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National Water-Quality Assessment Program

County-Level Estimates of Nitrogen and Phosphorus from Commercial Fertilizer for the Conterminous United States, 1987–2006

Scientific Investigations Report 2012-5207

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

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By Jo Ann M. Gronberg and Norman E. Spahr

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Forward

The U.S. Geological Survey (USGS) is committed to providing the Nation with reliable scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). The NAWQA Program is designed to answer: What is the quality of our Nation's streams and groundwater? How are conditions changing over time? How do natural features and human activities affect the quality of streams and groundwater, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991 to 2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/studies/study_units.html).

National and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are selectively reassessed. These assessments extend the findings in the Study Units by determining water-quality status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and groundwater. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Included are studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

William H. Werkheiser
USGS Associate Director for Water

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	907.2	kilogram (kg)

Abbreviations used in this report

AAPFCO Association of American Plant Food Control Officials
LULC Land Use and Land Cover
NAWQA National Water-Quality Assessment
NLCD National Land Cover Data
SIR Scientific Investigations Report
TIGER Topologically Integrated Geographic Encoding and Referencing system
USGS U.S. Geological Survey

County-Level Estimates of Nitrogen and Phosphorus from Commercial Fertilizer for the Conterminous United States, 1987–2006

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Abstract

The U.S. Geological Survey's National Water-Quality Assessment program requires nutrient input for analysis of the national and regional assessment of water quality. Detailed information on nutrient inputs to the environment are needed to understand and address the many serious problems that arise from excess nutrients in the streams and groundwater of the Nation. This report updates estimated county-level farm and nonfarm nitrogen and phosphorus input from commercial fertilizer sales for the conterminous United States for 1987 through 2006. Estimates were calculated from the Association of American Plant Food Control Officials fertilizer sales data, Census of Agriculture fertilizer expenditures, and U.S. Census Bureau county population. A previous national approach for deriving farm and nonfarm fertilizer nutrient estimates was evaluated, and a revised method for selecting representative states to calculate national farm and nonfarm proportions was developed. A national approach was used to estimate farm and nonfarm fertilizer inputs because not all states distinguish between farm and nonfarm use, and the quality of fertilizer reporting varies from year to year. For states that distinguish between farm and nonfarm use, the spatial distribution of the ratios of nonfarm-to-total fertilizer estimates for nitrogen and phosphorus calculated using the national-based farm and nonfarm proportions were similar to the spatial distribution of the ratios generated using state-based farm and nonfarm proportions. In addition, the relative highs and lows in the temporal distribution of farm and nonfarm nitrogen and phosphorus input at the state level were maintained—the periods of high and low usage coincide between national- and state-based values. With a few exceptions, nonfarm nitrogen estimates were found to be reasonable when compared to the amounts that would result if the lawn application rates recommended by state and university agricultural agencies were used. Also, states with higher nonfarm-to-total fertilizer ratios for nitrogen and phosphorus tended to have higher urban land-use percentages.

Introduction

In 1991, the U.S. Geological Survey (USGS) began full implementation of the National Water-Quality Assessment (NAWQA) program to assess the status and trends of the Nation's surface and groundwaters (Leahy and Thompson, 1994). As part of this national and regional assessment of water quality, Ruddy and others (2006) derived county-level fertilizer nutrient input from commercial fertilizer sales data for 1987–2001. Historically, several methods have been used to estimate county-level nutrients in fertilizer (Alexander and Smith, 1990; Battaglin and Goolsby, 1995), but Ruddy and others (2006) were the first to make a distinction between farm and nonfarm portions at the county level. Because farm and nonfarm sales are not distinguished for all states, Ruddy and others (2006) developed a procedure to estimate nonfarm fertilizer sales for all states from the Association of American Plant Food Control Officials (AAPFCO) fertilizer sales data by summing farm and nonfarm sales for each fertilizer product for selected states and converting these to proportions. These proportions were then applied to the annual reported sales of each fertilizer product to estimate farm and nonfarm sales within each state. State totals were then allocated to each county within the state on the basis of Census of Agriculture fertilizer expenditures for farm fertilizer and U.S. Census Bureau county population for nonfarm fertilizer.

Analysis of estimates from Ruddy and others (2006) and the computer programs used to produce the estimates revealed that allocation of fertilizer to farm and nonfarm portions was not calculated as described in the SIR 2006-5012 report. Instead of using only states that reported nonfarm sales for at least 11 fertilizer products to eliminate states with limited or erroneous data on nonfarm sales, as described in Ruddy and others (2006), all states were used to calculate the national farm and nonfarm proportions of each fertilizer product. By using all states, the calculation inflated the farm tonnage estimates, and therefore, the nonfarm proportion was lower than would be expected from using the procedure described in the report. At the state level, for 1987 through 2001, average estimates of farm nitrogen input, based on using all states to calculate the national farm and nonfarm proportions, were higher by 2 to 4 percent, and estimates of nonfarm nitrogen were lower by 23 to 55 percent compared to estimates based on using only states that reported nonfarm sales for at least 11 fertilizer products; estimates of farm phosphorus were higher by 2 to 4 percent, and estimates of nonfarm phosphorus were lower by 29 to 50 percent.

The method described in Ruddy and others (2006)—using only states that reported nonfarm sales for at least 11 fertilizer products—would include some states with limited nonfarm sales data: Alabama for 1992, Colorado for 1998 and 2003, Kansas for 2002, 2003, and 2005, South Dakota for 2002, Vermont for 1989, and Wyoming for 1992. This method would also exclude some states with significant data (large nonfarm tonnage), including California for 1996 through 2006, Montana for 1990 through 1993, and Washington for 1997. In addition, the described method would not screen out states that contained errors or estimates.

To rectify these shortcomings, the method for selecting states to estimate the national farm and nonfarm proportions of each fertilizer product in Ruddy and others (2006) was reevaluated and a new approach developed. This necessitated an analysis of AAPFCO fertilizer sales data to develop a better understanding of the information available.

Purpose and Scope

This report provides background information and a description of the AAPFCO fertilizer sales data and presents the revised method for selecting representative states to calculate national farm and nonfarm proportions of fertilizer products. In addition, this report provides updated estimates of county-level nitrogen and phosphorus from fertilizer for both farm and nonfarm use for the conterminous United States for 1987 through 2006, a description of the methods used to derive these values, and an evaluation of the farm and nonfarm fertilizer estimates.

These estimates of nitrogen and phosphorus provide information on the largest nonpoint sources of nutrients in the Nation, information that is critical for characterizing the nutrient inputs to surface water basins and groundwater areas. These estimates consequently provide a means for explaining the occurrence of nutrients in surface water and groundwater for national and regional assessments of water quality, and for evaluating agricultural management practices.

Description of the Association of American Plant Food Control Officials Fertilizer Sales Data

Annual fertilizer sales data are compiled by AAPFCO (Association of American Plant Food Control Officials, 2010). Gaither and Terry (2004) provide a detailed description of the AAPFCO data reporting system. Ruddy and others (2006) provide a summary of the data set. Reported annual sales data compiled by AAPFCO include state, county, quantity (in tons) sold, a fertilizer code (for the type of fertilizer), an optional code distinguishing the intended use as farm or nonfarm, and the individual percentage content of nitrogen-phosphate-potash for the fertilizer, hereinafter referred to as N-P-K percent content. Each “fertilizer product” is defined by the unique combination of the 9-digit field containing the N-P-K percent content and the 3-digit AAPFCO field containing the fertilizer code. The total number of fertilizer products reported, and the number reported for nonfarm use, also varies from state to state and from year to year (appendix 1). There are over 90,000 fertilizer products reported in the AAPFCO data set.

The temporal distribution of the state fertilizer product tonnage totals, as reported in raw AAPFCO data, for farm, nonfarm, uncoded (use code is not populated with a valid value), and nonfarm-to-total ratio are shown in appendix 2. These graphs show that reporting practices vary from state to state. Some states regularly distinguish between farm and nonfarm tonnage (appendix 2, California, Florida, Illinois, and Indiana, to name a few), while other states do not (appendix 2, Arkansas, Georgia, Montana, and Iowa). Farm tonnage is usually a much larger portion of the total tonnage than nonfarm tonnage, except in some northeastern states.

