential for each state. California had the highest estimated corn prices of $2.56 per bushel, while Minnesota had the lowest at $1.82 per bushel in 2004. To determine the price of soybeans the "Agricultural Prices" report was used. This report is disaggregated by state but by production region as shown in Figure 30. Therefore, all states within the same region are assumed to have the same price for soybean meal. The national average price paid for soybean meal is $19.60 per ton.

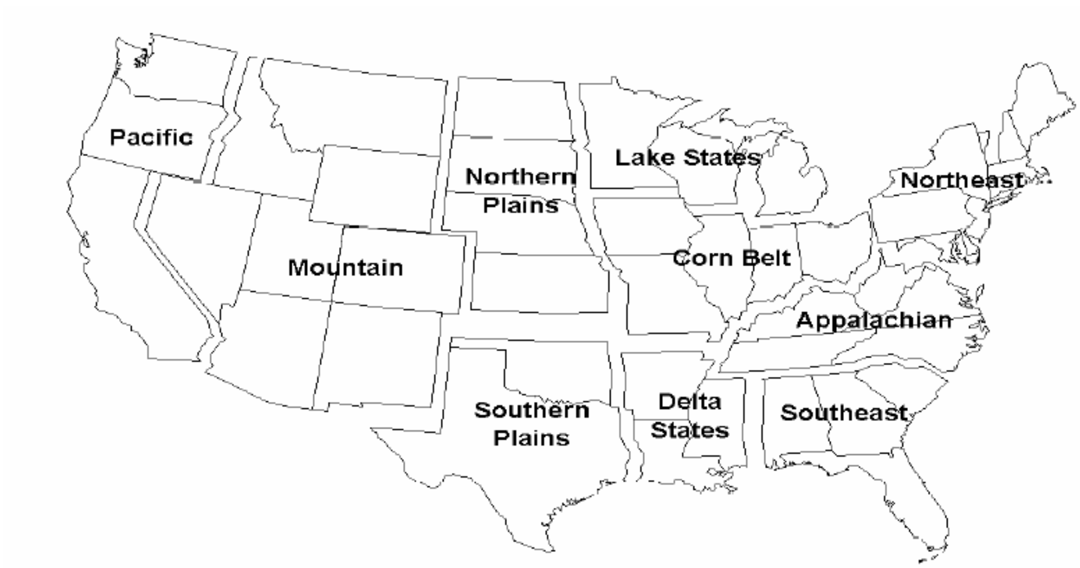

Figure 30: United States Production Regions[35]

Harvesting Capacity

To measure the harvesting capacity of the state the "Livestock Slaughter 2004 Summary" is used. This report gives the total head slaughtered in both federally and non-federally inspected processing plants for cattle, calves, and swine by state. Using this data the various states' percentage of head slaughtered nationally can be calculated. Then states with advantages in the processing of different livestock species can be determined. The 21 states included in this study account for 55% of the total cattle slaughtered and 76% of the total swine slaughtered in the nation for 2004. Kansas with 7.1 million head and Texas with 6.1 million head slaughtered were

[35] Source: NASS – "Agricultural Prices"

the two largest cattle slaughtering states in this study. For total swine slaughtered, Iowa had 29.8 million head and North Carolina had 10.7 million head slaughtered in 2004. The states with the largest number of federally inspected plants were Pennsylvania with 105 and Texas with 41. For the production of dairy products, California had the largest number of dairy cows as well as the largest number of dairy processing facilities with 114. The 21 states in this study accounted for 54% of the milk production in the nation but only 39% of the milk processing facilities in the nation.

Population and Animal Density

Population density for each of the 21 states was calculated as a measure of urban pressures in the various states. The two largest states in this study in terms of population are California with over 35 million and Texas with over 22 million people in 2004 (USDA [d]). In addition to human populations, an animal population density was also calculated using a form of Animal Units. To find the animal units in each state, a new measure of animals units is calculated using phosphorus excretion for each of the production groups listed in Table 11. NRCS does not provide a factor for all of the livestock types needed for this study, and the production groups used by NRCS are very broad allowing for the misplacement of livestock types. In Table 11, a comparison of Phosphorus Production Animal Units and the National Resource Conservation Service (USDA [e]) is provided to show the differences in the animal units. The major difference is that NRCS calculates its animals units using the weight of animals, whereas phosphorus-producing animal units measure bases the calculations on the animals' excretion of phosphorus. Equations 1-20 below are the complete formulas used to calculate phosphorus producing animal units.[36]

1. Cow (confinement) = Excretion value * 365 days
2. Growing Calf (confinement) = (P Excretion value * 365 days) / Cow (confinement)
3. Lactating Dairy Cow = (P Excretion value * 305 days) / Cow (confinement)
4. Dry Dairy Cow = (P Excretion value * 60 days) / Cow (confinement)
5. Dairy Heifer = (P Excretion value * 365 days) / Cow (confinement)
6. Veal Calf = (P Excretion value * 365 days) / Cow (confinement)
7. Bulls = (P Excretion value * 365 days) / Cow (confinement)
8. Finishing Cattle = (P Excretion value * 1.5 turns per year) / Cow (confinement)
9. Gestating Sow 440-lb = (P Excretion value * 120 days * 2.6 turns per year) / Cow (confinement)
10. Lactating Sow 423-lb = (P Excretion value * 20 days * 2.6 turns per year) / Cow (confinement)
11. Boar 440-lb= (P Excretion value * 365 days) / Cow (confinement)
12. Nursery Pig = (P Excretion value * 7.3 turns per year) / Cow (confinement)
13. Grow-Finish = (P Excretion value * 3 turns per year) / Cow (confinement)
14. Layer = (P Excretion value * 365 days) / Cow (confinement)
15. Broiler = (P Excretion value * 7.65 turns per year) / Cow (confinement)
16. Turkey (male) = (P Excretion value * 2.7 turns per year) / Cow (confinement)
17. Turkey (female) = (P Excretion value * 3.5 turns per year) / Cow (confinement)
18. Duck = (P Excretion value * 9.4 turns per year) / Cow (confinement)

[36] P excretion values are found in Figure 3.6.

