Availability, Application, and Economic Values of Poultry Manure for Cropland in Indiana



Department of Agricultural and Biological Engineering
Purdue University
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Final Report

Survey of Availability, Application, and Economic Values of Poultry Manure for Cropland in Indiana

(Project #00026411)

to

Andy Tauer
Director of Livestock

Indiana Soybean Alliance
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by

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Executive Summary

This project was conducted to study the production, availability, geographical distribution, transportation, application, and economics of poultry manure in the state of Indiana. Data and information were collected from various databases and sources; and via phone interviews, face-to-face discussions, and an on-line survey. Year 2007 was selected as the primary year of data analysis because of the availability of the most comprehensive data sets. Data in other periods from 2002 to 2012 were also used to study the development of the Indiana poultry industry and the production of poultry manure within the state.

There were 4,545 Indiana farms that raised poultry of various species in 2007. The number increased by 53.5% from 2,961 farms in 2002. The sizes of layer farms varied considerably. The majority of the farms was below the CFO threshold, raised small numbers of poultry, and were scattered all over Indiana. About 98% of the layer hens were raised in only 2% of the layer farms in 2007. Poultry CFOs and CAFOs constituted only 11.7% and 6.9% of the total number of poultry farms in 2002 and 2007, respectively. The changes in the Indiana poultry industry demonstrated that while the total number of Indiana poultry farms increased, the number of CFO/CAFO decreased.

Because of the continuous development of the poultry industry in Indiana, poultry manure production has been increasing. Indiana produced 1.885 million tons of total "as-excreted" poultry manure in 2007, a 26.7% increase as compared with 2002. Layer manure (0.840 million tons) consisted of 44.6% of all manure produced, followed by turkey manure (0.534 million tons or 28.3%), and pullets (0.177 million tons or 9.4%). Among the five major poultry species, the manure produced by ducks (0.101 million tons) had the smallest proportion of 5.4%. The manure produced by three poultry species (layers, pullets, and turkeys) increased by 31% between 2002 and 2011. The rates of increase were largest for turkeys (84%) and smallest for layers (4%).

As the number of CFO/CAFO poultry farms decreased and their sizes increased, poultry manure production has become more concentrated geographically. Indiana poultry manure distributions vary greatly among different counties. In general, there was more poultry manure available in northern and southern Indiana. Among the 92 counties, Dubois County in southern Indiana had the highest manure production of approximately 268,400 tons in 2007. Benton County had the least available poultry manure of only about two (2) tons.

The equivalent amounts of plant nutrients available in as-excreted poultry manure produced in Indiana were 30,370 tons of nitrogen and 9,433 tons of phosphorus in 2007. When divided by the total "land in farms", there were averages of 4.11 lbs of nitrogen and 1.28 lbs of phosphorus per acre of land in 2007 in Indiana. Compared with the 3.24 lbs of nitrogen and 1.01 lbs of phosphorus per acre of land in 2002, the increases were 26.7% and 26.2% for nitrogen and phosphorus in poultry manure, respectively, during the five-year period.

The recoverable poultry manure nitrogen and phosphorus (the amount available for land application) in Indiana in 2007 were 13,667 tons and 3,585 tons, respectively. The recoverable

poultry nutrients per acre of Indiana farm land were 1.85 lb/acre of nitrogen and 0.49 lb/acre of phosphorus in 2007.

There were manure brokers or contract manure haulers in Indiana providing various services, including manure transportation and land application; but only a small number worked with poultry manure. The average transportation radius of solid poultry manure was about 25 to 30 miles. The maximum transportation distance was 100 miles. Some manure brokers' service areas were at a radius of about 200 miles (not the manure transportation distance).

Poultry manure prices differed based on geographical areas and times but had a general increasing trend over the years. The actual manure-only costs obtained in the survey ranged from $9.5 to $60/ton of solid manure. Rising inorganic fertilizer prices in the past decade were the driving force behind the increasing economic value of poultry manure.

The surveyed willingness-to-pay costs for solid-manure-only ranged from $0 to $50/ton and averaged $17/ton. Those costs for manure, transportation, and application ranged from $0 to $100/ton and averaged $26/ton. For liquid poultry manure including transportation and application, the willingness-to-pay costs ranged from 1 to 30¢/gallon and averaged 5¢/gallon. The cost was lower for liquid-manure-only without transportation and application. It ranged from 0 to 20¢/gallon and averaged 3¢/gallon.

About 25% of the surveyed croplands applied poultry manure as organic fertilizer. More than two thirds of the surveyed poultry manure users had applied poultry manure to fields for at least 2 years. The longest history of using poultry manure was 75 years. The users were well aware of the benefits of using poultry manure. All of them planned to continue applying it to their croplands.

For crop producers who had not applied poultry manure, the top reason was its unavailability. Difficulty of poultry manure application was the second reason, followed by lack of experience or familiarity (never used poultry manure). About a quarter of the survey respondents had concerns about its economics (more expensive than inorganic fertilizers). Negative environmental effects were also among the concerns, which included potential nutrient runoff, odor nuisance, and groundwater contamination.

Recommendations for future work are to develop and distribute educational materials for poultry manure applications; update the Indiana poultry manure production and availability in 2014 when the new USDA Census data are published; study value-added utilizations of poultry manure; survey manure production and application from the swine and dairy industries; and conduct scientific research to develop more reliable production rates for calculations of poultry manure nutrient productions.

Introduction

Indiana is one of the leading states in poultry production. Indiana ranks first in ducks, third in eggs, and eighth in turkeys. Poultry industry is very important in the Indiana economy. According to USDA-NASS, Indiana poultry and eggs accounts for 9.8% of the total agricultural cash receipts and remained as the fourth leading contributor with $938 million in the state in 2010 (IFO, 2012). The total impacts of Indiana's poultry industry were about $1.7B on labor and $369 M on income, and had more than 12,277 employments in 2007 (Table 1).

Table 1. Direct, indirect, and induced impacts attributed to Indiana's poultry industry.

Output	Labor	Income	Employment
Direct	$806,594,240	$141,886,960	5031
Indirect	$707,309,699	$153,757,291	4672
Induced	$225,650,003	$73,285,607	2574
Total	$1,739,553,923	$368,929,866	12,277

Source: Mayen and McNamara (2007).

Indiana' poultry industry has been growing in the past decade. For example, the value of the state's turkey production in 2008 was $306.3 million based on 14.5 million marketed turkeys, which represented a 20% increase from 2003 (USDA, 2010).

The industry's growth has increased its demand for feed. The Indiana poultry industry consumes large quantities of corn and soybeans. The total feed, corn, and SBM consumed in 2007 were about 1.90M, 1.26M, and 0.45M tons, respectively (Table 2), which represented an estimated overall increase of 25% between 2002 and 2007. Based on the latest statistics from the American Soybean Association, Indiana planted 5,350,000 acres of soybeans in 2010, produced 258.5M bushels (7.04M metric tons) of soybeans at $11.80 per bushel or $434 per metric ton (Anonymous, 2012). A substantial portion of the state's production was purchased by the poultry industry.

Table 2. Total feed, corn and SBM consumption by poultry industry in Indiana in 2007.

Bird category	Total consumption (tons)		
	Feed	Corn	SBM
Broiler	187,585	122,153	53,013
Turkey male	413,944	253,033	124,673
Turkey female (light)	68,468	39,907	22,036
Turkey female (heavy)	36,176	21,890	7345
Duck	68,214	48,788	15,719
Pullet to 13 wk	139,984	98,512	32,793
Pullet 13 to 20 wk	47,444	33,924	9731
Laying hen	939,485	638,927	183,243
Total	1,901,299	1,257,134	448,553

Note: Calculated based on USDA-NASS poultry data and the methods described by Applegate (2011).

The industry's growth also resulted in increasing production of poultry manure, which is a mixture of bedding material, poultry excreta, and wasted feed. Poultry manure is recognized as an excellent source of plant nutrients. Upon clean-out, it can be applied to cropland and pastureland in order to recycle essential plant nutrients like nitrogen (N), phosphorus (P), and potassium (K). In addition, poultry manure contains 10 other essential plant nutrients which are calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo).

Poultry manure applied to land returns organic matter and other nutrients to the soil, building soil fertility and quality. Poultry manure on land growing soybeans is desirable because legumes biologically fix nitrogen gas (N_2) from the atmosphere, allowing manure to be applied at rates needed only to satisfy crop P and/or K requirements (Slaton et al., 2008). Significant soybean yield increases from poultry manure were observed in Mississippi (Adeli et al., 2005) and Arkansas (Slaton et al., 2008). Ashes from incinerated poultry manure also provided a good source of fertilizer for corn and soybean farmers (Morrison, 2009). Given the increasing costs for inorganic fertilizer, poultry manure can potentially lower the production costs of crops, including corn and soybeans.

Nevertheless, nutrient excesses can occur in areas where poultry production has expanded faster than the willingness and/or ability of agricultural land owners to utilize manure nutrients (Collins and Budumuru, 2005). Therefore, manure should be adequately managed and utilized to avoid potential short term and long-term adverse impacts on water quality and air quality.

Data on poultry manure quantities, distributions, and characteristics are necessary to assist in the planning, design, and operation of manure collection, storage, pretreatment, and utilization systems for poultry and crop producers. Manure transport is a commonly utilized strategy to address nutrient excesses. State governments in Maryland, Virginia, and West Virginia have utilized transport subsidy programs to encourage this practice. Pelletier et al. (2001) interviewed potential poultry manure users and identified several obstacles to poultry manure acceptance. Most crop producers will pay a positive price close to the savings in commercial inorganic fertilizer, but approximately 25% require a payment before accepting manure (Norwood et al., 2005).

In addition to the rapid development, Indiana poultry farm sizes vary considerably and are not evenly distributed geographically in the state. Poultry populations in different counties are with large variation of density. Poultry manure production and its value-added use, especially as fertilizer on croplands became a complicated issue concerning the availability and transportation to local farmland. Its economical and sustainable application is affected by poultry farm size and distribution, poultry farm operations, inorganic fertilizer prices, acceptance of manure as fertilizer and other applications by the users, infrastructure, and business success of manure brokers and manure consulting companies.

However, little hard information is currently available on the statewide transport and fate of poultry manure, and the willingness of crop producers to accept poultry manure in Indiana. More comprehensive data and in-depth knowledge about Indiana's poultry manure related to its

quantity of production, geographical distribution, transportation, land application, and economics will help to maximize poultry manure value as a crop nutrient and minimize its adverse environmental impacts. It will contribute to Indiana's agriculture and crop production.

Therefore, a study was needed to investigate current poultry manure production, transportation, and application situations, summarize successful experiences, identify potential problems related to these issues, and provide educational information to producers, commodity groups, extension educators, and policy makers for improvement of poultry manure management.

The objectives of this survey on poultry manure in Indiana were to document its production, availability, and geographical distribution; evaluate its movement (transportation) and application; examine the interest in and willingness of crop (especially soybean and corn) producers to pay for manure; and assess the obstacles and economics of using it as nutrient for land application.

Poultry Manure Availability and Geographical Distribution

Procedures and Methods

The study of the availability and geographical distribution of poultry manure started with a literature review, which continued throughout the project period. The search of literature covered peer-reviewed journals, scientific conference papers, research project reports, and extension publications. It included publications all over the world and back in history as early as the 1940s (Yushok and Bear, 1943). The review of literature enabled a broader view for the researchers of this study on the poultry manure management issues, revealed the current knowledge and knowledge gaps, and facilitated the development of survey methodologies and interpretation of research results.

In addition to literature review and methodology development, three major steps were taken for the Indiana manure availability and geographical distribution study:

1. Data collection and evaluation
2. Data analysis and interpretation
3. Result presentation and discussion

Sources of Poultry Data

Two types of data needed to evaluate the manure production and geographical distribution are essential:

1. Numbers and species (e.g., layer, turkey, and duck) of poultry at different locations in Indiana;
2. Rates of manure production and nutrient contents of each species under different production practices.

Additionally, historical data are also necessary to study the changes and predict future trends in poultry production in the state. The most important data were collected from the following sources:

1. The Indiana Department of Environmental Management (IDEM, Indianapolis, IN). There were two data sources from IDEM:
    a. Permits for Indiana Confined Feeding Operation (CFO) and Concentrated Animal Feeding Operation (CAFO) issued by IDEM.
    b. Annual reports submitted by Indiana CAFO to IDEM.
2. The USDA National Agricultural Statistics Service (NASS, www.nass.usda.gov). Publications of NASS cover statewide poultry data and statistics. There are also two data sources from NASS:
    a. Indiana agricultural statistics
    b. USDA agricultural census

In Indiana, any farm with 300 or more cattle, 600 or more swine or sheep, 30,000 or more poultry, or 500 or more horses in confinement is a CFO. A CAFO is a CFO that meets the threshold animal numbers for a large CAFO in Table 3 (IDEM, 2012).

Table 3. Threshold number of animals for CAFO and CFO in Indiana.

Species/Sector	Threshold number of animals	
	Large CAFO	CFO
Beef:		≥300
Cattle	≥1000	
Cow/Calf Pairs	≥1000	
Dairy:		
Mature Dairy Cow	≥700	
Other than Mature Dairy Cows (dairy heifers, dairy calves, veal calves)	≥1000	
Swine:		≥600
Growers/Finishers/Sows (greater than 55 lbs)	≥2500	
Nursery Pig (less than 55 lbs)	≥10,000	
Chickens:		≥30,000
Layers/Broilers (liquid manure handling system)	≥30,000	
Chickens other than Layers (not in a liquid manure handling system)	≥125,000	
Layers (not in a liquid manure handling system)	≥82,000	
Ducks:		
Liquid Manure System	≥5000	
Not in a Liquid Manure System	≥30,000	
Others:		
Turkeys	≥55,000	
Horses	≥500	≥500
Sheep/Lambs	≥10,000	≥600

Source: IDEM (2012).

Due to the confidentiality and protection of agricultural producers, poultry farm contact information and poultry production data from non-CFO/CAFO producers were unavailable. Therefore, the data relevant to poultry production in this study was mainly based on the publically accessible sources. Additional information was obtained from Purdue Extension specialists and professional associations. Discussions and interviews with some individual producers in Indiana and other states also helped to provide much needed information.

Each data source had its own benefits and limitations (Table 4); but data from different sources can complement each other and provide more comprehensive information to study the availability and geographical distributions of Indiana poultry manure.

Table 4. Characteristics of poultry data sources.

Parameter	IDEM		USDA-NASS	
	Permits	Annual report	Annual statistics	Census
Farm coverage	CFO and CAFO	CAFO	All farms	All farms*
Publication interval	Annual/monthly	Annual	Annual	Five years
Data spatial resolution	Farm	Farm	State	County
Data temporal resolution	Monthly	Annual	Annual/monthly	Annual
Level of details	High	High	Low	Medium*
Manure production data	No	Yes	No	No

Note: *Data collection from farms of all sizes. Statistical data for the public are at county level.

Data about the poultry CFOs and CAFOs in different counties were studied based on the characteristics of the different data sources by evaluating their farm coverage, geographical resolution, temporal resolution, level of details, and data accuracy.

IDEM CFO/CAFO Permits

The IDEM issues CFO approval or a federal National Pollutant Discharge Elimination System (NPDES) permit, depending on the size of the operation (IDEM, 2012). The summarized data about CFO/CAFO from IDEM are tabulated in an Excel spreadsheet and provides details about the farms, including addresses and contacting phone numbers (Table 5). Five poultry species (layers, pullets, broilers, turkeys, and ducks) are included. The permit data were available from IDEM since 2001, providing a valuable source for analyzing the history of poultry CFO/CAFO development. These data were an essential information source for this study.

Table 5. List of poultry CFO/CAFO information available from IDEM.

Information Category	Information
ID and name	TEMPO ID # (Agency Interest #)
	CFO Farm ID #
	Operation Name and Owner's Name
Operation location	Mailing Address and Phone Number
	Section, Township, Range
	Latitude and Longitude
Permit information	Current Permit Type (CFO or CAFO)
	Most Recent Construction Approval # and Date
	NPDES Permit #; Most Recent NPDES Received and Issued
	Most Recent Approval Received and Issued
	Most Recent MMP Received and Issued
	Expiration Date and Date Renewal Due
Poultry species and inventory	Layers
	Pullets
	Broilers
	Turkeys
	Ducks

However, the IDEM permit records only reflect a small portion of the actual producers because permits are required for only farms classified as CFO or CAFO. There were 315 poultry CFO/CAFO according to the IDEM permit list, but 4545 Indiana operations classified as "any poultry farms" according to the USDA census in 2007. In terms of the number of poultry farms, the total CFO/CAFO listed by IDEM was only about 7% of all the poultry farms counted by USDA. For poultry species such as ducks, the number of CFO/CAFO was <1% of all duck farms because most of the duck farms were relatively small contract producers.

Moreover, there were also discrepancies between the number of birds listed in the IDEM permits and the USDA statistics. The USDA census data covered all poultry farms regardless of their sizes. The IDEM permits were only required for large farms (CAFO and CFO). Therefore, the IDEM numbers of poultry farms and numbers of birds should both be subsets of the USDA census data. However, while this is confirmed for the number of farms, it is not the case for the numbers of birds for some species. Comparison of the two 2007 data sources in Table 6 shows that for layers, broilers, and turkeys, the inventories from the USDA census were larger than the numbers of birds in IDEM permits.

Table 6. Comparison of USDA and IDEM 2007 poultry data.

Poultry	USDA census		IDEM CFO/CAFO permits	
	Number of birds (inventory)	Farms	Number of birds	Farms
Layers	24,238,513	3583	30,623,358	72
Pullets	6,928,062	519	9,375,708	49
Broilers	5,536,933	594	3,886,151	34
Turkeys	5,971,548	498	5,892,439	149
Ducks	1,538,664	793	258,700	11

Note: (1) Inventory poultry.

The possible reason for this discrepancy may be because the actual numbers of birds at the CFOs/CAFOs were smaller than the permitted numbers of birds. The producers tended to keep their inventories less than the permitted maximum numbers of birds allowed at their facilities.

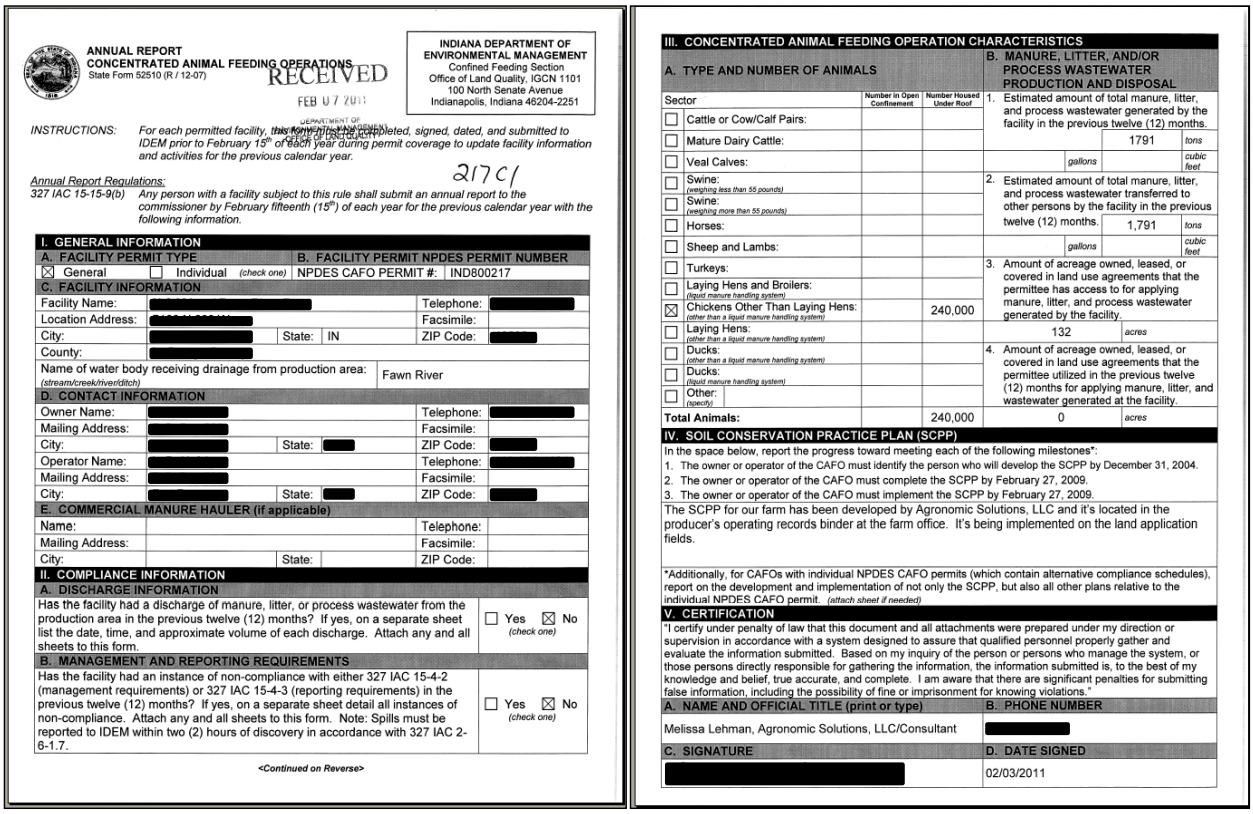
IDEM CAFO Annual Report

Poultry producer annual reports (Form 52510) are available from the IDEM on-line Virtual File Cabinet (VFC) for download. Annual reports of CAFOs provided more detailed information of individual facilities including manure production and disposal (Figure 1) than the IDEM permits.

However, annual reports to IDEM are only required for CAFOs, not AFOs. Therefore, only 73 poultry CAFOs out of 307 poultry CFO/CAFO (or 21%) had reports available in the VFC in 2011. As a consequence, the VFC can only provide limited amounts of information about poultry manure production.

Inconsistent methodologies of manure production estimation in the annual report were found. Some farms calculated the amount of total manure by multiplying the total number of animals on the farm by the bird-specific manure production rates obtained from Purdue University Extension publication ID-101 (Sutton et al., 1994), or the ASAE standard of manure production and

characteristics (ASABE, 2005). Other farms measured the quantities of manure in fixed-volume pits. A number of CAFOs hired consultants to prepare Form 52510, most of them using permitted number of poultry, although the actual number of poultry on the farm were typically less. Some discrepancies between the total quantities of manure reported in Form 52510 and those calculated by using bird numbers and manure production rates were identified; but the cause of the discrepancies was unclear.