Reporting of nonfarm sales is inconsistent for some states. The following are examples of deviations from the norm for particular state data:

- From 1987 to 2000, Arkansas did not distinguish between farm and nonfarm sales. Beginning in 2001, they distinguished between farm and nonfarm sales, and nearly all the tonnage was allocated to farm use. In 2002, nearly all the tonnage was allocated to nonfarm use, however (appendix 2, page 3). From 2003 to 2006, all tonnage was allocated to farm use.

- In the first half of the data record (1987–96), Nevada reported less than 50 percent of the tonnage as nonfarm (appendix 2, page 26). From 1997 through 2006, except for 2000 when more than 80 percent of the tonnage was reported as nonfarm, all tonnage was reported as nonfarm. Census of Agriculture data for 1997 and 2002 indicate over 11 million dollars in fertilizer expenditures for Nevada (U.S. Department of Agriculture, National Agriculture Statistics Service, 1999 and 2004), making it highly unlikely that 100 percent of the fertilizer was nonfarm.

- New Hampshire usually reports less than 40 percent of fertilizer tonnage as nonfarm (appendix 2, page 27). In 2003, 100 percent of the fertilizer product tonnage was reported as nonfarm.
- Ohio usually does not report nonfarm tonnage (appendix 2, page 33). In 2004 and 2005 minor amounts of tonnage were reported as nonfarm.
- Rhode Island usually reports less than 40 percent of fertilizer tonnage as nonfarm (appendix 2, page 37). In 1989 and 1990 more than 70 percent was reported as nonfarm tonnage, and in 2003 all fertilizer product tonnage was reported as nonfarm.

State data are sometimes estimated from previous years or from surrounding states. These are usually characterized by constant nonfarm-to-total tonnage ratios (appendix 2). States with estimated values were identified from the Data Sources documentation from AAPFCO (David Terry, AAPFCO, written commun., 2008) and are summarized in appendix 3.

Although AAPFCO data contain county-level information for some states (appendix 4), many state regulators/reporters do not consider county sales data a reflection of point of contact with soils. Distribution centers and farms are getting larger, and reported sales in a county can represent distribution and use in many counties (David Terry, University of Kentucky and Joe Slater, University of Missouri, oral commun. July 24, 2008). Also, farmers can use fertilizer in a different county from where it was sold.

Estimation of State-Level Farm and Nonfarm Portions of Fertilizer Sales

The initial step to obtaining the county-level nutrient input was to estimate the state-level farm and nonfarm portions of the fertilizer sales data. States with data that met screening criteria were used to determine the national farm and nonfarm proportions of each fertilizer product for each year. These proportions were applied to fertilizer sales data for all states. The departure from Ruddy and others (2006) was in the procedure to select states used to determine the national farm and nonfarm proportions.

This revised method took a more comprehensive approach to selecting state sales data from the AAPFCO data base to calculate the national farm and nonfarm proportions. The annual sales data for each state were subject to a screening procedure consisting of four steps: (1) identify and eliminate records with nonfarm tonnage not reported, (2) identify and eliminate records with estimated values, (3) identify and eliminate records with large inconsistencies that indicate errors in the use codes, and (4) for each state, identify and eliminate records from years that have a lower reported nonfarm tonnage in comparison to the nonfarm tonnage from other years (fig. 1).

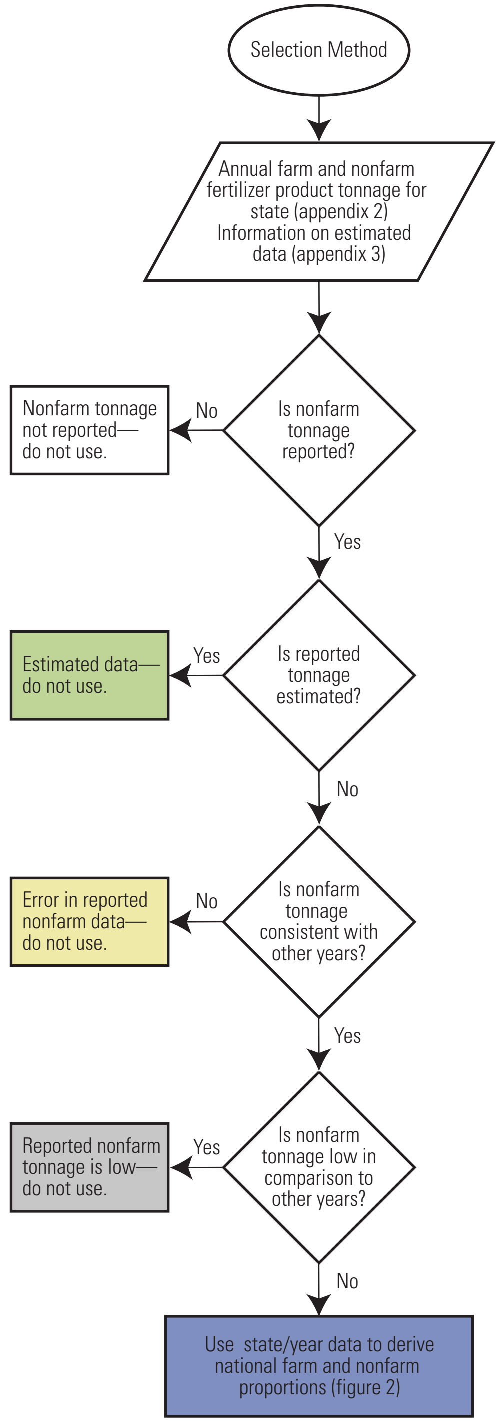


Figure 1. Method for selecting annual data for each state.

The graphs showing farm, nonfarm, and uncoded fertilizer product tonnage and ratios of nonfarm-to-total tonnage (appendix 2), and the table of the number of fertilizer products by state and by year (appendix 1), were reviewed to identify general patterns of use for each state. Deviations in those patterns were indications of potential errors.

Once the records with missing, estimated, and erroneous nonfarm tonnage were identified and eliminated from the data set, the statistical distribution of nonfarm tonnage was calculated and graphed to find a reasonable lower limit of the remaining nonfarm tonnage for each state. For each state, a yearly value below one tenth of the average yearly value was assumed to reflect incomplete coding of the sales data. For a given state, any year with nonfarm tonnage below the limit was not used in the farm-nonfarm processing. A summary of this evaluation of the data available for each state and for each year is shown in figure 2.

National totals of farm and nonfarm sales from the selected states (fig. 2) were computed for each fertilizer product for each year. Following the methodology of Ruddy and others (2006) any fertilizer product not specifically coded as nonfarm was set to "farm." In addition, six fertilizer products identified as only for farm use (Joe Slater, AAPFCO, written commun., 2008) were recoded to "farm" if found to be coded otherwise. There were no fertilizer products identified as having only nonfarm use. These totals were converted to national farm and nonfarm proportions (or rates), which were applied to the annual sales of each fertilizer product in each state to estimate farm and nonfarm tonnage. By using the fertilizer N-P-K percent content information, the farm and nonfarm tonnage for each the fertilizer product was then converted to farm and nonfarm nitrogen and phosphate estimates for each state and year. This procedure, from Ruddy and others (2006), is summarized below and illustrated in figure 3:

A. Calculate national farm and nonfarm rates for each fertilizer product from *selected states* (to be applied to *all states*) for each year.

   1. Using data from the selected states, sum farm and nonfarm tonnage for each fertilizer product.

   2. Calculate national farm and nonfarm rates from tonnage for each fertilizer product:

      a. farm rate = farm tonnage / (farm tonnage + nonfarm tonnage)

      b. nonfarm rate = (1 – farm rate)

B. Calculate farm and nonfarm nitrogen and phosphate tonnage for each state for each year.

   1. Derive nitrogen and phosphate percentage from N-P-K values.

   2. Obtain the farm and nonfarm rates from step A, by matching AAPFCO data by fertilizer product (If fertilizer product is unique to states not used in step A, then farm rate = 1).

   3. For each state, for each fertilizer product, calculate:

      a. Farm nitrogen tonnage = Fertilizer product tonnage * (nitrogen percentage * 0.01) * farm rate

      b. Farm phosphate tonnage = Fertilizer product tonnage * (phosphate percentage * 0.01) * farm rate

      c. Nonfarm nitrogen tonnage = Fertilizer product tonnage * (nitrogen percentage * 0.01) * nonfarm rate

      d. Nonfarm phosphate tonnage = Fertilizer product tonnage * (phosphate percentage * 0.01) * nonfarm rate

   4. For each state, sum tonnage calculated from each fertilizer product for farm nitrogen, farm phosphate, nonfarm nitrogen and nonfarm phosphate.

