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Estimates of Recoverable and Non-Recoverable Manure Nutrients Based on the Census of Agriculture

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Executive Summary

The structure of animal agriculture continues to shift toward fewer and larger operations, concentrating livestock in local areas. As a consequence, the utilization and disposal of animal manure from animal feeding operations continues to be an important farm management challenge if producers are to be successful in reducing water quality degradation related to land application of manure. When nutrients are recycled on the land at rates that exceed the capacity of the land to utilize the nutrients, continued manure applications can lead to a buildup of nutrients in the soil. This increases the potential for nutrients to move from the field through leaching and runoff to pollute groundwater and surface water.

This study provides insight into issues associated with the increasing concentration in the confined livestock industry. We inform policy initiatives and policy choices by describing the recoverable manure nutrients, the excess nutrients, and areas with excess nutrients. By describing these changes in indicator variables, we establish an "upper" bound on the reach of polices to manage manure nutrients. In addition, we provide a consistent comprehensive data set for further analysis by NRCS and other natural resource agencies.

This study used data from six Censuses of Agriculture from 1982 through 2007 to estimate the quantity of recoverable (generally concentrated in a small area) and non-recoverable (generally dispersed over the landscape as with grazing animals) manure nutrients produced by the animal agriculture sector. Using Census inventory and sales data, we estimated manure nutrients based on estimates of the number of animal units, by animal type, for each Census farm. Based on animal numbers and type, farms were classified into groups of no livestock, livestock farms with non-recoverable manure, and two size classifications of livestock farms with recoverable manure; the smaller generally referred to as animal feeding operations (AFOs) and the larger generally referred to as concentrated animal feeding operations (AFO-CAFOs). (CAFOs are defined by the Environmental Protection Agency using animal numbers and farm conditions. We can only estimate the number of AFOs that are potential CAFOs, hence AFO-CAFO.) Estimates of the quantity of manure were based on literature coefficients and the average animal unit numbers per operation.

Over the study period, numbers of farms without livestock increased as did farms with livestock but without recoverable manure, such as very small farms or livestock operations with primarily pastured livestock. In contrast, the number of farms with recoverable manure sharply and steadily declined—by 60 percent—especially in the Midwest and among small and very small farms. The shift in the number of farms by type was led by a 35-percent increase in the number of medium and large farms with recoverable manure.

While the total number of animal units (AU) on all farms remained relatively constant over the 25-year period, increasing only about 2 percent since 1982, the increasing number of confined animal units on AFOs, especially on AFO-CAFO livestock operations, is notable. The number of confined AU on AFOs has increased at a steady pace to 48 million in 2007, a 15-percent increase over the number of confined AU on AFOs in 1982. The number of the largest operations that are potential CAFOs increased more than three-fold from 1982 to 2007. Moreover, the proportion of all confined AU on these larger operations increased from 24 percent in 1982 to 59 percent in 2007. In contrast, the number of confined AU on the smaller AFOs decreased over time, as did the number of these smaller operations. Confined AUs are most concentrated in areas within California, North Carolina, around the Chesapeake Bay, and from the Texas Panhandle through western Kansas, Nebraska, and Iowa into southern Minnesota and across Wisconsin.

The number of confined animals per operation has increased for all major livestock types and confined livestock populations have become more spatially concentrated in high-production areas. The combination of the significant decline in the number of AFOs together with the large and increasing share of the AUs on larger farms constitutes a dramatic structural change in animal agriculture. A significant shift in the mix of livestock types also occurred as numbers of dairy cattle decreased (14 percent) and poultry and swine populations increased (91 and 48 percent respectively).

Problems associated with animal waste utilization are becoming more widespread and ever-more challenging as the structure of animal agriculture shifts toward fewer, larger, and more spatially concentrated animal feeding operations. As livestock production has become more spatially concentrated, the amount of manure nutrients relative to the assimilative capacity of land available on AFO and AFO-CAFO farms for application has grown and often exceeds the individual farm's capacity. In 2007, we found that almost 60 percent of recoverable manure nutrients exceeded individual AFO's assimilative capacity, compared to 30 percent in 1982. Consequently, off-farm export requirements are increasing. In some counties, where a "county" is the proxy for a distribution area, the production of recoverable manure nutrients exceeds the assimilative capacity of all the cropland and pastureland available for manure application. The number of these counties has increased from 48 counties in 1982 to 179 counties in 2007 (of the 3,076 counties with farms in 2007).

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Introduction

Data from the Census of Agriculture show that the structure of animal agriculture continues to shift toward fewer but larger operations over time, concentrating livestock in local areas. As a consequence, the utilization and disposal of animal manure from confined livestock operations has become an important farm management challenge. In addition to being a source of nutrients, manure is also a source of concern for environmental quality, especially water quality. When nutrients are applied at rates that exceed the capacity of the land to utilize nutrients, continued applications can lead to a buildup of nutrients in the soil. This increases the potential for nutrients to move from the field through leaching and runoff to pollute groundwater and surface water.

The Census of Agriculture reports the number of animals on farms, which can be used to approximate the amount of manure produced on livestock operations. This report is an update and extension of previous similar studies conducted using the Census of Agriculture databases.

Moffitt and Lander (1997) and Lander, Moffitt, and Alt (1998) evaluated the potential for cropping systems to assimilate manure nutrients and found that in 1992 there were several counties in the United States where nutrients from animal manure exceeded the capacity of the cropping systems to assimilate nutrients even if manure could be applied to all the suitable land in those counties. Letson and Gollehon (1998) used a similar approach to publish an assessment of the economics of targeting manure policies. Using published Census of Agriculture data for 1949 to 1992, Kellogg and Lander (1999) showed that the number of counties with the potential for "excess" manure nutrients increased from 1949 through 1964, remained stable until 1982, and then increased again through 1992. Kellogg, Lander, Moffitt, and Gollehon (Kellogg et al., 2000; Gollehon et al., 2001) extended the analysis to include the 1997 Census of Agriculture, showing that livestock operations became more concentrated in high production regions between 1982 and 1997 as the structure of animal agriculture shifted toward fewer but larger livestock operations. Methods for identifying Animal Feeding Operations (AFOs) using Census of Agriculture data were refined and revised estimates of manure nutrient production for 1997 were developed for a study on the potential costs of full implementation of Comprehensive Nutrient Management Plans (CNMPs) by the Natural Resources Conservation Service (NRCS) (USDA/NRCS, 2003).

Livestock populations reported in the Census of Agriculture are used in this report to estimate total manure and manure nutrients *as excreted*, which are then disaggregated into two parts—

- recoverable manure from animal feeding operations (AFOs), where manure from confined animals is assumed to be collectable and available for land application after recovery, and
- non-recoverable manure from all farms with livestock.

Non-recoverable manure includes manure deposited by pastured animals and manure that was assumed to not be recoverable from AFOs. Manure from confined livestock types on farms too small to qualify as AFOs (based on the size of the on-farm livestock population of confined livestock types) was included with pastured livestock, representing nutrient loadings on farmland in the vicinity of small farms.

Specifically, data from the Census of Agriculture databases are used to estimate[1]—

1. average annual on-farm livestock population,
2. quantity of manure and manure nutrients *as excreted* for all farms with livestock,
3. quantity of recoverable manure and manure nutrients for AFOs,
4. quantity of non-recoverable manure nutrients for all farms with livestock,
5. capacity of farmland to receive land-applied manure nutrients, and
6. potential application rates of recoverable manure on crops and pastureland.

This information was then used to identify areas where the amount of recoverable manure nutrients exceeds the assumed availability of farmland for land application. Results from this estimation process identify areas potentially needing more land for manure application or alternative manure utilization options.

In this report, estimates of livestock populations and manure production are presented based on the 1982, 1987, 1992, 1997, 2002, and 2007 Census of Agriculture databases. Procedures for the 1982-1997 estimates have been revised slightly from previously published estimates to be as consistent as possible with procedures used for the 2002 and 2007 estimates.

Presented along with this report is a database supplement that includes estimates by 6-digit Hydrologic Unit Codes (HUCs) of manure, manure nutrients, and other selected variables derived from the 2007 Census of Agriculture Database. See Box 1.

[1] The Census of Agriculture is conducted by the National Agricultural Statistics Service (NASS), Department of Agriculture. Electronic databases of farm-level responses maintained by NASS were used to make the calculations at the farm level. Farm-level estimates were then aggregated for reporting. Access to the farm-level data base is restricted to protect the confidentiality of respondents. All estimates published in this report meet the disclosure criteria used by NASS to assure confidentiality.

Box 1: **Census Database Includes Hydrologic Unit Codes (HUCs)**

Beginning in 2007, the National Agricultural Statistics Service (NASS) assigned Hydrologic Unit Codes (HUCs) to all farms. Initial watershed assignments were made based on the principal state, principal county, and zip code for each operation. If the principal county was contained completely within a watershed and the zip code was valid for the principal county, the operation was deterministically assigned to that watershed. Operations that could not be deterministically assigned were probabilistically assigned. Probabilistic assignments were made based on the proportion of agricultural land each watershed had within the principal county. For example, if a watershed represents 60 percent of the agricultural land in a county, a record would have had a 6 out of 10 chance of being assigned to that watershed. HUCs at the 2-, 4-, and 6-digit level were assigned. There are a total of 334 6-digit HUCs for the 48 states. All large farms and ranches that were probabilistically assigned were examined by NASS Field Office staff to verify or correct the 6-digit HUC assignments.

In order to provide a comparative history, NASS also made 6-digit HUC assignments to all 2002 Census of Agriculture farms. Forty-one percent of the farms reporting in 2002 could be matched to a 2007 response, and these were given the same 6-digit HUC as the 2007 record. Six-digit HUCs for the remaining 2002 records were determined by applying the assignment algorithm described above.

Presented along with this report is a database supplement that includes estimates by 6-digit Hydrologic Unit Codes (HUCs) of manure, manure nutrients, and other selected variables derived from the 2007 Census of Agriculture Database. The supplement is titled “Database of Estimates by 6-Digit HUC of Animal Units and Recoverable and Non-Recoverable Manure Nutrients based on the 2007 Census of Agriculture” and can be accessed at the same Website location as this report.

This information was excerpted from a NASS summary of the methodology at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Watersheds/wtrsheds.txt

Average Annual Animal Units

Estimating Average Annual Animal Units

The basic building block of the estimation process is an animal unit (AU), which represents 1,000 pounds of live animal weight. AU is a convenient measure for aggregating over different types of livestock. The number of AUs on a farm varies throughout the year as livestock grow and are bought or sold. An estimate of the average annual AUs on the farm is needed for calculation of annual manure and manure nutrient production.

The average annual number of AUs on each farm was estimated from reported data on number of livestock sold or on hand at the end of the year. The Census of Agriculture provides the following information on livestock populations.