ANNUAL REPORT
CONCENTRATED ANIMAL FEEDING OPERATIONS
State Form 52510 (R / 12-07)

RECEIVED
FEB 07 2011
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF LAND QUALITY

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
Confined Feeding Section
Office of Land Quality, IGCN 1101
100 North Senate Avenue
Indianapolis, Indiana 46204-2251

INSTRUCTIONS: *For each permitted facility, this form shall be completed, signed, dated, and submitted to IDEM prior to February 15th of each year during permit coverage to update facility information and activities for the previous calendar year.*

2171

Annual Report Regulations:
327 IAC 15-15-9(b) *Any person with a facility subject to this rule shall submit an annual report to the commissioner by February fifteenth (15th) of each year for the previous calendar year with the following information.*

I. GENERAL INFORMATION

A. FACILITY PERMIT TYPE: ☒ General ☐ Individual (check one)
B. FACILITY PERMIT NPDES PERMIT NUMBER: NPDES CAFO PERMIT #: IND800217

C. FACILITY INFORMATION

Facility Name:	[redacted]	Telephone:	[redacted]
Location Address:	[redacted]	Facsimile:	
City:	[redacted] State: IN	ZIP Code:	[redacted]
County:	[redacted]		
Name of water body receiving drainage from production area: (stream/creek/river/ditch)	Fawn River		

D. CONTACT INFORMATION

Owner Name:	[redacted]	Telephone:	[redacted]
Mailing Address:	[redacted]	Facsimile:	
City:	[redacted] State: [redacted]	ZIP Code:	[redacted]
Operator Name:	[redacted]	Telephone:	[redacted]
Mailing Address:	[redacted]	Facsimile:	
City:	[redacted] State: [redacted]	ZIP Code:	[redacted]

E. COMMERCIAL MANURE HAULER (if applicable)

Name:		Telephone:	
Mailing Address:		Facsimile:	
City:	State:	ZIP Code:	

II. COMPLIANCE INFORMATION

A. DISCHARGE INFORMATION

Has the facility had a discharge of manure, litter, or process wastewater from the production area in the previous twelve (12) months? If yes, on a separate sheet list the date, time, and approximate volume of each discharge. Attach any and all sheets to this form. ☐ Yes ☒ No (check one)

B. MANAGEMENT AND REPORTING REQUIREMENTS

Has the facility had an instance of non-compliance with either 327 IAC 15-4-2 (management requirements) or 327 IAC 15-4-3 (reporting requirements) in the previous twelve (12) months? If yes, on a separate sheet detail all instances of non-compliance. Attach any and all sheets to this form. Note: Spills must be reported to IDEM within two (2) hours of discovery in accordance with 327 IAC 2-6-1.7. ☐ Yes ☒ No (check one)

<Continued on Reverse>

III. CONCENTRATED ANIMAL FEEDING OPERATION CHARACTERISTICS

A. TYPE AND NUMBER OF ANIMALS

Sector	Number in Open Confinement	Number Housed Under Roof
☐ Cattle or Cow/Calf Pairs:		
☐ Mature Dairy Cattle:		
☐ Veal Calves:		
☐ Swine: (weighing less than 55 pounds)		
☐ Swine: (weighing more than 55 pounds)		
☐ Horses:		
☐ Sheep and Lambs:		
☐ Turkeys:		
☐ Laying Hens and Broilers: (liquid manure handling system)		
☒ Chickens Other Than Laying Hens: (other than a liquid manure handling system)		240,000
☐ Laying Hens: (other than a liquid manure handling system)		
☐ Ducks: (other than a liquid manure handling system)		
☐ Ducks: (liquid manure handling system)		
☐ Other: (specify)		
Total Animals:		240,000

B. MANURE, LITTER, AND/OR PROCESS WASTEWATER PRODUCTION AND DISPOSAL

1. Estimated amount of total manure, litter, and process wastewater generated by the facility in the previous twelve (12) months.
   1791 tons
   gallons cubic feet
2. Estimated amount of total manure, litter, and process wastewater transferred to other persons by the facility in the previous twelve (12) months.
   1,791 tons
   gallons cubic feet
3. Amount of acreage owned, leased, or covered in land use agreements that the permittee has access to for applying manure, litter, and process wastewater generated by the facility.
   132 acres
4. Amount of acreage owned, leased, or covered in land use agreements that the permittee utilized in the previous twelve (12) months for applying manure, litter, and wastewater generated at the facility.
   0 acres

IV. SOIL CONSERVATION PRACTICE PLAN (SCPP)

In the space below, report the progress toward meeting each of the following milestones*:
1. The owner or operator of the CAFO must identify the person who will develop the SCPP by December 31, 2004.
2. The owner or operator of the CAFO must complete the SCPP by February 27, 2009.
3. The owner or operator of the CAFO must implement the SCPP by February 27, 2009.

The SCPP for our farm has been developed by Agronomic Solutions, LLC and it's located in the producer's operating records binder at the farm office. It's being implemented on the land application fields.

*Additionally, for CAFOs with individual NPDES CAFO permits (which contain alternative compliance schedules), report on the development and implementation of not only the SCPP, but also all other plans relative to the individual NPDES CAFO permit. *(attach sheet if needed)*

V. CERTIFICATION

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations."

A. NAME AND OFFICIAL TITLE (print or type)	B. PHONE NUMBER
Melissa Lehman, Agronomic Solutions, LLC/Consultant	[redacted]
C. SIGNATURE	**D. DATE SIGNED**
[redacted]	02/03/2011

Figure 1. An example Annual Report of confined animal feeding operations.

However, the IDEM CAFO Annual Reports are the only source of information that provided poultry manure production estimations. They were used in this study for data verification and comparison.

Indiana Agricultural Statistics

The annual Indiana Agricultural Statistics reports are compiled by the USDA-NASS, Indiana Field Office. Hardcopies of the reports (e.g., IFO, 2012) are available upon request to the office. The data are also available on-line (www.nass.usda.gov/in). Each annual statistics report include a section on poultry and egg production in Indiana and the production comparisons with previous years and with other states. Monthly egg production data are also published.

However, the annual statistics do not provide poultry data at county levels. Additionally, data on broilers and ducks are not available even at the state level, although they are major poultry species in Indiana. The latest published annual statistical data were for 2011.

USDA Agricultural Census

The census data developed by USDA-NASS every five years contained the most detail and had the highest geographical resolution (Table 4). The census data related to poultry production are published at county levels. Publications based on the 2007 census are available online (USDA, 2009). Comparison of some 2007 census data with the 2002 census data is also provided. The 2012 census is not yet published.

The U.S. Census data associated with Indiana poultry contain both inventory and sales. The main poultry species are layers, broilers, pullets, turkeys, and ducks. Additional species listed were geese, emus, ostriches, pheasants, pigeons or squab, quail, and "other poultry". "Other poultry" are those poultry not having a specific code on the report form.

In keeping with the provisions of Title 7 of the United States Code, no data can be published that would disclose information about the operations of an individual farm or ranch. All tabulated census data are subjected to an extensive disclosure review prior to publication. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived, was suppressed and coded with a '*D*'. However, the number of farms is not considered confidential information and is provided even though other information is withheld.

Sources of Manure Production Rate Data

The quantity of manure produced by a particular species over a given period can be estimated as the product of number of the poultry and its bird-specific manure production rate according to Eqn. (1)

$$M = Pn \cdot Rm \cdot Dp \tag{1}$$

where: *M* is the manure production, lb or kg; *Pn* is the number of birds; *Rm* is the bird-specific manure production rate, lb/bird-day or kg/bird-day; and *Dp* is the period of manure production, days.

Manure production calculations using Eqn. (1) are applicable to meat producing poultry (broilers, turkeys, and ducks) as well as egg-producing poultry (e.g., in the calculation methods published by Barker et al., 2001). There are also other methods (e.g., ASABE, 2005), in which manure production by meat poultry are calculated on flock-per-bird (or finished animal).

There are numerous publications describing and listing animal manure production rates; but the majority of them only provide secondary or tertiary data sources, i.e., not directly from experimental measurements of actual manure production. Table 7 lists three typical manure production calculation methods. The production rates calculated by Sutton et al. (1994) were published by the Purdue University Cooperative Extension Service (PUCES) (Table 4 in PUCES publication ID-101). It used to be the main reference method for calculating manure production from poultry and other livestock in Indiana. The set of North Carolina State University manure production rates was one of a few that were largely developed from experimental data (Barker et al., 2001). It was also a popular method adopted by manure management consulting companies

before the ASAE (American Society of Agricultural Engineers) Standard of Manure Production and Characteristics (ASABE, 2005) was widely accepted by producers and consulting companies.

Table 7. Three typical poultry manure production calculation methods.

Species	Production rate			Converted, lb/bird-d	Moisture, % wet base	Manure status
	kg/bird	lb/ bird	Period, days			
Source: (Sutton et al., 1994)						
Layer	14.53	32	365	0.09	NA	As leaves
Broiler	8.17	18	365	0.05	NA	As leaves
Turkey (male)	20.88	46	365	0.13	NA	As leaves
Turkey (female)	20.88	46	365	0.13	NA	As leaves
Ducks	27.24	60	365	0.16	NA	As leaves
Pullet	9.99	22	365	0.06	NA	As leaves
Source: (Barker et al., 2001)						
Layer (4 lb)	0.12	0.26	1	0.26	75	As-excreted
Broiler (2 lb)	0.07	0.16	1	0.16	75	As-excreted
Turkey (15 lb)	0.31	0.68	1	0.68	75	As-excreted
Duck (3 lb)	0.15	0.33	1	0.33	73	As-excreted
Source: (ASABE, 2005)						
Layer	0.088	0.19	1	0.19	75	As-excreted
Broiler*	4.9	11	48	0.23	74	As-excreted
Turkey (male)*	36	78	133	0.59	74	As-excreted
Turkey (female)*	17	38	133	0.29	74	As-excreted
Duck*	6.5	14	39	0.36	74	As-excreted

Notes: * production rates based on finished animal. NA = not available. As leaves = as manure leaves storage for land application. As-excreted = feces and urine as excreted.

The ASAE standard was originally developed by the Engineering Practices Subcommittee of the ASAE Agricultural Sanitation and Waste Management Committee. It was approved by the Structures and Environment Division Standards Committee and has gone through several reconfirmations, revisions, and reaffirmations:

- Adopted by ASAE in December 1976;
- Reconfirmed in December 1981, December 1982, December 1983, December 1984, December 1985, December 1986, December 1987;
- Revised in June 1988;
- Revised editorially and reaffirmed in December 1993 as version “ASAE EP384.1 DEC93”;
- Revised editorially in March 1995 (ASAE, 1997);
- Reaffirmed in December 1998, December 1999, December 2001, February 2003;
- Revised in March 2005 by a joint committee of ASAE and Federation of Animal Science Societies members as version “ASABE D384.2 MAR2005” (ASABE, 2005);
- Reaffirmed in January 2010 as version “ASABE D384.2 MAR2005 (R2010)” (ASABE, 2010).

Method Selection and Total Manure Production Calculation

Year 2007 was selected as the primary year of Indiana poultry manure availability and geographical distribution study because 2007 is the latest year that both the USDA census data and IDEM CFO/CAFO permit data are available. Moreover, only the USDA census data have sufficient details that can be used to study poultry manure production at both county and state levels. Statewide poultry manure production by certain poultry species from 2002 to 2011 were also studied using USDA annual statistical data. In addition, the USDA 2002 census data were also used as historical data to compare with the relevant data in the 2007 census.

The USDA and IDEM data complemented each other and were used as the primary source of poultry data to estimate poultry manure production at state and county levels. The withheld data "*D*" in the USDA census for certain poultry species and counties created some data gaps. These "missing data" were assessed and replaced with the IDEM 2007 CFO/CAFO permit data if the data demonstrated some confidence, e.g., confirmed by the number of farms, which was not withheld in the census, for the same poultry species and the same county, and evaluated with multi-year CFO/CAFO permit data. However, this method may still have some errors, although relatively small compared with leaving the data gaps, due to the fact that the permitted number of poultry for a CFO/CAFO was often larger than the actual number of poultry raised in the facility.

To maintain consistency with data from other sources, e.g., the IDEM CAFO annual reports, methods based on the ASAE standard (ASABE, 2010) and combined with other publications were selected to analyze the as-excreted manure production in this project (Table 8).

Table 8. As-excreted manure production rates selected and used in this project.

Poultry species	Production per finished bird		Production per bird-d, lb/bird-d	Moisture, % w.b.	References
	lb/bird	Finish period, days			
Layer			0.19	75	ASABE (2010)
Pullet			0.14	75	Sutton et al. (1994); Turn et al. (2002)
Broiler	11	48	0.23	74	ASABE (2010)
Turkey*	30	133	0.49	74	ASABE (2010)
Duck	14	39	0.36	74	ASABE (2010)

Notes: * averaged by using a ratio of male and female turkeys = 2:1 (Applegate, 2011).

Different status of manure has been recommended and used for manure production calculation in different publications. They include as-excreted (or fresh manure) by animals (Kellogg et al., 2000; Henuk and Dingle, 2003; ASABE, 2005), as-leaves (or as-removed) from manure storage (Sutton et al., 1994), recoverable manure nutrients available for application (Kellogg et al., 2000), and dried manure (Reardon et al., 2001; Turn et al., 2002; Henuk and Dingle, 2003). The volume and weight of manure produced by poultry also can differ due to bird age, body weight, and feed consumption. The resulting manure weights calculated with different manure status and poultry conditions varied considerably (e.g., Bell, 1990; Lorimor and Xin, 1999; Henuk and Dingle, 2003).

To reduce errors due to different manure status, it was found that calculation of manure production in fresh manure (as-excreted) based on the ASAE standard (ASABE, 2010) was most appropriate. Another advantage of using as-excreted, compared with other status like as-removed, is that the part of nutrients emitted or run off during storage is taken into account.

However, the ASAE standard (ASABE, 2010) does not provide manure production rates for pullets. Moreover, the USDA inventory and sales data do not distinguish between male and female turkeys. To fix these problems when using the ASAE standard, the following manure production rates were used:

- A manure production rate for pullets, equivalent to as-excreted, derived from the methods by Sutton et al. (1994) and Turn et al. (2002).
- An average ratio of male and female turkeys of 2:1 in Indiana based on the data from the Indiana State Poultry Association (Applegate, 2011).

In this project, manure production rates for layers and pullets were calculated as per bird per day. For meat-producing poultry, both production rates per day and per finished-animal over the growing period (e.g., 48 days for broilers and 133 days for turkeys) were used for comparison (Table 8). Production per bird per day for all poultry species were used to calculate the total manure production. To keep the confidentiality of the non-CFO/CAFO producers, the highest geographical resolution was set at the county level.

The quantities of manure produced from *n* different poultry species over a given period in a county or in the entire state were calculated using Eqn. (2).

$$M = \sum_{i=1}^{n} Pn_i \cdot Rn_i \cdot Dp_i \qquad (2)$$

The unit of weight for manure production at county and state levels is in ton (or short ton = 2000 lbs).

Poultry Manure Nutrient Value Assessment

To assess the total nutrient values of the Indiana poultry manure, the typical manure characteristics (as-excreted) and calculation methods in the ASAE standard D384.2 MAR2005 (ASABE, 2010), and in Sutton et al. (1994) and Turn et al. (2002) were used (Table 9). Table 10 converts the nutrient contents as percentages of the fresh manure from the data in Table 9 for quick calculation using the total poultry manure production in each county.

However, the typical manure characteristics in the ASABE standard (ASABE, 2010) were based on the animals on national demographics, rather than on Indiana demographics (Applegate, 2013). Therefore, adjustments could still be made when the Indiana demographics are available.

Table 9. Poultry manure nutrient calculation methods.

Species	Total solids	Nitrogen	Phosphorus	Potassium	Calcium	Total manure	Units
Layer	0.049 [a]	0.0035 [a]	0.0011 [a]	0.0015 [a]	0.0048 [a]	0.19 [a]	lb/d-bird
Pullet	0.036 [c]	0.0030 [c]	0.0010 [c]	0.0011 [c]		0.14 [c]	lb/d-bird
Broiler	2.8 [a]	0.12 [a]	0.035 [a]	0.068 [a]		11 [a]	lb/bird
Turkey	16.6 [b]	0.99 [b]	0.29 [b]			65 [b]	lb/bird
Duck	3.7 [a]	0.14 [a]	0.048 [a]			14 [a]	lb/bird

Note: [a] Based on Table 10a and Table 12a in ASABE (2010); [b] Based on Table 10a in ASABE (2010) and a 2:1 ratio of male to female turkeys (Applegate, 2011); [c] Estimated by combining data in Table 4 of Sutton et al. (1994) and Table 5 in Turn et al. (2002).

Table 10. Poultry manure nutrients as percentages of as-excreted manure.

Types	Total solids, %	Nitrogen, %	Phosphorus, %	Potassium, %	Calcium, %
Layer	26	1.842	0.579	0.807	2.526
Pullet	25	1.789	0.597	0.629	NA
Broiler	25	1.091	0.318	0.618	NA
Turkey	26	1.531	0.454	NA	NA
Duck	26	1.000	0.343	NA	NA

Note: NA = not available.

Indiana Poultry Farms

Overview

According to the results of the agricultural census, the total number of Indiana poultry farms increased by 53.5% from 2002 to 2007. There were 4545 farms, which raised various species of poultry in 2007, up from 2961 farms in 2002 (Figure 2).

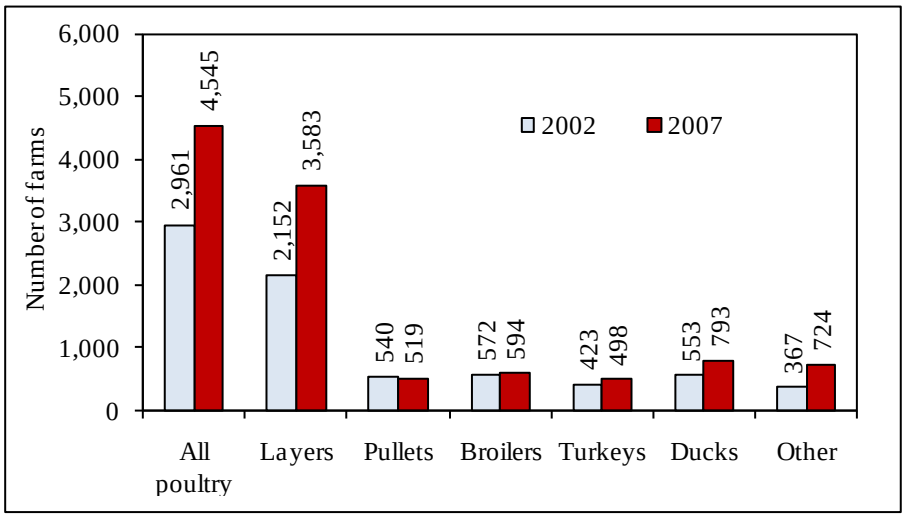


Figure 2. Number of Indiana poultry farms in 2002 and 2007.

Layer hen farms consisted of 78.8% of all Indiana poultry farms in 2007. There were 3853 layer farms in 2007, up from 2152 farms in 2002 (Figure 2). The number of duck farms was the second largest and there were 793 in 2007, up from 553 in 2002. Other farms in 2007 included emus (20), geese (333), ostriches (2), pheasants (113), pigeons or squab (138) and quail (75). The total inventory of poultry on the "other farms" species was less than 100,000 in 2007.

Pullet, broiler, and turkey farms had similar numbers of farms, ranging from 498 (turkey) to 594 (broiler) in 2007. The number of farms of all major species increased from 2002 to 2007, except for pullet farms, which decreased by 21 during the five year period. The counties that had the largest numbers of poultry farms in each county (>100) were La Grange, Elkhart, Noble, Kosciusko, and Adams in the northeast, and Daviess in the southwest (Figure A.1, page 43).

According to IDEM, the total number of poultry CFO/CAFO was 347 in 2002 and 315 in 2007. The poultry CFO/CAFO operations were only 11.7% and 6.9% of the total poultry farms in 2002 and 2007, respectively. Most Indiana poultry farms were below the CFO threshold. These trends demonstrated that while the total number of Indiana poultry farms increased, the number of CFO/CAFO decreased.

Layer Farms

The sizes of layer farms varied considerably. The majority (about 92.8%) of the layer farms only had inventories of less than 100 layers (Table 11). Most of these can be called hobby farms, or small farms that are maintained without expectation of being a primary source of income. Some are managed as working farms for sideline incomes, or run at an ongoing loss as a lifestyle choice by people with the means to do so, functioning more like a country home than a business. The largest numbers of layer farms were found in a few counties (La Grange, Elkhart, Adams, and Daviess) that had more than 100 layer farms (Figure A.2, page 44).

Table 11. Size distributions of layer farms in Indiana in 2007.

Farms with inventory of	Farms		Layers	
	Total number	%	Total number	%
All sizes	3,583	100.00%	24,238,513	100.00%
1 to 49	3,053	85.21%	51,921	0.21%
50 to 99	271	7.56%	16,716	0.07%
100 to 399	150	4.19%	24,360	0.10%
400 to 3199	18	0.50%	30,694	0.13%
3200 to 9999	4	0.11%	28,100	0.12%
10,000 to 19,999	19	0.53%	332,464	1.37%
20,000 to 49,999	21	0.59%	535,830	2.21%
50,000 to 99,999	11	0.31%	677,838	2.80%
100,000 or more	36	1.00%	22,540,590	92.99%

Source: USDA-NASS.

About 98% of the layer hens were raised on less than 2% of the farms (Table 11). The locations of layer CFO/CAFO farms were mostly in the north and south of Indiana (Figure A.3, page 45).

According to the 2007 USDA census, there were 68 layer farms (1.90% of the total layer farms) that had inventories of more than 20,000 layers in Indiana. According to the IDEM permits, there were 72 active layer CFO/CAFO (>30,000 layers/farm) in the same year. There are some discrepancies that were probably due to the fact that the actual number of birds at a CFO/CAFO could be smaller than the permitted capacity.

Pullet Farms

The total number of pullet farms of 519 in 2007 was smaller than layer farms. La Grange, Elkhart, Kosciusko, and Adams counties in northeast had the largest number of pullet farms (Figure A.4, page 46). According to the size distribution data by USDA-NASS for the pullet farms for laying flock replacement, there were more small farms (<2,000 pullets sold) and large farms (≥ 100,000 pullets sold) than the medium size (between 2,000 and 100,000) farms in 2007 (Table 12). The small farms consisted of about 61% of total farms but only sold 0.04% pullets, while the big farms (24% of total farms) produced 94.2% of the pullets.

Table 12. Size distribution of pullet farms for laying flock replacement in Indiana in 2007.

Farms with number sold	Farms		Pullets sold	
	Total number	%	Total number	%
All sizes	121	100.00%	12,505,394	100.00%
1 to 1,999	74	61.16%	5,248	0.04%
2,000 to 15,999	3	2.48%	26,400	0.21%
16,000 to 29,999	4	3.31%	87,000	0.70%
30,000 to 59,999	7	5.79%	331,600	2.65%
60,000 to 99,999	4	3.31%	275,000	2.20%
100,000 or more	29	23.97%	11,780,146	94.20%

Source: USDA-NASS.

The IDEM CFO/CAFO permit data listed 49 pullet farms in 2007 (Figure A.5, page 47). Most pullet CFO/CAFO farms were located in the northern and southern Indiana. There were 52 pullet farms in 2002, 47 in 2011, and 48 in 2012.

Broiler Farms

The sizes of broiler farms also varied considerably. About 75% of the farms sold less than 2000 broilers in 2007 representing only about 0.1% of all broilers. The second largest broiler farms sold between 100,000 to 200,000 birds each in 2007 and their total number of birds accounted for about 20% of the state total. The largest Indiana broiler farms (each sold >500,000 birds in 2007) made up less than 6% of the number of farms, but sold about 71% of the birds (Table 13).

La Grange, Elkhart, and Daviess counties had more than 30 broiler farms each (Figure A.6, page 48). There were 34 broiler CFO/CAFO farms according to the 2007 IDEM permit records. This number was 23 in 2002 and increased to 50 in 2012, indicating an important increase in the past decade. Broiler CFO/CAFO farms were located mostly in the southern part of Indiana. There were also a few CFO/CAFO broiler farms scattered in the northern part of Indiana (Figure A.7, page 49).

Table 13. Size distributions of broiler farms in Indiana in 2007.

Farms with number sold	Farms, %	Broilers, %
All sizes	100.00%	100.00%
1 to 1999	74.69%	0.11%
2000 to 15,999	0.75%	0.04%
16,000 to 29,999	0.75%	0.17%
30,000 to 59,999	1.25%	0.58%
60,000 to 99,999	1.25%	1.05%
100,000 to 199,999	13.53%	20.26%
200,000 to 299,999	0.75%	2.00%
300,000 to 499,999	1.25%	5.26%
500,000 or more	5.76%	70.53%

Source: USDA-NASS.

Turkey Farms

About 41% of the Indiana turkey farms sold < 2,000 turkeys each in 2007. The production of the 144 farms accounted for 0.02% of the statewide total. About 58% of the farms sold more than 8000 turkeys each in 2007. There were 156 CFO/CAFO turkey farm permits issued by IDEM in 2002, 149 in 2007, and 152 in 2012. The numbers of CFO/CAFO turkey farms were relatively stable during the past decade.

Although turkey farms were found in 82 Indiana counties (Figure A.8, page 50), most of the CFO/CAFO's were located in southwestern Indiana. There were also a few scattered in the middle and eastern sections of the state (Figure A.9, page 51).

Table 14. Size distributions of turkey farms in Indiana in 2007.