Further refinements were accomplished by examining the results from the initial processing for inconsistencies that could be caused by possible data coding errors in the AAPFCO data. These were identified by looking for abnormal nonfarm tonnage with respect to adjacent years, abnormal nonfarm nitrogen with respect to a recommended lawn application of 1 pound per 1,000 square feet (Florida Department of Agriculture and Consumer Services, 2007; Mugass, 1995; Rosen and Horgan, 2005; and University of California, 2004), and unusually high nonfarm proportion with respect to adjacent years. To aid in identifying the errors and the causes, farm and nonfarm tonnage contributing to the calculation of the nonfarm proportions were examined. Several issues were identified from the additional screening:

- Estimates of nonfarm nitrogen in several states were unusually high in 2006 compared to other years. This large discrepancy in nonfarm nitrogen was likely caused by a high nonfarm use of urea (fertilizer product 460000000.066) in South Dakota. An evaluation of the pattern of urea farm and nonfarm use from other states for 2003 through 2006 (North Dakota, South Dakota, Montana account for almost half of the urea use, 1987–2006) revealed that this high nonfarm use is anomalous and inconsistent with the extremely small amount of residential and urban land use in South Dakota. To address this issue, the USE field for one entry of 109,000 tons of urea in South Dakota for 2006 was recoded from nonfarm to farm.

- Nonfarm nitrogen and phosphate estimates in Georgia were unusually high in 2004 compared to other years. This large discrepancy was likely caused by allocating 88,000 tons of a single fertilizer product (080120180.000) to nonfarm use. Georgia did not report nonfarm sales in 2004 and, therefore, does not contribute to the national calculation of the farm and nonfarm proportions for this year. In fact, with the exception of Georgia, only a few states reported use of this fertilizer product and the amounts were small. The national nonfarm proportion for 2004 for this fertilizer product was solely based on 1 ton of nonfarm use reported in Vermont. This proportion caused 88,000 tons to be allocated as nonfarm use in Georgia. Because all other tonnage from 2003 through 2006 has been reported as farm use, it is believed that this fertilizer product should be allocated to farm usage. To address this, the USE field for one entry of 1 ton of this fertilizer product in Vermont was recoded as “farm” so that when the 2004 national farm and nonfarm proportions were applied, the Georgia tonnage was assigned to farm use.

- Estimates of nonfarm phosphate in Missouri were unusually high in 2005 compared to other years. This large discrepancy was likely caused by a change in reporting fertilizer sales by Missouri. From 1987 through 2004, Missouri differentiated between farm and nonfarm usage (appendix 2, page 23). During these years, Missouri always reported mono ammonium phosphate (fertilizer product 110550000.209) as farm tonnage. In 2005, when Missouri stopped differentiating between farm and nonfarm tonnage, it was no longer a significant contributor toward the national nonfarm proportion. To address this, the 2005 nonfarm proportion for this fertilizer product was set equal to the 2004 value.

- Nonfarm phosphate estimates in Oregon were unusually high in 2004 and 2005 compared to other years. This large discrepancy was likely caused by a change in reporting fertilizer sales by Oregon. In 2004 and 2005, Oregon reported nonfarm tonnage that was over six times the amount previously reported (appendix 2, page 35). In addition, all nonfarm tonnage was reported by using one fertilizer product. To address this, Oregon data were not used in calculating the national nonfarm proportions for 2004 and 2005.

- Nonfarm nitrogen and phosphate estimates in Texas were unusually high in 2004 through 2006 compared to other years. Also, in 2005 and 2006, nonfarm nitrogen was unusually high with respect to a recommended lawn application of 1 pound per 1,000 square feet. This large discrepancy was likely caused by a change in the method of fertilizer sales reporting by Texas. From 1987 through 2003, Texas did not populate the USE field; therefore, farm and nonfarm use could not be distinguished. In 2004 through 2006, Texas reported all nonfarm tonnage as use of one fertilizer product. To address this, Texas data were not used in calculating the national nonfarm proportions in 2004 through 2006.

- Nonfarm nitrogen and phosphate estimates in Arizona were unusually high in 2004 compared to other years. Also, in 2004, nonfarm nitrogen was unusually high with respect to a recommended lawn application of 1 pound per 1,000 square feet. This large discrepancy was likely caused by large tonnage of two fertilizer products (150050030.000 and 210020040.000) being allocated to nonfarm use because of a national nonfarm proportion based on small amounts of these fertilizer products reported in only a few states. To address this, the USE field was set to “farm” for both of these fertilizer products.

The farm and nonfarm nitrogen and phosphate estimates for each state and year were recalculated after implementation of the above data refinements and are shown in appendix 5. The revised data were compared to the 1987–2001 values from Ruddy and others (2006): average state-level farm nitrogen estimates were 3 to 6 percent lower, and nonfarm nitrogen estimates were 6 to 82 percent higher; average state-level farm phosphorus estimates were 2 to 3 percent lower, and nonfarm phosphorus estimates were 32 to 114 percent higher.

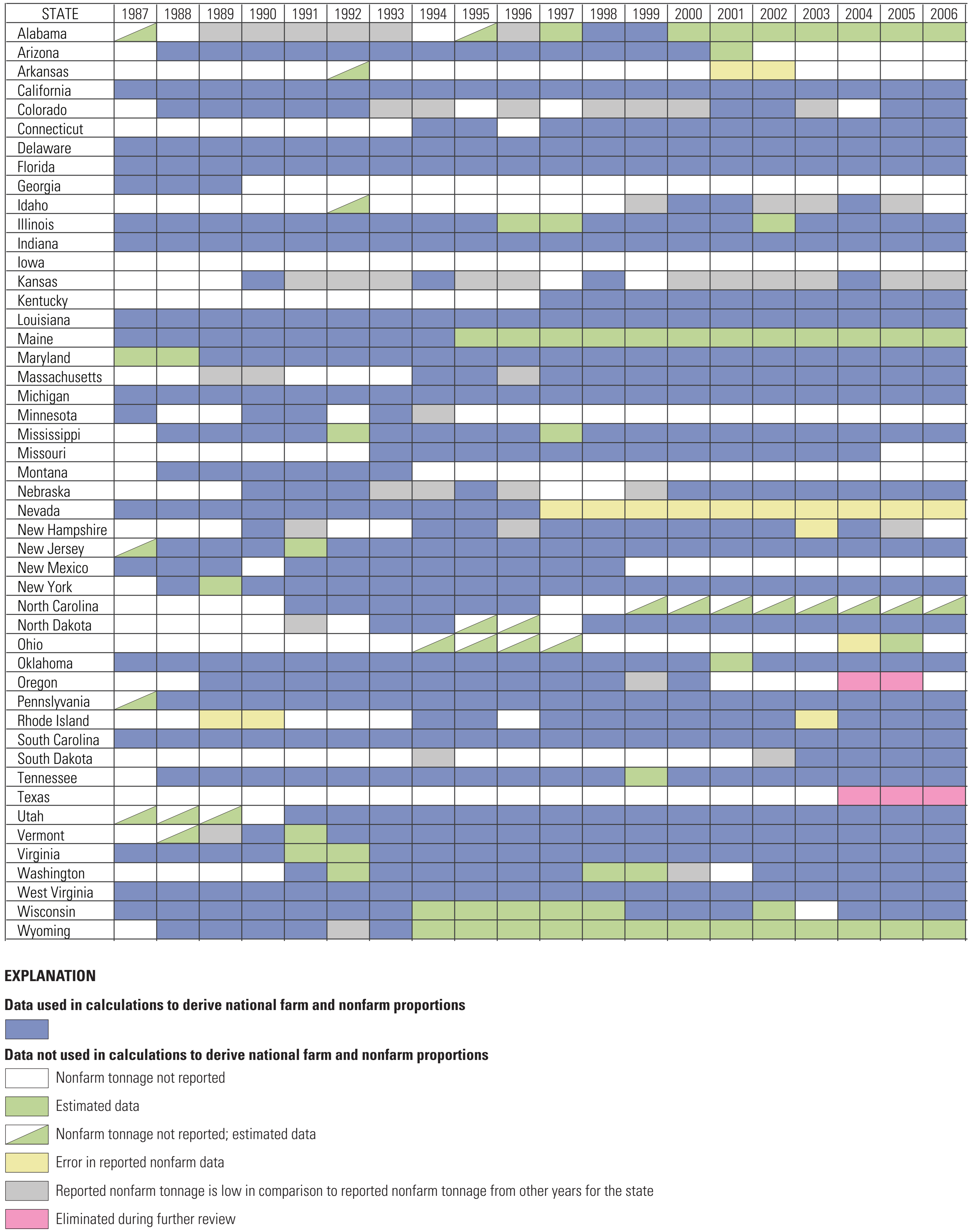


Figure 2. Summary of results of the selection process for including states used to derive the national farm and nonfarm proportions for each year (1987–2006).