1. Confined Livestock Types—
    a. Cattle and calves:
        i. Number of fattened cattle sold
        ii. Fattened cattle end-of-year inventory[2]
        iii. Milk cows, end-of-year inventory (including dry milk cows and milk heifers that had calved)
    b. Hogs and pigs:
        i. Hogs and pigs used for breeding, end-of-year inventory
        ii. Other hogs and pigs, end-of-year inventory
        iii. Hogs and pigs sold, including the number of feeder pigs sold[3]
        iv. Type of swine operation (more than one could be recorded)[4]—
            a. Farrow to wean
            b. Farrow to feeder
            c. Farrow to finish
            d. Finish only
            e. Nursery
            f. Other
    c. Poultry:
        i. Chicken layers 20 weeks old and older, end-of-year inventory and number sold
        ii. Pullets for laying flock replacement, end-of-year inventory and number sold
        iii. Chicken broilers, fryers, and other meat-type chickens, end-of-year inventory and number sold
        iv. Turkeys for slaughter, end-of-year inventory and number sold
        v. Turkey hens for breeding, end-of-year inventory and number sold
        vi. All turkeys, end-of-year inventory and number sold[5]
        vii. Ducks, end-of-year inventory and number sold

2. Pastured Livestock Types—
    a. Cattle and calves:
        i. Beef cows, end-of-year inventory (including heifers that had calved)
        ii. Other cattle, end-of-year inventory (heifers, steers, calves, and bulls combined)
        iii. Cattle and calves on feed, end-of-year inventory
        iv. Calves sold weighing less than 500 pounds
        v. Cattle and calves sold weighing more than 500 pounds
    b. Horses, sheep, and goats:
        i. Horses, ponies, mules, burros, and donkeys[6], end-of-year inventory
        ii. Sheep and lambs, end-of-year inventory
        iii. Goats, all types, end-of-year inventory

3. Specialty Livestock Types—
    a. Emus, geese, ostriches, pheasants, pigeons or squab, quail, other poultry, end-of-year inventory
    b. Bison, elk, deer, llama, mink, rabbit, other, end-of-year inventory

To convert head-count data reported in the Census of Agriculture to average annual AUs, assumptions are needed on how long the animals are kept on the farm and the average weight of the animal while on the farm. For cattle, this required deconstructing the "other cattle" inventory and the non-fattened cattle sold into the following categories:

- Veal (calves sold from operations without sufficient on-farm pastureland to support grazing)
- Beef calves
- Beef heifers
- Beef stockers and grass-fed beef
- Beef breeding cows and bulls
- Dairy calves
- Dairy heifers for herd replacement
- Dairy stockers sold as beef

Animal unit conversions (number of animals per AU) were based on determinations of the *average* live weight associated with each livestock category**.** For some livestock categories (such as poultry), the animal unit conversion represents the average weight from birth to market. For others, such as beef and dairy calves, it represents the average weight for the time period that the animal was assumed to be in the specified category.

[2] Fattened cattle end-of-year inventory is available only for 2002 and 2007.
[3] Census data on feeder pigs sold was not provided in 2002 or 2007.
[4] In 2002 and 2007, end-of-year inventory and number of hogs or pigs sold were reported for each type of swine operation.
[5] Sales and inventory information for turkeys for breeding and turkeys for slaughter was not collected in 2002; "all turkeys" was reported instead. The 2007 data were used to derive county-level percentages of turkeys for breeding (percentage of all turkeys). These percentages were used to disaggregate the "all turkeys" data reported in 2002.
[6] The census does not account for all equine, only animals on operations that meet the definition of a farm are included.

Average weights of confined livestock types can vary over time depending on markets and production technologies. Average weights for 1982–97 are the same as those reported in USDA/NRCS 2003, which were based on USDA/NRCS (1992), ASAE (1995), and other sources. Average weights for 2002–07 were based on ASABE Standards revised and published in 2005 (ASABE, 2005) and other recent sources. These sources did not include data on all of the specific livestock types and ages of animals for which Census of Agriculture data were available, so in several cases the published values were adapted to conform to the type and size of animal for which head counts were available or could be derived. Derivation of average weights for livestock and poultry are documented in appendix A.

Coefficients used to estimate average annual AUs for each livestock type are summarized in tables 1–3. These coefficients were derived to represent general production practices across the Nation for all operations, large and small. For any specific part of the country, farm size, local market conditions, or time period, prevailing practices could result in different values for these parameters. For example, industry sources indicate that the time in a confined setting for fattened cattle ranges from 60 to 200 days, depending on season, cost of feed, and changes in sale price. The typical time in confinement for fattened cattle is 120 to 180 days. A value of 2.5 cycles per year (146 days) was selected to estimate fattened cattle animal units for all operations. Similar information was evaluated to set these coefficients for other livestock categories.

Estimates of average annual AUs may be overstated or understated for individual farms because of the numerous assumptions required to make the calculations. The estimates are not intended to accurately represent each individual farm. The estimates are reasonable, however, for aggregations over large numbers of farms and are appropriate for quantifying trends in the magnitude of livestock populations and manure production and changes in the size and distribution of livestock operations over time.

Average annual AUs for confined livestock types based on both inventory and sales data

An important aspect of the average annual AU calculation is the amount of time that an animal is assumed to be on the farm during the year. For fattened cattle, hogs for slaughter, and poultry, it was assumed that the animals were present on the operation throughout the year. Coefficients used to calculate average annual AUs for this group of confined livestock types are presented in table 1. For all livestock types shown in the table, data on both end-of-year inventory and annual sales were reported and used to estimate average annual AUs.

The general algorithm was obtained using the following simplifying assumptions.

- End-of-year inventory represents the partial cycle at the end of the year and the partial cycle at the beginning of the year, making up a full cycle.
- Sales throughout the year do not fluctuate (i.e., no seasonal variation), and thus the average sales per cycle can be used to estimate the number of animals on the farm in each of the remaining cycles.

The general formula for the livestock types recording both year-end inventory and sales numbers is:

Equation 1*: Average annual AU= {(inventory x 1/cycles) + [sales/cycles x ((cycles-1)/cycles)]} x (1/animals per AU)*

Equation 1 estimates the average number of animal units on the farm throughout the year. Inventory data are used to estimate the average AU for one cycle, and average sales data (sales per cycle) were used to estimate the average AU for the remaining cycles.

Table 1. Coefficients used to calculate average annual AU for confined livestock types based on inventory and sales data

Livestock category	Source of data for number of head present on farm	Animals per animal unit 2002-2007	Animals per animal unit 1982-1997	Number of cycles per year
Fattened cattle	Year-end inventory and sales*	1.02	1.14	2.5
Hogs for slaughter	Year-end inventory and sales	NA	9.09	2
Finish only	Year-end inventory and sales	6.7	NA	2.6
Farrow to finish	Year-end inventory and sales	7.4	NA	2
Farrow to feeder	Year-end inventory and sales	50	NA	8
Farrow to wean	Year-end inventory and sales	143	NA	18
Nursery	Year-end inventory and sales	37	NA	13
Chickens, layers	Year-end inventory and sales	293	250	1
Chickens, pullets	Year-end inventory and sales	350	350	2.25
Chickens, broilers	Year-end inventory and sales	382	455	6
Turkeys for breeding	Year-end inventory and sales	50	50	1
Turkeys for slaughter	Year-end inventory and sales	59	67	2
Ducks	Year-end inventory and sales	286	286	6

* Inventory data are not available for 1982–97. Estimates of AU were based only on sales for 1982–97.

For example, in the hypothetical case where three cycles of production are probable during a year and the livestock category spans from birth to market, equation 1 reduces to equation 2.

***Equation 2**: Average annual AU= {(inventory x 1/3) + [sales/3 x (2/3)]} x (1/animals per AU)*

Because the production cycle for a given farm probably did not begin exactly on the first day of the year, some of the sales represent animals that were on the farm for a portion of the last cycle of the previous year. These animals should not be counted as full AUs for the current year. Similarly, the inventory present at the end of the year may be at the beginning of a cycle or near the end of a cycle. It is clear, however, that of the three cycles possible during a year, sales from two of the cycles were present on the farm from birth to market.

Not all farms had both inventory and sales data recorded. Farms starting up a livestock operation sometimes had only end-of-year inventory, and farms going out of business or with production during times of the year other than the December 31 inventory date had sales, but no end-of-year inventory.

For farms with year-end inventory only, the animals were assumed to be in mid-cycle at the end of the year, and annual average AU was calculated as shown in equation 3.

***Equation 3**: Average annual AU= {inventory x ½ x 1/cycles} x (1/animals per AU)*

For farms that have only sales data and no inventory data (when the census requests information on both), it was assumed that all the animals represented by sales were present on the farm throughout the period associated with the livestock category (e.g., from birth to market), and annual average AU was calculated as shown in equation 4.

***Equation 4**: Average annual AU= {sales/cycles} x (1/animals per AU)*

Most of the Census of Agriculture data elements have remained the same from 1982 through 2007, but some data elements have changed, requiring adaptations to the estimation procedures for animal units. Consequently, estimates for 1982-1997 will differ slightly from previously published estimates, and in some cases estimates for 2002 and 2007 are based on estimation procedures that could not be applied to 1982–97 data.

There were two changes in the data elements that had a significant effect on how animal units were calculated as follows.

- Only fattened cattle sales were reported for 1982–97, requiring use of equation 4 for the calculation of animal units. In 2002 and 2007, however, end-of-year inventory was also reported, enabling use of equation 1, 3, or 4 for estimation of animal units.
- In 2002 and 2007, inventory and sales information for hogs and pigs other than breeding stock was reported separately for six types of swine operations, and the total number of feeder pigs sold was not reported. In addition, survey respondents could report data for more than one type of operation. Parameters for calculating average annual AU (as well as manure nutrients) were derived specifically for each operation type for 2002 and 2007. For 1982–97, hog and pig animal units were calculated assuming all operations were farrow-to-finish with 2 cycles per year; feeder pig sales were subtracted from total hog and pig sales to prevent double counting of those animal units.[7]

Average annual AU for livestock types based only on year-end inventory data

Some livestock types were assumed to be in continuous production at stable population levels throughout the year (steady-state production). These included milk cows, cattle held as breeding stock, horses, ponies, mules, donkeys, burros, sheep, and goats. For these livestock categories, only year-end inventory data are used to estimate the average annual AUs using coefficients presented in table 2 and the formula in equation 5, even when data on sales during the year were reported.

***Equation 5**: Average annual AU= inventory x (1/animals per AU)*

For all livestock types included in table 2, it was assumed that the animal was on the farm throughout the year or there was continuous replacement. Average annual AU estimates for all specialty livestock types were estimated using only end-of-year inventory data and the coefficients presented in table 2.

[7] The calculation of hog and pig animal units for 1982–97 overstates animal units for farms with some swine operation types and under-states average annual animal units for farms with other swine operation types. When these estimates are aggregated over all farms, however, these errors cancel out and a reasonable estimate of swine animal units is obtained. The additional information available for 2002–07 results in more accurate estimates of average annual animal units for individual farms.

Average annual AUs for remaining cattle livestock types

For the remaining cattle categories (veal calves, beef and dairy calves, heifers, and stockers), the number of livestock is derived through assumption for calves and replacement heifers and derived from "other" cattle inventory and sales of calves and cattle for beef and dairy stockers. For the various cattle categories, the AU calculation was based on the proportion of the year that the animals were in the specified category, presented in table 3.

Animal units for veal calves were estimated only for farms that had significant sales of cattle less than 500 pounds with no dairy or beef cows and did not appear to have sufficient pastureland on the farm to raise the calves without confinement. Veal calf AUs were distinguished from other beef and dairy calves only when there were more than 12 average annual AUs of calves on the farm and the ratio of calf AUs to pastureland acres exceeded 8. Thus, veal calf AU reported here represents only a portion of veal calf production. Remaining veal calf production is represented as beef and dairy calf AUs in this study.