Farms with number sold	Farms		Turkeys	
	Total number	%	Total number	%
All sizes	351	100.00%	13,487,899	100.00%
1 to 1999	144	41.03%	2725	0.02%
2000 to 7999	4	1.14%	16,438	0.12%
8000 to 15,999	14	3.99%	166,200	1.23%
16,000 to 29,999	23	6.55%	518,050	3.84%
30,000 to 59,999	82	23.36%	3,513,313	26.05%
60,000 to 99,999	61	17.38%	4,484,940	33.25%
100,000 or more	23	6.55%	4,786,233	35.49%

Source: USDA-NASS.

Duck Farms

Northeastern Indiana has the largest number of duck farms, especially in Elkhart, La Grange, Kosciusko, and Adams counties (Figure A.10, page 52). No data about the duck farm size distribution in Indiana were published in the USDA census.

Although Indiana is ranked the number one duck production state, the majority of duck producers are small scale contractors. There were only 12 duck CFO/CAFO permits issued by IDEM in 2002, 11 in 2007 (Figure A.11, page 53), 6 in 2011, and 4 in 2012. The number of duck CFO/CAFO has been decreasing rapidly.

Indiana Poultry Manure Production

Overview

Indiana produced approximately 1.885 million tons of poultry manure in 2007 (Figure 3). Compared with the manure produced in 2002 (1.488 million tons), there was a 26.7% increase in total poultry manure production in the five-year period. Layer manure (0.840 million tons) consisted of 44.6% of all manure produced, followed by turkey manure (0.534 million tons) that was 28.3% and pullets (0.177 million tons) that was 9.4%. Among the five major poultry species in the state, the portion of the manure produced by ducks (0.101 million tons) was the smallest at 5.4%.

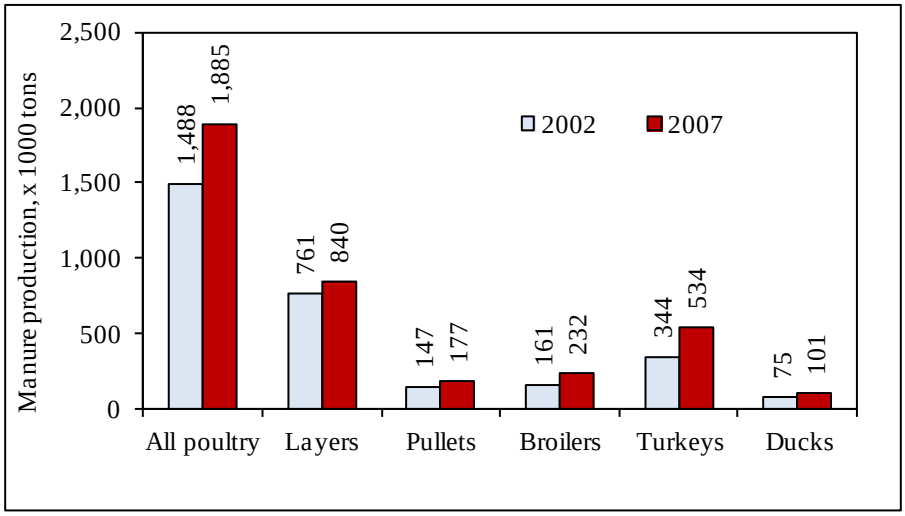


Figure 3. Production of as-excreted manure from Indiana poultry farms in 2007.
Note: Manure from other poultry (emus, geese, ostriches, pheasants, pigeons or squab, and quail) were not included due to lack of available manure production rates for these species.

Analysis of poultry data from 2002 to 2011 revealed that there was generally an increasing trend in the manure production of three of the major poultry species (Figure 4). The total manure produced by layers, pullets, and turkeys increased 31% from 2002 to 2011. The rate of increase was the largest for turkeys (84%) and the smallest for layers (4%).

Indiana poultry manure distributions vary greatly among different counties. In general, there was more poultry manure available in northern and southern Indiana (Figure A.12, page 54). Among the 92 counties in 2007, Dubois County in southern Indiana had the highest manure production of approximately 268,400 tons, followed by Kosciusko County (211,800 tons), Jackson Country (165,100 tons), and Jay County (142,000 tons). Twenty-three counties produced between 10,000

and 100,000 tons of poultry manure each. Fifty other counties produced less than 1,000 tons of poultry manure. Benton County had the least available poultry manure of about 2 tons.

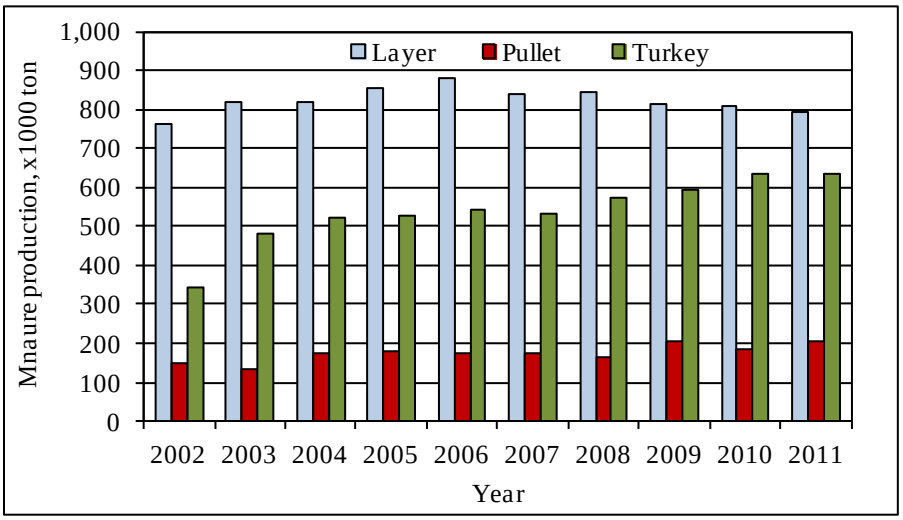


Figure 4. Annual Indiana manure production by three major poultry species from 2002 to 2011.

Layer Manure

A total of 761,200 tons layer manure was produced in Indiana in 2002. The quantity increased to 840,500 tons in 2007. It decreased slightly to 795,000 tons in 2011 (Figure 4). Most of the layer-manure-rich counties were located in northern Indiana. However, the two counties that produced the largest quantities of manure were Kosciusko County (142,000 tons) in the north and Jackson County (126,000 tons) in the south. About 69% of the counties had less than 100 tons of layer manure produced in 2007. Most of these counties are in central Indiana (Figure A.13, page 55).

Pullet Manure

There was a net increase in pullet manure production in Indiana from 2002 to 2011 (Figure 4). Indiana produced 147,300, 177,000, and 207,800 tons of pullet manure in 2002, 2007, and 2011, respectively. The geographical distribution of the pullet manure in Indiana is similar to that of layer manure (Figure A.14, page 56). Most of the pullet-manure-rich counties were located in the northern and southeast parts of the state. The largest pullet manure producing counties in 2007 were Jackson County (39,000 tons) in the south and Kosciusko County (34,000 tons) in the north.

Broiler Manure

Indiana produced 160,500 tons of broiler manure in 2002 and 232,400 tons in 2007. There was an increase of about 45% during that period. Because of the data unavailability, the broiler manure production in 2011 could not be estimated. There were only 34 of the 92 counties, where broiler manure was produced in 2007. Twenty-four of the 34 counties produced less than 65 tons of manure each. The six counties that had the highest broiler manure production were Washington County (82,000 tons), LaGrange County (60,000 tons), Elkhart County (29,000

tons), Harrison (15,000 tons), Crawford County (12,000 tons), and Orange County (11,000 tons). These counties are located in the northeast and southeast of Indiana (Figure A.15, page 57).

Turkey Manure

Indiana produced 344,100 and 534,000 tons of turkey manure in 2002 and 2007, respectively. This quantity was 633,800 tons in 2011, an increase of 84% in the nine-year period compared with 2002. Turkey manure was largely produced in southwest counties. There were 14 southwest counties shown in Figure A.16 (page 58) that produced more than 1,000 tons of manure in 2007. The largest turkey manure producing county was Dubois County that had 213,400 tons of turkey manure produced, almost 40% of all the turkey manure in Indiana.

Due to the withheld numbers of turkeys for farms in a large number of counties by the USDA census and most of these farms were non CFO/CAFO, turkey manure production from 27 of the 92 Indiana counties could not be calculated. Thirty other counties had only less than 5 tons of turkey manure produced. However, these withheld numbers of turkeys were included in the total number of turkeys in the entire state. Therefore, they did not affect the state level turkey manure production calculation.

Duck Manure

A total of 75,100 tons of duck manure was produced in 2002. It was 101,100 tons in 2007, a 35% increase from 2002. Production of duck manure was concentrated in northeast Indiana (Figure A.17, page 59). Three counties (Elkhart County, LaGrange County, and Kosciusko County) produced more than 20,000 tons of duck manure each. Because there were many small duck producing contractors, and only 11 CFO/CAFO in 2007 (6 in 2011, and 4 in 2012), a large proportion of manure was distributed around the counties.

Nutrients from Indiana Poultry Manure

The equivalent amounts of nutrients from poultry manure (as-excreted) in Indiana, based on the estimation methods in Table 9 and Table 10, was 30,370 tons of nitrogen and 9,433 tons of phosphorus in 2007 (Table 15). The equivalent nitrogen in poultry manure in 2007 increased by 24.3% and that of phosphorus increased by 23.8% compared with 2002. Similar to the largest percentage of layer manure in the total manure production, layer manure contributed to the largest portion of nutrient among all poultry species, followed by turkey manure.

When divided by the total "land in farms" in Indiana, there were averages of 4.11 lbs of nitrogen and 1.28 lbs of phosphorus per acre in 2007, compared with 3.24 lbs of nitrogen and 1.01 lbs of phosphorus per acre of land in 2002 (Table 15). There were 26.7% and 26.2% increases in nitrogen and phosphorus from 2002 to 2007, respectively.

The Indiana poultry manure nutrients were unevenly distributed across the state. Fifty counties had less than 0.15 lb nitrogen and 0.05 lb phosphorus per acre of farm land (Figure A.18, page 60 and Figure A.19, page 61). Thirteen other counties had more than 10 lb nitrogen and 3 lb phosphorus per acre. Dubois County had the highest available poultry nutrients with 46.9 lb nitrogen and 14.2 lb phosphorus per acre. Most "nutrient-rich" counties were located in southern

and northern Indiana, while the state's corn (Figure A.20, page 62) and soybean (Figure A.21, page 63) production were concentrated in central Indiana.

Table 15. Nitrogen and phosphorus in as-excreted poultry manure in Indiana in 2002 and 2007.

Parameters	Nitrogen		Phosphorus	
	2002	2,007	2002	2007
Layer, ton	14,021	15,481	4407	4866
Pullet, ton	2635	3167	879	1057
Broiler, ton	1751	2536	510	739
Turkey, ton	5268	8176	1562	2424
Duck, ton	751	1011	258	347
Total, ton	24,427	30,370	7617	9433
Per acre farm land, lb/acre	3.24	4.11	1.01	1.28

Note: Data of the total "land in farms" in Indiana are from the USDA agricultural censuses and were 15,058,670 acres in 2002 and 14,773,184 acres in 2007.

Based on incomplete statistical data of three of the major Indiana poultry species (Figure 4), it is estimated that the total nutrient from poultry manure in 2011 was likely increased by 5% from 2007. Assessment of poultry manure demonstrated that, with the development of the Indiana poultry industry, more nutrients from poultry manure became available in the past decade.

However, the nitrogen and phosphorus from poultry manure in Table 15 were calculated on the as-excreted basis using ASAE standards. In reality, some nutrients will be lost before poultry manure is applied in croplands, depending on the manure collection and storage methods and storage time. Therefore, the actual quantity of nutrients applied to the fields should be smaller.

According to Kellogg et al. (2000), poultry had the largest share of recoverable manure nutrients: 45% of the nitrogen and 38% of the phosphorus in 1997. Recoverable manure nutrients is the portion of as-excreted manure nutrients that can be collected from confinement facilities after accounting for losses during collection, transfer, storage, and treatment. Recoverable manure nutrients are, therefore, the amounts that are available for land application.

Assuming that these ratios were valid for 2007, then the recoverable poultry manure nitrogen and phosphorus in Indiana for 2007 were 13,667 tons and 3585 tons, respectively. The recoverable poultry nutrients per acre of Indiana farm land were 1.85 lb/acre of nitrogen and 0.49 lb/acre of phosphorus.

Poultry Manure Transportation

Procedures and Methods

Concentrated poultry operations result in large quantities of poultry manure in limited areas. Many Indiana CFO/CAFO cannot utilize all the manure on their own croplands. Sales and transportation is therefore necessary to distribute the manure to croplands that can be miles or dozens of miles away from the facilities. To study Indiana poultry manure transportation, four major procedures were taken:

1. Data collection
2. Phone interviews and face-to-face discussions with manure brokers and other manure service providers
3. Consulting with manure management specialists and professionals
4. Data analysis and presentation

Information about manure service providers (usually brokers, traders, or contract haulers) were collected from Purdue University's Manure Locator website (www.ansc.purdue.edu/ManureLocator/), Manure Manager Magazine website (www.manuremanager.com/), online business directories, and manure management consultants, and word-of-mouth. Historical data in Indiana were also collected for comparisons with more current data.

Two phone interview sessions were conducted, one in 2011 and another in 2012. Face-to-face discussions with professionals were made during meetings, seminars, extension workshops and farm visits. Consulting with manure management specialists and professionals took place throughout the project period. Data and information about manure sales and transportation collected from different sources were compared, analyzed, and summarized.

Overview of Commercial Manure Service Providers

There were 41 manure service providers identified from various information sources since 2006 in Indiana. They were located in 18 counties (Figure 5), most of them are in central and northeast Indiana. There were also a few manure service providers conducting business in Indiana but located in neighboring states, especially in Michigan and Ohio.

Among the identified companies, 32% of the owners either did not respond for phone interviews, or were too busy to answer questions or unwilling to share business information. The remaining 28 companies, who answered questions during phone calls or face-to-face discussions, provided information at various degrees of detail. The responses of three manure haulers during the interviews are listed in Table 16.

Various Commercial Services

Most of the companies did not broker or transport poultry manure. Among the 28 interviewed companies, 11 provided service exclusively on dairy and/or swine manure. There were only eight or 29% who worked directly on transporting and applying poultry manure. Four of the eight

provided service solely on poultry manure and four others covered different types of manure including poultry manure. Additionally, the services of interviewed 28 companies have the following characteristics:

- Five had left the business or moved to a neighboring state by the time of the interviews.
- Two provided manure management services, but not manure sales, transportation, and application.
- Two poultry manure service providers only sold, transported, and applied manure from their own poultry CAFO. Another one had its own poultry CAFO, but also brokered manure from other farms.
- Two companies provided multiple on-farm manure services, including barn cleaning and air quality testing.
- Most brokers offered manure application services, which were considered to really give the manure its worth. There were some crop producers who did not want to pay for manure (only pay for application).
- Spring, summer, and fall were the most frequent time of manure application.

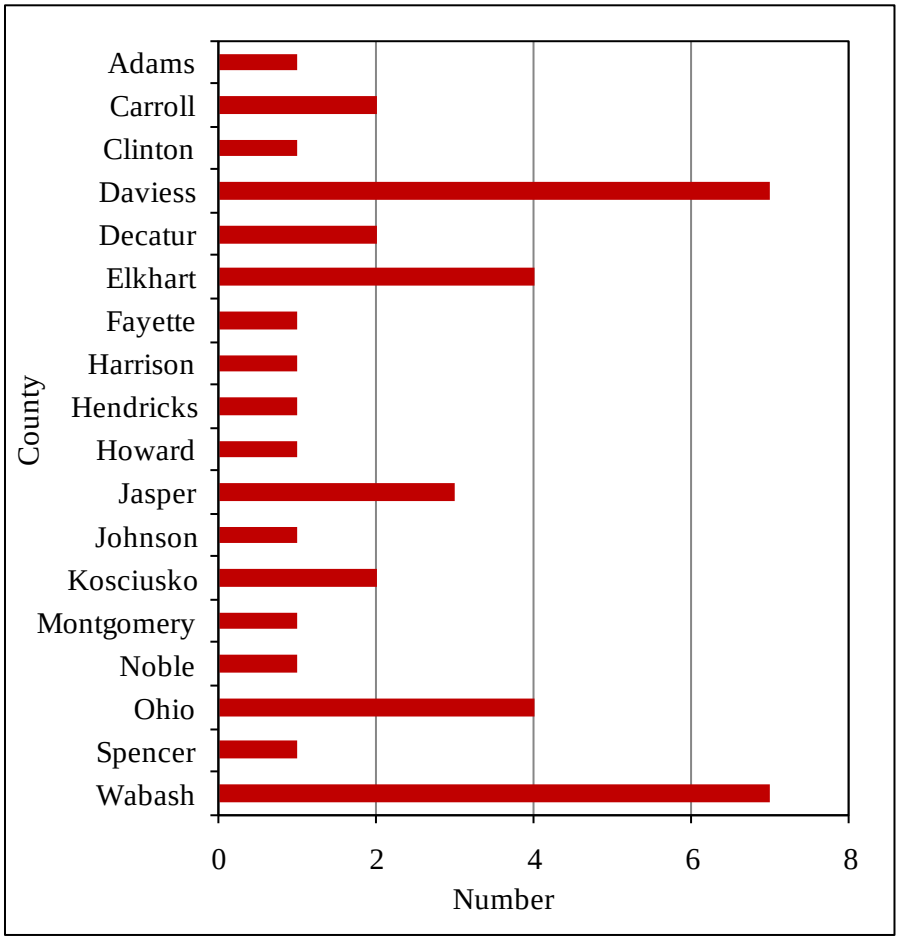


Figure 5. Manure service providers identified in Indiana since 2006.

Table 16. Summary of phone interview responses from three manure haulers.

Topic	Manure hauler 1	Manure hauler 2	Manure hauler 3
Types of manure hauled	Poultry	10% poultry, 40% dairy, 50% swine	Poultry
Sources of manure	14 producers	12 producers	5 houses
Manure from own operation	No	No	5%
Quantity of manure	17–20,000 tons	100M gallons	> 3500 tons
Number of trucks/capacity	2–9/2010 tons	2–4/6000 gal each	---
Seasons of manure removal	All seasons, mainly May to Nov	Fall	Daily to storage
Seasons of application	June to Oct	Aug. to Dec.	---
Time of manure delivery	Mon to Thurs 7 am – 7 pm	7 days a week, daylight to 7 pm.	Weekdays, early morning
Customers	40-50 operations	30 operations	---
Average transportation distance	25 miles	30 miles	---
Maximum transport distance	40 miles	100 miles	---
State served	10–15% IN, 85–90% OH	100% IN	100% IN
Pollution liability insurance	Yes	Yes	---
Own application equipment	Yes	Yes	---
Spreader calibration frequency	Daily	Annually	---
Effect on poultry manure cost	Price of fertilizer	Cost of transport	---
Manure charge	$15/ton	---	$17/ton

Transportation Distances

The distances of poultry manure transportation vary considerably; but the maximum distance is limited by economics. Compared with liquid dairy and swine manure, which has high moisture content and is generally not brokered because of its prohibitive cost for long-distance transportation, poultry manure tends to be economical to haul to outlying croplands.

However, poultry manure brokers in Indiana had different expectations. One of the brokers claimed that they usually haul manure for 10 miles maximum before the cost of transport breaks even with the value of the nutrients. Two of the manure brokers listed in Table 16 have average transportation distances of 25 and 30 miles. Another broker described procuring manure from farms in a 70-mile radius in Indiana and Ohio (not listed in Table 16). The longest transportation distance acceptable by a broker was within a 100-mile radius from where the manure was produced (Table 16).

Interstate transportation was common in some regions, especially in eastern Indiana, in counties that border Ohio, including Adams County, Jay County, Randolph County, and even Delaware County. However, evidence for this was mostly anecdotal. It was stated that loads of poultry manure were transported into the fields in these counties. There were also local people's complaints about all the manure from Ohio, because it potentially might have run off onto their acres of produce. This has become one of the hot issues over there. It was estimated by a manure broker that in some areas in Indiana, where there was not much poultry production around, about

90% of chicken manure was from Ohio. Nevertheless, the exact volumes of the imported manure were not available.

Service Areas

The business scales of the brokers and contract manure haulers also vary. There were co-ops that had good coverage for all services with millions of dollars of business across different states (mainly Michigan, Ohio, and Indiana). A nationwide company had local centers in Indiana. There were also businesses with limited manure resources. More demands than supplies were seen in some areas. One broker stated that they had to turn customers away because of their limited service capacity.

The manure brokers' service areas could be at a radius of 200 miles (not the manure transportation distance). Some were looking to go out even further, to 300 and 400 miles to take advantage of how different areas require fertilizer at different seasons.

Manure Economics

Poultry manure prices also differ from areas and times but had a general increasing trend over the years. Rising inorganic fertilizer prices in the past decade are the driving force of the increasing economic values of the poultry manure. According to USDA, the prices of selected nitrogen, phosphorus, and potassium fertilizers were approximately doubled or tripled from 2002 to 2012 (Figure 6 and Figure 7).

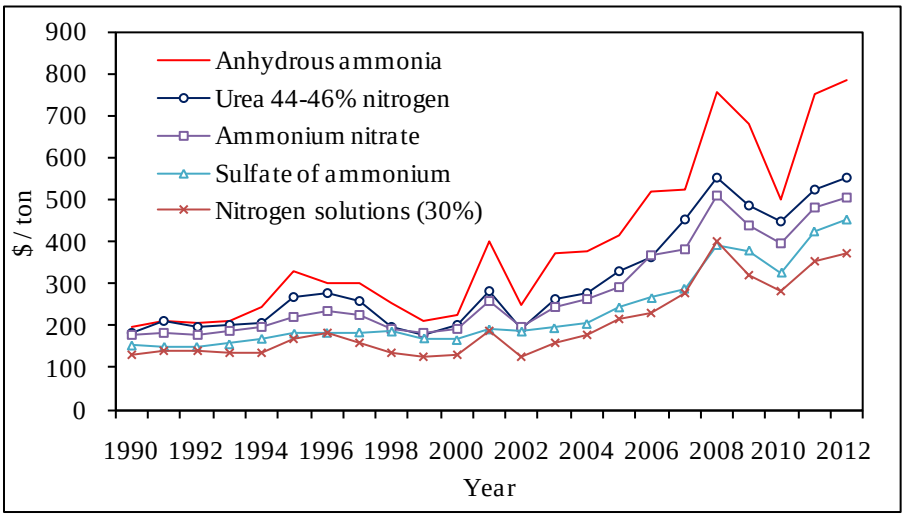


Figure 6. Average U.S. farm prices of selected nitrogen fertilizers.
Source: Agricultural Prices, USDA-NASS
(http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1002).

The cost of using poultry manure as organic fertilizer consists of three components: manure, transportation, and application. According to one manure seller, the price of layer manure increased recent year considerably. Manure prices can vary and are usually negotiable based on supply and demand, seasons and locations, and manure moisture and nutrient contents. The

recent layer manure-only price of one seller was as high as $60/ton, while the manure from a turkey farm could be as low as $5/ton in some seasons (Table 17). The manure moisture and nutrient contents can also vary considerably, depending on poultry species, production practices, manure storage methods and duration, and methods and location of manure sampling for nutrient analysis. Long-time contracts with negotiated manure prices were often signed between poultry producers and manure brokers.

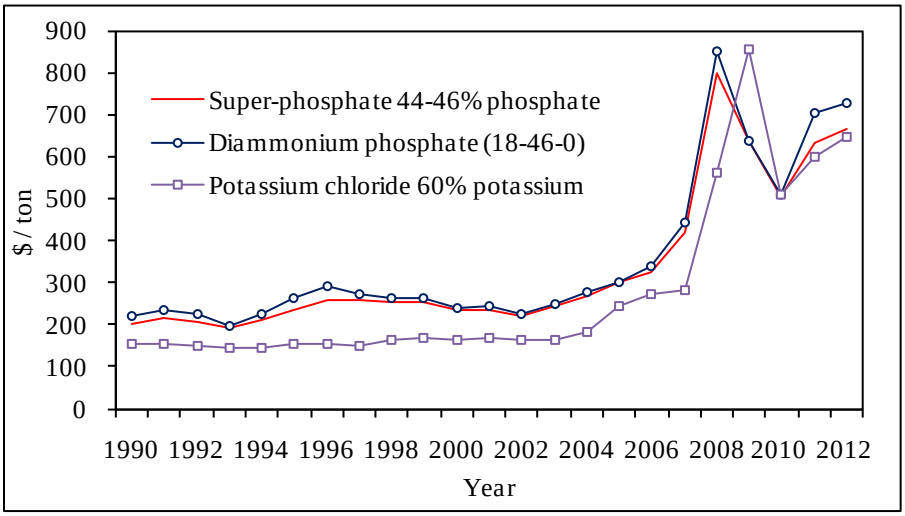


Figure 7. Average U.S. farm prices of selected phosphate and potassium fertilizers. Source: Agricultural Prices, USDA-NASS.