19. Pullet 13 wk and less = (P Excretion value * 2.6 turns per year) / Cow (confinement)
20. Pullet 13-20 wk = (P Excretion value * 2.6 turns per year) / Cow (confinement)

Table 11: Phosphorus Producing Animal Units vs. NRCS Animal Units[37]

Phosphorus Animal Units		NRCS Animal Units	
Segment	# per beef cow	Segment	# per one animal unit
Cow (confinement)	1.00	Cows	1
Growing Calf (confinement)	1.76	Fattened Cattle	1.14
Lactating Cow	0.67	Milk cows	0.74
Dry Cow	8.93	Breeding Hogs	2.67
Heifer	2.20	Slaughter Hogs	9.09
Veal Calf	9.78	Chicken Layers	250
Bulls	1.28	Broiler	455
Finishing Cattle	3.24	Pullets	250
Gestating sow 440-lb	5.72	Breeding Turkeys	50
Lactating sow 423-lb	12.32	Slaughter Turkeys	67
Boar 440-lb	4.53		
Nursery Pig	32.33		
Grow-Finish	7.07		
layer	91.51		
Broiler	132.20		
Turkey (male)	36.34		
Turkey (female)	62.48		
Duck	78.81		
Pullet 13 wk and less	341.32		
Pullet 13-20 wk	411.09		

Using the phosphorus producing animal-units measure, the state with the largest number of animal units is Texas with 10.3 million. The next closest state is Iowa with 4.5 million animal units. There are 86.9 million animal units in the United States and this study is accounting for 56% of them. If the animal units are converted into animal densities, then Iowa would be the densest with 80 animal units per square mile and Arkansas would be second with 60 animal units per square mile. As for the United States, there are 25 animal units per square mile.

Environmental Capacity

The data needed to calculate environmental capacities are livestock inventories and crop production records. This data for 2004 livestock inventories and crop production is obtained from a variety of reports published by the United States Department of Agriculture (USDA) and

[37] Source: ASAE provides excretion values to calculate phosphorus producing animal units and NRCS provides conventional animal unit index

industry professionals. For some states, select livestock inventories were not disclosed due to concentration within the industry or the lack of that species of livestock or crops in the state. Industry professionals in the state were contacted to determine whether concentration or no production was the case. If concentration within the industry was identified as the reason for missing data, then industry professionals were called upon to provide an estimate of 2004 production.

With the nutrients produced by four species of livestock and the assimilation capacity of 15 different crops in each state computed, the surplus or deficit in phosphorus can be calculated. Based on the difference between the amount produced and the amount absorbed, the states can be compared in terms of utilization of assimilation capacity. Once the capacity used by livestock production is calculated, the fertilizer sale of phosphorus for each state is added. Then the surplus or deficits are calculated again. Once again, the states can be compared by the percentage of assimilation capacity that is presently being used by both livestock production and commercial fertilizer usage.[38] A complete description of how livestock nutrient production and crop assimilation capacities were calculated can be found under animal nutrient production and crop nutrient assimilation.

Indiana Specific Methodology

The same four dimensions of livestock location and growth potential used in the state comparison are used in the Indiana specific portion of the study. To acquire the necessary livestock inventories and crop production at the county level the 2002 Census of Agriculture livestock inventories were used in conjunction with the average crop production from 2000 to 2004. Livestock industries in Indiana continue to increase in concentration, resulting in the poultry and swine industries becoming too concentrated to report on a county basis. In 1995, the National Agricultural Statistics Service (NASS) discontinued the publishing of yearly county level swine numbers for Indiana, and county poultry inventories were discontinued five years prior. Only beef and dairy inventories are published on a yearly basis for Indiana counties. Thus, one issue with using the USDA data is that with increased concentration some counties are not able to report their inventories. To solve this problem some additional calculations had to be made which are explained below under example disaggregating.

Disaggregating the data to the county level is done for two reasons. First, at the crop reporting district level, county constraints are not realized. Second, decisions are made at the county level with respect to allowing the construction or expansion of livestock facilities. However, by disaggregating to the county level more error is induced. Therefore, in the final summarization of this appendix counties are aggregated back to the crop reporting district level.

Feed

The feed dimension is analyzed in a two-step process: 1) feed usage and 2) corn price. To determine the feeding usage of Indiana, the average amount of corn, corn silage, soybeans, and forage produced in Indiana from 2000 to 2004 was obtained from NASS. Then using the typical

[38] Environmental Capacities can change from year to year with crop rotations, crop mixes, livestock mixes, and livestock inventories.

Indiana rations developed by or in conjunction with Purdue Animal Scientists, the total consumption of these four crops was determined for Indiana and each county. These typical rations have been developed with the intentions that they are representative rations of what actual Indiana livestock producers are feeding throughout the state and are summarized in Appendix E. In addition, all of the assumptions made for each of the rations are shown in the ration section of this appendix. After determining feed usage, the areas in the state that have either a surplus or deficit can be located.

On average, Indiana produced over 808.5 million bushels of corn, 2.5 million tons of silage, 26.7 million bushels of wheat, 251.3 million bushels of soybeans, and 5.7 million tons of forage according to NASS.[39] The top four producing counties for each of these crops are shown in Figure 31. In addition to crop production, Indiana also had 1,098,301 acres of pastureland in the state (IASS (2004)). This pastureland can have the ability to produce between 2 and 4 tons per acre of forage (Johnson (2005)). For the purposes of this study, it is assumed that the pastureland for Indiana is producing 3.26 tons per acre, which is the average yield per acre for all hay in Indiana from 2000 to 2004.