Table 2. Coefficients used to calculate average annual AU based only on end-of-year inventory

Livestock category	Source of data for number of head present on farm	Animals per animal unit (all years)
Confined livestock types		
Milk cows	Year-end inventory	0.73
Breeding hogs	Year-end inventory	2.27*
Pastured livestock types		
Beef breeding herds (cows and bulls)	Year-end inventory**	1
Horses and ponies	Year-end inventory	0.9
Mules, burros, and donkeys	Year-end inventory	1.8
Sheep and goats	Year-end inventory	8
Specialty livestock types		
Bison	Year-end inventory	0.81
Deer	Year-end inventory	4.76
Elk	Year-end inventory	1.67
Llamas	Year-end inventory	3.13
Minks	Year-end inventory	476
Rabbits	Year-end inventory	204
Emus	Year-end inventory	10
Geese	Year-end inventory	125
Ostriches	Year-end inventory	5.4
Pheasants	Year-end inventory	625
Pigeons and squab	Year-end inventory	1,250
Quail	Year-end inventory	5,882

* The coefficient for animals per AU is 2.67 for 1982-1997.
**Year-end inventory for beef cows was reported in the Census. Beef bulls were estimated as 5 percent of the number of beef cows, as long as that estimate was less than the end of year inventory value reported for "other cattle."

Table 3. Coefficients used to calculate average annual AU for other cattle livestock types

Livestock category	Source of data for number of head present on farm	Animals per animal unit (all years)	Proportion of year on the farm
Confined livestock types			
Veal calves	Derived from cattle sales	4.4	3.5/12
Pastured livestock types			
Beef calves	Based on calving rate	4	5/12*
Beef heifers for replacement herds	Based on replacement rate	1.14	5/12
Beef stockers and grass-fed beef	Derived	1.73	6/12
Dairy calves	Based on calving rate	4	5/12*
Dairy heifers for replacement herds	Based on replacement rate	1.04	5/12
Dairy stockers and grass-fed animals marketed as beef	Derived	1.73	6/12

*Time on farm is assumed to be 2.5 months for calves bought and later sold.

Algorithms for estimating average annual AUs for the six remaining pastured livestock types (table 3) were constructed assuming herds were maintained at stable levels represented by the end-of-year inventories reported in the Census and so as to exhaust all the cattle reported for the farm as either—

- other cattle inventory at end of year (excludes beef cows, milk cows, and fattened cattle),
- cattle less than 500 pounds sold, or
- cattle more than 500 pounds sold.

Beef and dairy calves were estimated based on assumptions about calving rates and the number of calves sold. Calving rates were assumed to be 82 percent for beef cattle and 65 percent for dairy cattle. Calving rate percentages were applied to end-of-year inventory reported for beef cows to estimate beef calves and applied to end-of-year inventory reported for milk cows to estimate dairy calves. It was assumed that calves in this category were on the farm for 5 months of the year (from birth).

If the number of calves sold on the farm exceeded the number of calves expected using the calving rate, the additional calves sold were assumed to have been purchased as young calves and later sold. These calves were assumed to have been on the farm half the amount of time as calves born on the farm—2.5 months during the year. The algorithm estimates calves bought and later sold by exhausting the balance of total calves reported as sold for each farm with either end-of-year beef cow inventory or end-of-year milk cow inventory. There were additional farms that reported calf sales but no end-of-year beef cow or milk cow inventory and did not meet criteria for veal calves. These residual calf sales were classified as beef calves and were assumed to have been purchased and held on the farm as a calf for 3.5 months of the year, the same coefficient used for veal calves.

Beef and dairy heifers for herd replacement were estimated based on assumptions about replacement rates. The number of heifers for replacement herds was assumed equal to 15 percent of the number of end-of-year beef cow inventory and 20 percent of the number of end-of-year milk cow inventory. However, if the initial estimate of the number of replacement heifers exceeded the end-of-year inventory reported for "other cattle" after adjusting for fattened cattle and calves expected to be on the farm at the end of the year, the number of replacement heifers was reduced to equal the number of remaining "other cattle." It was assumed that heifers for replacement were on the farm as heifers for 5 months of the year.

Remaining cattle were classified as either grass-fed beef or stockers to be sold or transferred to fattened cattle operations (feedlots). The average annual stocker and grass-fed cattle AUs assumed to be on the farm was estimated using equation 1 with 2 cycles, where—

- the end-of-year inventory for stockers and grass-fed cattle is "other cattle" end-of-year inventory reported for the farm after excluding fattened cattle, veal calves, dairy calves, bulls, and replacement heifers, and
- stocker and grass-fed cattle sales are equal to cattle sold weighing more than 500 pounds excluding fattened cattle.

Estimating average annual AU for confined and partially confined pastured livestock types

Pastured livestock (cattle, horses, sheep, and goats) on some farms were classified as being confined, thus making the manure collectable and recoverable. The confinement assumption was based on the amount of grazing land reported for each farm in the Census; grazing land is the sum of three Census variables—(1) permanent pasture and rangeland, (2) woodland pastured, and (3) cropland used only for pasture or grazing. Insufficient grazing land available to support the pastured livestock population resulted in a determination of partial to total confinement of pastured livestock types according to the following rules.[8]

- If there was no grazing land on the farm, all pastured livestock types were assumed to be confined.
- If the ratio of pastured livestock AUs to acres of grazing land available on the farm was less than 8, no pastured livestock types were assumed to be confined.
- If the ratio of pastured livestock AUs to acres of grazing land available on the farm was between 8 and 13, pastured livestock types were assumed to be 25 percent confined.
- If the ratio of pastured livestock AUs to acres of grazing land available on the farm was between 13 and 18, pastured livestock types were assumed to be 50 percent confined.
- If the ratio of pastured livestock AUs to acres of grazing land available on the farm was greater than 18, pastured livestock types were assumed to be 75 percent confined.

These criteria are in place ***only*** to define "confinement" for the purposes of estimating recoverable manure. The criteria are not directly related to EPA criteria for AFOs and or to any grazing pressure calculations. The criteria were set extra high (that is, erring on the side of missing some recoverable manure) because there are a myriad of extending circumstances that are not reflected in the Census dataset. The calculation of partial recoverable manure was developed to address farms with few acres of pastureland but large numbers of AU that did not fit well with other "pastured livestock farms." Some of these farms are largely holding pens and others leased public land and have no recoverable manure at

[8] These rules are not intended to represent appropriate or inappropriate stocking rates for grazing. Supplemental feeding, if necessary, is assumed. Rules were derived specifically to avoid overestimating the extent of pastured livestock AUs that were treated as confined livestock. Threshold values were based on estimates of vegetation loss from hoof action. The number of pastured livestock classified as being confined will be overestimated for farms that have access to public lands for grazing. The Census no longer records whether or not a farm has land leases for grazing, nor does it record the number of acres of leased grazing land available to the farm.

all, with all combinations in-between. The Census dataset does not allow a more refined estimate.

Animal Units by Type of Livestock Farm

A farm is defined for purposes of the Census of Agriculture as a place from which $1,000 or more of agricultural products were, or normally would be, produced and sold during the Census year. This definition implies that an enterprise would not have to sell $1,000 or more of gross agricultural product sales in the Census year, but report adequate land and/or livestock to generate sales at this level.[9] Farms vary by size and type of operation. Some farms are primarily crop producing farms with no or few livestock. Other farms are livestock operations that primarily raise confined livestock types or primarily raise pastured livestock.

AFOs are an important focus for this report as they are considered to be the farms that generate recoverable manure—that is, manure that would be available for land application. EPA defines an AFO as a "lot or facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and where crops, vegetation forage growth, or post-harvest residues are not sustained over any portion of the lot or facility in the normal growing season."

The Census of Agriculture has information about the number and types of livestock on each farm, but provides no information on how the animals are raised or to what extent or how long animals are held in confinement. Consequently, it is not possible to identify whether or not a farm in the census database is an AFO using the EPA definition. Instead, criteria were developed based on the number of confined livestock type AUs and the estimated amount of manure generated on the farm during a year of operation. Farms were considered AFOs if the population of livestock on the farm was large enough to require manure handling equipment and storage facilities on the farm, and where manure collection and removal from the animal holding facilities would be expected to occur routinely throughout the year.

For this analysis, a farm was identified as an AFO if both of the following criteria were met—

1. 12 or more average annual AUs of confined livestock types, (fattened cattle or veal calves, milk cows, swine, or poultry) including the portion of pastured livestock that were assumed to be confined, and
2. 40 or more tons of manure at hauling weight produced by confined livestock types on the farm in a year (see next section for how hauling weight was estimated).

Farms that did not meet these criteria would not be expected to have sufficient manure production to require on-going removal and disposal. In most cases, the volume of manure would be too small to require manure handling equipment other than a small tractor with a loader or scraper, and any manure disposal would take place on the farm. It is possible that these farms with small livestock populations could be maintained on only a few acres (10 to 15) and would not be expected to meet the EPA definition of an AFO. It is also likely that livestock on these farms would be mostly or at least partially pastured or free-roaming, regardless of the livestock type.

Potential Concentrated Animal Feeding Operations (CAFOs) represent the largest of the animal feeding operations. EPA provides livestock population criteria for “large CAFOs.” EPA further provides livestock population criteria for “medium CAFOs” for farms that might also be designated by EPA as a CAFO if they also meet certain “method of discharge” criteria.

End-of-year inventory and sales data provided in the Census of Agriculture are not adequate to identify a farm as a potential CAFO, largely because the EPA criteria are based on livestock thresholds at any point in time throughout the year. The EPA livestock population criteria are useful, however, for identifying the largest two groups of AFOs when applied to the average annual number of AU on the farm as derived in this study.

EPA livestock population criteria for “large CAFOs” were applied to the Census of Agriculture data to identify “large potential AFO-CAFOs” as follows.

- 700 or more head of dairy cows, based on end-of-year inventory.
- 1,000 or more head of fattened cattle, based on average annual population.
- 1,000 or more veal calves, based on average annual population.
- 2,500 or more breeding hogs or hogs and pigs, based on average annual population (for 2002 and 2007, hogs and pigs were estimated only from “finish-only” and “farrow-to-finish” operations).
- 10,000 or more pigs, based on average annual population from “farrow-to-wean,” “farrow-to-feeder,” and “nursery” operations for 2002 and 2007 and based on average annual feeder pig sales for 1982–97.
- 500 or more horses on farms with partially confined pastured livestock types, based on end-of-year inventory.
- 10,000 or more sheep and lambs on farms with partially confined pastured livestock types, based on end-of-year inventory.
- 55,000 or more turkeys (all types), based on average annual population.
- 125,000 or more chicken broilers or pullets, based on average annual population.
- 82,000 or more chicken layers, based on average annual population.
- 30,000 or more ducks, based on average annual population.

[9] Some farms in the Census of Agriculture report no sales but have a combination of acres and livestock that qualify them as a farm. In 1997, for example, an enterprise with 5 cattle of any kind, 5 horses, 7 hogs and pigs, 142 poultry of any kind, or 25 sheep and goats qualifies as a farm even without any agricultural sales.

EPA livestock population criteria for "medium CAFOs" were applied to the Census of Agriculture data to identify "medium potential AFO-CAFOs" as follows.