Table 17. Some examples of poultry manure prices.

	Seller 1	Seller 2	Seller 3	Seller 4
Location in Indiana	North	Central	Southwest	South
Year of information	2012	2013	2013	2013
Manure type	Layer hen	Layer hen	Turkey	Broiler
Quantity, ton/yr	1000	60,000	2200	150
Manure price, $/ton	22–23	60	5–20[3]	10–15
Manure hauling	No	Yes	No	No
Hauling fee, ($/mile)	NA	2.85[2]	NA	NA
Manure spreading	No	Yes	No	No
Spreading fee, $/ton	NA	8–12	NA	NA
Moisture, %[1]	55	15–20	41	15
Total N, lb/ton[1]	29	60	53	52
P_2O_5, lb/ton[1]	46	75–80	50	47
K_2O, lb/ton[1]	32	60	30	50

Sources: [1] The moisture and nutrient contents of Sellers 1, 3, and 4 were actual sample analysis results of the year. [2] Price per truck per mile. Loading cost of $51 per 20-ton truck load was extra. [3] Price depends on seasons and is usually offered by buyers. NA = not available.

Poultry manure is a resource that can have multiple uses depending on the poultry species and quality of the manure. Manure typically is only useful for fertilizer. However, there were no uses

other than field application found in the broker interviews although other uses were reported during the manure application survey (see page 32 under Poultry Manure User).

Different perspectives existed among manure buyers. Many viewed manure as better for crops and soil than inorganic fertilizers. The high inorganic fertilizer prices made manure a viable option. One broker estimated that it can save $150/acre over inorganic fertilizers. However, there were also buyers' concerns about poultry manure, including weed seeds in manure, price, logistics, performance, and regulations.

Regulations and Environmental Concerns

Manure service providers actively followed environmental regulations in Indiana and in neighboring states where their business covered. They passed their certification exams in Indiana. They were aware of when their practices needed to change to meet new regulations. One Indiana-based manure broker said in the interview that they attended meetings in Indiana and courses in Ohio State throughout the year whenever their schedule allowed. However, it was also learned that there were people that were not sure who to contact and how to get their certification to be manure haulers although they knew that some kind of certification must be obtained.

Some of the major environmental concerns about poultry manure that surfaced during the interviews of the manure service providers were as follows:

- Most crops are more nitrogen-demanding and as poultry manure is richer in phosphorus compared with other livestock manure, phosphorus can build up over the years and cause watershed pollution and algae blooms.
- There is sometimes outrage from the community over poor farmer practices/application related to poultry manure odor. To minimize odor nuisance, the manure applicators took some measures, e.g., apply during the week, not the weekend; not applying in high winds; inject, not spread + till; recommending planting trees.
- Farmers in some areas in the eastern Indiana imported manure from Ohio because there was very little poultry production in these areas due to restrictive regulations. However, there was also concerns that manure from Ohio was not regulated and this issue needed to be addressed.
- Various methods and facilities for poultry manure storage were used in Indiana. For temporary storage or stockpiling, tarp and plastic sheeting, or open storage was usually used. For permanent or long-term storage, manure sheds with either concrete or earthen floors were used. Uncovered manure can become emit nonpoint source pollutants. When manure gets wet, it also decomposing quicker and loses more nutrients than if it was dry. When it rains, there can also be nutrient runoff and contamination of the environment unless the runoff is contained.

Poultry Manure Application to Crop Fields and Other Uses

Procedures and Methods

The purpose of this part of the project is to obtain information about the current situation, experiences, obstacles, and future perspectives of poultry manure land-application to replace inorganic fertilizers.

A survey questionnaire for poultry manure application by crop producers and other users was developed. It was updated after consulting with extension specialists in the Departments of Animal Sciences, Agronomy, and Agricultural Economics at Purdue University. The survey was designed for three types of producers: crop farmers who are non-poultry-producers but use poultry manure, crop farmers who are non-poultry-producers and do not use poultry manure, and crop farmers who are also poultry producers. The survey consists of the questions regarding utilization of fertilizer, crop management, and fertilizer market (Appendix II). To obtain the most recent data and avoid confusion, the survey were designed to ask questions only related to manure application in 2012.

The questionnaire was submitted to and reviewed by the Institutional Review Board (IRB). Two revisions were made following the IRB comments. The survey was approved on March 5, 2013 (IRB Protocol#: 1212013039) and posted on-line. One amendment for distributing survey requests via extension newsletter was filed to IRB on March 19, 2013. It received IRB approval on April 16, 2013.

Due to the requirement of confidentiality and protection of respondents' identity, the survey requests were distributed via Purdue University's county extension educators who work in Agriculture and Natural Resources. The county educators distributed the survey via email to crop producers and other possible poultry manure users. One county also distributed the survey via a mail-in extension newsletter.

Emails were sent to about 2000 recipients and hard copy questionnaire were handed to >20 extension meeting participants. By the end of July 2013, 161 survey responses were obtained and validated, in which 105 were completed and 57 were partially completed. One reason for the low return rate, as explained by someone who had good knowledge about the local situation, was that, with the new Indiana manure regulations coming out, many people dealing with manure tended to be cautious and wished to not say anything about it.

Nevertheless, although the survey return rate could be higher, the responses obtained were very useful to understand the application of poultry manure in Indiana.

Characteristics of Respondents

The producers who responded to the survey indicated to have land located in 53 out of 92 (or 58% of) Indiana counties. Two respondents also had land in Ohio and three had land in Illinois. The total land owned by individual respondents covered a wide range from 0.5 to 8760 acres and

averaged 1057 acres. About 49% owned more than 500 acres (Figure 8). Four smallest landowners (≤ 1 acre) were vegetable and potato growers who applied manure as fertilizer.

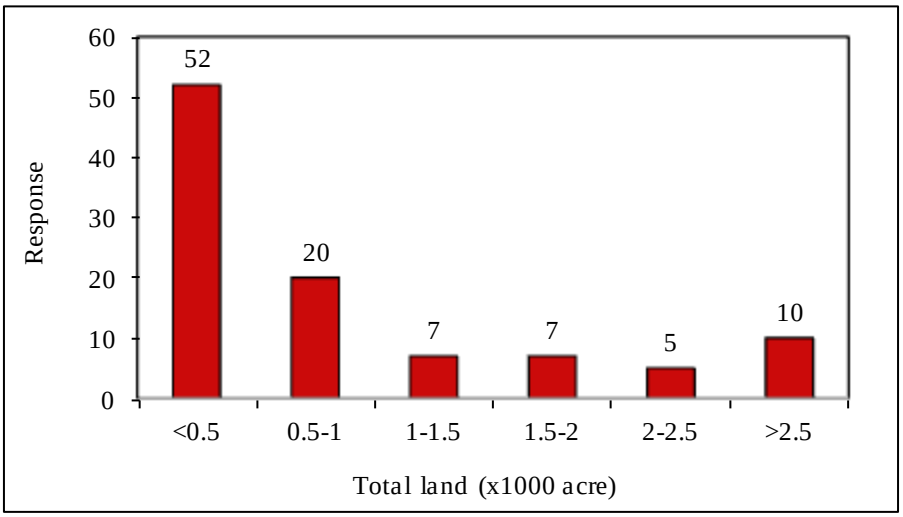


Figure 8. Distribution of land acreages of the respondents.

Concerning the five main crops (corn, soybean, wheat, oats, and potato) in Indiana, corn and soybean producers consisted of 53.7% and 39.1%, respectively, among all the acreage reported by the responded producers (Table 18). No oats was reported and there were only two producers reported potato with small acreages. Instead, hay, pasture, tomato, pumpkin, and alfalfa consisted 3.4% of the reported acreage. Other crops, including popcorn, sod, vegetable, and flower, also had 0.9% of the surveyed land.

Table 18. Crops and acreages reported by the responded producers.

Crop	Total surveyed		Acreage per producer, acre		
	Acreage, acre	Percentage, %	Min	Max	Mean
Corn	58,103	53.7	6	6000	735
Soybean	42,300	39.1	20	2700	596
Wheat	3,259	3.0	20	560	155
Potato	1.0	0.0	0.3	1.0	0.7
Hay	553	0.5	5	200	50
Pasture	590	0.5	10	500	118
Tomato	910	0.8	110	500	303
Pumpkin	506	0.5	6	500	253
Alfalfa	1,072	1.0	5	999	357
Other	924	0.9	0.5	600	132
Total	108,218	100.0			

Note: Other crops included popcorn, sod, vegetable, and flower.

About 39% of the responses (total of 41) claimed raising different types of poultry (Table 19). Seven producers (about 17%) of the producers owned two different poultry species, e.g., layer hens and pullets. So there were 34 producers had poultry. Among the six species specified in the

survey questionnaire and a choice of "other poultry", no one selected "turkey breeders". One respondent filled data of "peacocks" in "other poultry".

Table 19. Poultry production from the respondents.

Poultry	Response	Number of poultry, head			
		Total	Min/producer	Max/producer	Mean/producer
Layer	15	4,375,802	1	2,950,000	291,720
Broiler	1	350,000	350,000	350,000	350,000
Pullet	6	2,697,050	50	1,000,000	449,508
Turkey	8	425,002	2	120,000	53,125
Turkey breeder	0	NA	NA	NA	NA
Duck	10	281,855	5	69,800	28,186
Peacock	1	3	NA	3	NA
Total	41	8,129,712			

Note: A total of 34 producers made 41 responses to different poultry species. NA = not available.

The size of the poultry farms varied from one head to several million head. The largest poultry producers participated in the survey owned 2.95M layers. The smallest reported numbers included 1 layer, 2 turkeys, 3 peacocks, and 5 ducks. About 47% of the surveyed farms had more than 30,000 fowl and were either CFO or CAFO (Figure 9). About 36% of the poultry producers claimed to have excess manure for sale, which ranged from 50% to 100% of their total manure production. The diversified poultry farms showed that the survey samples covered a wide range of representatives from the industry.

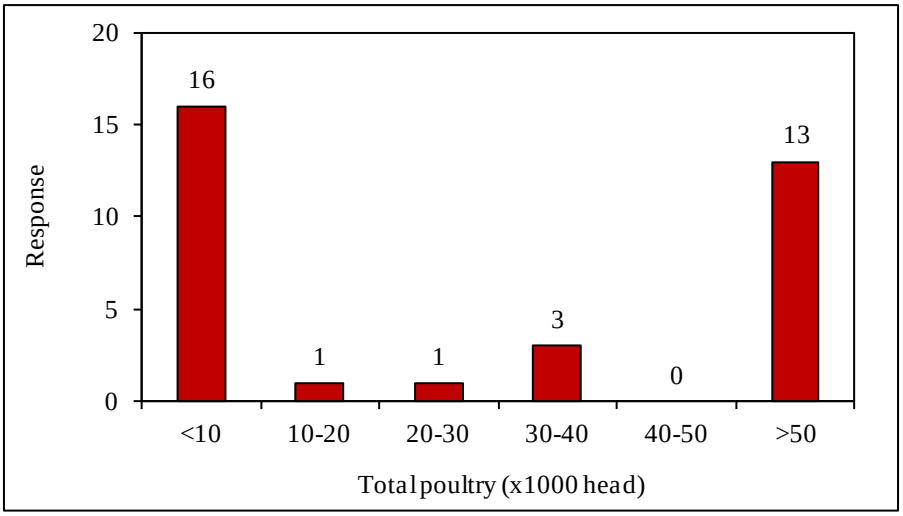


Figure 9. Distribution of surveyed poultry farm sizes.

Manure Application

Poultry Manure User

A little more than quarter of the corn producers (22 out of 79, or about 28%) applied poultry manure to their crops. The percentage for soybeans (about 7%) was much lower (Figure 10). About 20% of wheat and 0% for potato received poultry manure as fertilizer. However, growers applied poultry manure to all other reported crops (e.g., hay, pasture, vegetables, etc.). In addition to using poultry manure as crop fertilizer, one respondent used or sold poultry manure to produce energy by thermo-chemical conversion, which is one of the technologies that use poultry manure for energy production (Roberts et al., 2004).

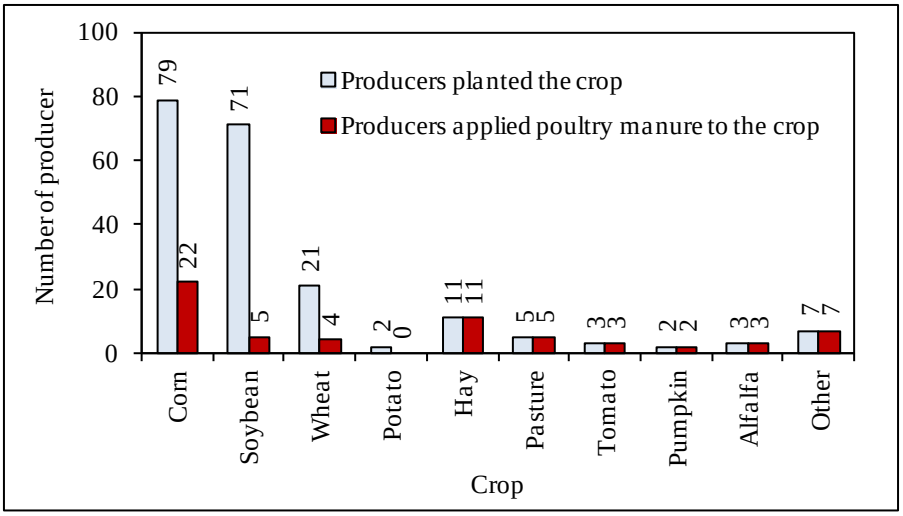


Figure 10. Percentages of producers who owned and applied poultry manure to different crops.

A total of 26,586 acres of cropland were reported to have applied poultry manure (Figure 11). This was about 25% of the 108,218 acres of all surveyed cropland. Corn fields that applied poultry manure consisted of 33% of all the surveyed corn fields. Soybean and wheat were 6% and 20%, respectively, of the total soybean and wheat lands. No oats and potato producers reported using poultry manure as fertilizer.

Crop producers indicated applying different types of manure to the land (Figure 12). Number of producers applying inorganic fertilizer had the highest percentage (37%), followed by that applying poultry manure (30%). There were also producers who applied swine manure (20%), dairy manure (8%) and beef manure (15%). The 13% "other" manure included manure from different animals, i.e., horse, veal, sheep, goat, steers, and llama. Most producers used more than one type of fertilizers (inorganic and manure).

Producers that used poultry manure had good awareness of its benefits to crops and soils (Table 20). The survey demonstrated that the benefits of organic nutrient contents to crops and soils were well recognized. Two respondents added additional comments of "beneficial microbial activity" and "has 13 micronutrients" in the survey. Economic benefit (less expensive than

inorganic fertilizers) was selected by 63% percent of the respondents. On the contrary, only 29% of the respondents thought that poultry manure was easy to store and apply.

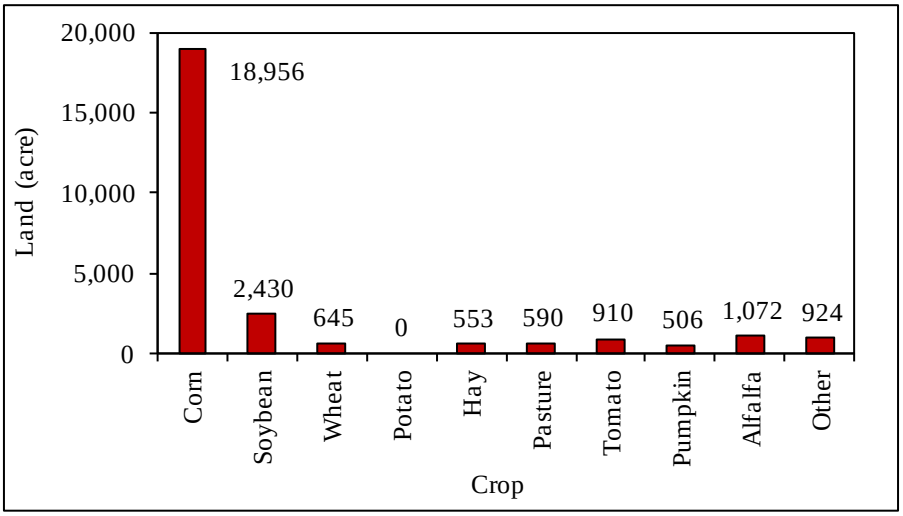


Figure 11. Acreage of different crops used poultry manure as fertilizer.

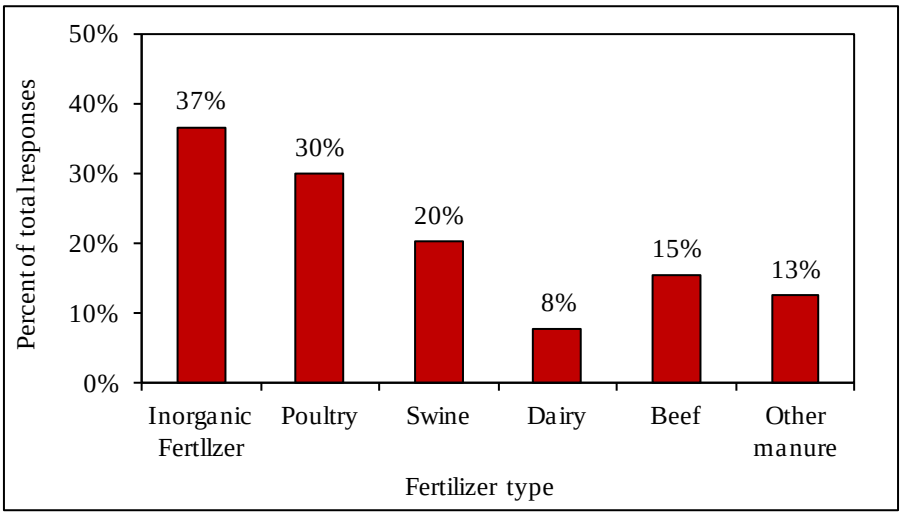


Figure 12. Percentage of different fertilizer or manure applied to the land.

Seasonal application of manure was reported at 75%, 38%, 63%, and 13%, for spring, summer, fall, and winter, respectively, by the poultry manure users. About 79% of the poultry manure users indicated that they had used poultry manure for at least two years. Nearly half of the users (41%) used poultry manure for less than 10 years and about 59% had used for more than 10 years (Figure 13). The longest history of using poultry manure was 75 years. All these poultry manure users planned to continue using poultry manure on their croplands. In addition, there were also 21% of the poultry manure users reported that they only occasionally (not every year) used it.

Table 20. Responses to the reasons for using poultry manure.

Reasons for using poultry manure	Response, %*
It is readily available on our farm or from other farms.	75
It has high organic nutrient content.	83
It is less expensive than inorganic fertilizers.	63
It is easy to store and apply.	29
Others: Beneficial microbial activity; Has 13 micronutrients	8

Note: * percent of the total poultry manure users.

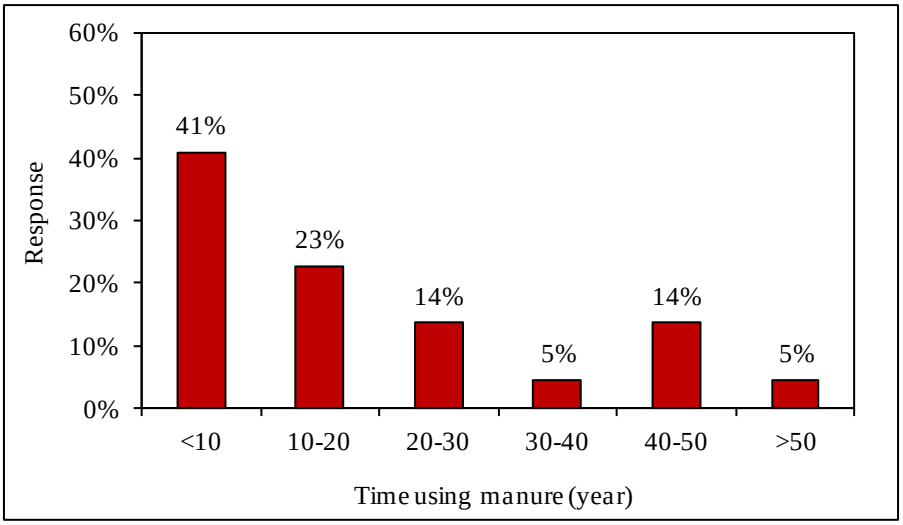


Figure 13. Distribution of years of poultry manure application.

Seven miscellaneous questions to the poultry manure users provided additional information about manure uses and applications (Table 21). More than 63% of the responses indicated using cover crops. Most of the producers used solid poultry manure (88%), and 4% of the users applied liquid poultry manure. There was less than half (46%) of producers who composted manure. For manure nutrient contents data, more than half of the producers took manure samples and had them tested. Poultry farms that sold manure also provided nutrient data to 50% of the buyers. Regulated poultry farms are required to provide the nutrient information. It was a little unexpected that no responses indicated that manure haulers provided nutrient information.

Table 21. Miscellaneous questions for poultry manure users.

Questions	Response, % *
We use cover crops.	63
We use solid poultry manure.	88
We use liquid poultry manure.	4
We compost poultry manure.	46
We had manure tested for nutrient content.	58
The poultry farm provided nutrient content data.	50
The manure hauler provided us nutrient content data.	0

Note: * percentage of total poultry manure users.

Non-Poultry Manure User

Forty-two surveyed crop producers did not apply poultry manure, but used other types of fertilizers (inorganic fertilizer and livestock manure). The responses to the survey questions demonstrated that the availability of poultry manure was the top reason (67%) of non-application (Table 22). No experience (never used poultry manure) was the second most important reason. Difficulty of application of poultry manure was the third reason of non-use, followed by the economics of poultry manure (more expensive than inorganic fertilizers). Negative environmental effects were also among the concerns, which included nutrient runoff, groundwater contamination, and odor nuisance. One respondent expressed concern about no-till that was not easy to incorporate poultry manure into soil.

Table 22. Reasons given for not using poultry manure on cropland.

Reason	Response, % *
Poultry manure was not readily available from our farm or from other sources.	67
We had never used poultry manure and were unsure of its benefits.	33
Poultry manure was more expensive than inorganic fertilizers.	14
Poultry manure would not satisfy my crop nutrient requirements.	3
Poultry manure is more difficult to apply.	17
We are concerned about its related environmental problems:	
Nutrient runoff	6
Groundwater contamination	3
Odor nuisance during manure application	2

Note: * percent of non-poultry manure users.

Manure Transportation, Transportation and Application Costs, and Willingness-to-Pay

Responses were obtained from two groups of questions related to manure transportation and the costs associated with transportation and application. One is the actual transportation and these costs and another is the expected transportation and these costs by the manure users. After comparing the results with other information sources and considering the fact that the responses were directly from poultry manure users (most of them long-time users), it is evident that the transportation distances reflected the actual economically break-even distances, and the actual and willingness-to-pay costs represented the fair market values.

Manure Transportation Distances

Among the poultry manure users who responded to the survey, 46% provided manure transportation and application themselves and 13% purchased from manure haulers who transported and applied the manure (Table 23). For those who transported their own poultry manure, the transportation distances varied considerably, mostly within 15 miles. However, two manure applicators from two different counties reported 120 and 125 miles transportation distance, respectively, farther than the 100-mile maximum distance reported by a manure broker (Table 16).

Table 23. Poultry manure prices paid by users for solid poultry manure.