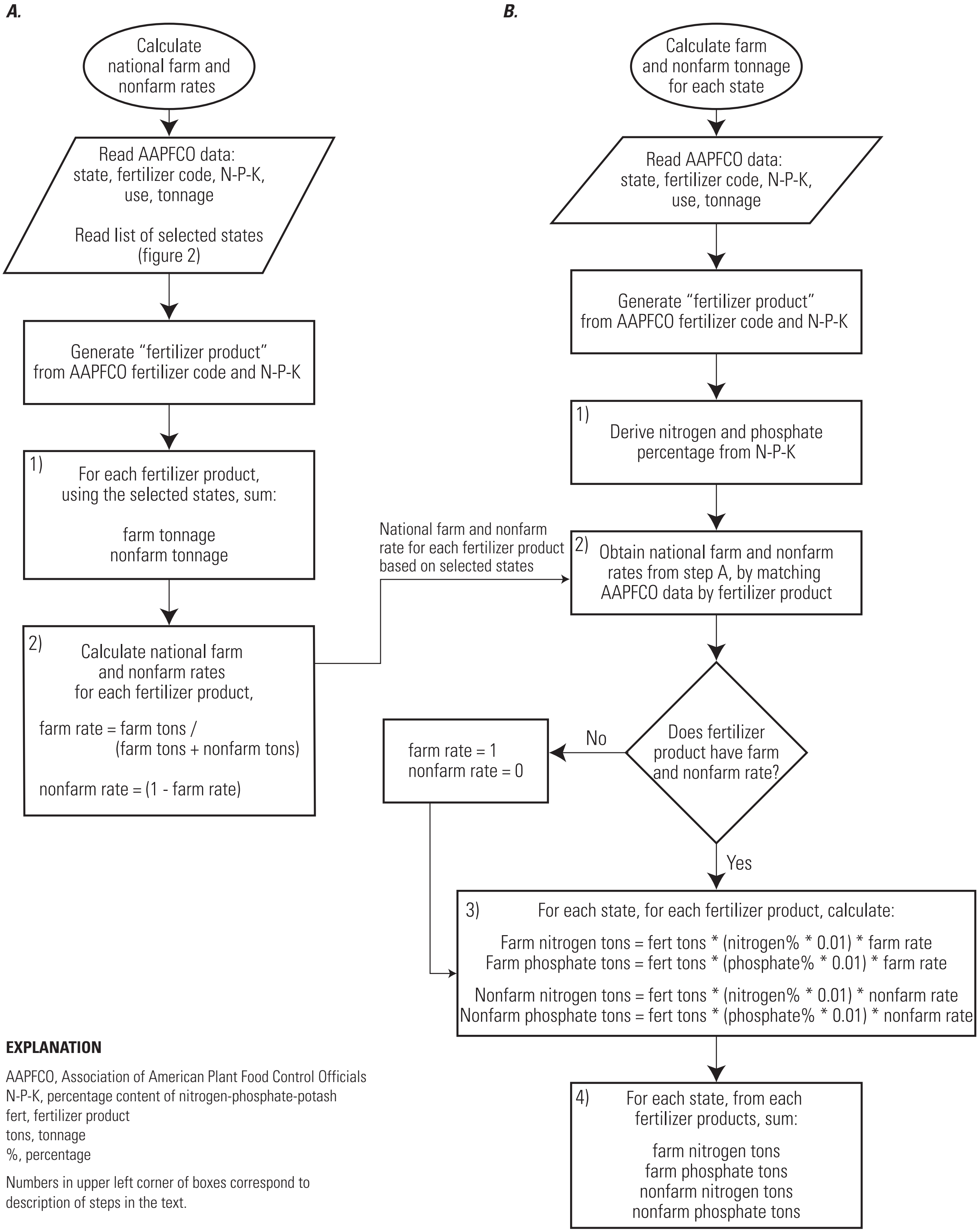


Figure 3. Process to (*A*) calculate the national farm and nonfarm rates for each fertilizer product, and (*B*) calculate farm and nonfarm nitrogen and phosphate tonnage, for each state, for each year.

Distribution to the County Level

State-level farm and nonfarm estimates of nitrogen and phosphate were distributed to the county level by using the methods established in Ruddy and others (2006). The method based on fertilizer expenditures was adopted by Ruddy and others (2006) and this report to distribute farm fertilizer for all states because it is thought to produce a more realistic point-of-use spatial distribution of the fertilizer than the raw data based on county point-of-sale. State-level farm nitrogen and phosphate were distributed to the county in proportion to fertilizer expenditure (Ruddy and others, 2006) as shown in figure 4:

$$FFCU_{ik} = FFSS_i \, (FCE_{ik}/FSE_i) \qquad (1)$$

where

- $FFCU_{ik}$ is the estimated nutrient input from farm-fertilizer use in county k of State i, in tons of nitrogen or phosphate;
- $FFSS_i$ is total farm-fertilizer sales for State i, in tons of nitrogen or phosphate;
- FCE_{ik} is fertilizer expenditure for county k of State i, in dollars; and
- FSE_i is total fertilizer expenditure for State i, in dollars.

County-level fertilizer expenditure data were obtained from the 1987, 1992, 1997, and 2002 Censuses of Agriculture (U.S. Department of Commerce, Bureau of the Census, 1989 and 1995; U.S. Department of Agriculture, National Agriculture Statistics Service, 1999 and 2004). For intervening years, state and county fertilizer expenditures were estimated by linear interpolation. In cases where fertilizer expenditures were not disclosed for a county in a particular Census of Agriculture year, an interpolation was done between the nearest census years that had disclosed values. If nondisclosed values occurred at either end of the time span, the nearest disclosed value was used for all previous or subsequent years (Ruddy and others, 2006). The 2002 fertilizer expenditure values were used for 2002 through 2006. At the time of processing, 2007 fertilizer expenditure data were not available.

Ruddy and others (2006) developed a relation between effective population and nonfarm fertilizer sales, which was used to distribute state sales of nonfarm fertilizer to the county level:

$$EPC_{ik} = A_{ik} \times \text{minimum}\,(P_{ik}, 700)^{1.3} \qquad (2)$$

where

- EPC_{ik} is the effective population of county k in State i;
- A_{ik} is the area of county k in State i, in square kilometers; and
- P_{ik} is the population density of county k in State i, in persons per square kilometer.

State-level nonfarm fertilizer was allocated to the county level in proportion to effective population (Ruddy and others, 2006) as shown in figure 5:

$$NFCU_{ik} = NFSS_i \, (EPC_{ik}/EPS_i) \qquad (3)$$

where

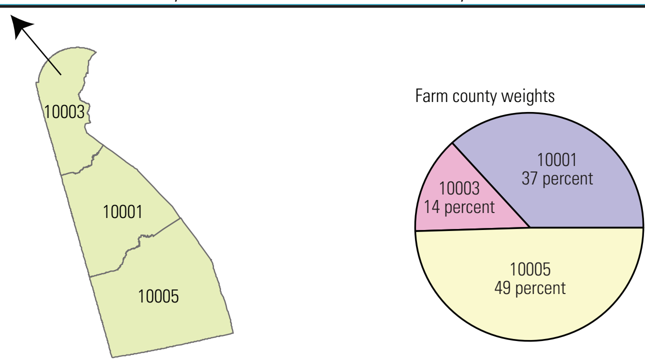
- $NFCU_{ik}$ is the estimated nutrient inputs from nonfarm-fertilizer use in county k of State i, in tons of nitrogen or phosphate;
- $NFSS_i$ is total nonfarm-fertilizer sales for State i, in tons of nitrogen or phosphate; and
- EPS_i is the sum of EPC_{ik} for State i.

