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County-Level Estimates of Nitrogen and Phosphorus from Animal Manure for the Conterminous United States, 2007 and 2012

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U.S. Department of the Interior
U.S. Geological Survey

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By Jo Ann M. Gronberg and Terri L. Arnold

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)

County-Level Estimates of Nitrogen and Phosphorus from Animal Manure for the Conterminous United States, 2007 and 2012

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Abstract

County-level estimates of nitrogen and phosphorus inputs from animal manure for the conterminous United States were calculated from animal population inventories in the 2007 and 2012 Census of Agriculture, using previously published methods. These estimates of non-point nitrogen and phosphorus inputs from animal manure were compiled in support of the U.S. Geological Survey's National Water-Quality Assessment Project of the National Water-Quality Program and are needed to support national-scale investigations of stream and groundwater water quality. The estimates published in this report are comparable with older estimates which can be compared to show changes in nitrogen and phosphorus inputs from manure over time.

Introduction

Lacking data for the mass of manure applied to the land surface of each watershed of the United States, scientists assessing the effects of nutrient sources on water quality have used instead estimates of manure production by farm animals (one of several watershed inputs of nutrients, which include nitrogen, phosphorus, and other minerals essential for plant growth), based on periodic, county-level data gathered for the Census of Agriculture. The U.S. Geological Survey (USGS) has published two in a sequence of reports of county-level estimates of nitrogen and phosphorus inputs to the land surface from animal manure (Ruddy and others, 2006; Mueller and Gronberg, 2013). Ruddy and others (2006) reported estimates of nitrogen and phosphorus inputs from manure for the years 1982–2001, and Mueller and Gronberg (2013) reported estimates for 2002. Updated, comparable estimates of these inputs were needed to support ongoing national- and regional-scale investigations of stream and groundwater water quality being undertaken as part of the USGS National Water-Quality Assessment (NAWQA) Project of the National Water-Quality Program (NWQP) (Rowe and others, 2010, 2013). This third report in the sequence documents the methodology used and presents county-level estimates for 2007 and 2012 of nitrogen and phosphorus inputs from animal manure for the principal groups of livestock (animal categories) raised in the United States.

Estimating Nitrogen and Phosphorus from Animal Manure

The procedures used in this report for estimating nitrogen and phosphorus from animal manure are the same as those described in Ruddy and others (2006) and Mueller and Gronberg (2013) and include (1) estimating animal populations when the primary category population was not disclosed and (2) calculating nitrogen and phosphorus content of the animal manure on the basis of animal populations (U.S. Department of Agriculture, 2009, 2014) and estimates of nitrogen and phosphorus content in manure (Ruddy and others, 2006). Similar methods have been used by Goolsby and others (1999) to estimate nitrogen and phosphorus inputs from manure using older data for a smaller area.

Because the same methods used by Ruddy and others (2006) and Mueller and Gronberg (2013) were used to create these data for 2007 and 2012, these data and the older data can be compared to show changes in nitrogen and phosphorus input from manure over time.

Description of the County-Level Nutrient-Input Dataset

Estimates of nitrogen and phosphorus from animal manure for 2007 and 2012 are presented in two formats, in tabular format as the spreadsheet *ofr2017-1021_manure_2007_2012.xlsx* and in two tab-delimited American Standard Code for Information Interchange (ASCII) text data files *ofr2017-1021_manure_2007.txt* and *ofr2017-1021_manure_2012.txt*. The data files have the same attributes, which are defined in table 1. The data and metadata are available online at https://dx.doi.org/10.5066/F7X34VMZ. The data consist of county-level farm animal population inventories for categories of farm animals in the conterminous United States, estimated nitrogen and phosphorus content (in kilograms) of the manure from each animal category (cattle, hogs, poultry, and others), total nitrogen and total phosphorus content (in kilograms) for all animal categories combined, and county total area (in square kilometers) for the years 2007 and 2012. County areas were derived from a 30-meter-resolution grid of counties from 2010 which is included in a data release which accompanies this report (https://dx.doi.org/10.5066/F7X34VMZ).

Table 1. Attribute labels and definitions for *ofr2017-1021_manure_2007.txt* and *ofr2017-1021_manure_2012.txt* data files.