Payment	Response, %*	Cost, $/ton		
		Min	Max	Mean
Manure only	46	9.5	25	18
Manure plus transportation and application	13	19	40	31

Note: * percentage of total poultry manure users

Actual Cost of Manure

For the actual manure costs, the data collected from the survey are reasonable. When the users provided their own transportation and application, the costs for solid manure ranged from $9.5 to $25/ton and averaged $18/ton (Table 23). These costs were only a little higher than the $15/ton and $17/ton given by the two manure brokers (Table 16), but much lower than the $60/ton maximum cost listed in Table 17. Variations in seasons and locations should be the main factor for the differences.

When transportation and application were included in the case of purchasing manure from manure haulers, the costs were higher, ranging from $19 to $40/ton and averaged $31/ton of solid manure. No actual costs for liquid poultry manure were collected.

Willingness-to-Pay Cost of Solid Poultry Manure

When divided into three subgroups, the costs for solid manure that include manure, transportation, and application ranged from $0 to $100/ton and averaged $26/ton (Table 24and Figure 14). The average price was close to the actual mean cost of $31/ton in Table 23. In this group of responses, there was also one that was willing to pay at FMV (fair market value). There were also six respondents from five different counties whose willingness-to-pay was $0.

Table 24. Willingness-to-pay for poultry manure by current and potential poultry manure users.

Deliverables	Response, %*	Cost, $/ton or ¢/gallon		
		Min	Max	Mean
Manure, transportation, and application:				
$/ton of solid manure	28	0	100	26
¢/gallon of liquid manure	12	0	30	5
Manure only when purchased from poultry farm:				
$/ton of solid manure	23	0	50	17
¢/gallon of liquid manure	9	0	20	3
Transportation and application only, after manure was purchased from a poultry farm:				
If done by myself: $/ton	15	0	50	11
If done by myself: ¢/gallon	8	0	20	3
If done by a contractor: $/ton	11	0	20	7
If done by a contractor: ¢/gallon	8	0	20	4

Note: * percentage of all respondents.

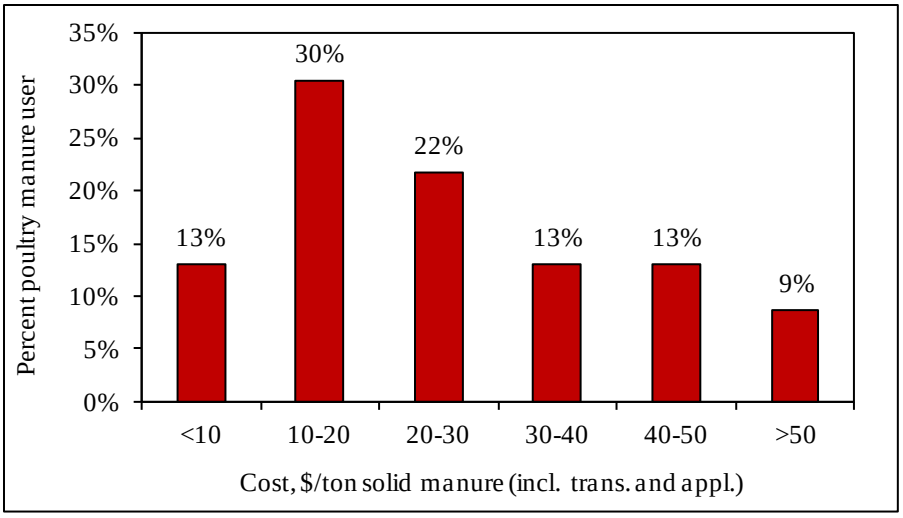


Figure 14. Distribution of willing-to-pay costs for solid manure, transportation and application.

The costs for purchasing only the solid manure ranged from $0 to $50/ton and averaged $17/ton. Interestingly, the mean cost was close to the actual mean cost listed in Table 23. The minimum ($0/ton) and maximum ($50/ton) willing-to-pay costs were out of the range of the actual costs, indicating a wider range of acceptable costs of poultry manure.

The respondents were prepared to pay from $0 to $50/ton (average of $11/ton) for the transportation and application of solid manure if they transport and apply the manure themselves. The maximum cost of $50/ton was expressed by a user for a 15-mile transportation distance. The remaining responses were all under $16/ton. When hiring a contractor for manure transportation, the willing-to-pay costs ranged from $0 to $20/ton and averaged $7/ton.

Willingness-to-Pay Cost of Liquid Poultry Manure

The availability of liquid poultry manure is much less than solid poultry manure in Indiana. The responses to this group of questions were also fewer. For liquid poultry manure including transportation and application, the willingness to pay costs ranged from 0¢ to 30¢/gallon and averaged 5¢/gallon. The costs were lower for liquid manure only without transportation and application. They ranged from 0¢ to 20¢/gallon and averaged 3¢/gallon.

There were eight respondents to the question of transportation and application of liquid poultry manure. Six of the eight entered zero costs for all the three subgroups of costs, including the costs for liquid manure. In the remaining two respondents, one expressed interest in do-it-yourself and another was willing to hire a contractor. The willingness-to-pay costs for them was 7¢/gallon and 10¢/gallon, respectively.

Manure Management and Regulations

The survey included a question about nutrient management plans. There were 63% of the 96 respondents who answered this question chose “Yes”. The average acreage of croplands of those

who had nutrient management plan was 1267 acres and that for those who did not have plans was 580 acres.

The survey also included questions about the respondents' awareness of the two new Indiana regulations related to manure. Positive answers to both questions were obtained from 72% of the respondents (Table 25). Six of the 96 respondents were only aware of one of the two regulations. All the remaining respondents were aware of both regulations. The date for full compliance with the requirements of the Agriculture Fertilizer Applicator Certification Rule was January 1, 2012. That date for the Fertilizer Material Use, Distribution, and Record Keeping was February 16, 2013. Considering that the rules are new, the high percentage of awareness by the respondents was encouraging.

Table 25. Responses to the awareness of two new regulations.

New regulations	Yes, %
Agriculture Fertilizer Applicator Certification Rule	72
Indiana regulation on Fertilizer Material Use, Distribution, and Record Keeping?	72

Recommendations

Based on the findings from this project, the authors recommend the following future work for more economical utilization of poultry manure and sustainable development of Indiana agriculture:

- Develop and distribute educational materials for poultry manure applications. Crop producers and other poultry manure users are interested in learning various aspects associated with manure. For example, one county educator received a question from a farmer about how to better apply poultry manure when side-dressing wheat. Other topics of interest include poultry manure storage, odor management, new environmental regulations, manure service providers, and available manure resources.

- Update the Indiana poultry manure production and availability in 2014. The agricultural census data are essential to calculate the overall poultry manure production in Indiana. The latest census data used in this survey was in 2007. Because of the rapid development of Indiana poultry industry, it will help to keep the Indiana poultry manure database updated if new analyses can be conducted after the 2012 USDA Agricultural Census data are published in 2014.

- Study value-added uses of poultry manure. Poultry manure can be used in other ways besides fertilizer. Indiana poultry manure was reportedly used or sold (probably to a neighboring state) to produce energy via thermo-chemical conversion. This use of poultry manure has opened doors for alternative value-added applications. Studies on the related issues (such as economics, technical feasibilities, environmental impacts, and animal welfare) of poultry manure alternative uses will help to contribute to the sustainable development of Indiana's agriculture and environment.

- Survey manure availabilities from other Indiana animal industries, especially swine and dairy. Compared with poultry, the swine and dairy industries might produce even larger volumes of manure. They could have considerate impacts on Indiana's soybean and corn production, environmental protection, and renewable energy generation; but these impacts could also be more localized because it is usually not economical for long-distance transportation of liquid swine and dairy manure. The geographical distributions of these livestock farms could be different from poultry farms. Manure produced by different industries might complement each other to satisfy crop needs in different areas.

- Conduct scientific research on more reliable poultry manure and nutrient production rates. Many significant changes in the way poultry is produced have occurred in the past decades. New developments in genotypes, feeding practices, and diet modification as influenced by environmental considerations (reduced nutrient excretion) have also occurred (Fulhage, 2003). Surprisingly, there have been only a few experimental studies on manure nutrient production from poultry in the world. For some poultry species, e.g., ducks, no such studies have been found in the literature. Moreover, most of the existing manure and nutrient production values were obtained prior to the recent changes in

production practices. Therefore, there is an urgent need to develop new methods to reliably predict current poultry manure and nutrient production.

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Assistance to this project by Mr. Leonard Meador, Mr. Daniel Kaelin, Mr. Jeffrey Lai, Mr. Zhong Qiao, Mr. Igor Lopes, and Mr. Chaowei Liu are acknowledged. Support from Purdue University extension specialists and educators, and the Indiana State Poultry Association, Indiana Department of Environmental Management, and Office of Indiana State Chemist are greatly appreciated. Special thanks go to Dr. Todd Applegate, Mr. Paul Brennan, Mr. Robert Kelly, Mr. Brad Kohlhagen, Dr. Robert Waltz, Mr. Matthew Pearson, Dr. Holy Wang, and Dr. Brad Joern.

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Appendix A: Maps of Indiana

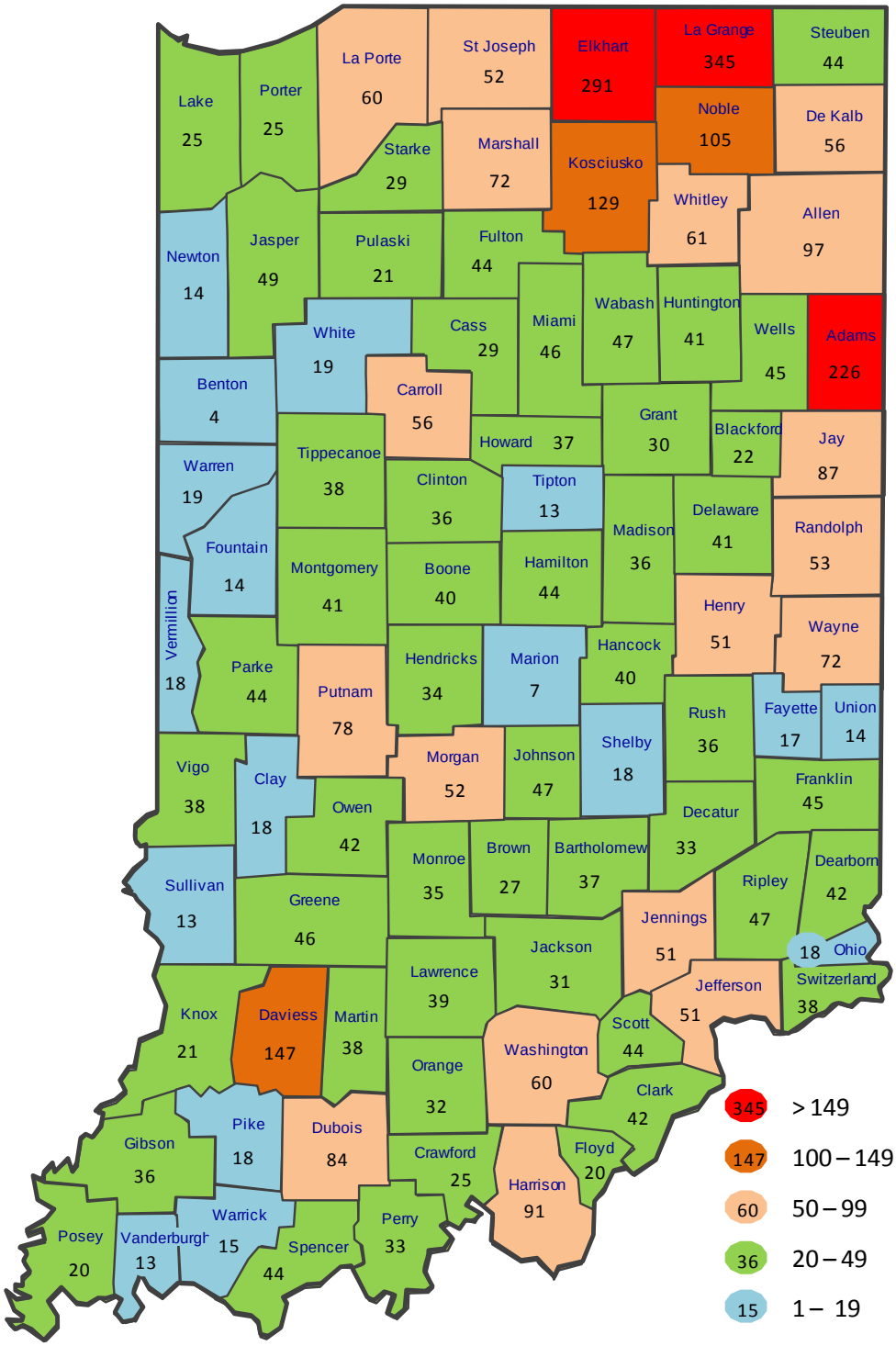

Figure A.1. Numbers of all poultry farms in Indiana in 2007.

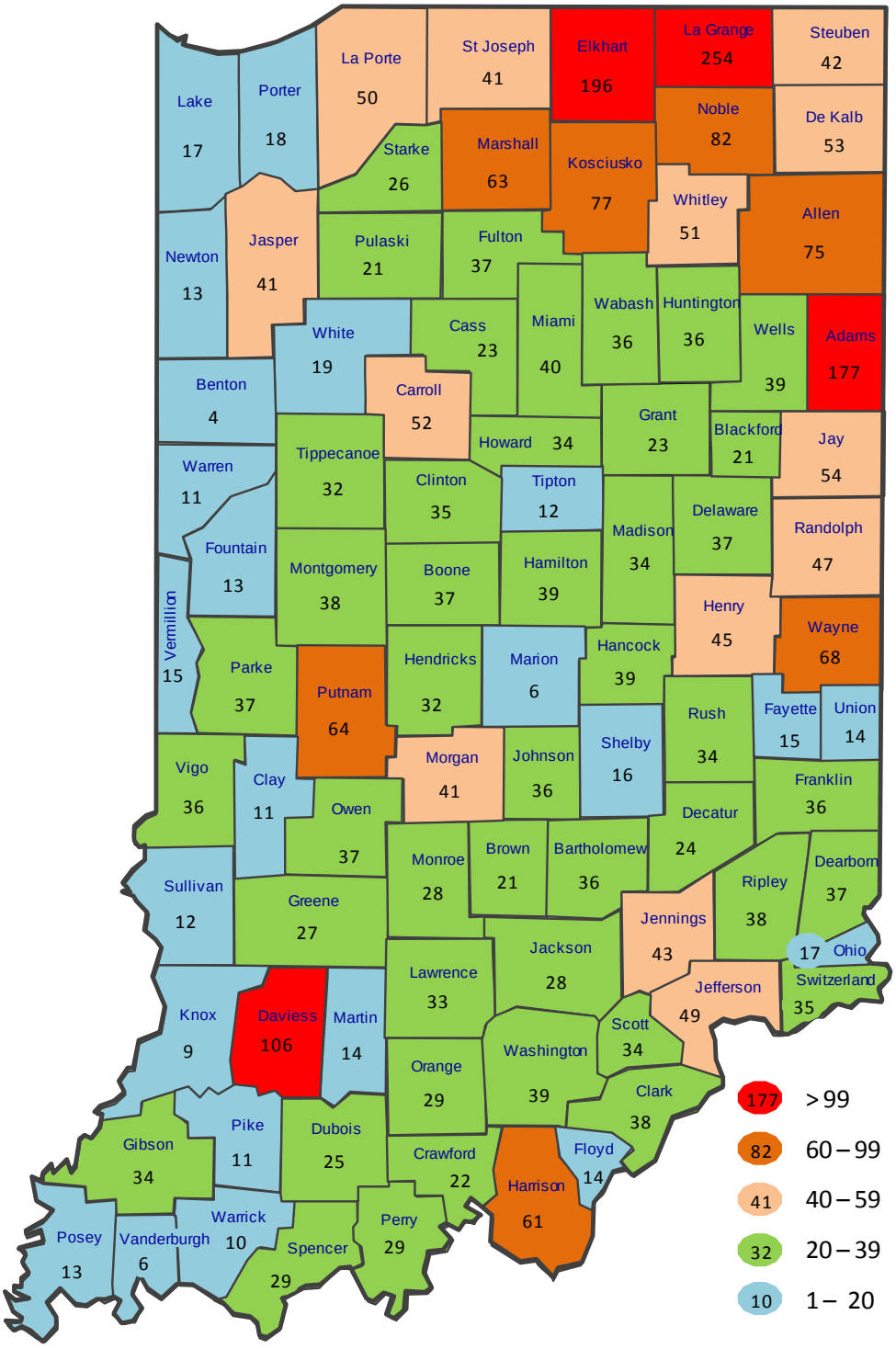

Figure A.2. Numbers of egg layer farms in Indiana in 2007.

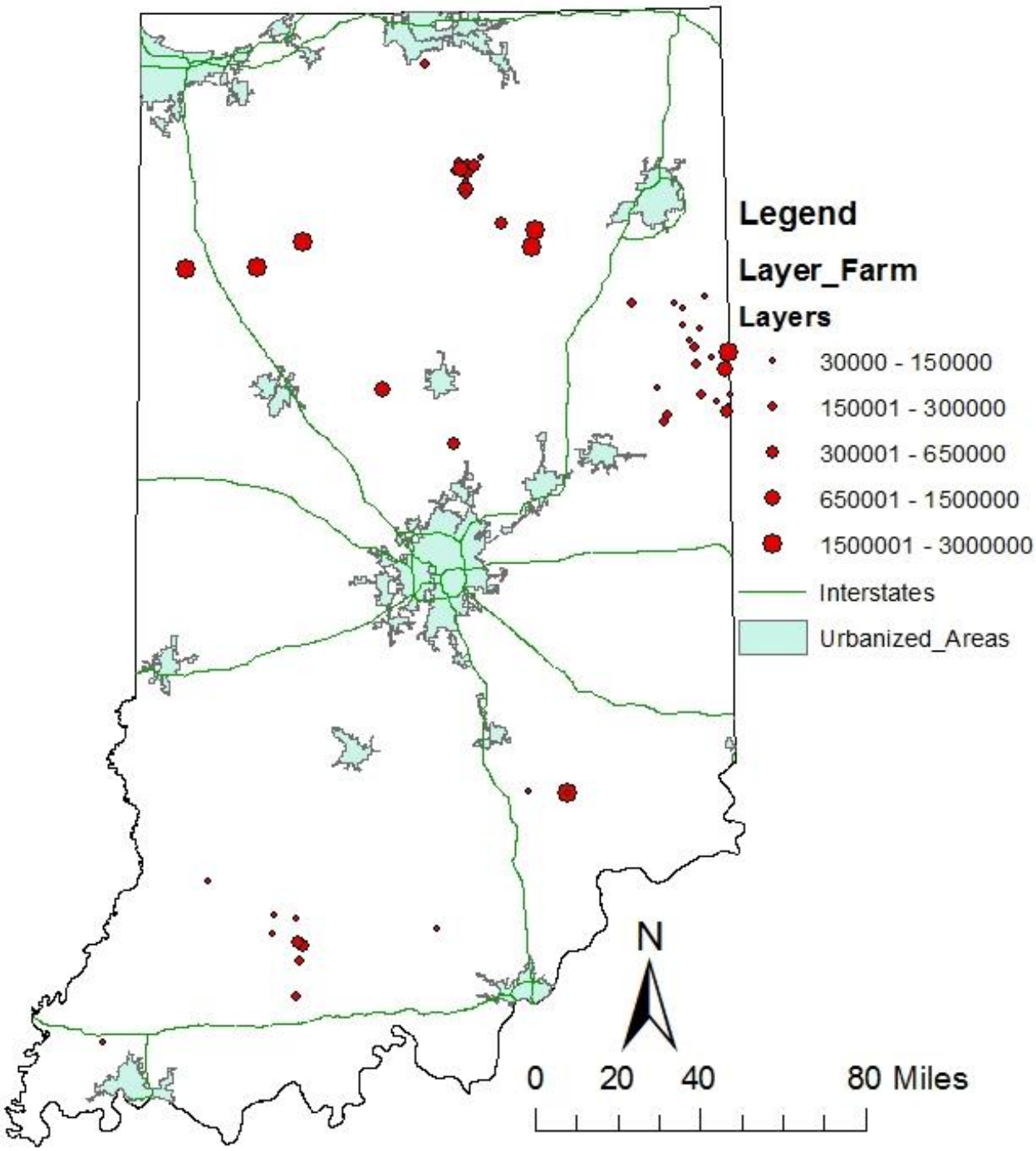

Figure A.3. Locations and sizes of Indiana layer CAFOs and CFOs in 2011.

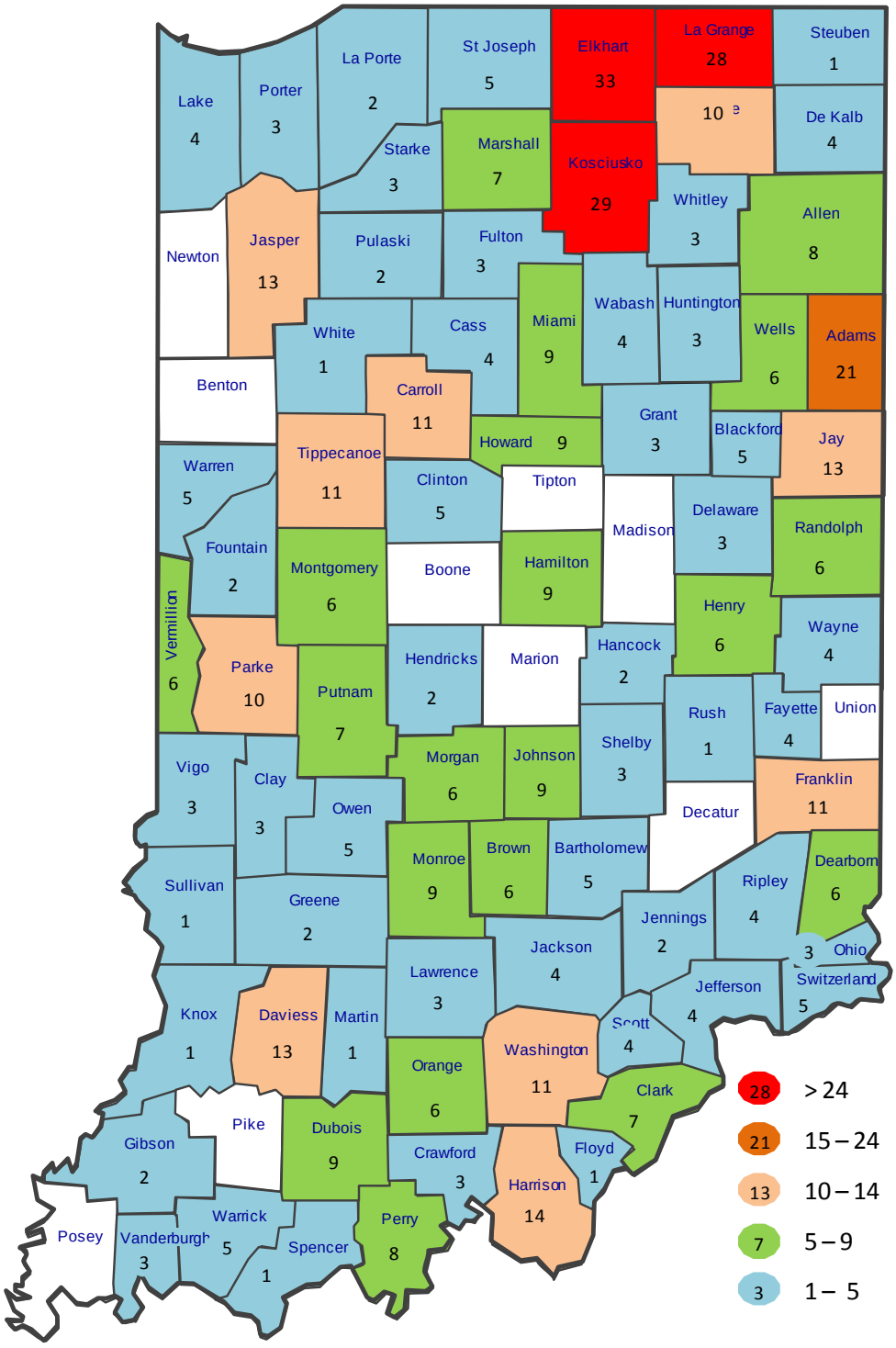

Figure A.4. Numbers of pullet farms in Indiana in 2007.