Rank	Corn	Silage	Wheat	Soybeans	Forage
1	White	Elkhart	Posey	Montgomery	Lawrence
2	Jasper	Jasper	Allen	White	Washington
3	Knox	Newton	Gibson	Boone	Lagrange
4	Benton	La Porte	Knox	Benton	Harrison

Figure 31: Top Producing Counties for 5 Crops[40]

Harvesting Capacity

Harvesting capacity in the state is assessed in two different ways: 1) plant location and 2) capacity of the plant versus production. To determine the location of the federally inspected processing plants in the state, industry professionals were used. Industry professionals were also called upon for estimations of industry size because the swine industry is the only industry that publicly publishes the slaughter capacity of each plant (National Pork Board). Due to concentration issues, these industries cannot release individual plant capacities. However, the number of plants and size of the industries are known (USDA [b] (2005)).

Population Density versus Animal Density

This dimension compares the population density to the animal density in each county. The population density for each individual county was calculated for 2002 using data from the U.S. Census Bureau. This provides information as to counties in the state where urban pressures could become a limitation to livestock growth. Animal densities are calculated based on phosphorus producing animal units using 2002 livestock inventories as described earlier.

[39] Forage include all hay, haylage, and grass produced by pastures
[40] Source: NASS

Environmental Capacity

The calculation of environmental capacities for Indiana follows the same procedure as discussed earlier for the state comparison. The only differences are that average production records are used, the number of crops is reduced from 15 to 6, and turkeys are separated into male and female. Once animal nutrient production and the crops assimilation capacity have been determined, an environmental capacity can be determined by county. Environmental capacities will be determined at the state and county level. After the environmental capacities have been determined for the production of animal nutrients, a second factor, commercial fertilizer usage is added to the animal nutrients produced. By adding commercial fertilizer to the analysis, the total amount of phosphorus produced and used in the state is assessed. In 2002 the top four counties in commercial fertilizer sales of phosphorus were Carroll, Randolph, Decatur, and Posey, respectively (OSIC (2002)).

Categorization of Livestock Segments for Estimation

Before determining any of the feeding and environmental capacities all livestock segments are disaggregated to a level that will allow for a measurement of feed consumption and nutrient excretion. All livestock inventories for both the state comparison and Indiana specific analysis will use this same disaggregating method. NASS provides the initial categorization of the livestock segments in Table 12.

Table 12: Initial Categorization of Livestock Segments[41]

Cattle and Calves	Hogs and Pigs
Cows and Heifers that have Calved	Breeding Stock
Beef Cows	Market Hogs
Dairy Cows	Layers
Heifers 500 Pounds and Over	Broilers
For Beef Cow Replacement	Turkeys
For Dairy Cow Replacement	Pullets
Other Heifers (Slaughter Heifers)	
Steers 500 Pounds and Over	
Bulls 500 Pounds and Over	
Calves Under 500 Pounds	

The initial categorization of the livestock segments provides a starting point for estimating, but further disaggregating is necessary. Different feeding and nutrient excretion values exist for animals depending on their phase of the life cycle. For example, a dairy cow that is lactating will on average excrete 0.17 pounds of phosphorus per day verses a dry dairy cow that will on average excrete 0.066 pounds of phosphorus. To insure an accurate measure of phosphorus produced, eleven additional categories were added to the initial categories. These additions and assumptions will be explained by species.

[41] Source: NASS

Cattle

Only one category is added that pertains to the beef segment. Encompassed under the heading "Calves Under 500 Pounds" are both beef calves and veal calves which are disaggregated into their respective segments. To do this the assumption is made that the distribution of beef and veal calves will follow the distribution of beef and dairy cows. Equation 21 is used to determine the number of beef calves.

21. Beef Calves = Calves Under 500 Pounds * (Beef Cows / Cows and Heifers that have Calved)

For the dairy segment, 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 intake two different rations resulting in different ratios of nutrients being excreted. Equation 22 is used to determine the head of lactating dairy cows and Equation 23 is used for dry dairy cows. Equation 24 is used to estimate the number of veal calves.

22. Lactating Dairy Cows = Dairy Cows * (305 / 365)
23. Dry Dairy Cows = Dairy Cows * (60 / 365)
24. Veal Calves = Calves Under 500 Pounds * (Dairy Cows / Cows and Heifers that have Calved)

Swine

There are five additional categories defined for this species. Breeding stock is more complicated to disaggregate, since the census combines both the sows and the boars together. To disaggregate the assumption is made that 85% of the swine industry uses Artificial Insemination (AI) and 15% uses conventional methods (Richert (2005)). In addition, the operators using AI only need one boar for every 100 sows, whereas for conventional methods the operator will need one boar for every 15 sows (Richert (2005)). Equation 25 is used to estimate the head of boars needed. To determine the number of gestating and lactating sows a ratio of days in each cycle over the total days to complete the cycle will be used. An average sow will be 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)). Equations 26 and 27 are used to estimate the head of lactating sows and gestating sows, respectively. As for the Market Hogs, these were separated into Nursery Pigs and Grow-Finish Pigs. Nursery pigs for this study are defined as pigs weighing less than 60 lbs and Grow-Finish will encompass 60 lbs to market weight. The "Quarterly Hogs and Pigs" report compiled by the NASS provides the head in each category for the state comparison. For the Indiana specific portion the "2002 Indiana Hog Highlights" report compiled by IASS provides the ratio of Nursery pigs to Grow-Finish pigs. This ratio is assumed constant for each county allowing for the estimation of these two categories. Equation 28 is used to estimate the head of nursery pigs. The residual left after the subtraction of nursery pigs from market hogs is assumed to be the head of grow-finish pigs.

25. Boars = ((85% * Breeding Stock) / 100) + ((15% * Breeding Stock) / 15)
26. Lactating Sows = (Breeding Stock – Boars) * (20 / 140)
27. Gestating Sows = (Breeding Stock – Boars) * (120 / 140)
28. Nursery Pigs = (Under 60lbs / Market hogs) * Market Hogs

Poultry

For the poultry segment, two additional categories are defined for use in the Indiana specific portion. Male and female turkeys are separated using a ratio provided by a survey (Applegate (2005)). Equations 29 and 30 are used to estimate the birds that are male and female, respectively.