Population data for 1990 and 2000 and estimates for 1987–89, 1991–99, and 2001–2006 were compiled from the U.S. Census Bureau (2003a, 2004a, 2004b, 2008) and Hitt (1992). County areas for 1987–2001 were derived from a 30-meter-resolution grid of 1990 counties (http://water.usgs.gov/lookup/getspatial?sir2012-5207_co1990g). This grid was created from 1990 county data set (U.S. Department of Commerce, Bureau of the Census, 1993) with the shoreline defined by the medium-resolution digital vector U.S. shoreline (National Oceanic and Atmospheric Administration, 1994) and the enhanced National Land Cover Data 1992 (NLCDe 92; Nakagaki and others, 2007) because the counties, as defined by the U.S. Department of Commerce, Bureau of the Census (1993) extended into the oceans and Great Lakes. County areas for 2002–2006 were derived from a 30-meter-resolution grid of 2001 counties (http://water.usgs.gov/lookup/getspatial?sir2012-5207_co2001g) created by updating the 1990 county data set with 2000 and 2004 TIGER/line files (U.S. Census Bureau, Geography Division, 2003b, and 2005) and defining the shoreline with the U.S. shoreline and the NLCDe 92 revised with 2000 population data to indicate urban development between 1992 and 2000 (NLCDep0905; Hitt, 2008).

County-level nutrient values of nitrogen and phosphate, calculated in tons, were multiplied by 907.2 to convert tons to kilograms. Phosphate values were subsequently multiplied by 0.4365 to convert kilograms of phosphate to kilograms of phosphorus.

Step 1: Calculate farm county weights

State ID (i)	County ID (k)	County fertilizer expenditure (FCE_{ik})	÷	State fertilizer expenditure (FSE_i)	=	Farm county weight (FCE_{ik}/FSE_i)
10	001	8,799		23,780		0.37
10	003	3,329		23,780		0.14
10	005	11,652		23,780		0.49



Step 2: Calculate county farm nitrogen tonnage

State ID (i)	County ID (k)	Farm county weight (FCE_{ik}/FSE_i)	x	State farm nitrogen tonnage ($FFSS_i$)	=	County farm nitrogen tonnage ($FFCU_{ik}$)
10	001	0.37		1,651.51		611.06
10	003	0.14		1,651.51		231.21
10	005	0.49		1,651.51		809.24

Figure 4. Distribution of state-level farm nitrogen to the county level by using county weights based on fertilizer expenditure.

Step 1: Calculate population density

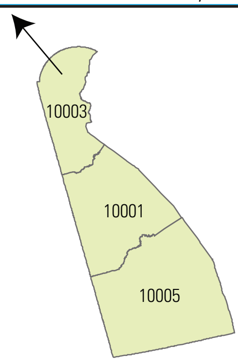
State ID (i)	County ID (k)	Population	÷	Area (A_{ik})	=	Population density (P_{ik})
10	001	134,424		1,545.65		87
10	003	513,471		1,113.85		461
10	005	167,903		2,448.51		69

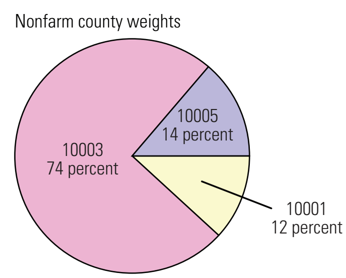
Step 2: Calculate effective population of county

State ID (i)	County ID (k)	Area (A_{ik})	x	minimum [population density (P_{ik}), 700]$^{1.3}$	=	Effective population of county (EPC_{ik})
10	001	1,545.65		332		513,200
10	003	1,113.85		2,903		3,233,126
10	005	2,448.51		244		596,905

Step 3: Calculate nonfarm county weights

State ID (i)	County ID (k)	Effective population of county (EPC_{ik})	÷	Sum of EPC_{ik} (EPS_i)	=	Nonfarm county weight (EPC_{ik}/EPS_i)
10	001	513,200		4,343,231		0.12
10	003	3,233,126		4,343,231		0.74
10	005	596,905		4,343,231		0.14





Step 4: Calculate county nonfarm nitrogen tonnage

State ID (i)	County ID (k)	Nonfarm county weight (EPC_{ik}/EPS_i)	x	State nonfarm nitrogen tonnage ($NFSS_i$)	=	County nonfarm nitrogen tonnage ($NFCU_{ik}$)
10	001	0.12		133.56		16.03
10	003	0.74		133.56		98.83
10	005	0.14		133.56		18.70

Figure 5. Distribution of state-level nonfarm nitrogen to the county level by using county weights based on population.

Description of the County-Level Fertilizer Nutrient-Input Dataset

The fertilizer nutrient-input data described in this report are in two files in a Microsoft Access database: *tblFarmNonfarmCountyNitrogen*, and *tblFarmNonfarmCountyPhosphorus*. The database is available on line at http://water.usgs.gov/lookup/getspatial?sir2012-5207_county_fertilizer. The data files contain estimates of nitrogen and phosphorus from farm and nonfarm fertilizer use, in kilograms, for each county in the conterminous United States for the period of 1987 to 2006. Counties are identified by state, county, and state and county Federal Information Processing System (FIPS) code, sorted alphabetically by state and numerically by FIPS code within each state. Attribute definitions for the two files are listed in table 1.

Table 1. Attribute labels and definitions for the *tblFarmNonfarmCountyNitrogen* and *tblFarmNonfarmCountyPhosphorus* data files.

[NA, not applicable]

tblFarmNonfarmCountyNitrogen			tblFarmNonfarmCountyPhosphorus		
Attribute label	Attribute definition	Units	Attribute label	Attribute definition	Units
FIPS_ST	The Federal Information Processing Standards (FIPS) 2-digit code of the State or State equivalent	NA	FIPS_ST	The Federal Information Processing Standards (FIPS) 2-digit code of the State or State equivalent	NA
FIPS_CO	The Federal Information Processing Standards (FIPS) 3-digit code of the county or county equivalent in the designated state	NA	FIPS_CO	The Federal Information Processing Standards (FIPS) 3-digit code of the county or county equivalent in the designated state	NA
STATE	The Federal Information Processing Standards (FIPS) 2-character abbreviation of the name of the State or State equivalent	NA	STATE	The Federal Information Processing Standards (FIPS) 2-character abbreviation of the name of the State or State equivalent	NA
CO	County name	NA	CO	County name	NA
farmN1987	Nitrogen from farm fertilizer, 1987	kilograms	farmP1987	Phosphorus from farm fertilizer, 1987	kilograms
nonfN1987	Nitrogen from nonfarm fertilizer, 1987	kilograms	nonfP1987	Phosphorus from nonfarm fertilizer, 1987	kilograms
farmN1988	Nitrogen from farm fertilizer, 1988	kilograms	farmP1988	Phosphorus from farm fertilizer, 1988	kilograms
nonfN1988	Nitrogen from nonfarm fertilizer, 1988	kilograms	nonfP1988	Phosphorus from nonfarm fertilizer, 1988	kilograms
farmN1989	Nitrogen from farm fertilizer, 1989	kilograms	farmP1989	Phosphorus from farm fertilizer, 1989	kilograms
nonfN1989	Nitrogen from nonfarm fertilizer, 1989	kilograms	nonfP1989	Phosphorus from nonfarm fertilizer, 1989	kilograms
farmN1990	Nitrogen from farm fertilizer, 1990	kilograms	farmP1990	Phosphorus from farm fertilizer, 1990	kilograms
nonfN1990	Nitrogen from nonfarm fertilizer, 1990	kilograms	nonfP1990	Phosphorus from nonfarm fertilizer, 1990	kilograms
farmN1991	Nitrogen from farm fertilizer, 1991	kilograms	farmP1991	Phosphorus from farm fertilizer, 1991	kilograms
nonfN1991	Nitrogen from nonfarm fertilizer, 1991	kilograms	nonfP1991	Phosphorus from nonfarm fertilizer, 1991	kilograms
farmN1992	Nitrogen from farm fertilizer, 1992	kilograms	farmP1992	Phosphorus from farm fertilizer, 1992	kilograms
nonfN1992	Nitrogen from nonfarm fertilizer, 1992	kilograms	nonfP1992	Phosphorus from nonfarm fertilizer, 1992	kilograms
farmN1993	Nitrogen from farm fertilizer, 1993	kilograms	farmP1993	Phosphorus from farm fertilizer, 1993	kilograms
nonfN1993	Nitrogen from nonfarm fertilizer, 1993	kilograms	nonfP1993	Phosphorus from nonfarm fertilizer, 1993	kilograms
farmN1994	Nitrogen from farm fertilizer, 1994	kilograms	farmP1994	Phosphorus from farm fertilizer, 1994	kilograms
nonfN1994	Nitrogen from nonfarm fertilizer, 1994	kilograms	nonfP1994	Phosphorus from nonfarm fertilizer, 1994	kilograms
farmN1995	Nitrogen from farm fertilizer, 1995	kilograms	farmP1995	Phosphorus from farm fertilizer, 1995	kilograms
nonfN1995	Nitrogen from nonfarm fertilizer, 1995	kilograms	nonfP1995	Phosphorus from nonfarm fertilizer, 1995	kilograms
farmN1996	Nitrogen from farm fertilizer, 1996	kilograms	farmP1996	Phosphorus from farm fertilizer, 1996	kilograms
nonfN1996	Nitrogen from nonfarm fertilizer, 1996	kilograms	nonfP1996	Phosphorus from nonfarm fertilizer, 1996	kilograms
farmN1997	Nitrogen from farm fertilizer, 1997	kilograms	farmP1997	Phosphorus from farm fertilizer, 1997	kilograms
nonfN1997	Nitrogen from nonfarm fertilizer, 1997	kilograms	nonfP1997	Phosphorus from nonfarm fertilizer, 1997	kilograms
farmN1998	Nitrogen from farm fertilizer, 1998	kilograms	farmP1998	Phosphorus from farm fertilizer, 1998	kilograms
nonfN1998	Nitrogen from nonfarm fertilizer, 1998	kilograms	nonfP1998	Phosphorus from nonfarm fertilizer, 1998	kilograms