Label	Definition
FIPS	The Federal Information Processing Standards (FIPS) 5-digit code of the county or county equivalent.
State	State name
County	County name
Area_km2	County area, in square kilometers
Data_flag	Flag for data availability [1, data available]
Beef cows	Number of beef cows
ND_flag1	Data flag for beef cows [1, Beef cows not disclosed; 2, Beef cows = 0.5 × Cows and heifers that had calved]
Milk cows	Number of milk cows
ND_flag2	Data flag for milk cows [1, Milk cows not disclosed; 2, Milk cows = 0.5 × Cows and heifers that had calved]
Cows and heifers that had calved	Number of cows and heifers that had calved
ND_flag3	Data flag for cows and heifers that had calved [1, Cows and heifers that had calved not disclosed]
Other cattle	Number of other cattle
ND_flag4	Data flag for other cattle [1, Other cattle not disclosed; 2, Other cattle = (cattle and calves) – (Beef cows + Milk cows)]
Cattle and calves	Number of cattle and calves
ND_flag5	Data flag for cattle and calves [1, Cattle and calves not disclosed]
Cattle N kg	Nitrogen in manure from cattle, in kilograms [Cattle N kg = (Beef cows × 0.15 × 365) + (Milk cows × 0.204 × 365) + (0.25 × Other cattle × 0.15 × 365) + (0.25 × Other cattle × 0.141 × 365) + (0.5 × Other cattle × 0.104 × 170)]
Cattle P kg	Phosphorus in manure from cattle, in kilograms [Cattle P kg = (Beef cows × 0.053 × 365) + (Milk cows × 0.032 × 365) + (0.25 × Other cattle × 0.048 × 365) + (0.25 × Other cattle × 0.018 × 365) + (0.5 × Other cattle × 0.034 × 170)]
Total hogs and pigs	Number of total hogs and pigs
ND_flag6	Data flag for total hogs and pigs [1, Total hogs and pigs not disclosed; 2, Total hogs and pigs = (Hogs and pigs used or to be used for breeding) + (Other hogs and pigs); 3, Total hogs and pigs = 0.5 × Hogs and pigs sold] the larger result of method 2 or 3 is reported
Hogs and pigs used or to be used for breeding	Number of hogs and pigs used or to be used for breeding
ND_flag7	Data flag for hogs and pigs used or to be used for breeding [1, Hogs and pigs used or to be used for breeding not disclosed]
Other hogs and pigs	Number of other hogs and pigs
ND_flag8	Data flag for other hogs and pigs [1, Other hogs and pigs not disclosed]
Hogs and pigs sold	Number of hogs and pigs sold

Table 1. Attribute labels and definitions for *ofr2017-1021_manure_2007.txt* and *ofr2017-1021_manure_2012.txt* data files.—Continued

Label	Definition
ND_flag9	Data flag for hogs and pigs sold [1, Hogs and pigs sold not disclosed]
Hogs N kg	Nitrogen in manure from hogs and pigs, in kilograms [Hogs N kg = Total hogs and pigs × 0.027 × 365]
Hogs P kg	Phosphorus in manure from hogs and pigs, in kilograms [Hogs P kg = Total hogs and pigs × 0.012 × 365]
Layers	Number of layers
ND_flag10	Data flag for layers [1, Layers not disclosed]
Pullets for laying flock replacement	Number of pullets for laying flock replacement
ND_flag11	Data flag for pullets for laying flock replacement [1, Pullets for laying flock replacement not disclosed]
Broilers and other meat-type chickens	Number of broilers and other meat-type chickens
ND_flag12	Data flag for broilers and other meat-type chickens [1, Broilers and other meat-type chickens not disclosed]
Turkeys	Number of turkeys
ND_flag13	Data flag for turkeys [1, Turkeys not disclosed]
Poultry N kg	Nitrogen in manure from poultry, in kilograms [Poultry N kg = (Layers 20 weeks old and older × 0.0015 × 365) + (Pullets for laying flock replacement × 0.001 × 365) + (Broilers and other meat-type chickens × 0.001 × 365) + (0.5 × Turkeys × 0.0054 × 133) + (0.5 × Turkeys × 0.0034 × 112)]
Poultry P kg	Phosphorus in manure from poultry, in kilograms [Poultry P kg = (Layers 20 weeks old and older × 0.0006 × 365) + (Pullets for laying flock replacement × 0.0003 × 365) + (Broilers and other meat-type chickens × 0.0003 × 365) + (0.5 × Turkeys × 0.0020 × 133) + (0.5 × Turkeys × 0.0013 × 112)]
Sheep and lambs	Number of sheep and lambs
ND_flag14	Data flag for sheep and lambs [1, Sheep and lambs not disclosed]
Horses and ponies	Number of horses and ponies
ND_flag15	Data flag for horses and ponies [1, Horses and ponies not disclosed]
Other N kg	Nitrogen in manure from sheep, lambs, horses, and ponies, in kilograms [Other N kg = (Sheep and lambs × 0.023 × 365) + (Horses and ponies × 0.127 × 365)]
Other P kg	Phosphorus in manure from sheep, lambs, horses, and ponies, in kilograms [Other P kg = (Sheep and lambs × 0.004 × 365) + (Horses and ponies × 0.022 × 365)]
Total N kg	Nitrogen in manure from all animal categories, in kilograms [Total N kg = (Cattle N kg) + (Hogs N kg) + (Poultry N kg) + (Other N kg)]
Total P kg	Phosphorus in manure from all animal categories, in kilograms [Total P kg = (Cattle P kg) + (Hogs P kg) + (Poultry P kg) + (Other P kg)]