29. Male Turkeys = (Male Turkeys / Turkeys) * Turkeys
30. Female Turkeys = (Female Turkeys / Turkeys) * Turkeys

These additions to the initial categorization result in the categorization of livestock summarized in Table 13. All livestock in both the state and Indiana specific portions of the study can be divided into their respective categories of phosphorus estimation. The one exception to this is that for the state comparison, turkeys remain one category whereas they are separated into male and female for the Indiana specific portion.

Table 13: Final Categorization of Livestock Segments

Cattle and Calves	Hogs and Pigs
Cows and Heifers that have Calved	Breeding Stock
Beef Cows	Gestating
Dairy Cows	Lactating
Lactating	Boars
Dry	Market Hogs
Heifers 500 Pounds and Over	Nursery Pigs
For Beef Cow Replacement	Grow-Finish
For Dairy Cow Replacement	Layers
Other Heifers (Slaughter Heifers)	Broilers
Steers 500 Pounds and Over	Turkeys
Bulls 500 Pounds and Over	Male
Calves Under 500 Pounds	Female
Beef Calves	Pullets
Veal	

Example Disaggregating

As noted earlier the following calculations were made for each county that exhibited a concentration problem. First, the counties were divided into the nine districts that IASS recognizes for Indiana. Then the inventories for the counties that can be reported are summed. Next, a difference is calculated between the accounted for amount and the actual inventory reported for the state. Once the difference is established, a ratio is calculated between the sum of each district and the actual inventory of the state. This ratio is then multiplied by the difference computed and the result is added to its respective district. The additional amount added to each district is then evenly distributed between the counties that are unable to report their actual inventories. An example of this procedure can be seen in Appendix D.

Typical Rations

For beef, all the rations are determined on a hay equivalent basis so there is not a measure for the amount of pasture that will be consumed during the days available for grazing. To correct for this, the tons of forage produced by pasture are added to the tons of hay produced. Hay is all hay produced irrelevant of the type of hay. All rations for the beef segment were developed in conjunction with Dr. Ron Lemenager the beef specialist in department of Animal Science at Purdue.

The rations used to compute feed usage for both dry and lactating dairy cows are the rations used by the Purdue University dairy. Dairy rations are much more complex because as the cows cycle from lactating to dry and then to a pre-fresh stage just before they begin to lactate again, their rations can change substantially. In addition, on a farm-by-farm basis, the rations can change as well, but there is no way to know exactly what every farm feeds. For the purposes of this study, the far off dry cycle (40 days) and the pre-fresh stage (20 days) make up the total dry cycle of 60 days for dairy cows (Schutz (2005)). To compute feed usage for the replacement heifers, an average of three different rations was taken from rations in "Feeding the Dairy Herd" (Linn, et. al. (1996)). This is done to capture the entire life of replacement heifers as they progress to the point where they can be introduced into the herd since there is no way to measure the number of heifers in the state that are in each phase of the cycle.

The rations used for computing feed usage for the swine industry were developed by Dr. Brian Richert, a swine nutritionist in the department of Animal Science at Purdue. In addition, these rations are used at the Purdue research farm.

The rations used to compute feed usage for poultry were developed by Dr. Todd Applegate, the poultry specialist in the department of Animal Science at Purdue.

All of the rations for each segment are formulated on an "as fed" basis, and total amount of each feed type that the animal will eat during a given year is given below. To compute the feed usage for each livestock group in Table 13, the inventory number for each is multiple by their feed usage factor for each feed ingredient as detailed in Appendix E; for meat animals the inventory is then multiplied by the number of turns that they will make during a year from Figure 33. The conversions in Figure 32 were used to convert pounds of each ingredient to bushels of corn or tons of forage. No conversion for soybeans hulls is indicated because it is assumed that the soybean hulls will come from the soybean crush plants that make soybean meal - - soybean hulls are just a by-product of that process.

From	To
47.5 lbs SBM	1 bu. soybeans
56 lbs of corn	1 bu. corn
70 lbs of ear corn	1 bu. corn
60 lbs of rolled roasted soybeans	1 bu. soybeans
2000 lbs forage	1 ton forage
2000 lbs silage	1 ton silage

Figure 32: Conversions[42]

Animal Nutrient Production

The first step in determining environmental capacities is to find the average excretion of manure for each of the groups of livestock listed in Table 11. The average excretion values used in this study come from the American Society of Agricultural Engineers Standards and are found in Figure 33 (ASAE (2005)). Phosphorus is the nutrient that this study focuses on because as the EPA tightens it regulations and transitions to a phosphorus application standard, it will become the limiting factor (Joern (2005)).

Meat-producing livestock and poultry						
		lb / finished animal				
Animal Type	Production Grouping	Nitrogen	P	K	Total Manure	Turns
Beef	Finishing Cattle	55.100	7.280	37.700	7440.000	1.5
Poultry	Broiler	0.117	0.035	0.068	10.800	7.7
Poultry	Turkey (male)	1.220	0.355	0.567	78.300	2.7
Poultry	Turkey (female)	0.057	0.163	0.249	32.900	3.5
Poultry	Duck	0.136	0.048	0.068	14.300	9.4
Swine	Nursery Pig	0.911	0.150	0.353	87.300	7.3
Swine	Grow-Finish	10.500	1.670	4.410	981.000	3
Poultry	Pullets		0.073			2.6
Poultry	Turkeys	0.639	0.259	0.408	55.600	3.1
Production Livestock						
		lb / day-animal				
Animal Type	Production Grouping	Nitrogen	P	K	Total Manure	Days
Beef	Cow (confinement)	0.419	0.097	0.300	110.000	365
Beef	Growing Calf (confinement)	0.287	0.055	0.187	40.300	365
Beef	Bulls	0.353	0.076	0.244	75.150	365
Dairy	Lactating Cow	0.977	0.172	0.227	151.000	305
Dairy	Dry Cow	0.503	0.066	0.326	82.900	60
Dairy	Heifer	0.258	0.044		48.400	365
Dairy	Veal	0.033	0.010	0.044	7.790	365
Layer	Layer	0.004	0.001	0.001	0.194	365
Swine	Gestating sow 440-lb	0.071	0.020	0.049	9.000	120
Swine	Lactating sow 423-lb	0.187	0.055	0.117	19.800	20
Swine	Boar -440lb	0.061	0.021	0.039	8.290	365