Table 1. Attribute labels and definitions for the *tblFarmNonfarmCountyNitrogen* and *tblFarmNonfarmCountyPhosphorus* data files.—Continued

[NA, not applicable]

tblFarmNonfarmCountyNitrogen			tblFarmNonfarmCountyPhosphorus		
Attribute label	Attribute definition	Units	Attribute label	Attribute definition	Units
farmN1999	Nitrogen from farm fertilizer, 1999	kilograms	farmP1999	Phosphorus from farm fertilizer, 1999	kilograms
nonfN1999	Nitrogen from nonfarm fertilizer, 1999	kilograms	nonfP1999	Phosphorus from nonfarm fertilizer, 1999	kilograms
farmN2000	Nitrogen from farm fertilizer, 2000	kilograms	farmP2000	Phosphorus from farm fertilizer, 2000	kilograms
nonfN2000	Nitrogen from nonfarm fertilizer, 2000	kilograms	nonfP2000	Phosphorus from nonfarm fertilizer, 2000	kilograms
farmN2001	Nitrogen from farm fertilizer, 2001	kilograms	farmP2001	Phosphorus from farm fertilizer, 2001	kilograms
nonfN2001	Nitrogen from nonfarm fertilizer, 2001	kilograms	nonfP2001	Phosphorus from nonfarm fertilizer, 2001	kilograms
farmN2002	Nitrogen from farm fertilizer, 2002	kilograms	farmP2002	Phosphorus from farm fertilizer, 2002	kilograms
nonfN2002	Nitrogen from nonfarm fertilizer, 2002	kilograms	nonfP2002	Phosphorus from nonfarm fertilizer, 2002	kilograms
farmN2003	Nitrogen from farm fertilizer, 2003	kilograms	farmP2003	Phosphorus from farm fertilizer, 2003	kilograms
nonfN2003	Nitrogen from nonfarm fertilizer, 2003	kilograms	nonfP2003	Phosphorus from nonfarm fertilizer, 2003	kilograms
farmN2004	Nitrogen from farm fertilizer, 2004	kilograms	farmP2004	Phosphorus from farm fertilizer, 2004	kilograms
nonfN2004	Nitrogen from nonfarm fertilizer, 2004	kilograms	nonfP2004	Phosphorus from nonfarm fertilizer, 2004	kilograms
farmN2005	Nitrogen from farm fertilizer, 2005	kilograms	farmP2005	Phosphorus from farm fertilizer, 2005	kilograms
nonfN2005	Nitrogen from nonfarm fertilizer, 2005	kilograms	nonfP2005	Phosphorus from nonfarm fertilizer, 2005	kilograms
farmN2006	Nitrogen from farm fertilizer, 2006	kilograms	farmP2006	Phosphorus from farm fertilizer, 2006	kilograms
nonfN2006	Nitrogen from nonfarm fertilizer, 2006	kilograms	nonfP2006	Phosphorus from nonfarm fertilizer, 2006	kilograms

Evaluation of the Farm and Nonfarm Fertilizer Data

Annual totals of state-level farm and nonfarm nitrogen and phosphorus fertilizer were evaluated by comparing results using the national farm and nonfarm proportions to results for states where reporting includes farm and nonfarm usage for ten or more years. Nonfarm usage was also compared to independent estimates of nonfarm fertilizer applications and land use.

Temporal Variability at the State Level

A comparison of farm and nonfarm nitrogen and phosphorus estimates based on *national* farm and nonfarm proportions versus specific *state* reported farm and nonfarm product use is shown in appendix 6. These figures show the year-to-year variability of the farm and nonfarm nitrogen and phosphorus estimates based on national and state proportions. The most useful way to examine the graphs is not to look at the differences between the national-based and state-based values, but to look at the relative change from year to year. In general, the periods of high and low usage coincide between the national- and state-based values. The national processing tends to smooth the values from year to year, limiting the spikes and dips seen in the state processing, and filling gaps in the state reporting. The inconsistent reporting of nonfarm usage in many states is apparent, however.

Spatial Distribution of Nonfarm-to-Total Fertilizer Ratios

Nonfarm-to-total fertilizer ratios for nitrogen and phosphorus were calculated by using state-based farm and nonfarm proportions for 1987 through 2006 for states with sufficient data (at least 10 years of data for the calculation of the national-based farm and nonfarm proportions, shown in figure 2). Median values for each state were then determined from the nonfarm-to-total fertilizer ratios. The same was done for the same states by using the national-based farm and nonfarm proportions. Comparisons of the results from these two approaches helped to determine if applying national farm and nonfarm proportions for each fertilizer product to each state maintained the spatial distribution of the nonfarm fertilizer ratios. The medians of the state- and national-based nonfarm-to-total ratios for nitrogen and phosphorus are shown in figure 6. The broad regional distribution of the nonfarm ratios appeared to be maintained for both nitrogen and phosphorus. Higher nonfarm ratios were present in the Northeast region and South Atlantic division of the South region. Lower nonfarm ratios were present in the West North Central division of the Midwest region and the Pacific division of the Northwest region. Regions and divisions are from the U.S. Census Bureau, Geographic Division (2011).