Nitrogen and phosphorus inputs from manure for the years 2007 and 2012 were estimated from county-level farm animal population inventories for categories of animals retrieved from the 2007 and 2012 Census of Agriculture (U.S. Department of Agriculture, 2009, 2014). The animal categories are cattle and calves; cows and heifers that had calved; beef cows; milk cows; other cattle; layers (chickens); pullets for laying flock replacement; broilers and other meat-type chickens; turkeys; total hogs and pigs; hogs and pigs used or to be used for breeding; other hogs and pigs; hogs and pigs sold; sheep and lambs; and horses and ponies. The livestock groups used by Ruddy and others (2006) do not all have direct equivalents in the categories used in the 2007 and 2012 Census of Agriculture, so a calculation was applied to some categories from the 2007 and 2012 Census of Agriculture to derive animal categories comparable to the livestock groups used in Ruddy and others (2006; table 2).

The definitions of the animal categories used in the 2007 and 2012 Census of Agriculture also differ from those used in the earlier, 1997 Census of Agriculture (U.S. Department of Agriculture, 2009, 2014) that were used by Ruddy and others (2006). Some categories reported individually in the 1997 Census of Agriculture had been merged with other categories for reporting the 2007 and 2012 Census of Agriculture (table 3). Differences in the categories that were reported each year introduced unquantifiable uncertainty; however assumptions shown in table 2 allowed a comparison of the 2007 and 2012 categories with the 1997 categories.

Table 2. Comparison of livestock groups used in Ruddy and others (2006) to animal categories used in this report from the 2007 and 2012 Census of Agriculture.

Livestock group (Ruddy and others, 2006)	2007 and 2012 Census of Agriculture category as used in this report
Milk cows	Milk cows
Beef cattle	Beef cows
Steers	0.25 × Other cattle
Heifers	0.25 × Other cattle
Slaughter cattle	0.5 × Other cattle
Hogs and pigs	Total hogs and pigs
Chickens and hens	Layers
Pullets and broilers	Pullets for layering flock replacement + Broilers and other meat-type chickens
Tom turkeys	0.5 × Turkeys
Hen turkeys	0.5 × Turkeys
Sheep and lambs	Sheep and lambs
Horses and ponies	Horses and ponies

In some cases, the primary 2007 or 2012 Census of Agriculture category population was not disclosed (not reported) because the information, if reported, could be used to identify an individual farm. In these cases, the population was calculated from other categories (table 4). In some cases, not all of the animal categories needed for the calculations were reported, and in these cases, the non-disclosed populations were assumed to be zero, and the calculated populations can be considered as a minimum possible value. Estimates of nitrogen and phosphorus content of manure for each livestock group were published in Ruddy and others (2006; table 3). Those estimates were also used to calculate the nitrogen and phosphorus content of manure for the 2007 and 2012 animal categories for this report (table 4). The total mass of nutrients (nitrogen and phosphorus) in manure from an animal category was calculated as the product of the population, the nutrient content of the manure, and the number of days in the life cycle (Ruddy and others, 2006). To calculate the total nitrogen and total phosphorus input for a county, the nitrogen or phosphorus contents in manure from all animal categories were summed for the county.