Figure 33: Average Nutrient Excretion Values for Livestock and Number of Turns or Days[43]

[42] Source: United States Soybean Board
[43] Source: ASAE

Nutrient excretion for animals used for meat production is in pounds excreted per finished animal. Pullets are the exception to this because they become layers once reaching 20 weeks of age. For all livestock used for breeding, excretion values are on a pounds 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. Taking the average, provides a more accurate measure so as not to overstate the nutrients excreted by mature bulls or understate excretion values of replacement bulls. For pullets the nutrient excretion is 0.07 pounds of phosphorus per finished pullet (Applegate (2005)). The pullet industry provides the new layers and not accounting for the phosphorus excretion, the livestock nutrient production would be understated.

The number of turns or days per cycle for each species is also found in Figure 33. However, the number of turns for finished cattle is adjusted from 2.3 to 1.5. Indiana’s lack of processing for beef creates a unique situation where beef producers in Indiana typically only feed one group of calves per year verses a feedlot that feeds multiple groups of calves per year. Therefore, for the purposes of this study, finishing cattle turn at a rate of 1.5 times per year (Lemenager (2005)). 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 for the Indiana specific portion of this study is used, resulting in turkeys turning over 3.1 times per year.

Cattle

Equation 1 is used to separate “Calves Under 500 Pounds” into beef calves and veal calves. Equations 33-42 are used to determine the nutrients produced by the cattle industry. Cattle inventories were provided by “Cattle” report (USDA [f] (2005)).

33. Beef Cows = Beef Cows Inv. * Cow Excretion Factor * 365 days
34. Dry Dairy = Dry Dairy Cows Inv. * Dry Cow Excretion Factor * 60 days
35. Lactating Dairy = Lactating Dairy Cows Inv. * Lactating Cow Excretion Factor * 305 days
36. Beef Replacements = Beef Replacements Inv. * Growing Calf Excretion Factor *365 days
37. Dairy Replacements = Dairy Replacements Inv. * Heifer Excretion Factor * 365 days
38. Other Heifer = Other Heifer Inv. * Finishing Cattle Excretion Factor * 1.5 turns
39. Steers = Steer Inv. * Finishing Cattle Excretion Factor * 1.5 turns
40. Bulls = Bull Inv. * Bull Excretion Factor * 365 days
41. Beef Calves = Beef Calf Inv. * Growing Calf Excretion Factor * 365 days
42. Dairy Calves = Dairy Calf Inv. * Veal Excretion Factor * 365

Swine

Equations 43-47 are used to determine the nutrients excreted by swine. One important detail to remember is that sows go through the lactating and gestating phases 2.6 times per year.

Swine inventories are provided by "Quarterly Hogs and Pigs". Industry professionals were consulted in cases of missing inventory information (USDA [g] (2004)).

43. Gestating Sow = Gestating Sow Inv. * Gestating Sow Excretion Factor * 120 days * 2.6 turns
44. Lactating Sow = Lactating Sow Inv. * Lactating Sow Excretion Factor * 60 days * 2.6 turns
45. Boars = Boar Inv. * Boar Excretion Factor * 365 days
46. Nursery Pigs = Nursery Pig Inv. * Nursery Pig Excretion Factor * 7.3 turns
47. Grow-Finish Pigs = Grow-Finish Inv. * Grow-Finish Excretion Factor * 3 turns

Poultry

Equations 28-34 are used to determine nutrients excreted by poultry. Turkey inventories are provided by "Turkeys Raised" (USDA [h] (2005)). Broiler inventories are found in "Poultry – Production and Value 2004 Summary" (USDA [i] (2005)). Layer and Pullet inventories are found in "Chickens and Eggs 2004 Summary" (USDA [j] (2005)).

48. Layers = Layer Inv. * Layer Excretion Factor * 365 days
49. Broilers = Broiler Inv. * Broiler Excretion Factor * 7.7 turns
50. Turkeys = Turkey Inv. * Turkey Excretion Factor * 3.1 turns[44]
51. Male Turkeys = Male Turkey Inv. * Male Turkey Excretion Factor * 2.7 turns
52. Female Turkeys = Female Turkey Inv. * Female Turkey Excretion Factor * 3.5 turns
53. Ducks = Duck Inv. * Duck Excretion Factor * 9.4 turns
54. Pullets = Pullet Inv. * Pullet Excretion Factor * 2.6 turns

Crop Nutrient Assimilation

Assimilation capacities were estimated using 15 different crops in the state comparison and 6 different crops in the Indiana specific portion. Shown in Table 3.7 are the crops used in the state comparison, and in Table 3.8 are the crops used in the Indiana specific analysis. These crops were chosen with the intent of including the field crops that are most likely to receive manure application.

Corn for Grain	Soybeans
Silage	Cotton
Sorghum	Potatoes
Oats	Rye
Barley	Canola
Wheat	Tobacco
Rice	Pastureland
Hay	

Figure 34: Selected Crops for State Comparison

[44] Only used for State Comparison

Corn for Grain	Soybeans
Silage	Pastureland
Wheat	
Hay	

Figure 35: Selected Crop for Indiana Specific Analysis

The phosphorus assimilation capacity for all crops is shown in Figure 36. Assimilation capacities for all crops are found in "Nutrient Recommendation for Field Crops in Michigan" and "Fertilizer Recommendations for Field Crops in Michigan" publications (MSU (2004)). In addition, the assimilation capacities are published in terms of P_2O_5 and need to be converted to phosphorus. To covert from P_2O_5 to Phosphorus P_2O_5 is divided by 2.29 (Peters (2005)).