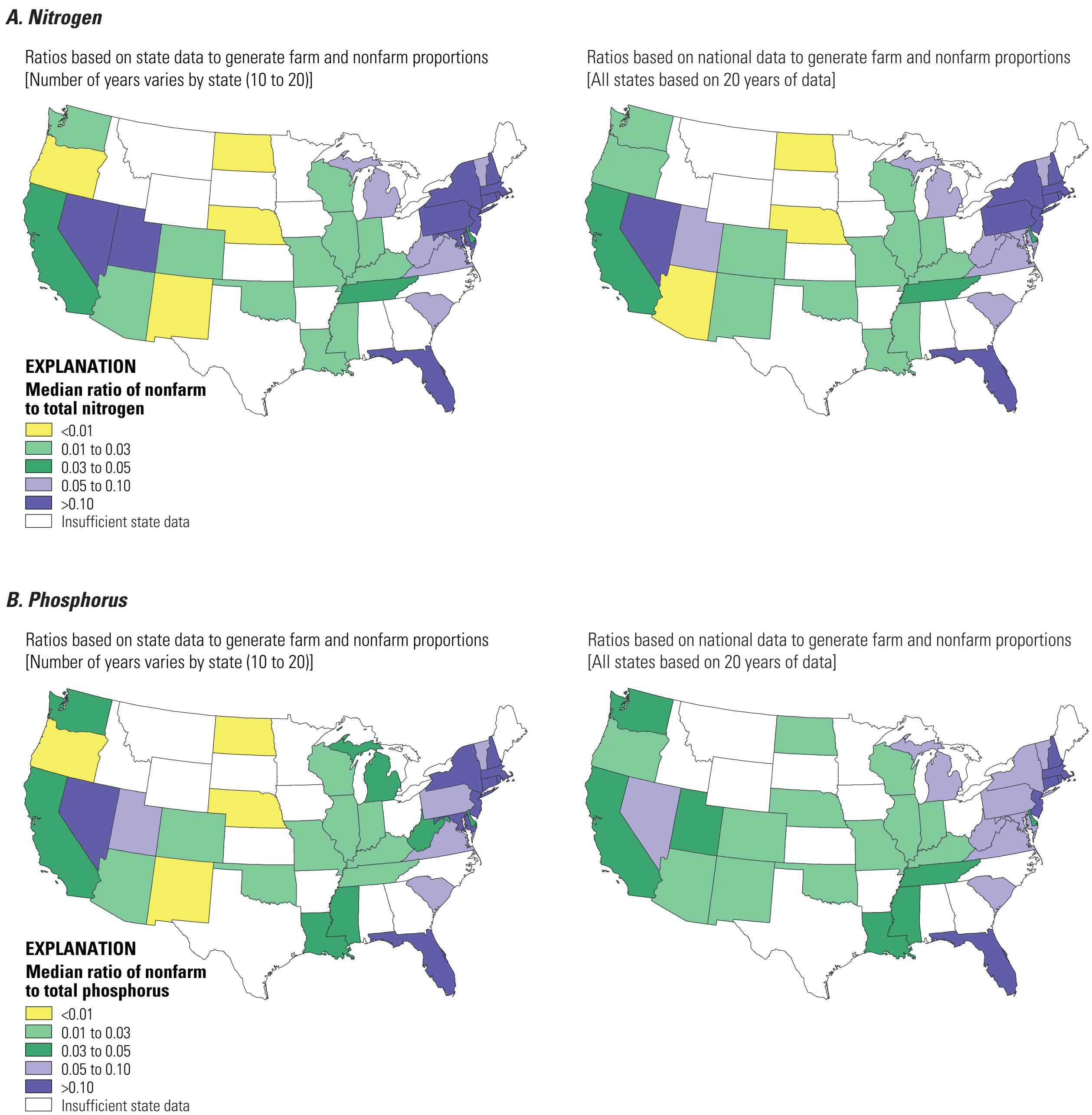


Figure 6. Spatial distribution of state- and national-based median nonfarm-to-total ratios during 1987–2006 for (*A*) nitrogen and (*B*) phosphorus.

Comparison to Independent Estimates of Nonfarm Fertilizer Application and Land Use

Recommended lawn application rates vary from about 1 to 4 pounds of nitrogen per 1,000 square feet for different areas of the country (Florida Department of Agriculture and Consumer Services, 2007; Mugass, 1995; Rosen and Horgan, 2005; and University of California, 2004). A comparison of the nonfarm nitrogen fertilizer values with these recommended application rates provides an independent measure of the nonfarm estimates. A comparison of the nonfarm phosphorus fertilizer values was not done because it was difficult to find a recommended application rate for phosphorus.

The nonfarm-fertilizer values for each state and year were compared to values that would be obtained if the lower bound of recommended use rates—one pound of nitrogen for each 1,000 square feet—were followed for urban land in each state. Land use was derived from the enhanced National Land Cover Data 1992 (NLCDe 92; Nakagaki, 2007), which was developed by overlaying satellite imagery-based 1992 National Land Cover Data (NLCD 92; Vogelmann and others, 2001) with selected classifications from aerial-photography-based Land Use and Land Cover (LULC) data (Price and others, 2007). For this comparison, the urban land use was estimated by summing four land-use classes from the NLCDe 92: low-intensity residential; LULC residential, not classified as forest, water, or urban by NLCD 92; LULC residential, classified as forest by NLCD 92; and urban and recreational grasses. The ratios of observed nonfarm-fertilizer values to recommended values calculated from the land-use data are shown as box plots of annual values for each state in figure 7. Most states had ratios of less than one. Ratios greater than one indicate that the nonfarm-fertilizer application rates are in excess of the low end of the recommended application rates, whereas ratios less than one indicate nonfarm-fertilizer application rates less than the low end of recommended application rates. The low ratios are consistent with the fact that the actual area of fertilizer application is only a small portion of the urban area. For example, vegetation often accounts for only 20 to 70 percent of the cover in low intensity residential (Nakagaki and others, 2007). Estimates of nitrogen input rate from nonfarm fertilizer for Arizona and Georgia were much lower when compared to the recommended lawn application rate, suggesting that the nonfarm-fertilizer values were underestimated. Nitrogen input rates from nonfarm fertilizer for North Dakota and South Dakota could be overestimated.

The plausibility of the nonfarm fertilizer use estimates was assessed by comparing the proportion of nonfarm fertilizer use (relative to total fertilizer use) in each state to the proportion of developed land in urban use. Ratios of nonfarm-to-total (nonfarm to nonfarm plus farm) fertilizer estimates for nitrogen and phosphorus were calculated for each state and year. These ratios were then compared to the urban land-use percentage ((urban land area divided by the sum of urban and agricultural land area) * 100) in each state (fig. 8). Agricultural land was estimated by summing six NLCDe 92 land use classes: orchards/vineyards/other, LULC orchards/vineyards/other, pasture/hay, row crops, small grains, and fallow. The data show that increases in nonfarm-to-total fertilizer ratios for nitrogen and phosphorus correspond to an increase in urban land-use percentages. This systematic trend is consistent with the hypothesis that the nonfarm portion of total fertilizer should increase as the urban area increases, and indicates that the calculated national nonfarm ratios provide a useful method to estimate nonfarm fertilizer use at the state level. Similar to figure 7, nonfarm-to-total fertilizer ratios for Arizona and Georgia were low compared to the other states with similar urban land-use percentages, and nonfarm-to-total ratios for North and South Dakota could be high.