In some cases, the Census of Agriculture combined animal population data for counties or statistically equivalent entities with those of an adjacent or surrounding county in order to prevent disclosure of information about individual operations. These data were used for this report "as is," with no attempt to allocate the reported population to the original counties. The effect on the estimates of nitrogen and phosphorus inputs from animal manure data was that data fields were left "blank" for the following areas in Maryland, Missouri, and Virginia:

- For Maryland, the independent city of Baltimore, which is included in Baltimore County, and the state equivalent of District of Columbia, which is included in Prince George's County.
- For Missouri, the independent city of St. Louis, which is included in St. Louis County.
- For Virginia, most independent cities are included in a surrounding county or in an adjacent, independent city.

Summary

County-level estimates of nitrogen and phosphorus inputs from animal manure for the conterminous United States were calculated from animal population inventories in the 2007 and 2012 Census of Agriculture, using previously published methods. These estimates of non-point nutrient inputs from animal manure were compiled in support of the U.S. Geological Survey's National Water-Quality Assessment Project of the National Water-Quality Program and are needed to support national-scale investigations of stream and groundwater water quality.

Previously published estimates of nitrogen and phosphorus inputs from manure were calculated using the same methods as used for this report. The estimates published in this report are therefore comparable with the older estimates which can be used to show changes in nitrogen and phosphorus inputs from manure over time.

Table 3. Differences in the animal categories used in the 2007 and 2012 Census of Agriculture compared to those used in the 1997 Census of Agriculture.

Animal category	2007 and 2012 Census	1997 Census
Other cattle	Data include heifers that have not calved, steers, calves, and bulls.	Heifers and heifer calves were tabulated separately from steers, steer calves, bulls, and bull calves.
Pullets for laying flock replacement	Pullet inventory for laying flock replacement was tabulated as a single item.	Pullets were tabulated as two categories: less than 13 weeks old and 13 to 19 weeks old.
Turkeys	Total turkey inventory and sales were tabulated.	Turkey data were tabulated as two categories: slaughter and breeding.

Table 4. Nitrogen and phosphorus content in manure and life cycle for livestock groups used in Ruddy and others (2006) and for animal categories from the 2007 and 2012 Census of Agriculture used in this report.

[The total mass of nutrients (nitrogen and phosphorus) in manure from an animal category was calculated as the product of the population, the nutrient content of the manure, and the number of days in the life cycle: Nitrogen in manure (kilograms per year) of an animal category = population of an animal category × nitrogen (kilograms per animal per day) × life cycle (days). Phosphorus in manure (kilograms per year) of an animal category = population of an animal category × phosphorus (kilograms per animal per day) × life cycle (days). Nitrogen in manure (kilograms per year) = sum of nitrogen in manure of all animal categories. Phosphorus in manure (kilograms per year) = sum of phosphorus in manure of all animal categories.

Livestock group (Ruddy and others, 2006)	2007 and 2012 Census of Agriculture animal category as used in this report		Nitrogen in manure (kilograms per animal per day)	Phosphorus in manure (kilograms per animal per day)	Life cycle (days per year)
	Population disclosed	Population not disclosed			
Beef cattle	Beef cows	0.5 × (Cows and heifers that had calved) OR (Cows and heifers that had calved) – (Milk cows)	0.15	0.053	365
Milk cows	Milk cows	0.5 × (Cows and heifers that had calved) OR (Cows and heifers that had calved) - (Beef cows)	0.204	0.032	365
Heifers	0.25 × (Other cattle)	0.25 × [(Cattle and calves) – ((Milk cows) + (Beef cows))]	0.141	0.018	365
Steers	0.25 × (Other cattle)	0.25 × [(Cattle and calves) – ((Milk cows) + (Beef cows))]	0.15	0.048	365
Slaughter cattle	0.5 × (Other cattle)	0.5 × [(Cattle and calves) – ((Milk cows) + (Beef cows))]	0.104	0.034	170
Hogs and pigs	Total hogs and pigs	(Hogs and pigs used for breeding) + (Other hogs and pigs) OR 0.5 × (Hogs and pigs sold)	0.027	0.012	365
Chickens and hens	Layers	Not applicable	0.0015	0.0006	365
Pullets and broilers	(Pullets for laying flock replacement) + (Broilers and other meat-type chickens)	Not applicable	0.001	0.0003	365
Tom turkeys	0.5 × (Turkeys)	Not applicable	0.0054	0.002	133
Hen turkeys	0.5 × (Turkeys)	Not applicable	0.0034	0.0013	112
Sheep and lambs	Sheep and lambs	Not applicable	0.023	0.004	365
Horses and ponies	Horses and ponies	Not applicable	0.127	0.022	365

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