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

Figure 36: Assimilative Capacity for Each of the Selected Crops[45]

The acres planted, yield, and production of crops was obtained from "Crop Production 2004 Summary" (USDA [k] (2005)). Only one crop cannot be found in this publication and that is pasture. The acres of pastureland are documented in the Census of Agriculture and the last Census was in 2002. Therefore, due to lack of data for 2004, acres of pasture for 2002 are used as a proxy. In addition, average production per acre of pasture is not documented. The simplifying assumption is made that the pastures in each state will mirror the average production of all hay. Pasture can be grazed differently as well; to account for this, the two types of pasture grazing in the Michigan State publications are averaged together. Equations 55-69 should be used to determine the assimilation capacity for each state.

55. Barley = Barley Production (bu) * 0.1659
56. Canola = Canola Production (bu) * 0.3974
57. Corn for Grain = Corn Production (bu) * 0.1616
58. Corn Silage = Corn Silage Production (tons) * 1.441
59. Oats for Grain = Oats for Grain Production (bu) * 0.1092

[45] Source: Tri-State Fertilizer Recommendations and Michigan State University

60. Pasture = Pasture Production (tons) * 2.7293
61. Potatoes = Potato Production (cwt) * 0.0568
62. Rye for Grain = Rye for Grain Production (bu) * 0.0895
63. Sorghum for Grain = Sorghum for Grain Production (bu) * 0.1703
64. Soybeans = Soybean Production (bu) * 0.3493
65. Wheat = Wheat Production (bu) * 0.2751
66. Rice = Rice Production (bu) * 0.1266
67. Tobacco = Tobacco Production (lbs) * 0.0033
68. Hay = Hay Production (tons) * 4.8035
69. Cotton = Cotton Production (500 lb bale) * 5.4585

Appendix C: Additional Literature

Other State Studies

- Goldsmith, Peter and Hedi Idris. "The Economic Impact of Illinois's Livestock Industry." *College of Agricultural Consumer and Environmental Sciences.* November 2001.
- Goldsmith, Peter and Jungik Kim. "The Economic Impact of Illinois's Livestock Industry: Supply-Chain Linkages. *College of Agricultural Consumer and Environmental Sciences.* August 2002.
- Governor Tim Pawlenty's Advisory Task Force. "Minnesota's Animal Agriculture Industry Report." June 2004.

Community Issues

- Ready, Richard C. and Charles W. Abdalla. "The Amenity and Disamenity Impacts of Agriculture: Estimates From A Hedonic Pricing Model." *American Journal of Agriculture Economics.* Vol. 87, No. 2, 314-326.
- Sharp, Jeff S. and Mark Tucker. "Awareness and Concern about Large-Scale Livestock and Poultry: Results from a Statewide Survey of Ohioans." *Rural Sociology.* Vol. 70, No. 2, 208-228.

Phosphorus Issues

- Roe, Brian, Elena G. Irwin, and Jeff S. Sharp. "Pigs in Space: Modeling the Spatial Structure of Hog Production in Traditional and Nontraditional Production Regions." *American Journal of Agriculture Economics.* 84. May 2002. 259-278.
- Fleming, Ronald A., Bruce A. Babcock, and Erda Wang. "Resource or Waste? The Economics of Swine Manure Storage and Management." *Review of Agricultural Economics.* Vol. 20, No. 1, 96-113.
- Lazarus, William F. and Robert G. Koehler. "The Economics of Applying Nutrient-Dense Livestock Waste at Low Rates." *Review of Agricultural Economics.* Vol. 24, No. 1, 141-159.
- Mallin, Michael A. and Lawrence B. Cahoon. "Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems." *Population and Environment.* Vol. 24, No.5, May 2003.
- Jones, Don, Brad Joern, Alan Sutton. "Livestock Manure Can Reduce Fertilizer Costs." http://www.agriculture.purdue.edu/agtransition/pubs/FF-2.html .
- Norwood, Bailey and Jan Chvosta. "Unintended Results from Phosphorus Rule Shown." *Feedstuffs.* January 10, 2005.
- Fleming, Ronald A. and James D. Long. " Measuring the Cost of Restricting Access to Cropland For Manure Nutrient Management." *Agronomy Journal.* 94:57-64 (2002).
- Kaplan, Jonathan D., Robert C. Johansson, and Mark Peters. " The Manure Hits the Land: Economic and Environmental Implications When Land Application of Nutrients Is Constrained." *American Journal of Agriculture Economics.* Vol. 86, No. 3, 688-700.
- Feinerman, Eli, Darrell J. Bosch, and James W. Pease. "Manure Applications and Nutrient Standards." *American Journal of Agriculture Economics.* Vol. 86, No. 1, 14-25.

Alternative Manure Management

- Lazarus, William F. and Margaretha Rudstrom. “Profits from Manure Power? Economic Analysis of the Haubenchild Farms Anaerobic Digester.” http://www.apec.umn.edu/documents/Lazarus-RudstromSem05.pdf
- Hannawald, James E. “Alternative Waste Management Technologies Summary of Available Resources.” http://www.nrcs.usda.gov/technical/ECS/nutrient/manureutil.doc