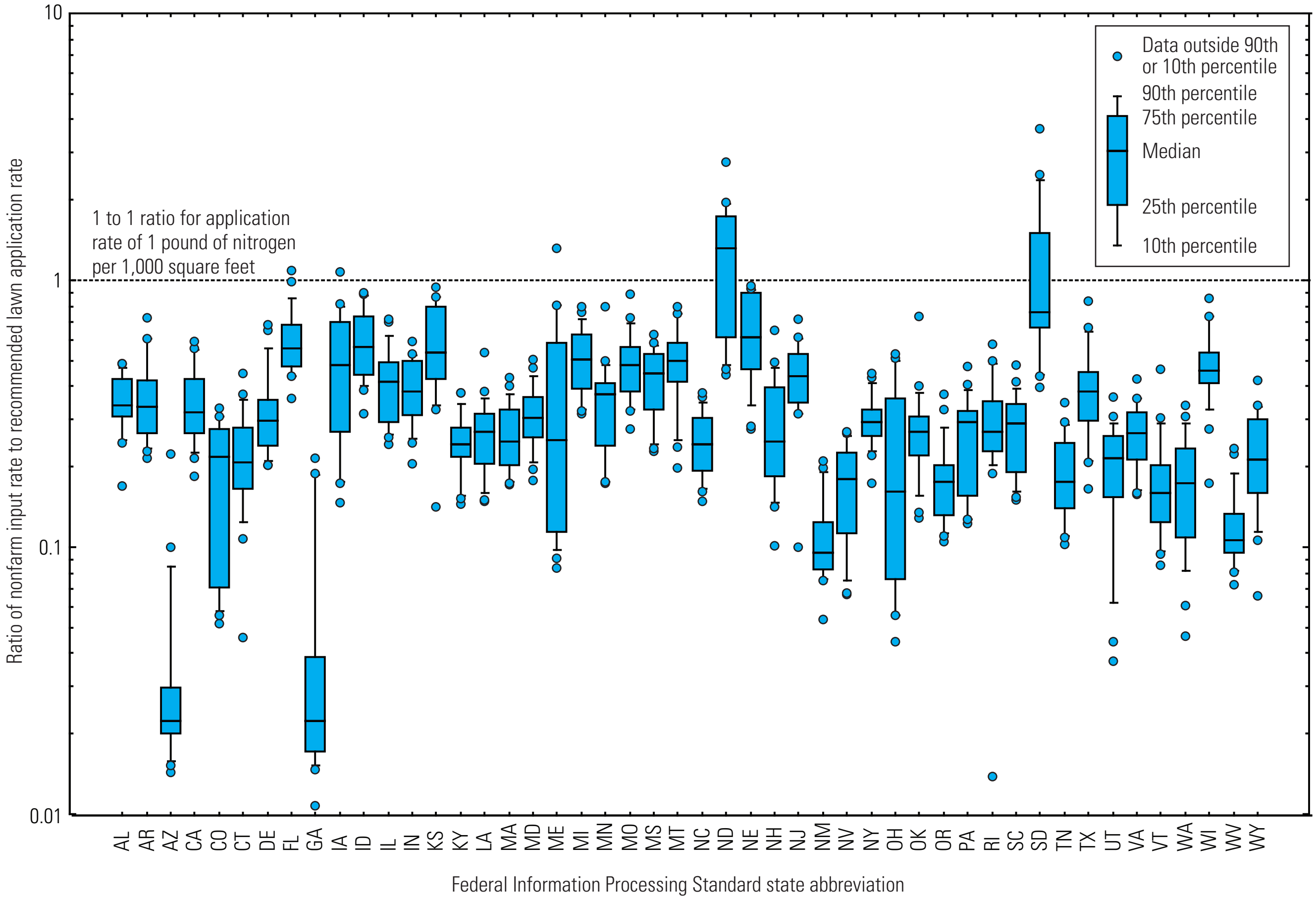


Figure 7. Ratio of estimated nonfarm nitrogen input rate to the recommended lawn application rate, by state,1987–2006.

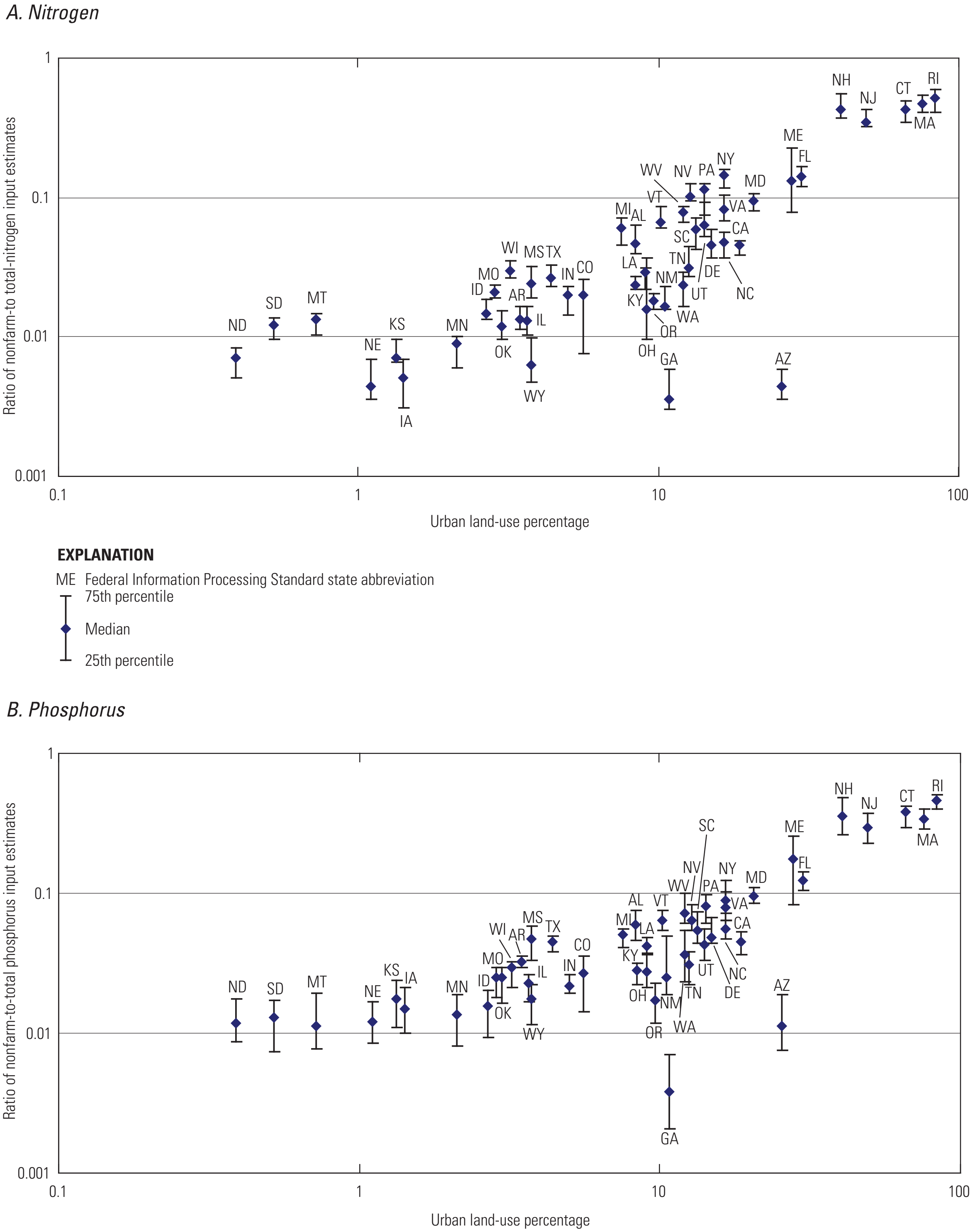


Figure 8. Nonfarm-to-total fertilizer ratio (median, 25th and 75th percentile) versus urban land-use percentage, 1987–2006, for (*A*) nitrogen and (*B*) phosphorus (Alaska, Hawaii, and the District of Columbia are not included).

Summary

County-level nitrogen and phosphorus from fertilizer, for both farm and nonfarm use, were estimated for the conterminous United States for 1987 through 2006. A national approach to estimate state-level farm and nonfarm portions of the fertilizer sales data was used because not all states distinguish between farm and nonfarm use. Data from selected states were used to derive national farm and nonfarm proportions for each fertilizer product. These proportions were applied to fertilizer sales data from all states. The selection of states used in determining the farm and nonfarm proportions differs from what was reported by Ruddy and others (2006). The revised method excludes the use of estimated state data as well as inconsistent or erroneous values. State totals of farm fertilizer were distributed to counties by using county weights based on fertilizer expenditure, and state totals of nonfarm fertilizer were distributed to counties by using county weights based on effective population, as described by Ruddy and others (2006).

Comparison of fertilizer inputs determined with the national proportions versus proportions developed from individual state reported data showed that periods of relative highs and lows were coincident between the national- and state-based values. Use of the national proportions also tended to reduce the extreme high values found in some individual state reported values. The national processing also was able to extrapolate values for states that do not report nonfarm use. The regional distribution of the nonfarm ratios also were maintained by using the national approach.

Nonfarm nitrogen values were found to be reasonable estimates when compared to lawn application recommendations. Exceptions were North Dakota and South Dakota, where values could be overestimated for several years, and Arizona and Georgia, where values could be underestimated. At the state level, increases in nonfarm-to-total fertilizer ratios for nitrogen and phosphorus also corresponded to an increase in urban land-use percentages, with the exception of underestimated values for Arizona and Georgia.

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Appendixes

Appendixes are available for download in PDF format at http://pubs.usgs.gov/sir/2012/5207/.

Appendix 1. Total Number of Fertilizer Products and Number of Nonfarm Fertilizer Products Summarized from the Association of American Plant Food Control Officials Data, by State, 1987–2006.

Appendix 2. Product Tonnage as Reported in Raw Association of American Plant Food Control Officials Data, by State, 1987–2006.

Appendix 3. (*A*) Location of States With at Least One Year (1987–2006) of Association of American Plant Food Control Officials (AAPFCO) Fertilizer Product Tonnage Data Estimated from Previous Years or from Surrounding States, and (*B*) Summary of States and Years with Estimated AAPFCO Fertilizer Product Tonnage Data (shaded), 1987–2006.

Appendix 4. Location of Counties with Association of American Plant Food Control Officials Fertilizer Product Tonnage data Reported at the County Level, 1987–2006.

Appendix 5. Farm and Nonfarm Nitrogen and Phosphate Tonnage, by State, 1987–2006 (blue line on plot B represents 1 pound of nitrogen per 1,000 square feet of urban area).

Appendix 6. Nitrogen and Phosphorus Tonnage Based on National (red) and State (green) Farm and Nonfarm Proportions, by State, 1987–2006.

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