- 200 to 700 head of dairy cows, based on end-of-year inventory.
- 300 to 1,000 head of fattened cattle, based on average annual population.
- 300 to 1,000 veal calves, based on average annual population.
- 750 to 2,500 breeding hogs or hogs and pigs, based on average annual population (for 2002 and 2007, hogs and pigs were estimated only from "finish-only" and "farrow-to-finish" operations).
- 3,000 to 10,000 pigs, based on average annual population from "farrow-to-wean," "farrow-to-feeder," and "nursery" operations for 2002 and 2007 and based on average annual feeder pig sales for 1982–97.
- 150 to 500 horses on farms with partially confined pastured livestock types, based on end-of-year inventory.
- 3,000 to 10,000 or more sheep and lambs on farms with partially confined pastured livestock types, based on end-of-year inventory.
- 16,500 to 55,000 or more turkeys (all types), based on average annual population.
- 37,500 to 125,000 or more chicken broilers or pullets, based on average annual population.
- 25,000 to 82,000 or more chicken layers, based on average annual population.
- 10,000 to 30,000 or more ducks, based on average annual population.

Based on the type and extent of livestock reported on the farm in the Census and the above definitions for AFOs and AFO-CAFOs, farms were categorized into one of nine farm types.

1. ***Farms without livestock***—no livestock sales or livestock AUs on farm.
2. ***Farms with a few livestock but not a livestock operation***—no livestock sales, less than 2 average annual AUs of confined livestock, less than 6 average annual AUs of confined and pastured livestock, less than 5 average annual AUs of specialty livestock, and less than 20 tons per year of manure production at hauling weight for all livestock (see next section for how hauling weight was estimated).
3. ***Farms with very small livestock operations***—less than 30 average annual AUs of all livestock, less than 12 average annual AUs of confined livestock, less than 60 tons per year of manure production at hauling weight for all livestock, and less than 40 tons per year of manure production at hauling weight for confined livestock.
4. ***Farms with specialty livestock operations with few confined livestock***—specialty livestock AUs more than 50 percent of total AUs, less than 12 average annual AUs of confined livestock, and less than 40 tons per year of manure production at hauling weight for confined livestock.
5. ***Farms with pastured livestock operations with few confined livestock***—specialty livestock AUs less than 50 percent of total AUs, less than 12 average annual AU of confined livestock, and less than 40 tons per year of manure production at hauling weight for confined livestock.
6. ***Very small AFOs***—less than 35 average annual AUs of confined livestock.
7. ***Small AFOs***—35 or more average annual AUs of confined livestock but livestock populations below criteria for medium or large AFO-CAFOs.
8. ***Medium AFO-CAFOs***—livestock population meets EPA head-count criteria for "medium CAFOs."
9. ***Large AFO-CAFOs***—livestock population meets EPA head-count criteria for "large CAFOs."

These criteria were applied sequentially in the order presented above. After a farm was classified, it was removed from the pool of farms yet uncategorized so that each farm would be uniquely assigned to only one of the nine farm types.
The farm-type criteria presented above were designed to segregate farms into four major groups—

1. farms without any livestock (farm type 1),
2. farms with too few livestock to have recoverable manure (farm types 2 through 4),[10]
3. farms with significant numbers of pastured livestock but too few confined livestock types to have recoverable manure (farm type 5), and
4. farms with recoverable manure—AFOs (farm types 6 through 9).

Table 4 contrasts the number of farms and the annual AU for the nine farm types using the 2007 Census of Agriculture. About 35 percent of farms in 2007 have no livestock inventory or sales. Another 34 percent of farms have only small numbers of confined or pastured livestock types (farm types 2 through 4). About 23 percent of farms have significant numbers of pastured livestock but too few confined livestock types to have recoverable manure (farm type 5). AFOs represented 8.6 percent of all farms in 2007 (table 4).

Farms designated as AFOs had nearly all (98.6 percent) of confined livestock AUs in 2007, including partially or wholly confined pastured livestock types. Farms with too few livestock to have recoverable manure (farm types 2 through 4) include less than 5 percent of all AUs and only 1 percent of confined livestock AU. These farms also include about 85 percent of specialty livestock AUs. The bulk of pastured livestock (81 percent of pastured livestock AUs) are on farms with pastured livestock operations with few confined livestock. About 11 percent of pastured livestock types are on farms designated as AFOs.

[10] Farms with "specialty livestock operations with few confined livestock" would be expected to have recoverable amounts of manure. However, sufficient information on manure characteristics was not available to estimate the quantity of manure for specialty livestock types. As these farms have too few confined livestock types to qualify as AFOs on the basis of those livestock types, no recoverable manure was estimated for these farms.

Table 4. Farm counts and average annual AUs by farm type, all U.S., 2007

	Farms		All livestock types		Pastured livestock types*		Confined livestock types**		Specialty livestock types	
	Number	Percent of total	1,000 AU	Percent of total	1,000 AU	Percent of total	1,000 AU	Percent of total	1,000 AU	Percent of total
Non-AFOs										
Farms without livestock	762,567	34.6	0	0.0	0	0.0	0	0.0	0	0.0
Farms with some livestock but not a livestock operation	101,467	4.6	248	0.2	227	0.4	11	<0.1	10	2.4
Very small livestock operations	642,921	29.2	4,238	4.1	3,639	6.9	525	1.1	74	18.5
Specialty livestock operations with few confined livestock	3,219	0.1	356	0.3	95	0.2	1	<0.1	260	64.8
Pastured livestock operations with few confined livestock	504,694	22.9	43,161	42.1	42,996	81.1	128	0.3	37	9.3
AFOs***										
Very small AFOs	61,051	2.8	2,113	2.1	890	1.7	1,220	2.5	4	0.9
Small AFOs	88,312	4.0	12,398	12.1	2,955	5.6	9,437	19.2	6	1.5
Medium AFO-CAFOs	27,409	1.2	10,351	10.1	1,275	2.4	9,074	18.5	2	0.5
Large AFO-CAFOs	13,152	0.6	29,614	28.9	965	1.8	28,640	58.4	8	2.1
All non-AFOs	2,014,868	91.4	48,003	46.8	46,957	88.5	665	1.4	381	95.0
All AFOs	189,924	8.6	54,476	53.2	6,085	11.5	48,371	98.6	20	5.0
Total	2,204,792	100.0	102,479	100.0	53,042	100.0	49,035	100.0	401	100.0

* Excludes partially or wholly confined pastured livestock types.
** Includes partially or wholly confined pastured livestock types.
*** See text for criteria used to identify an AFO. Criteria do not correspond to the EPA definition of an AFO.

The composition of farm types has changed over time, as shown in figure 1. The percentage of farms without livestock has increased over time while the percentage of farms classified as AFOs in this study has decreased over time. The number of farms with significant populations of pastured livestock but few confined livestock types (farm type 5) has remained fairly stable, fluctuating around 500,000 between 1982 and 2007 (fig. 2). The number of other non-AFOs with few livestock or specialty livestock (farm types 2, 3, and 4) has fluctuated more, ranging from a low of 533,000 farms in 1997 to 748,000 farms in 2007.

The number of farms classified as AFOs has steadily decreased from a high in 1982 of 471,000 to 190,000 in 2007 (fig. 3), representing a 60-percent decrease over the 25 years. In contrast, the large potential AFO-CAFOs have steadily increased from about 3,658 in 1982 to over 13,000 in 2007 (fig. 3). Large potential AFO-CAFOs steadily increased from less than 1 percent of all AFOs in 1982 to 7 percent of AFOs in 2007. The number of medium potential AFO-CAFOs has fluctuated between a low of 26,000 in 1982 to a high of 33,000 in 1992. Proportionally, medium potential AFO-CAFOs steadily increased from 6 percent of all AFOs in 1982 to 14 percent of AFOs in 2007 even though the number of medium AFO-CAFOs had increased only slightly. Most AFOs are small AFOs in all years.

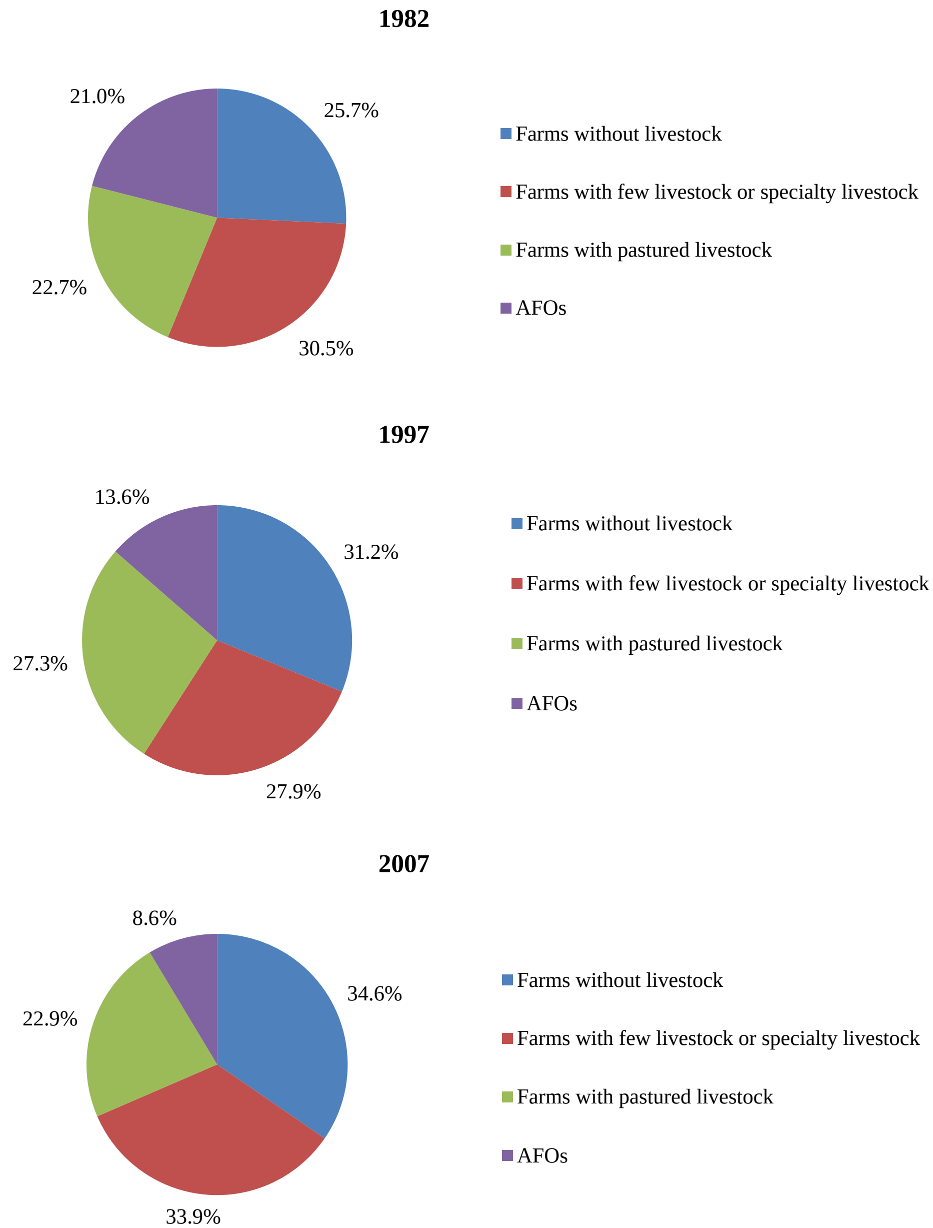
Map 1 provides a six panel visual representation of the number and county locations[11] of potential medium and large AFO-CAFOs in 1982, 1997, and 2007. The first three panels (a-c) show a general increase in the number of operations and an increasing concentration of potential medium and large AFO-CAFOs. The final three panels, d-f, show changes from 1982-1997, 1997-2007, and for 1982-2007. Panel d, presenting the 1982-1997 period, shows the gains in the number of larger AFOs in the central to northern Midwest and Southeast. (Increases and decreases in farm numbers also reflect changes in a farm status shifting from a small to medium classification or *visa-versa*.) This trend continued to a lesser extent during the 1997-2007 period, with losses of larger AFOs throughout Iowa, Illinois, Indiana, Missouri and Nebraska during the same period. There was a decline in the number of operations in a few areas of the Southeast (especially Georgia, Florida, and western Tennessee), and California (especially southern California), over the 1982-2007 period. (Note Appendix B indicates the national number of medium AFO-CAFOs peaked in 1992 and then began to decline. Large AFO-CAFOs, however, increased throughout the years without a decline.) Panel e reflects the loss of

[11] Maps indicating county locations are prepared using a randomized dot placement within the county and are rounded to the nearest unit, which is map specific.

medium AFO-CAFOs from central Midwest, replaced to some extent by large AFO-CAFOs further north and across the South.