Appendix D: Example Disaggregating

Counties	Item	Data	District	Transfer Column for Data	Sum Per Distict	District Percentage of Accounted	Added Inventory to Distict	New Total Inventory for District	New County Totals
Indiana\Benton	Inventory - Turkeys (number,2002)	-	10	0					-
Indiana\Jasper	Inventory - Turkeys (number,2002)	10	10	10					10
Indiana\La Porte	Inventory - Turkeys (number,2002)	112	10	112					112
Indiana\Lake	Inventory - Turkeys (number,2002)	14	10	14					14
Indiana\Newton	Inventory - Turkeys (number,2002)	-	10	0					-
Indiana\Porter	Inventory - Turkeys (number,2002)	(D)	10	0					5
Indiana\Pulaski	Inventory - Turkeys (number,2002)	16	10	16					16
Indiana\Starke	Inventory - Turkeys (number,2002)	(D)	10	0					5
Indiana\White	Inventory - Turkeys (number,2002)	(D)	10	0	152	0.004%	16	168	5
Indiana\Carroll	Inventory - Turkeys (number,2002)	-	20	0					-
Indiana\Cass	Inventory - Turkeys (number,2002)	6	20	6					6
Indiana\Elkhart	Inventory - Turkeys (number,2002)	82	20	82					82
Indiana\Fulton	Inventory - Turkeys (number,2002)	(D)	20	0					10
Indiana\Kosciusko	Inventory - Turkeys (number,2002)	(D)	20	0					10
Indiana\Marshall	Inventory - Turkeys (number,2002)	33	20	33					33
Indiana\Miami	Inventory - Turkeys (number,2002)	32	20	32					32
Indiana\St. Joseph	Inventory - Turkeys (number,2002)	129	20	129					129
Indiana\Wabash	Inventory - Turkeys (number,2002)	(D)	20	0	282	0.008%	29	311	10
Indiana\Adams	Inventory - Turkeys (number,2002)	10	30	10					10
Indiana\Allen	Inventory - Turkeys (number,2002)	24	30	24					24
Indiana\De Kalb	Inventory - Turkeys (number,2002)	(D)	30	0					10
Indiana\Huntington	Inventory - Turkeys (number,2002)	-	30	0					-
Indiana\LaGrange	Inventory - Turkeys (number,2002)	111	30	111					111
Indiana\Noble	Inventory - Turkeys (number,2002)	16	30	16					16
Indiana\Steuben	Inventory - Turkeys (number,2002)	(D)	30	0					10
Indiana\Wells	Inventory - Turkeys (number,2002)	26	30	26					26
Indiana\Whitley	Inventory - Turkeys (number,2002)	-	30	0	187	0.005%	19	206	-
Indiana\Clay	Inventory - Turkeys (number,2002)	(D)	40	0					307
Indiana\Fountain	Inventory - Turkeys (number,2002)	(D)	40	0					307
Indiana\Montgomery	Inventory - Turkeys (number,2002)	17,914	40	17914					17,914
Indiana\Owen	Inventory - Turkeys (number,2002)	(D)	40	0					307
Indiana\Parke	Inventory - Turkeys (number,2002)	(D)	40	0					307
Indiana\Putnam	Inventory - Turkeys (number,2002)	(D)	40	0					307
Indiana\Tippecanoe	Inventory - Turkeys (number,2002)	24	40	24					24
Indiana\Vermillion	Inventory - Turkeys (number,2002)	-	40	0					-
Indiana\Vigo	Inventory - Turkeys (number,2002)	19	40	19					19
Indiana\Warren	Inventory - Turkeys (number,2002)	(D)	40	0	17957	0.515%	1,843	19,800	307
Indiana\Bartholomew	Inventory - Turkeys (number,2002)	22	50	22					22
Indiana\Boone	Inventory - Turkeys (number,2002)	101,565	50	101565					101,565
Indiana\Clinton	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Decatur	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Grant	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Hamilton	Inventory - Turkeys (number,2002)	10	50	10					10
Indiana\Hancock	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Hendricks	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Howard	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Johnson	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Madison	Inventory - Turkeys (number,2002)	9	50	9					9
Indiana\Marion	Inventory - Turkeys (number,2002)	-	50	0					-
Indiana\Morgan	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Rush	Inventory - Turkeys (number,2002)	(D)	50	0					1,043
Indiana\Shelby	Inventory - Turkeys (number,2002)	3	50	3					3
Indiana\Tipton	Inventory - Turkeys (number,2002)	(D)	50	0	101609	2.912%	10,430	112,039	1,043
Indiana\Blackford	Inventory - Turkeys (number,2002)	13	60	13					13
Indiana\Delaware	Inventory - Turkeys (number,2002)	46	60	46					46
Indiana\Fayette	Inventory - Turkeys (number,2002)	-	60	0					-
Indiana\Henry	Inventory - Turkeys (number,2002)	(D)	60	0					15,865
Indiana\Jay	Inventory - Turkeys (number,2002)	208,440	60	208440					208,440
Indiana\Randolph	Inventory - Turkeys (number,2002)	100,611	60	100611					100,611
Indiana\Union	Inventory - Turkeys (number,2002)	3	60	3					3
Indiana\Wayne	Inventory - Turkeys (number,2002)	(D)	60	0	309113	8.858%	31,730	340,843	15,865
Indiana\Daviess	Inventory - Turkeys (number,2002)	632,560	70	632560					632,560
Indiana\Dubois	Inventory - Turkeys (number,2002)	1,399,776	70	1399776					1,399,776
Indiana\Gibson	Inventory - Turkeys (number,2002)	(D)	70	0					102,867
Indiana\Greene	Inventory - Turkeys (number,2002)	234,864	70	234864					234,864
Indiana\Knox	Inventory - Turkeys (number,2002)	93,000	70	93000					93,000
Indiana\Martin	Inventory - Turkeys (number,2002)	429,702	70	429702					429,702
Indiana\Pike	Inventory - Turkeys (number,2002)	136,000	70	136000					136,000
Indiana\Posey	Inventory - Turkeys (number,2002)	(D)	70	0					102,867
Indiana\Spencer	Inventory - Turkeys (number,2002)	80,502	70	80502					80,502
Indiana\Sullivan	Inventory - Turkeys (number,2002)	(D)	70	0					102,867
Indiana\Vanderburgh	Inventory - Turkeys (number,2002)	-	70	0					-
Indiana\Warrick	Inventory - Turkeys (number,2002)	-	70	0	3006404	86.148%	308,601	3,315,005	-
Indiana\Brown	Inventory - Turkeys (number,2002)	(D)	80	0					1,109
Indiana\Crawford	Inventory - Turkeys (number,2002)	-	80	0					-
Indiana\Floyd	Inventory - Turkeys (number,2002)	-	80	0					-
Indiana\Harrison	Inventory - Turkeys (number,2002)	10	80	10					10
Indiana\Jackson	Inventory - Turkeys (number,2002)	(D)	80	0					1,109
Indiana\Lawrence	Inventory - Turkeys (number,2002)	(D)	80	0					1,109
Indiana\Monroe	Inventory - Turkeys (number,2002)	17	80	17					17
Indiana\Orange	Inventory - Turkeys (number,2002)	(D)	80	0					1,109
Indiana\Perry	Inventory - Turkeys (number,2002)	(D)	80	0					1,109
Indiana\Washington	Inventory - Turkeys (number,2002)	54,016	80	54016	54043	1.549%	5,547	59,590	54,016
Indiana\Clark	Inventory - Turkeys (number,2002)	(D)	90	0					2
Indiana\Dearborn	Inventory - Turkeys (number,2002)	-	90	0					-
Indiana\Franklin	Inventory - Turkeys (number,2002)	69	90	69					69
Indiana\Jefferson	Inventory - Turkeys (number,2002)	-	90	0					-
Indiana\Jennings	Inventory - Turkeys (number,2002)	(D)	90	0					2
Indiana\Ohio	Inventory - Turkeys (number,2002)	-	90	0					-
Indiana\Ripley	Inventory - Turkeys (number,2002)	(D)	90	0					2
Indiana\Scott	Inventory - Turkeys (number,2002)	(D)	90	0					2
Indiana\Switzerland	Inventory - Turkeys (number,2002)	14	90	14	83	0.002%	9	92	14
					Accounted for	3,489,830	100%	358,224	3,848,054
(-) = 0					Actual Reported by Census	3,848,054			
(D) inventory information could not be disclosed					Difference between Accounted and Actual	358,224			