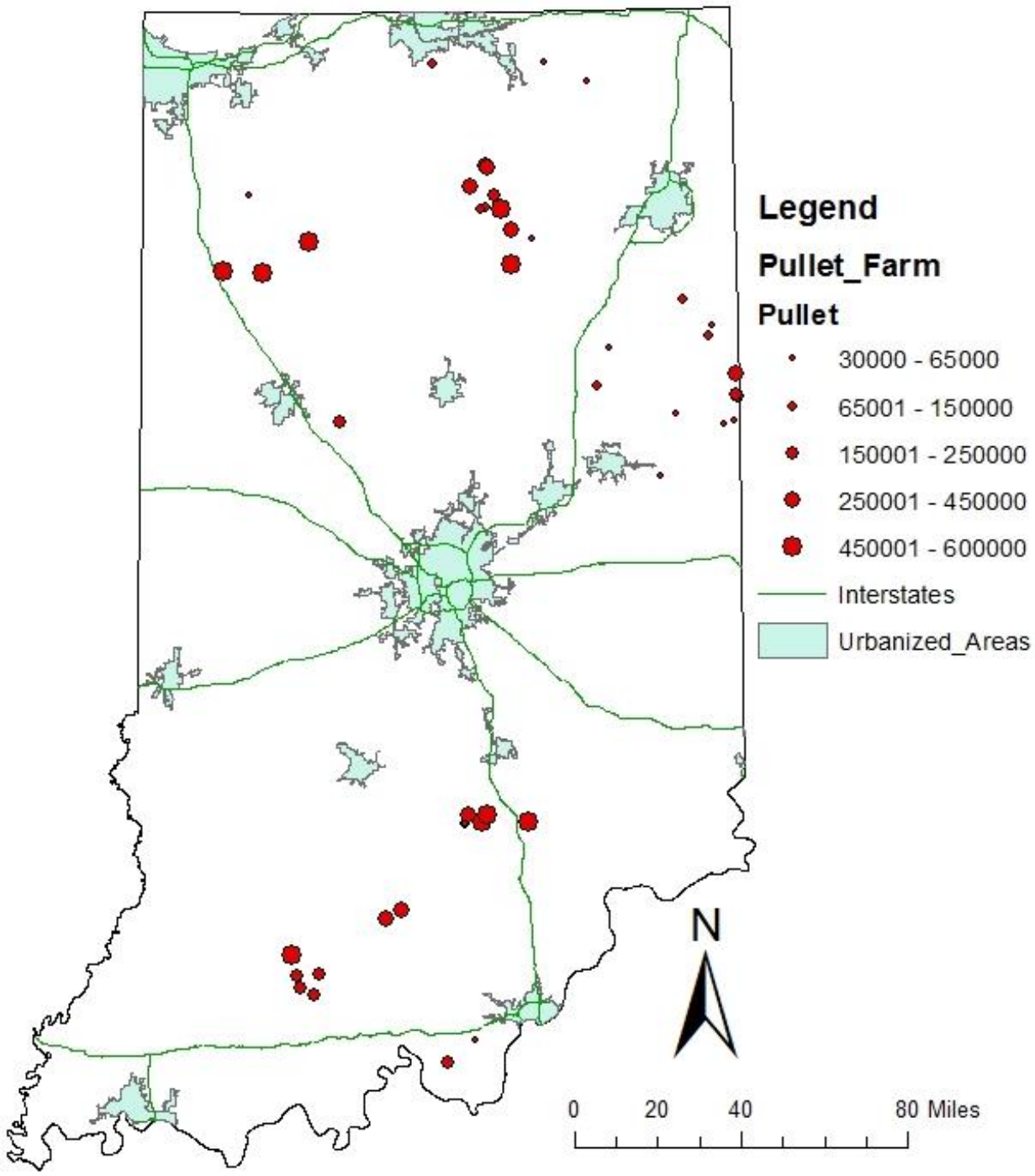

Figure A.5. Locations and sizes of Indiana pullet CAFO and CFO in 2011.

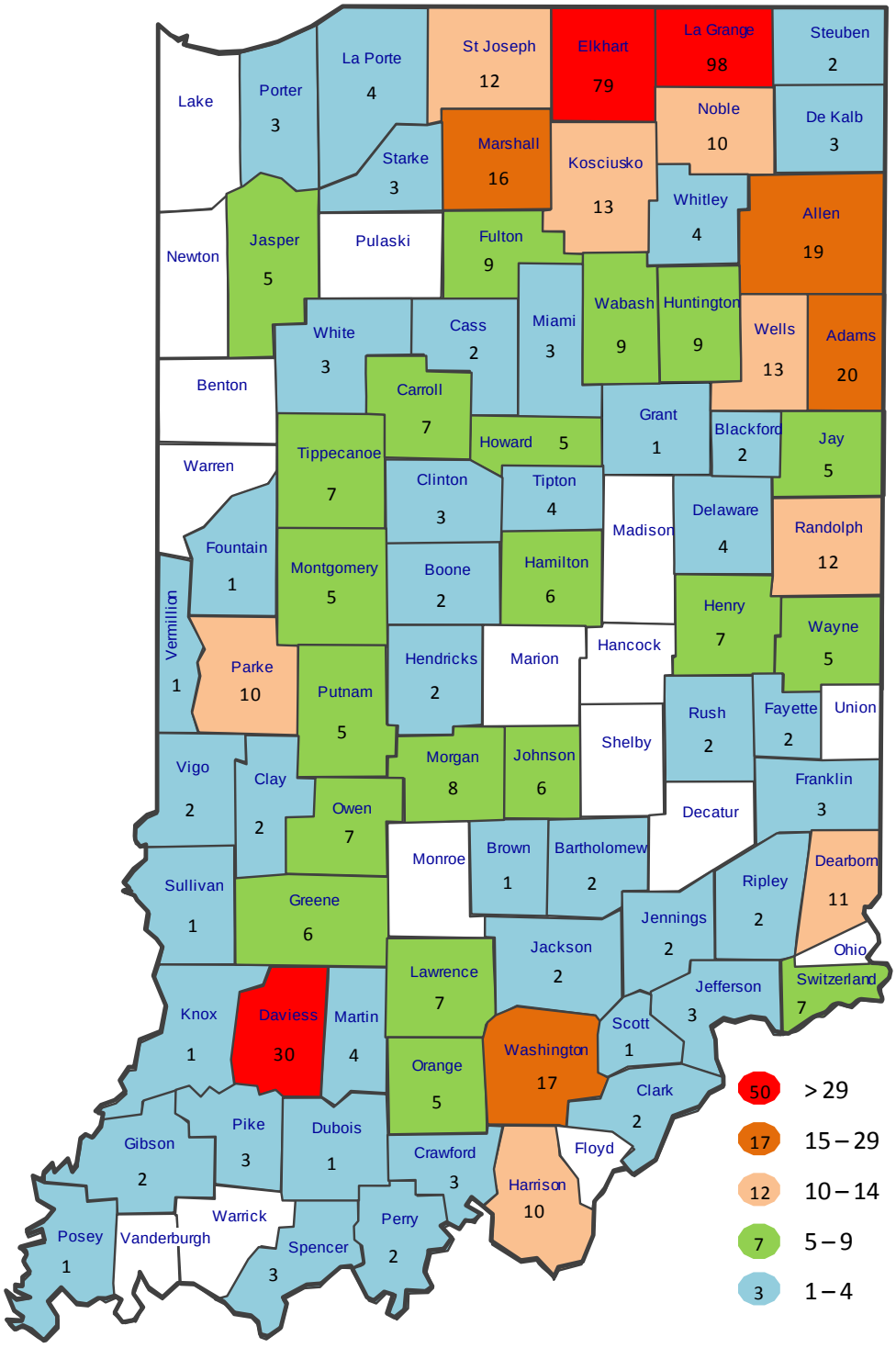

Figure A.6. Numbers of broiler farms in Indiana in 2007.

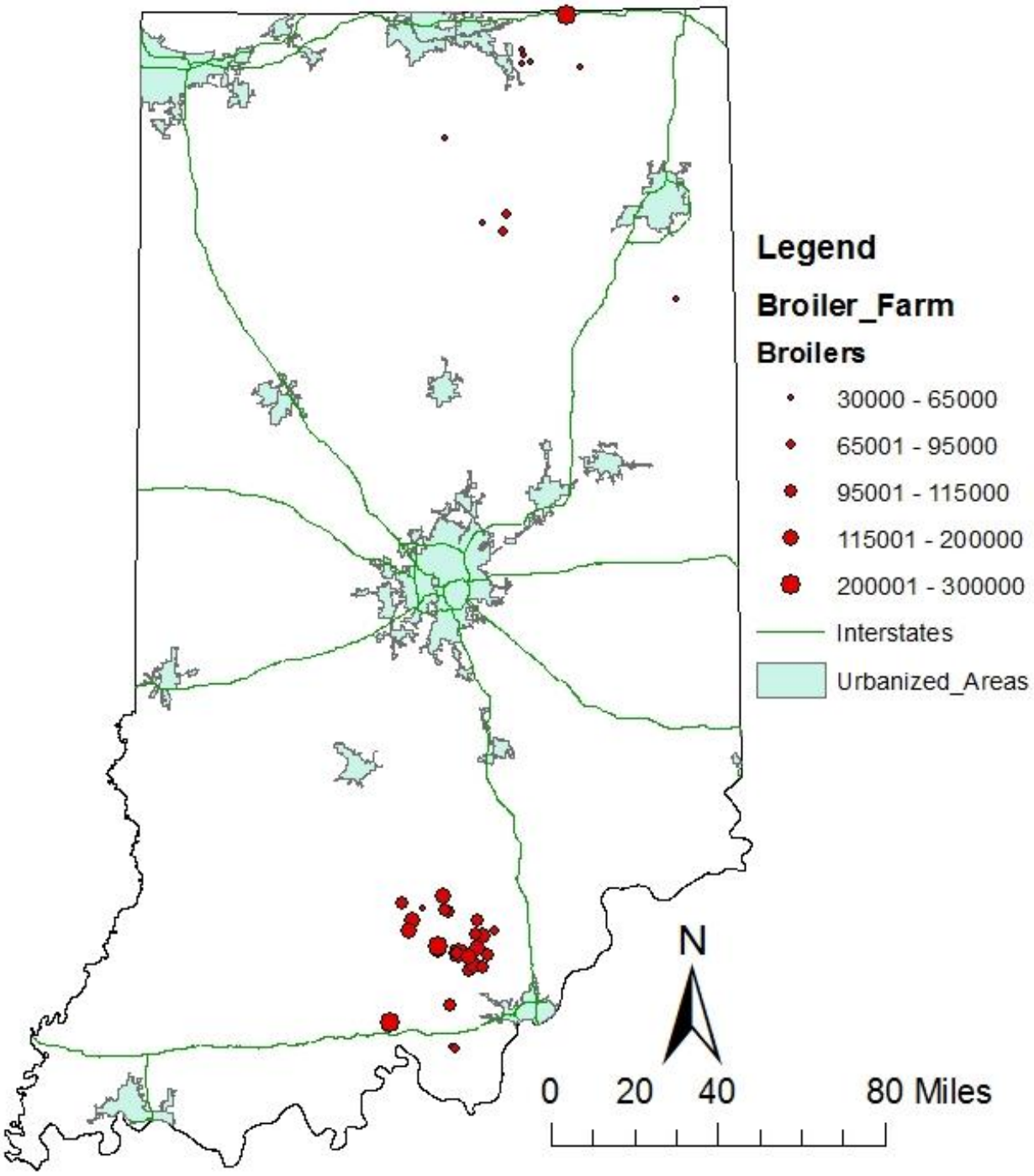

Figure A.7. Locations and sizes of Indiana broiler CAFO and CFO in 2011.

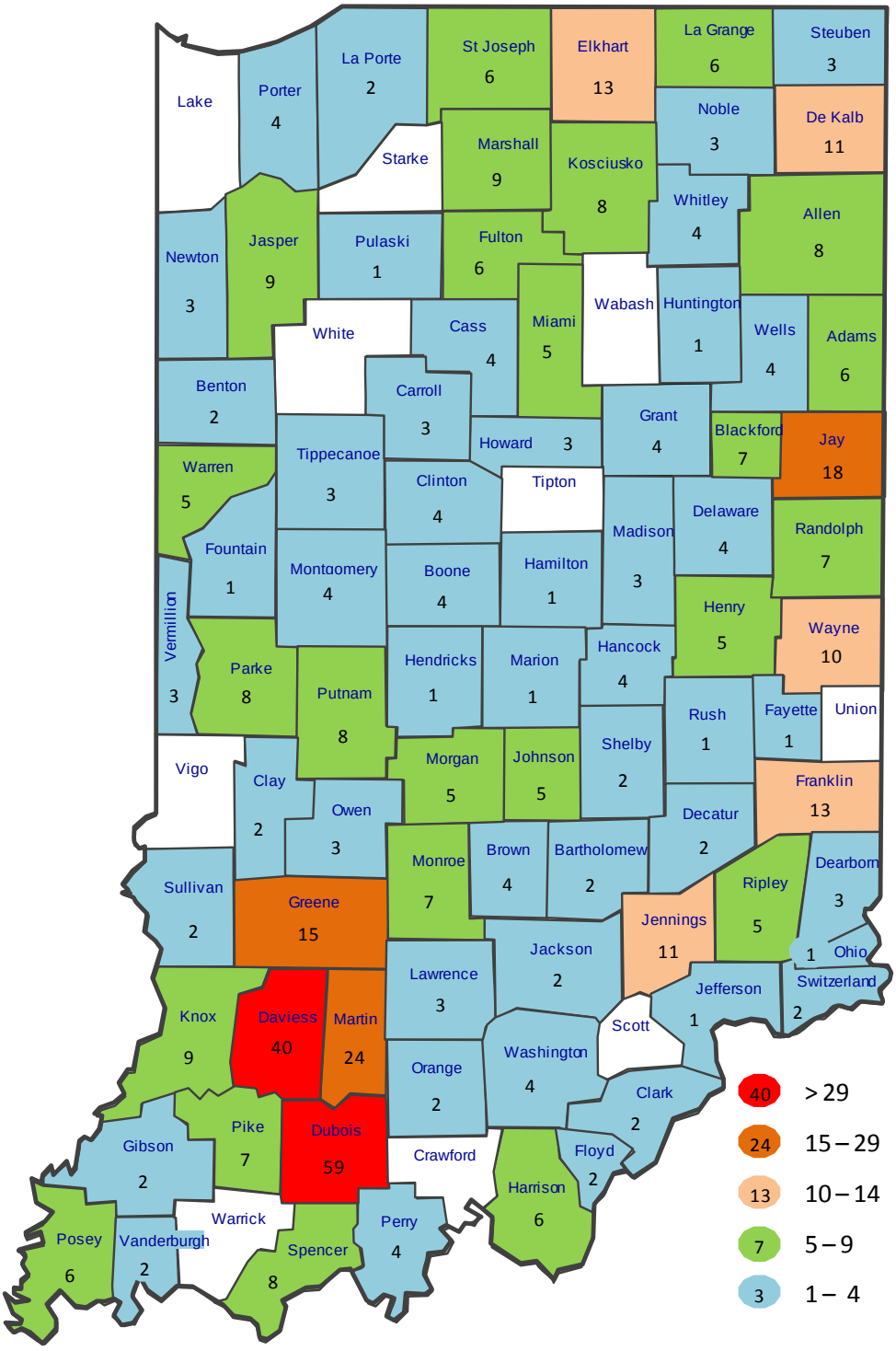

Figure A.8. Numbers of turkey farms in Indiana in 2007.

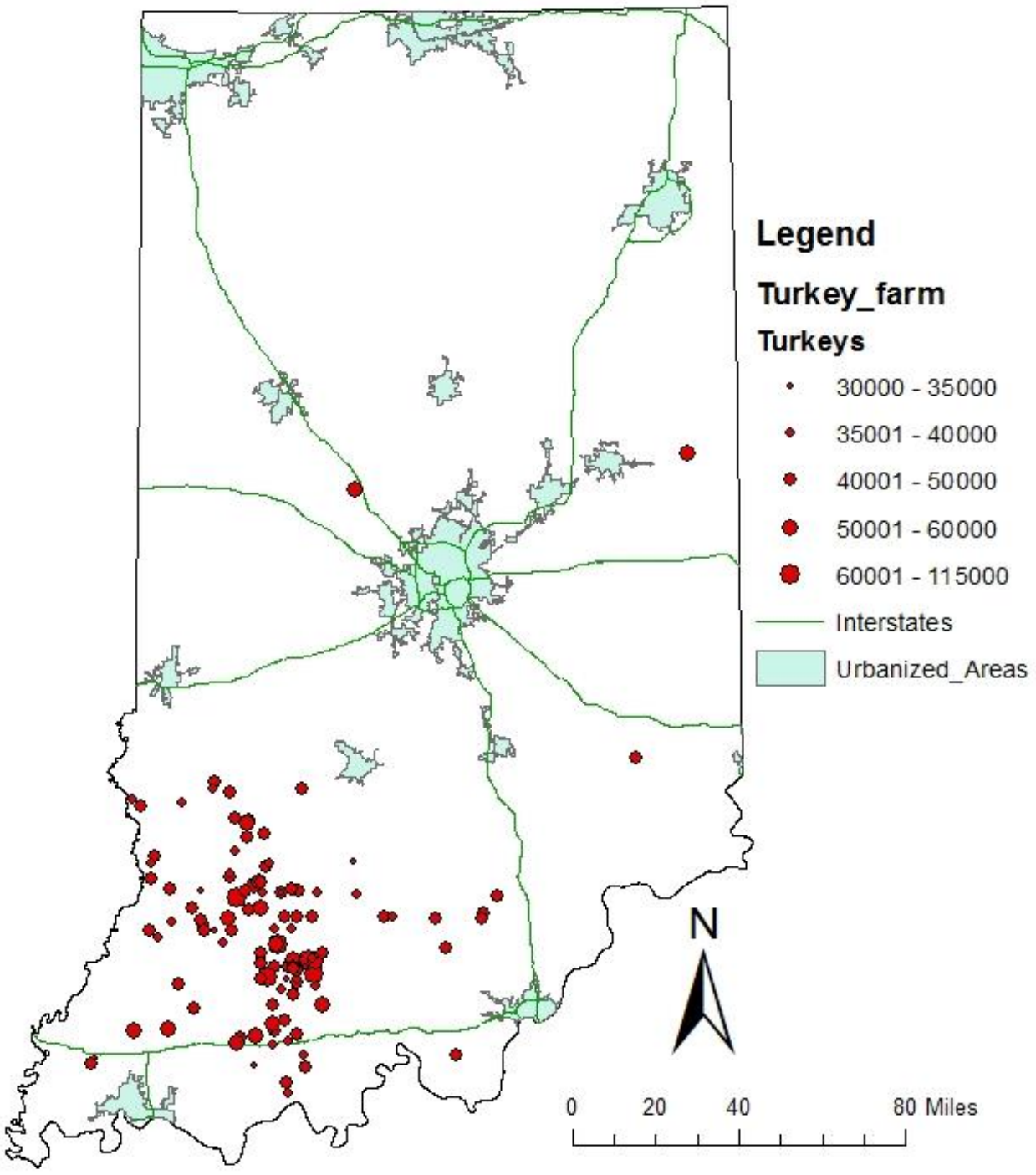

Figure A.9. Locations and sizes of Indiana turkey CAFO and CFO in 2011.

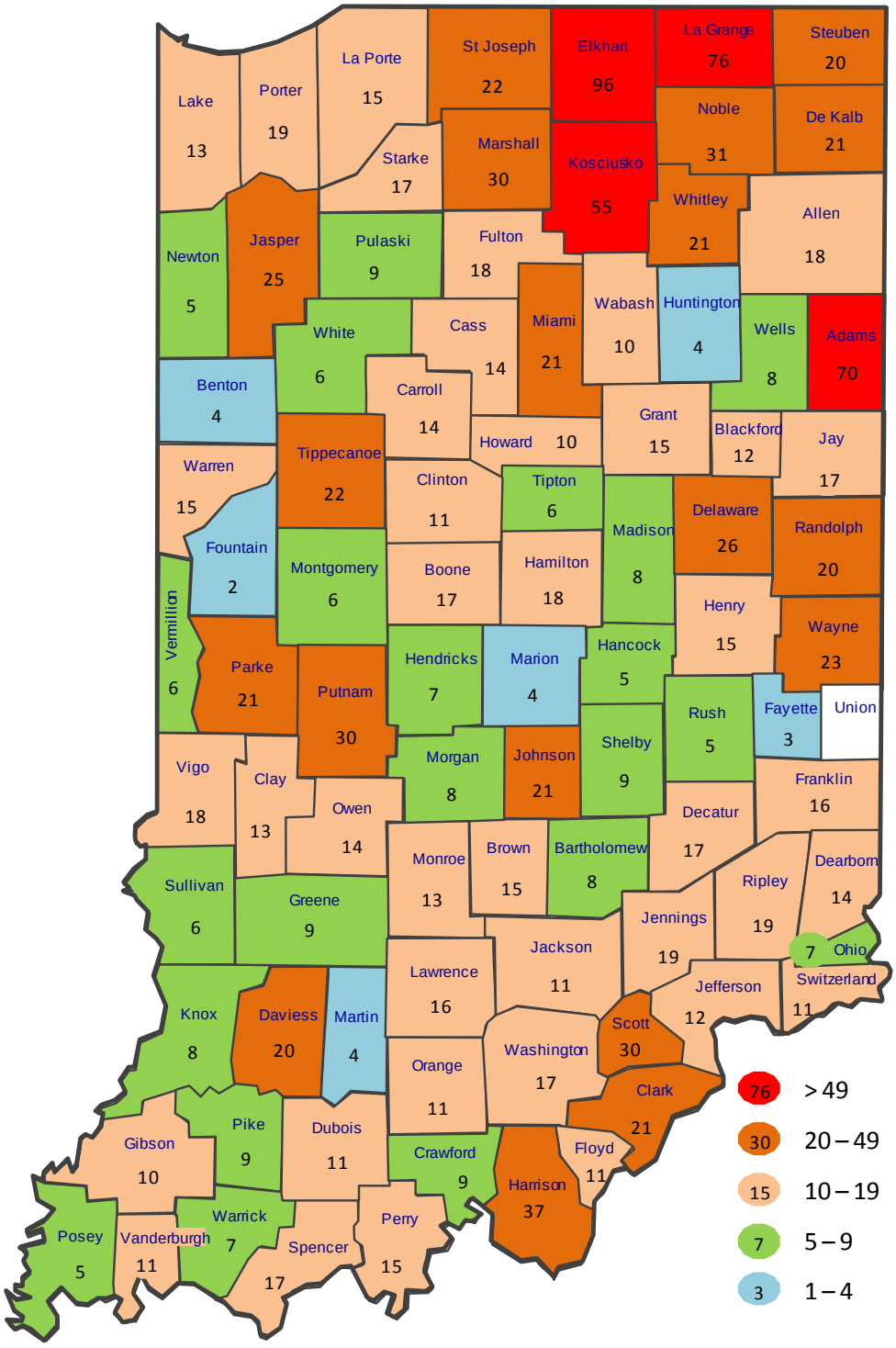

Figure A.10. Numbers of duck and other poultry farms in Indiana in 2007.