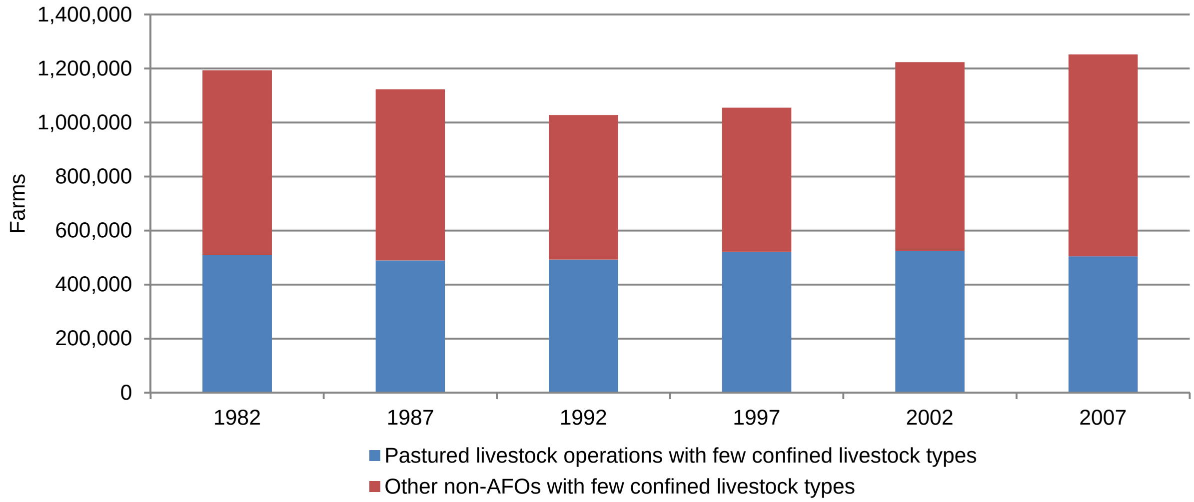
Map 2 presents a six-panel representation of the number and county locations of small and very small AFOs for the period of 1982-2007. In general the panels document the 67 percent decline in the number of small and very small AFOs across the country, with the greatest decline in the Midwest, particularly in Iowa, Wisconsin, and Minnesota. The decline in farms is greatest in the 1982-1997 period shown in panel d. The decline rate slowed over the 1997-2007 period, shown in panel e. (Increases and decreases in farm numbers also reflect changes in a farm status shifting from a medium to small classification or *visa-versa*.) There is one notable increase in small and very small AFOs in Northwest New Mexico and Northern Arizona largely attributable to the manner that the Agricultural Census collected and classified data from Native American operators (panels e and f). The increase in the number of farms with AFOs likely reflects farms that have been present for some time but were individually recognized in the 2007 Census of Agriculture.

Figure 1. Percent of farms by farm types for 1982, 1997, and 2007



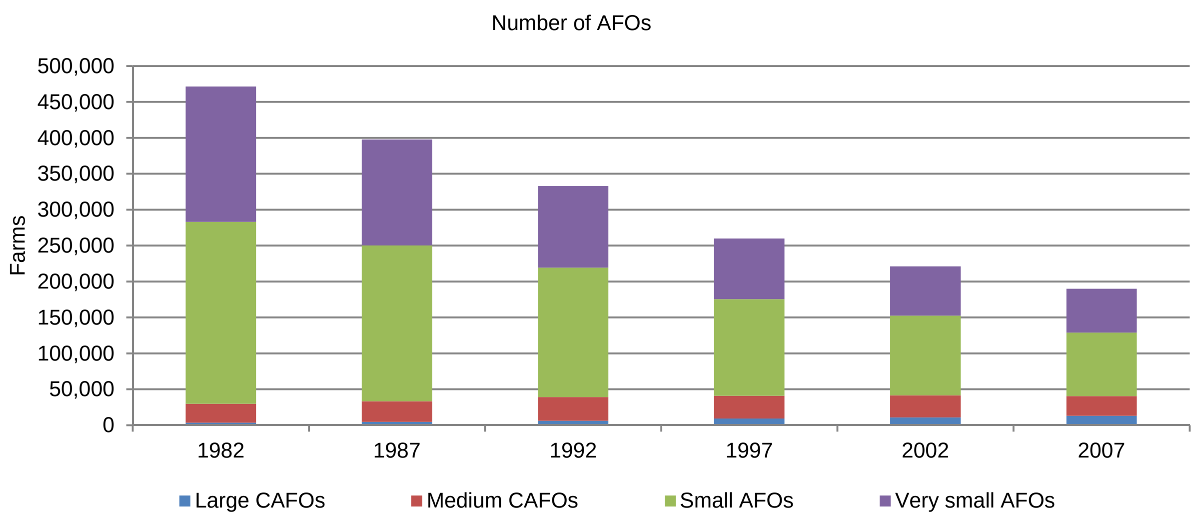
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

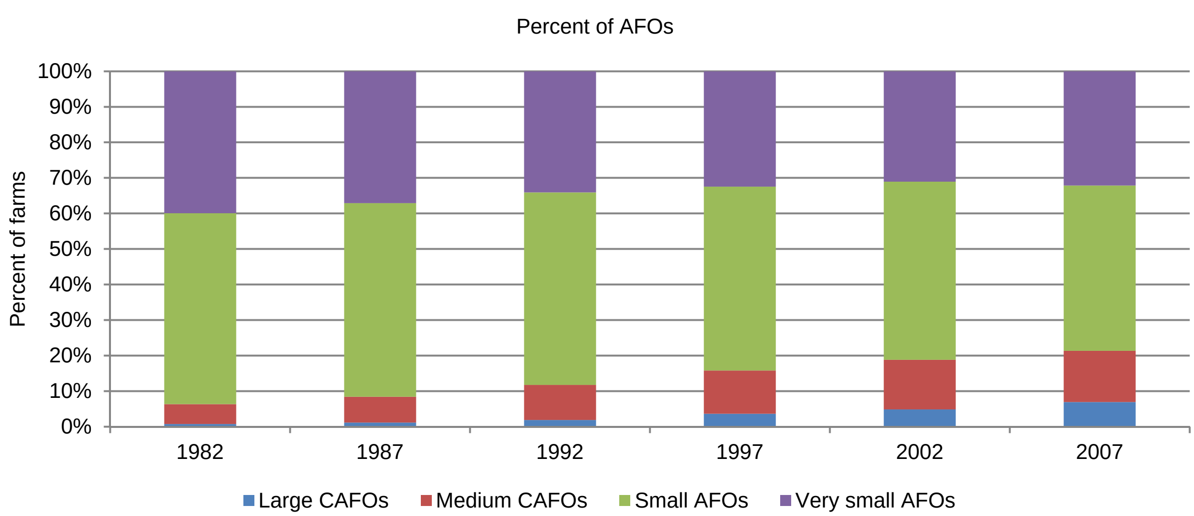
Figure 2. Number of farms for non-AFOs, excluding farms without livestock



Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

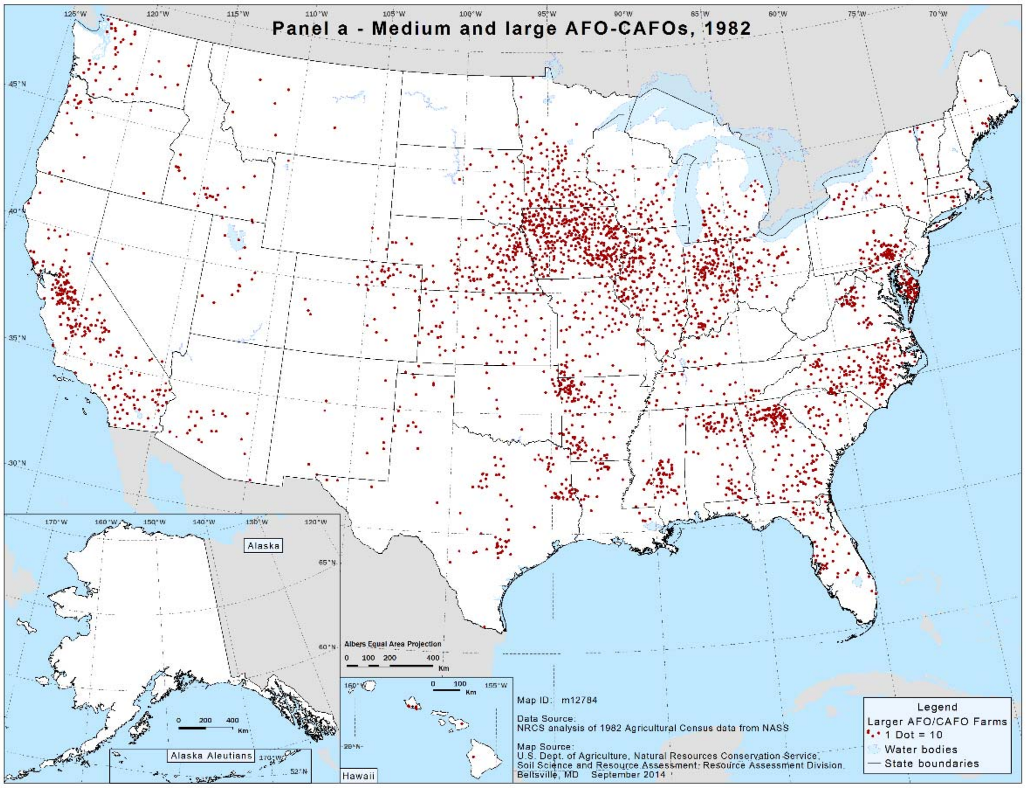
Figure 3. Number and percent of AFOs by farm type