Appendix E: Typical Indiana Feed Rations

Beef

Cows

- Assume 1250 lb cow that consumes 2.5% of body weight per day
- 11,406 lbs of dry matter hay per year or 31.25 lbs per day
  - As Fed basis 13,419 lbs per year
- 3 bu. corn/year/cow

Herd Bulls

- 18,250 lbs of dry matter hay per year or 50 lbs per day
  - As Fed 21,470 lbs per year
- 5 bu. corn/year/bull

Replacement Bulls

- 13,687 lbs of dry matter hay per year or 37 lbs per day
  - As Fed 16,103 lbs per year
- 15 bu. corn/year/bull

Replacement Heifers (weaning-breeding)

- 3,145 lbs of dry matter hay
  - As Fed 3,700 lbs
- 28 bu. corn

Replacement Heifers (breeding-calving)

- 8,662 lbs of dry matter hay
  - As Fed 10,190 lbs
- 5 bu. corn

Other Heifers (slaughter heifers) 500 lbs & over

- Assume 200 day finish at 1,100 lbs
- Assume heifer consumes 2.2% of body weight with an average needed gain of 800 lbs
- 17.6 lbs of dry matter per day needed to achieve 1,100lb finish with a ration of 20% corn silage, 10% soybean meal, and 70% corn
- 704 lbs of dry matter silage or 3.52 lbs/day/heifer
  - As Fed 2,011 lbs
- 414 lbs of soybean meal per heifer As Fed or 2.07 lbs/day
- 2,464 lbs of dry matter corn or 12.32 lbs/day/heifer
  - As Fed 2,899 lbs

Steers 500 lbs & Over

- Assume 220 day finish at 1,250 lbs
- Assume steer consumes 2.2% of body weight with an average needed gain of 875 lbs

- 19.25 lbs of dry matter per day is need to achieve 1,250 lb finish with a ration of 20% corn silage, 10% soybean meal, and 70% corn
- 847 lbs of dry matter silage or 3.85 lbs per day
  - As Fed 2,420 lbs
- 498 lbs of soybean meal per steer As Fed or 2.25 lbs/day
- 2,963 lbs of dry matter corn or 13.47 lbs/day/steer
  - As Fed 3,487 lbs

Dairy

Lactating
- 16,205 lbs of silage/hd As Fed
- 1,485 lbs of soybean meal/hd As Fed
- 1,080 lbs of soybean hulls/hd As Fed
- 945 lbs of soybeans rolled roasted/hd As Fed
- 5131 lbs of forage/hd As Fed

Dry
- 1,900 lbs of silage/hd As Fed
- 34 lbs of soybean meal/hd As Fed
- 230 lbs of soybean hull/hd As Fed
- 520 lbs of forage/hd As Fed

Replacement Heifers
- 6,083 lbs of silage/hd As Fed
- 561 lbs of ear corn/hd As Fed
- 134 lbs of soybean meal/hd As Fed
- 3,650 lbs of forage/hd As Fed

Swine

Lactating
- 384 lbs of corn/hd As Fed
- 132.6 lbs of soybean meal/hd As Fed

Gestating
- 1,182.3 lbs of corn/hd As Fed
- 157.6 lbs of soybean meal/hd As Fed

Nursery Pigs
- 49.62 lbs of corn/pig As Fed
- 20.7 lbs of soybean meal/pig As Fed

Grow-Finish
- 541.43 lbs of corn/pig As Fed
- 92.9 lbs of soybean meal/pig As Fed

<u>Poultry</u>

Broiler

- 6.59 lbs of corn/bird As Fed
- 2.86 lbs of soybean meal/bird As Fed

Turkey (Male)

- 56.28 lbs of corn/bird As Fed
- 27. 73 lbs of soybean meal/bird As Fed

Turkey (Female)

- 31.31 lbs of corn/bird As Fed
- 13.07 lbs of soybean meal/bird As Fed

Duck

- 9.87 lbs of corn/bird As Fed
- 3.18 lbs of soybean meal/bird As Fed

Pullet

- 41.09 lbs of corn/bird As Fed
- 12.8 lbs of soybean meal/bird As Fed

Layer

- 52.72 lbs of corn/bird As Fed
- 15.12 lbs of soybean meal/bird As Fed