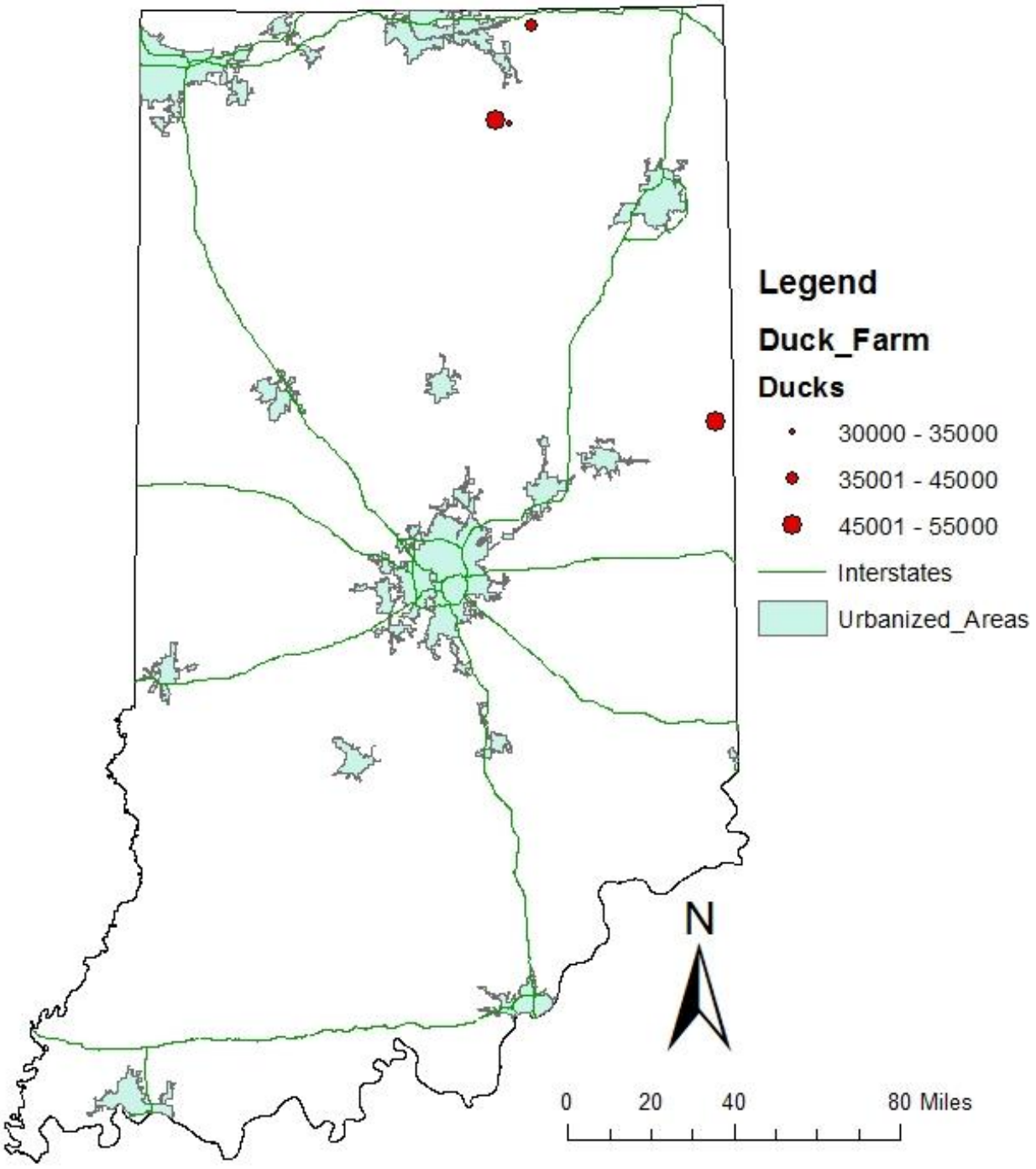

Figure A.11. Locations and sizes of Indiana duck CAFO and CFO in 2011.

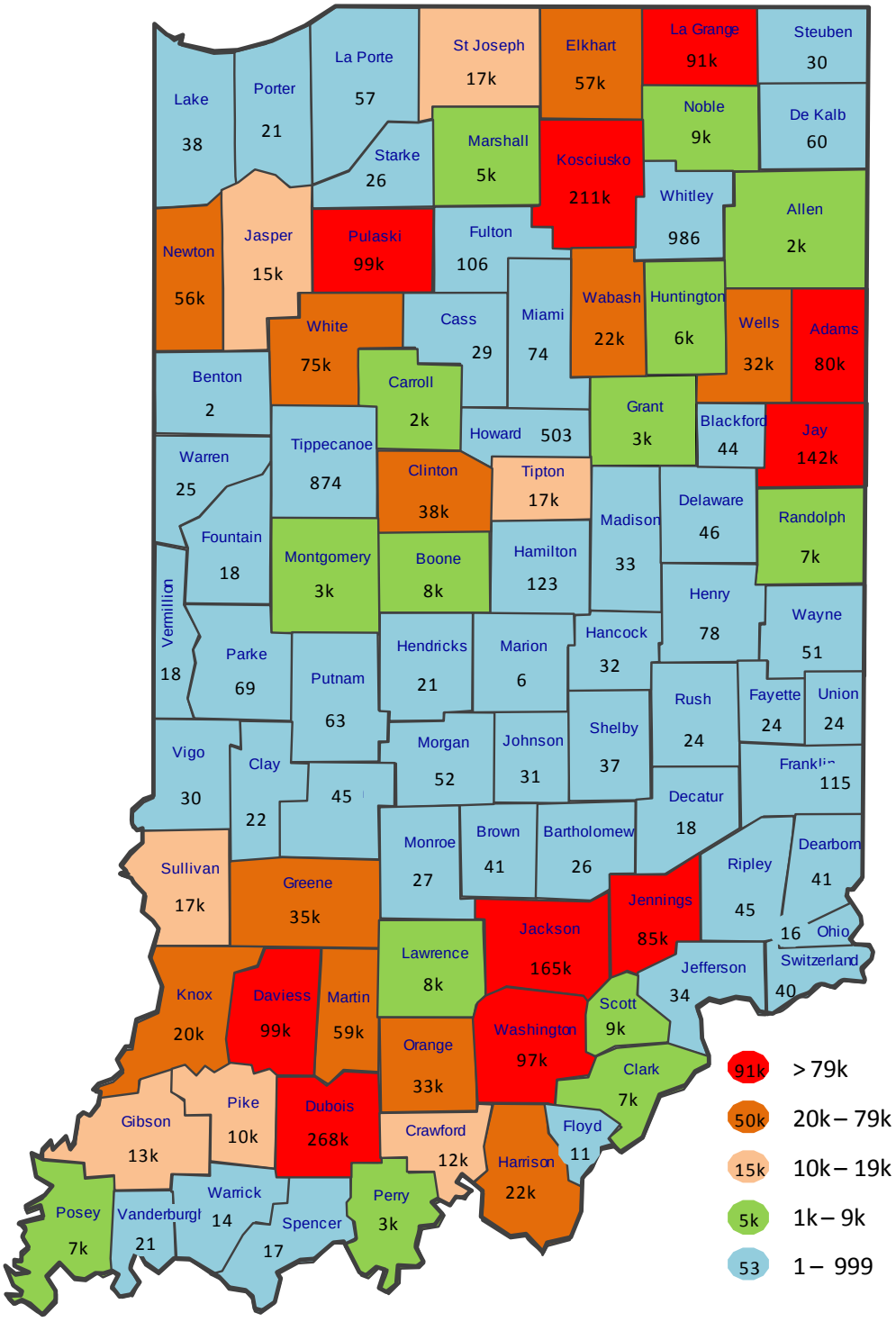

Figure A.12. Indiana total poultry manure production (tons) in 2007.

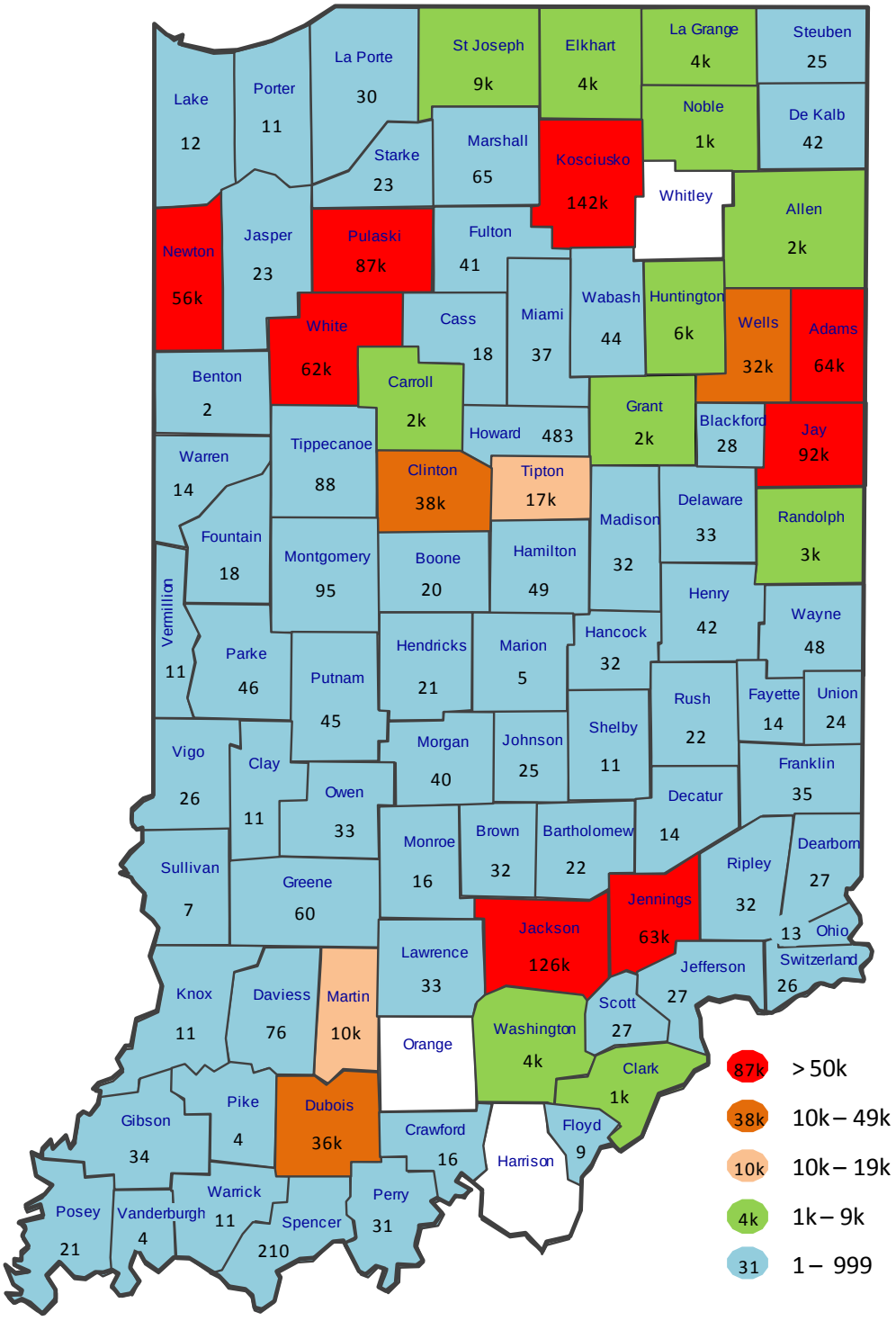

Figure A.13. Indiana layer manure production (tons) in 2007.

Due to the withheld data in USDA Census, the manure productions in 3 layer-raising counties could not be calculated and are not shown in the map.

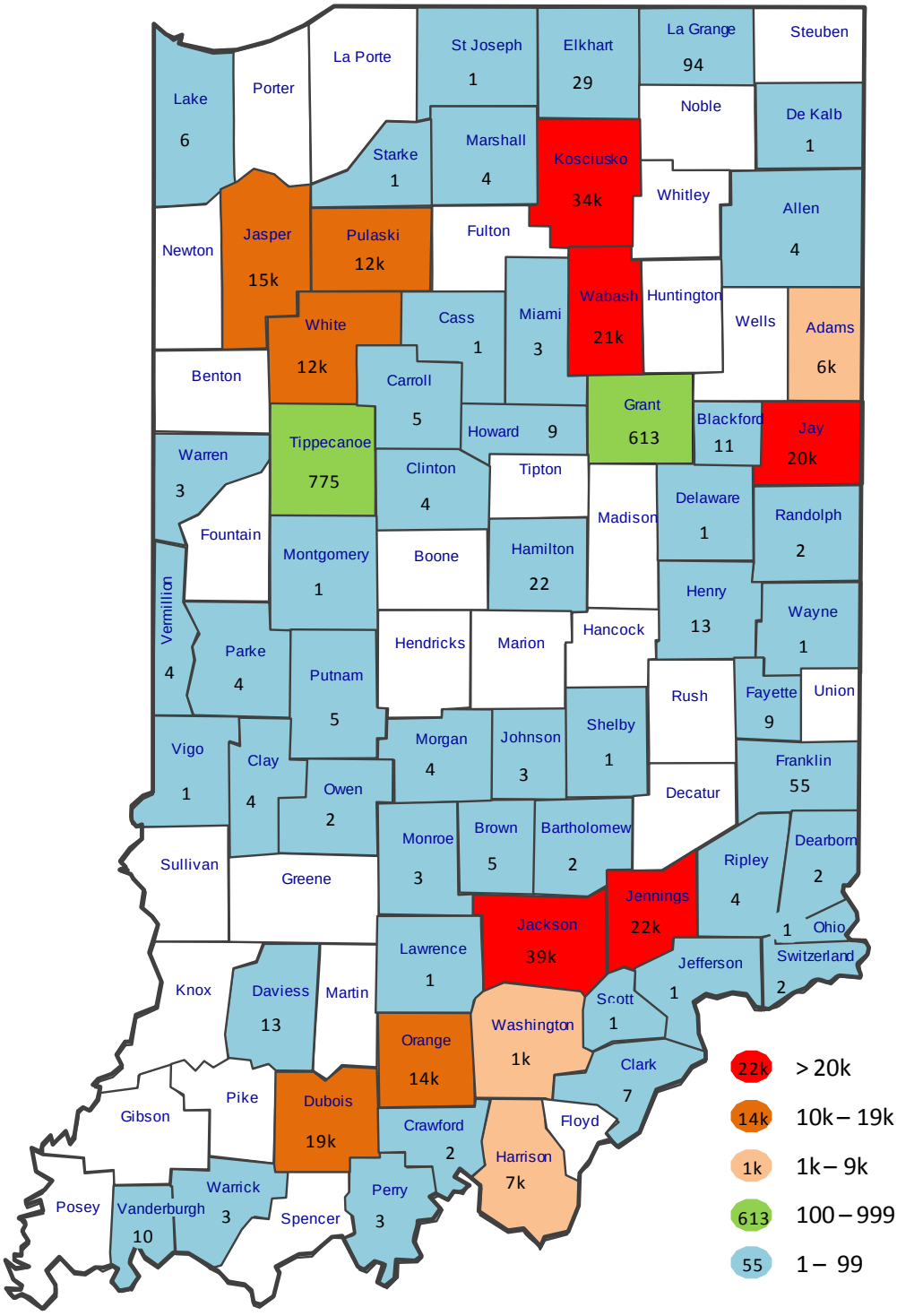

Figure A.14. Indiana pullet manure production (tons) in 2007.

Due to the withheld data in USDA Census, the pullet manure productions in 17 pullet-raising counties are not shown in the map. There were other 10 counties without pullet farms.

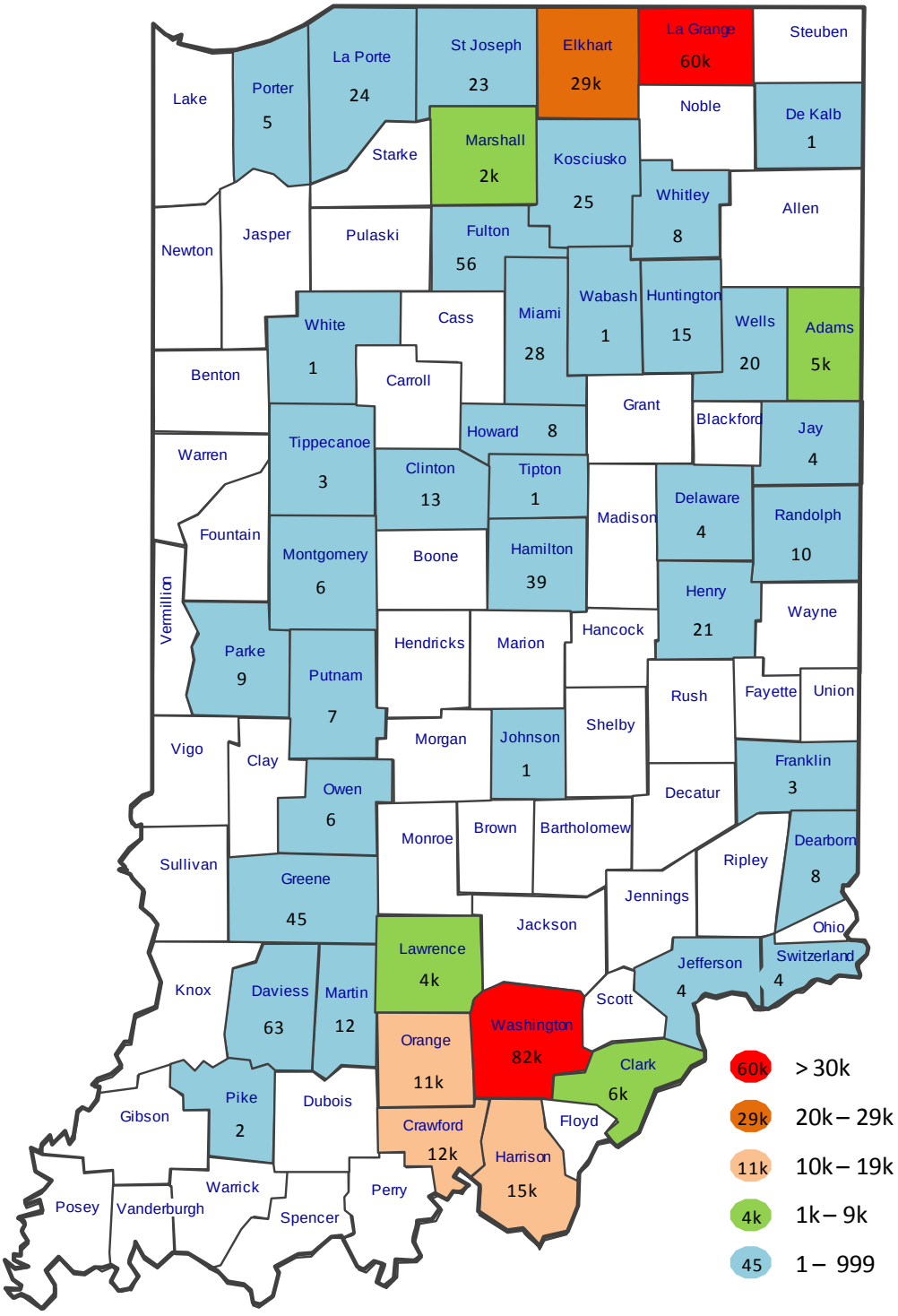

Figure A.15. Indiana broiler manure production (tons) in 2007.

Due to the withheld data in USDA Census, broiler manure production in 31 broiler-raising counties are not shown in the map. There were other 16 counties without broiler farms.

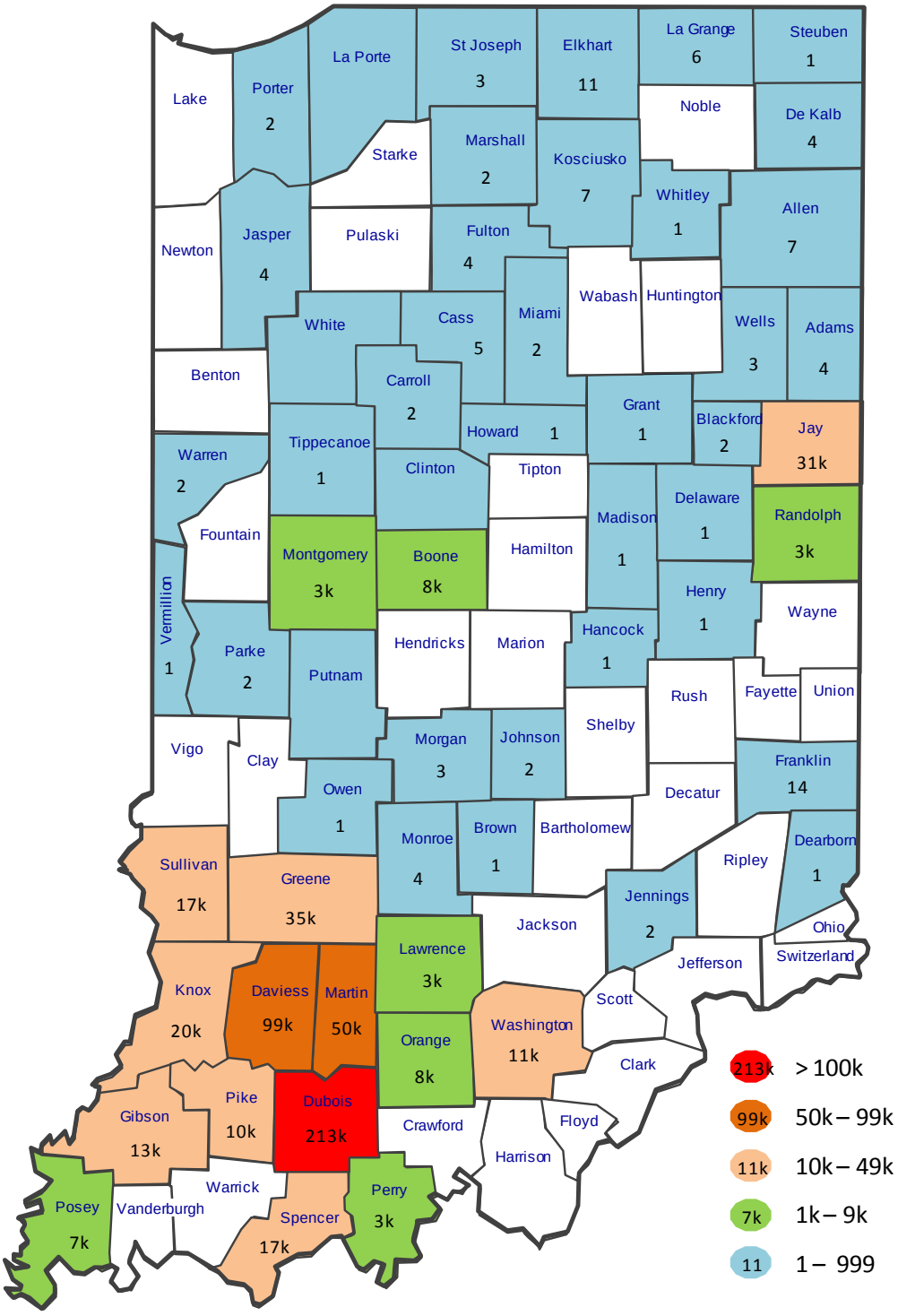

Figure A.16. Indiana turkey manure production (tons) in 2007.

Due to the withheld data in USDA Census, turkey manure productions in 27 turkey-raising counties are not shown in the map. There were other 10 counties without turkey farms.