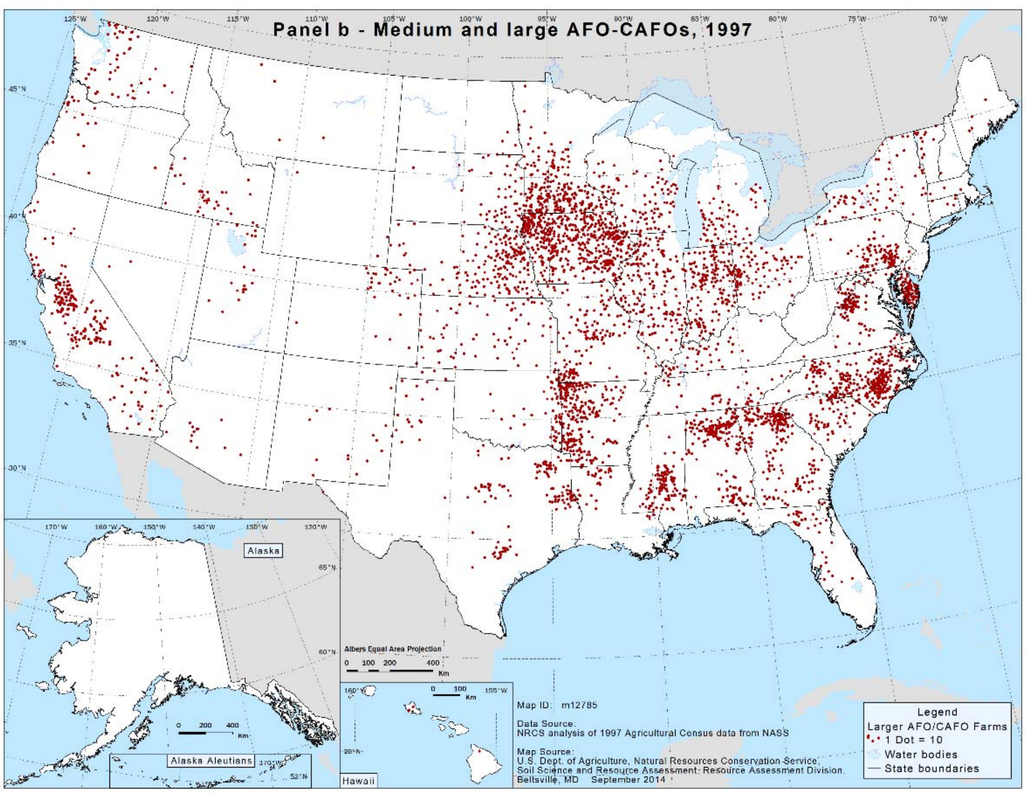


Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases

Map 1. County location of potential medium and large AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential medium and large AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007

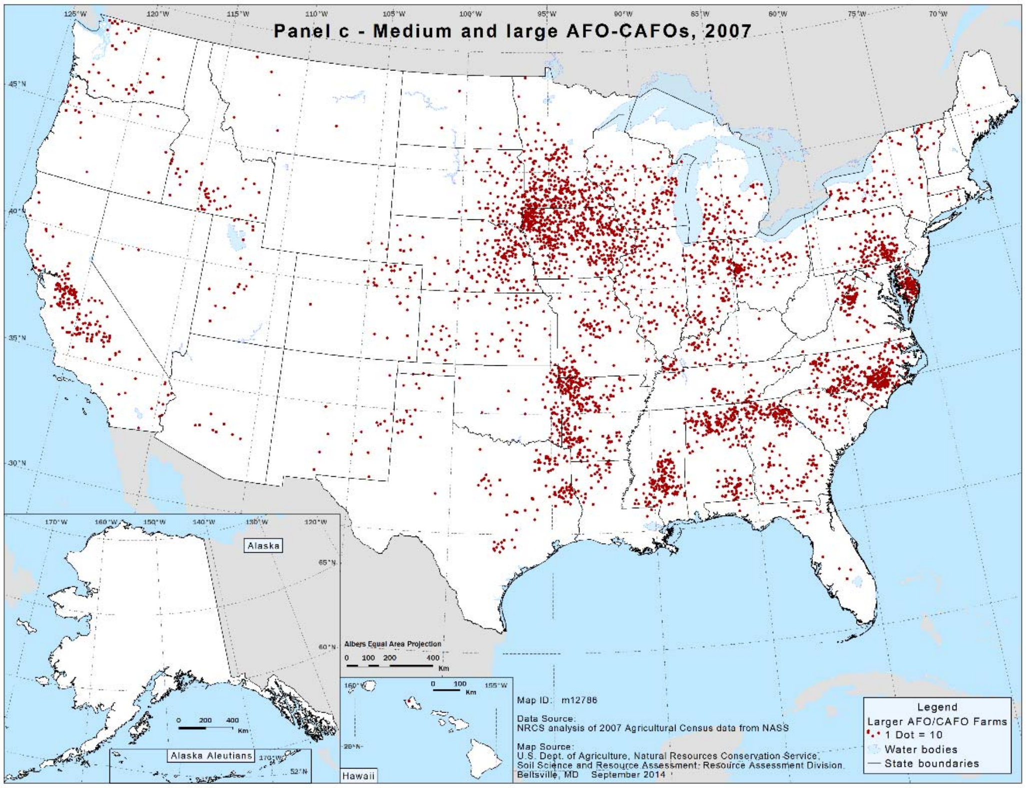


Legend: Dot = 10 farms
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

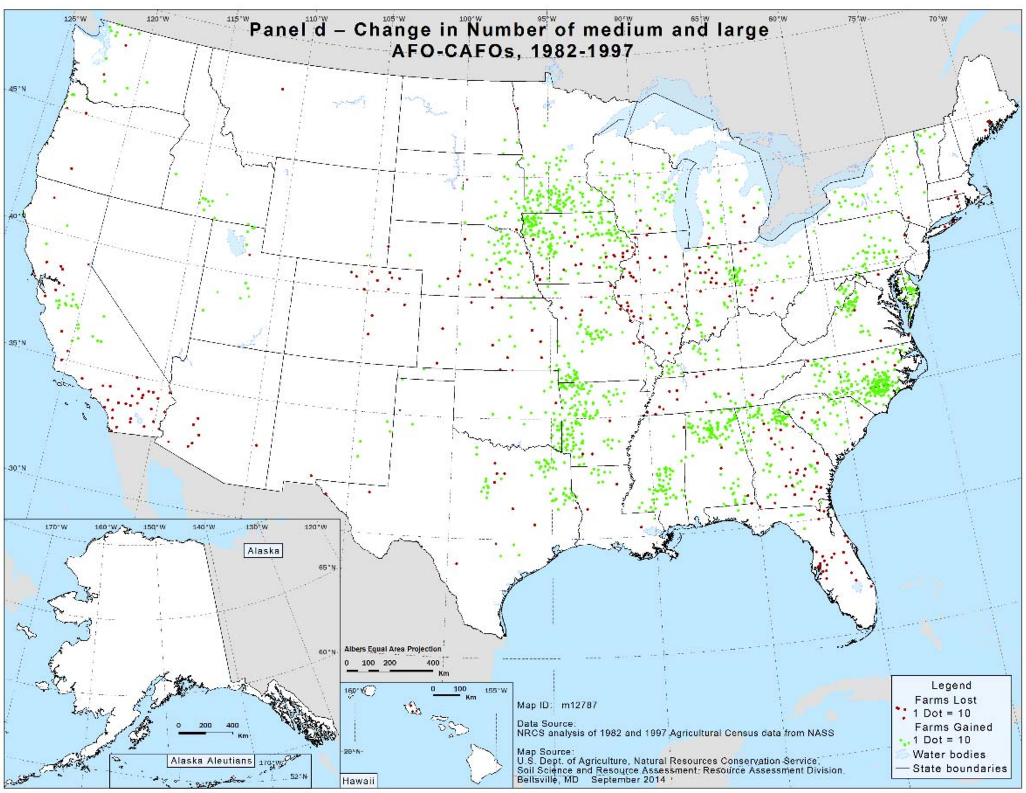


Legend: Dot = 10 farms
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 1. County location of potential medium and large AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential medium and large AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

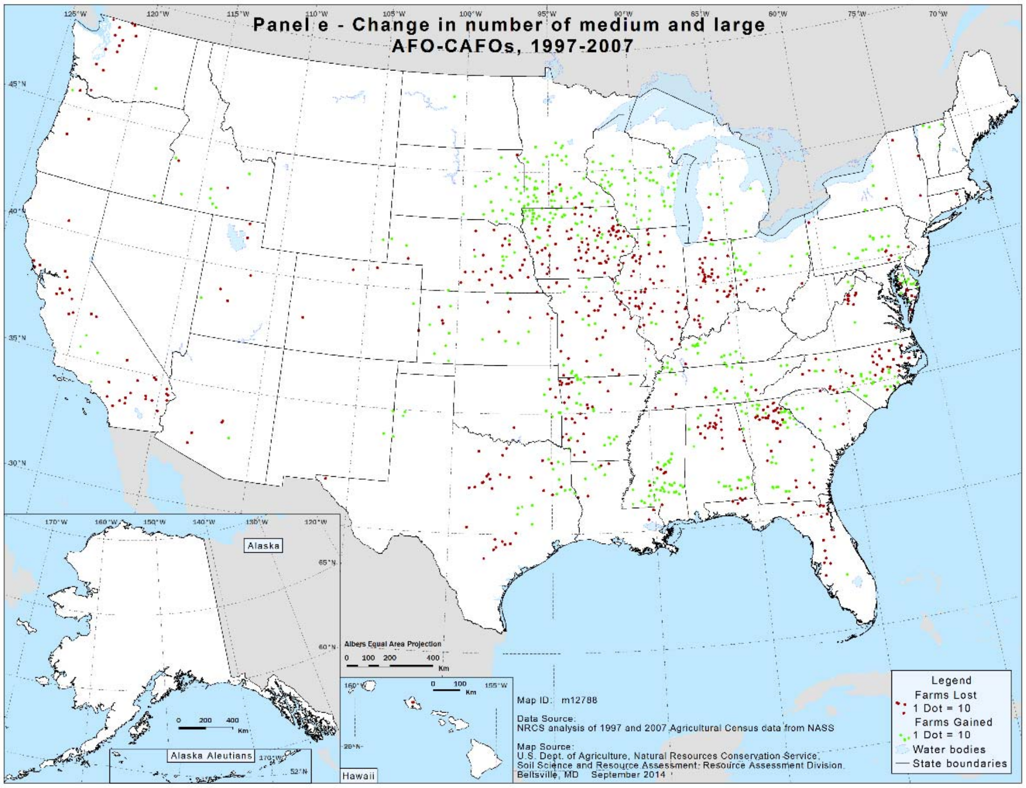


Legend: Dot = 10 farms
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

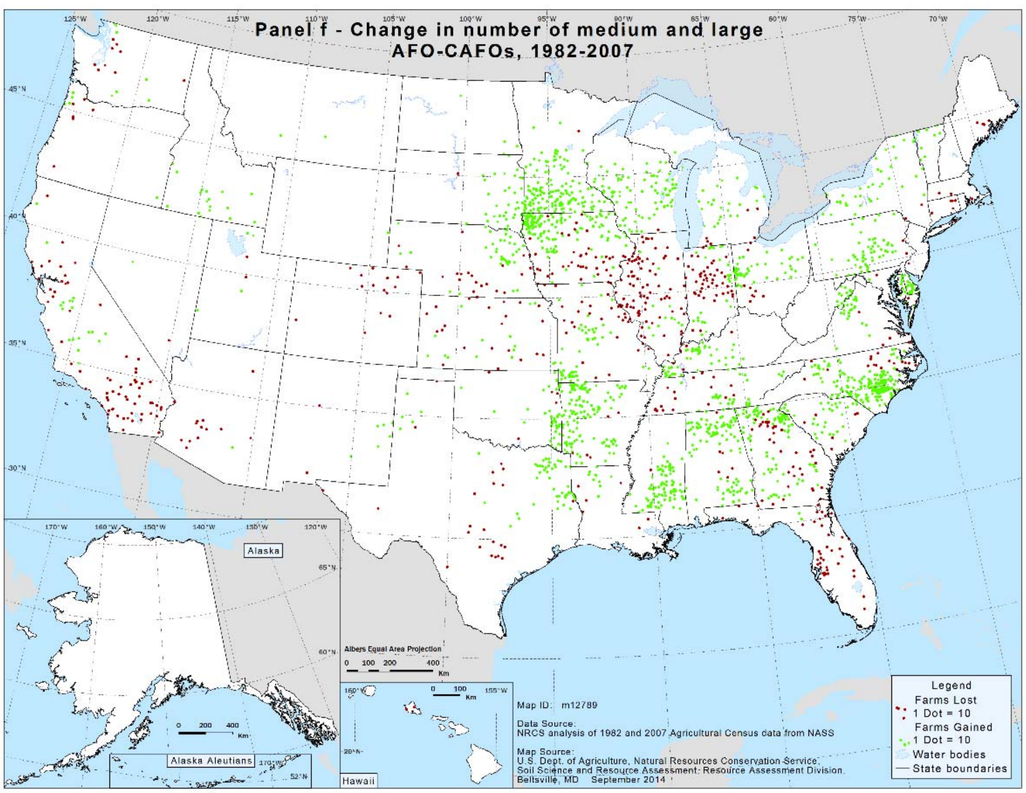


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 1. County location of potential medium and large AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential medium and large AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

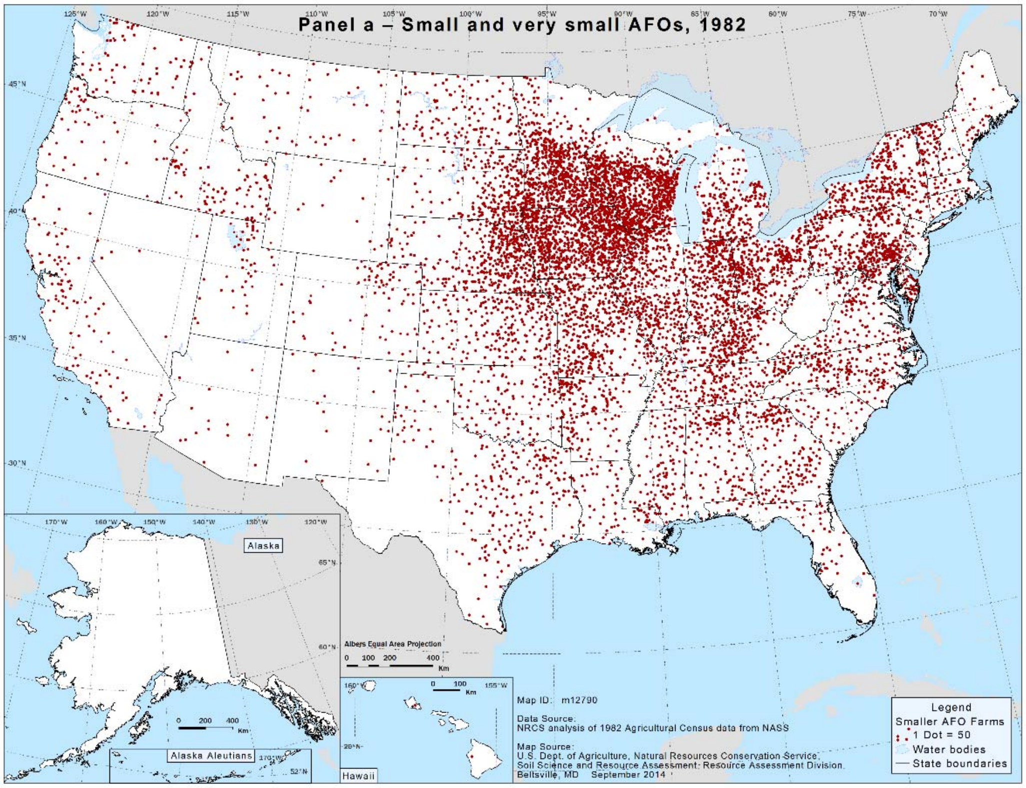


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS

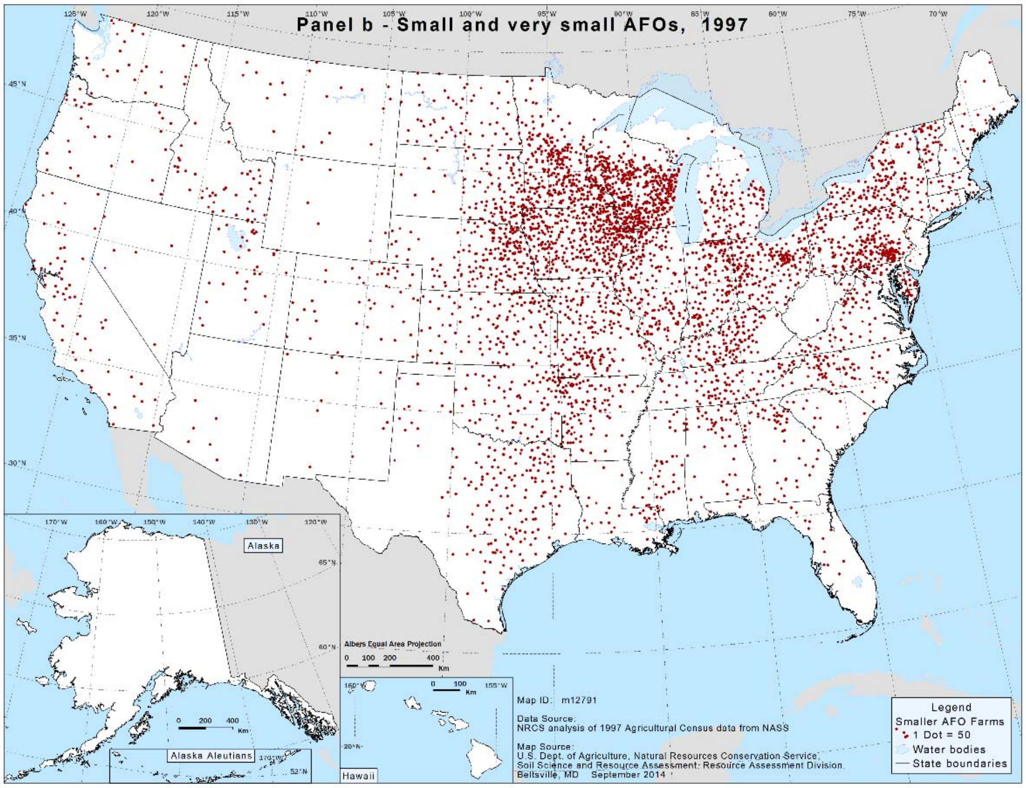


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Map 2. County location of potential small and very small AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential small and very small AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007

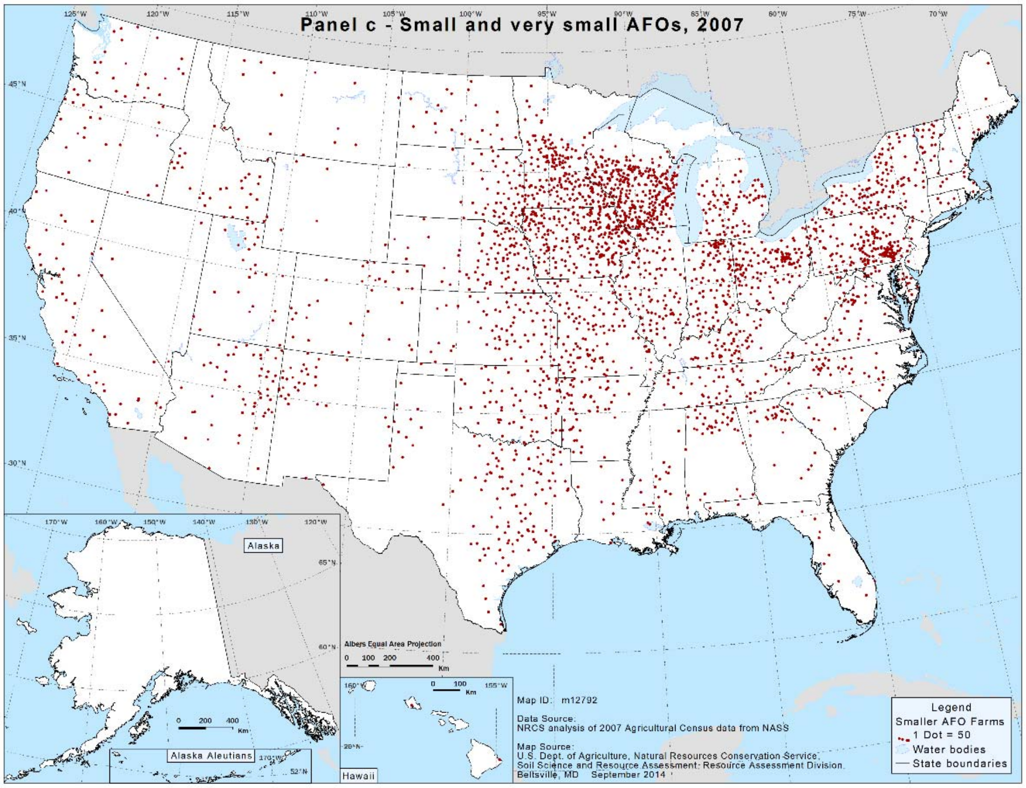


Legend: Dot = 50 farms
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

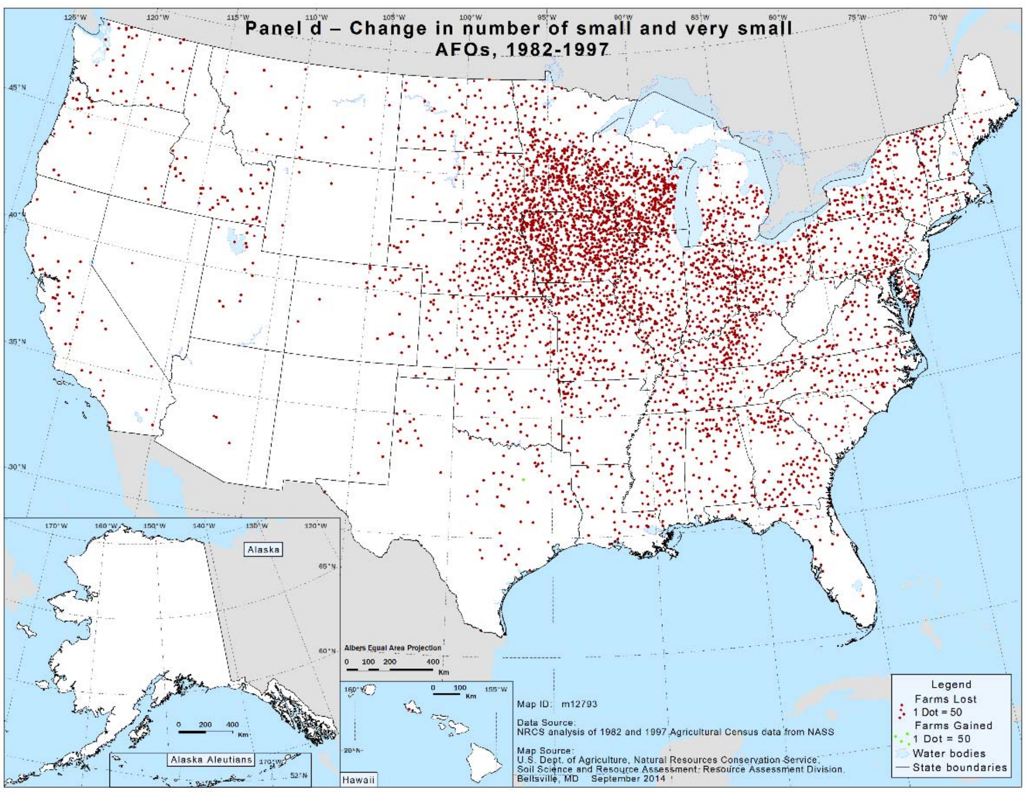


Legend: Dot = 50 farms
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 2. County location of potential small and very small AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential small and very small AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