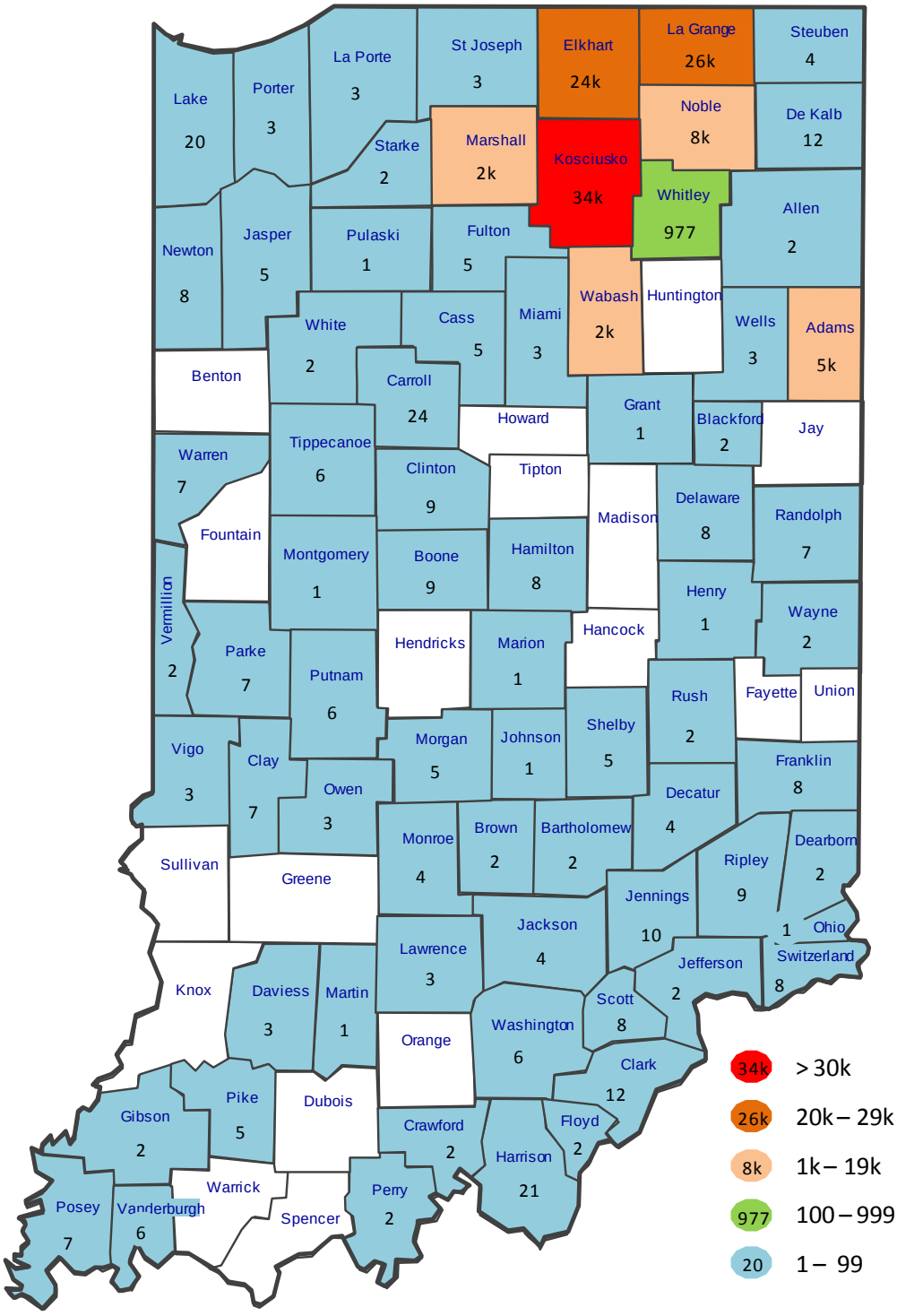

Figure A.17. Indiana duck manure production (tons) in 2007.

Due to the withheld data in USDA Census, duck manure productions in 13 duck-raising counties are not shown in the map. There were other 5 counties without duck farms.

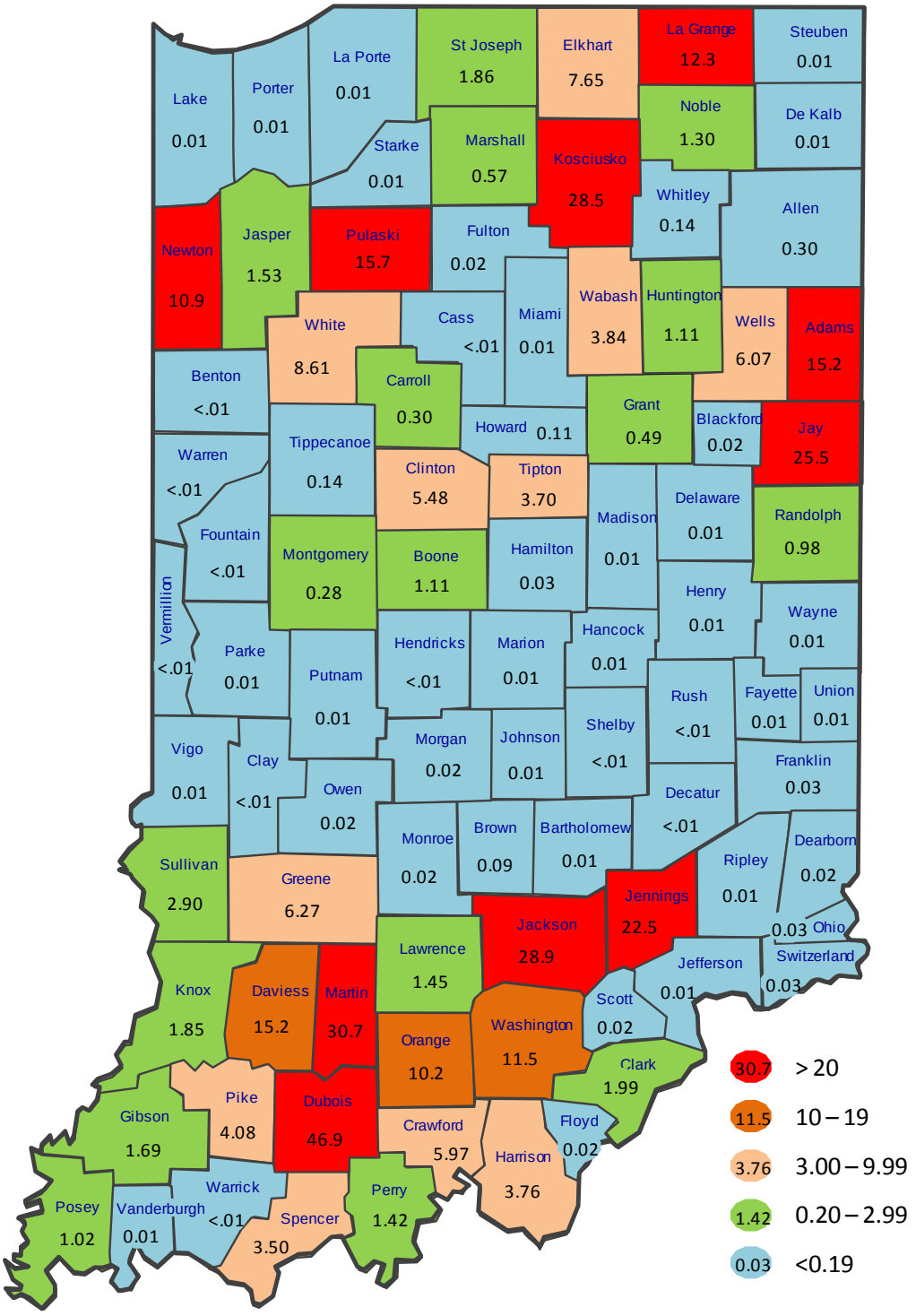

Figure A.18. Indiana available nitrogen from as-excreted poultry manure (lb/acre) in 2007.

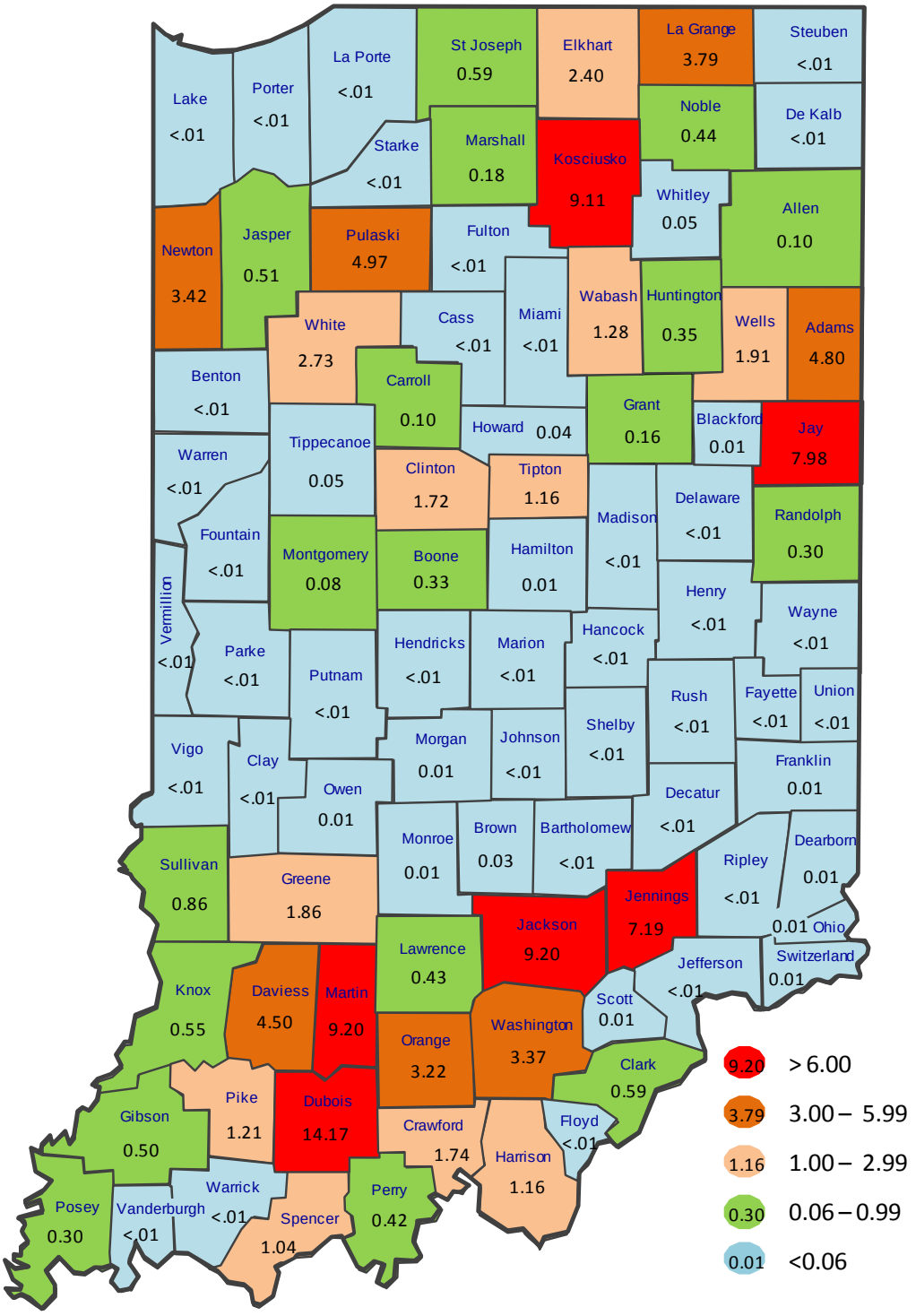

Figure A.19. Indiana available phosphorus from as-excreted poultry manure (lb/acre) in 2007.

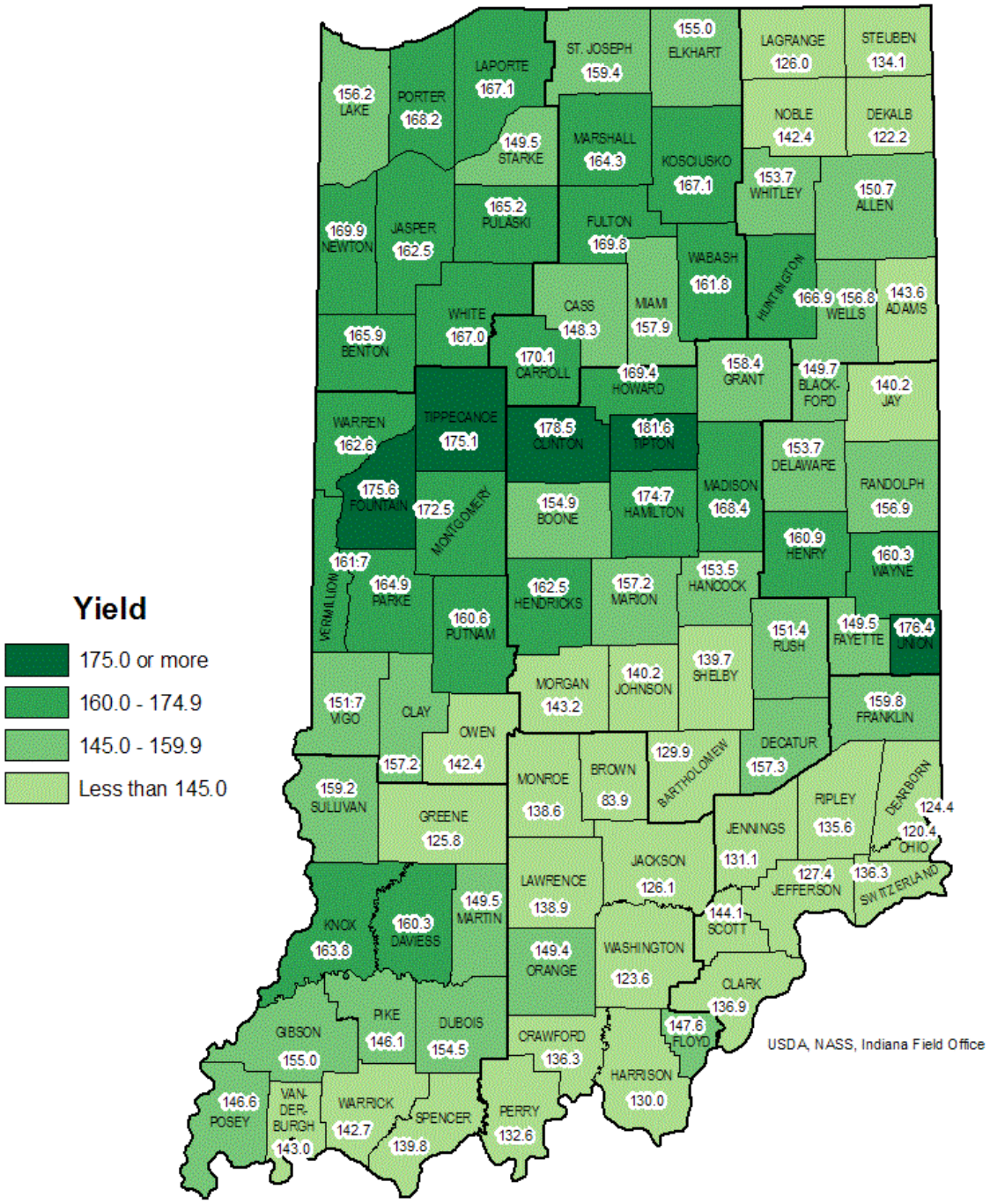

Figure A.20. Indiana corn yields in 2010.
Source: www.nass.usda.gov/Statistics_by_State/Indiana/Charts_and_Maps/2012/12crnyld.gif

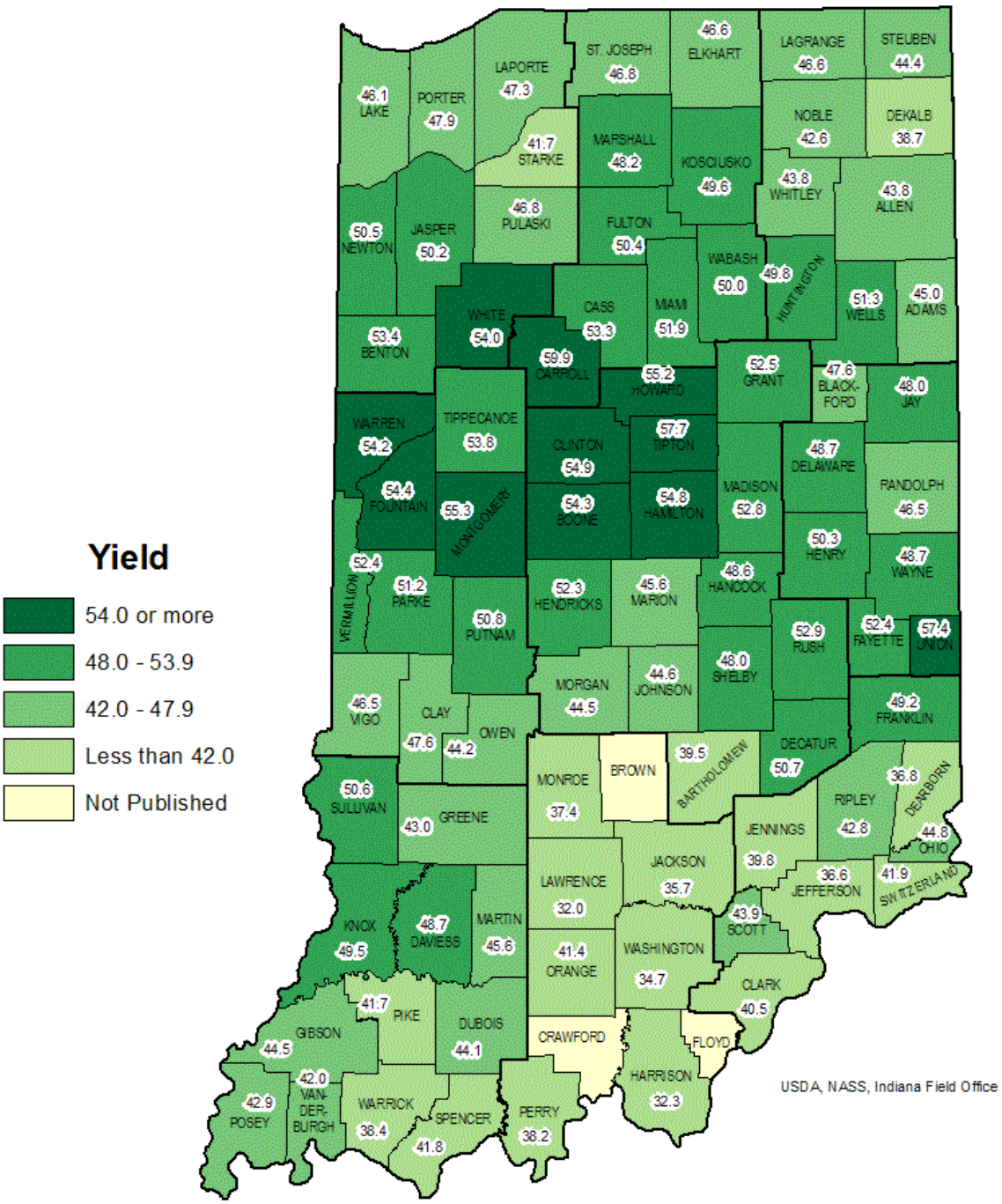

Figure A.21. Indiana soybean yields in 2010.
Source: www.nass.usda.gov/Statistics_by_State/Indiana/Charts_and_Maps/2010/10sbyld.gif

Appendix B: Survey Questionnaire of Poultry Manure Application in Indiana

By Purdue University, West Lafayette, Indiana (IRB Approved Protocol # 1212013039)

The purpose of this survey is to collect data that will help to identify statewide issues related to manure management, and to increase the value of poultry manure as a nutrient source for crops and other value-added products. The survey results will be used in scientific research and by Purdue Extension personnel for Indiana's sustainable agriculture. All of your answers will be CONFIDENTIAL.

To avoid data overlaps, please only enter information relevant to 1) the land that you own or rent to grow crops (excluding land that you rent to others), and 2) livestock and poultry farm(s) that you directly operate (i.e., do not include those that you contract to others).

For questions, please contact Jiqin (Jee-Chin) Ni (jiqin@purdue.edu, 765-496-1733) or Albert Heber (heber@purdue.edu, 765-494-1214).

This survey will take an average of 5 to 15 minutes to complete.

The completed survey can be mailed back to the county educator:

_____

_____

_____

This survey is also available online at:

https://purdue.qualtrics.com/SE/?SID=SV_a64N2cSopRRhki1

Q1: Where in Indiana is your land located? (Check all counties that apply).

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

Q2: Do you also have crops grown in the following neighboring states? (Check all that apply).

□ Ohio □ Michigan □ Illinois □ Kentucky

Q3: What poultry types did you have <u>in 2012</u>?

	Number of birds
Layers	_____
Broilers	_____
Pullets	_____
Turkeys	_____
Turkey breeders	_____
Ducks	_____
Other (please specify) _____	_____
Other (please specify) _____	_____

***If you did not have any poultry production in 2012, skip to Q5.**

Q4: Did you have excess poultry manure to sell <u>in 2012</u>?

□ Yes, about _____% manure marketed/sold. □ No

Q5: What crops did you grow and how many acres did you allocate to each crop <u>in 2012</u>?

	Number of acres	Check if you applied poultry manure to this crop
Corn	_____	□
Soybeans	_____	□
Wheat	_____	□
Oats	_____	□
Potatoes	_____	□
Other (please specify) _____	_____	□
Other (please specify) _____	_____	□

Q6: What fertilizers and how much of each did you apply to your total cropland <u>in 2012</u>?

	Quantity of fertilizer	Check if in Tons	Check if in Gallons
Inorganic fertilizer	_____	□	□
Poultry manure	_____	□	□
Swine manure	_____	□	□
Dairy manure	_____	□	□
Beef manure	_____	□	□
Other (please specify) _____	_____	□	□
Other (please specify) _____	_____	□	□

***If you did NOT apply poultry manure as fertilizer, please skip to Q14.**

Q7: About poultry manure transportation and application in 2012. (Check all that apply).

- □ We use cover crops.
- □ We use solid poultry manure.
- □ We use liquid poultry manure.
- □ We compost poultry manure.
- □ We had manure tested for nutrient content.
- □ The poultry farm provided nutrient content data.
- □ The manure hauler provided us nutrient content data.
- □ We provided transportation and application of poultry manure ourselves for $ _____/ton of solid manure only or _____¢/gallon of liquid manure only.
- □ We purchased manure from manure hauler who transported and applied manure for $ _____/ton or _____¢/gallon, including transportation, application, and manure).

Q8: If you provide transportation and application of poultry manure in 2012, what is the maximum transportation distance from the poultry farm to your crop field?

_____ miles

Q9: What are the main reasons that you use poultry manure? (Check all that apply).

- □ It is readily available on our farm or from other farms.
- □ It has high organic nutrient content.
- □ It is less expensive than inorganic fertilizers.
- □ It is easy to store and apply.
- □ Other (please specify): _____
- □ Other (please specify): _____

Q10: About using poultry manure as a plant-nutrient fertilizer.

How long have you been using poultry manure?

For _____ years. □ I only use poultry manure occasionally (not every year).

Q11: When do you apply poultry manure? (Check all that apply).

□ spring □ summer □ fall □ winter

Q12: Do you plan to continue using poultry manure on your farms?

□ Yes □ No

Q13: Additional information about poultry manure use. (Check all that apply).

- □ We use poultry manure as feed in aquaculture.
- □ We use poultry manure as feed for beef cattle.
- □ We use/sell poultry manure to produce energy in anaerobic digesters.
- □ We use/sell poultry manure to produce energy by thermo-chemical conversion.

***If you DID apply poultry manure, please skip to Q15.**

Q14: If you did NOT utilize poultry manure on your cropland in 2012, what were the main reasons? (Check all that apply).

□ Poultry manure was not readily available from our own farm or from other sources.
□ We had never used poultry manure and were unsure of its benefit.
□ It was more expensive than inorganic fertilizers.
□ It would not satisfy my crop nutrient requirements.
□ Poultry manure is more difficult to apply.
□ We are concerned about its related environmental problems:
    □ Nutrient runoff
    □ Groundwater contamination
    □ Odor nuisance during manure application
    □ Other (please specify) _____
□ Other (please specify) _____

Q15: What is the price you are willing to pay for poultry manure? (Enter all prices that apply).

For manure, transportation, and application:
$_____/ton of solid manure or _____¢/gallon of liquid manure.

For manure only when purchased from a poultry farm:
$_____/ton or _____¢/gallon.

For transportation and application only after manure was purchased from a poultry farm:

If done by myself: $_____/ ton or _____¢/ gallon.

If done by a contractor: $_____/ ton or _____¢/ gallon.

Q16: Do you have a nutrient management plan?

□ Yes □ No

Q17: Are you aware of the new *Agriculture Fertilizer Applicator Certification Rule* (www.isco.purdue.edu/pesticide/pest_pdf/fert_app_outreach_11_23_2010.pdf)?

□ Yes □ No

Q18: Are you aware of the new *Indiana regulation on Fertilizer Material Use, Distribution, and Record Keeping* (www.isco.purdue.edu/fertilizer/fert_pdf/fert_use_rules_and_faq.pdf)?

□ Yes □ No

Thank you for participating in the Indiana poultry manure application survey 2013!