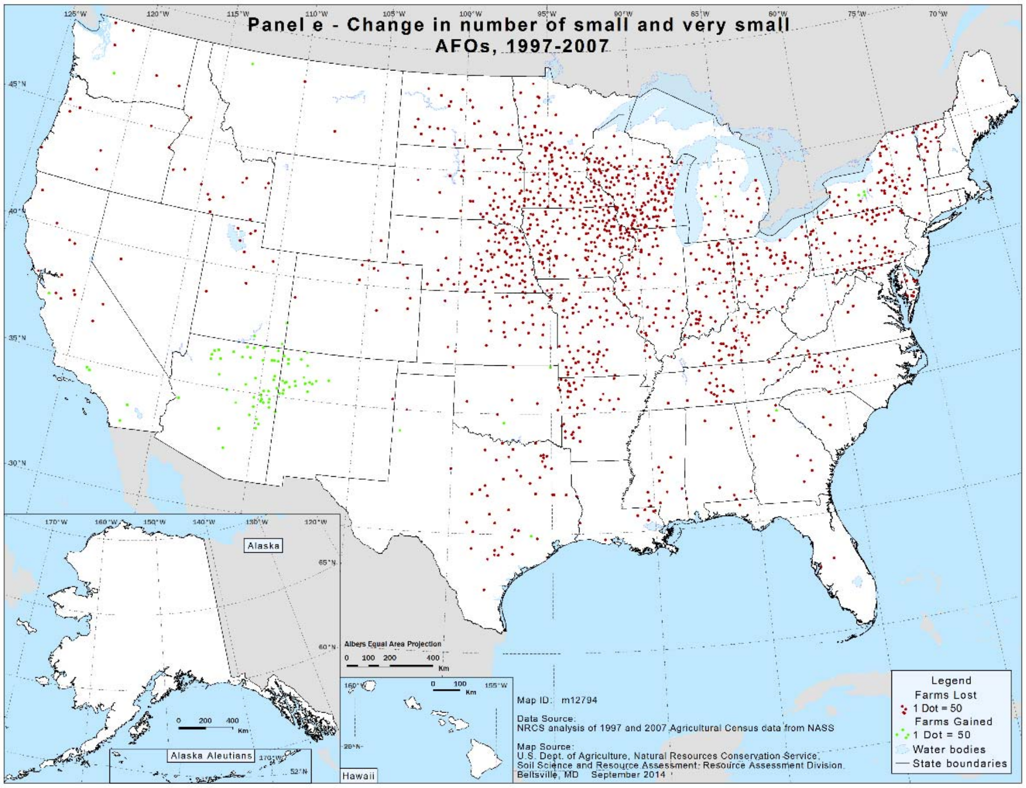


Legend: Dot = 50 farms
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

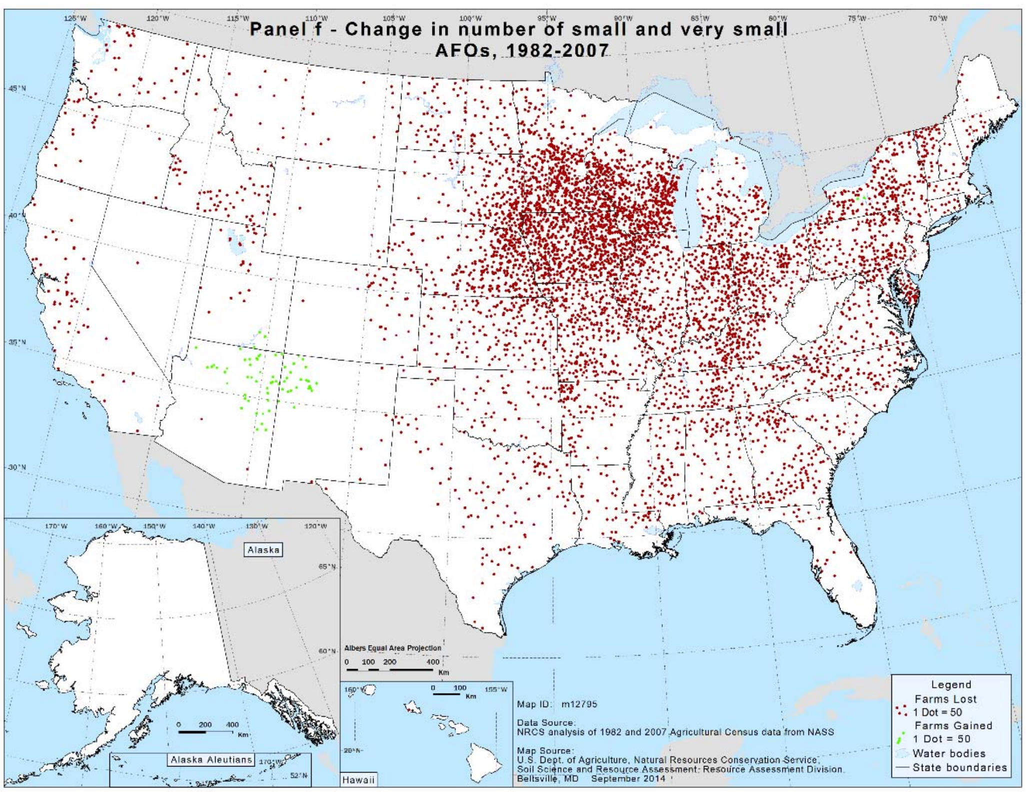


Legend: Green dot = 50 farm gain and red dot = 50 farm loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 2. County location of potential small and very small AFO-CAFOs for 1982, 1997, and 2007 and change in the county location of potential small and very small AFO-CAFOs for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 50 farm gain and red dot = 50 farm loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



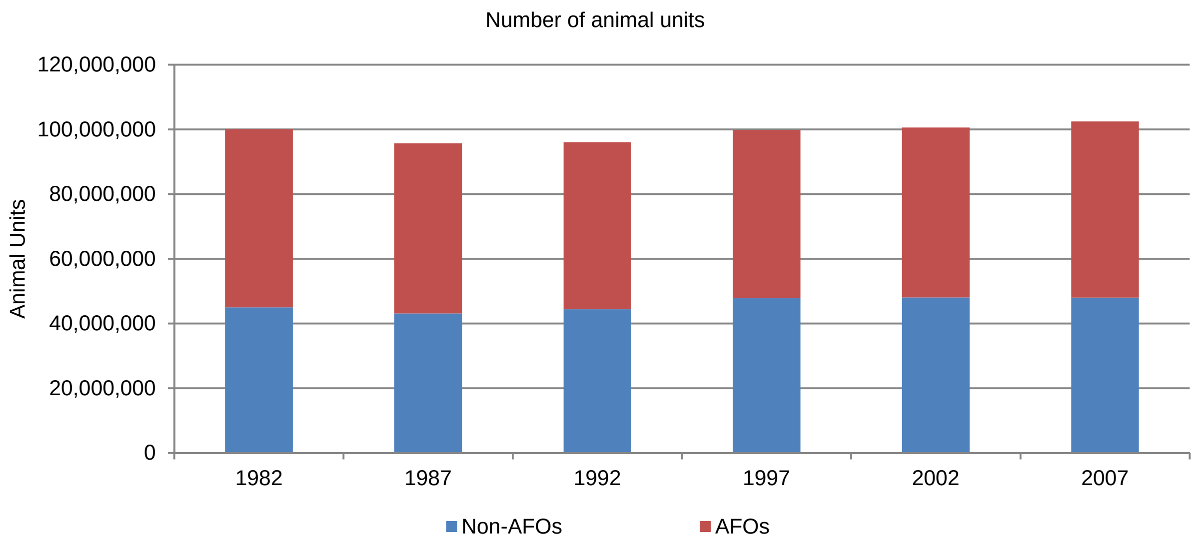
Legend: Green dot = 50 farm gain and red dot = 50 farm loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

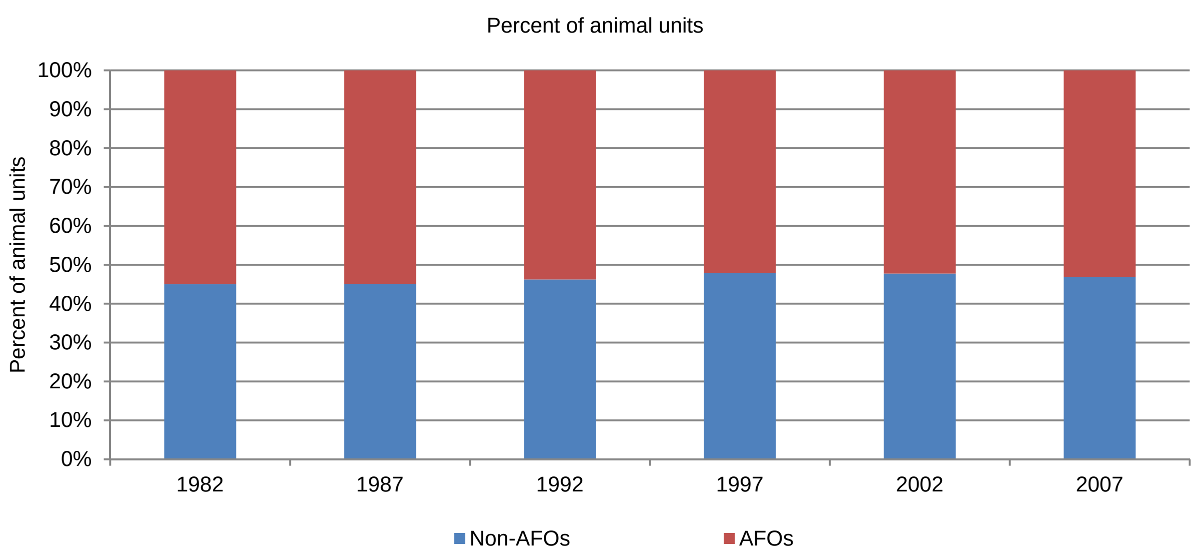
Even though the number of farms by farm type has shifted over time, the total number of animal units has remained relatively constant, ranging from a low of 96 million in 1987 to a high of 102 million in 2007 (fig. 4). The percent change over the 25 years was about 2 percent. About 53 percent of all annual AUs were on farms designated as AFOs and 47 percent on non-AFOs in 2007 (table 4).

There are slightly more pastured livestock types than confined livestock types in all years, but the difference narrowed in 2007 to about 4 million AU (fig. 5). In 2007 there were 53 million pastured livestock types and 49 million confined livestock types, including partially or wholly confined pastured livestock types (table 4).

AFOs had the bulk of the confined livestock types, increasing in numbers by 15 percent over the 25-year period. Non-AFOs had a few confined livestock types in the early years, but populations decreased 57 percent between 1982 and 2007. Pastured livestock types on non-AFOs increased 8 percent over the 25 years, while pastured livestock types on AFOs fell 53 percent.

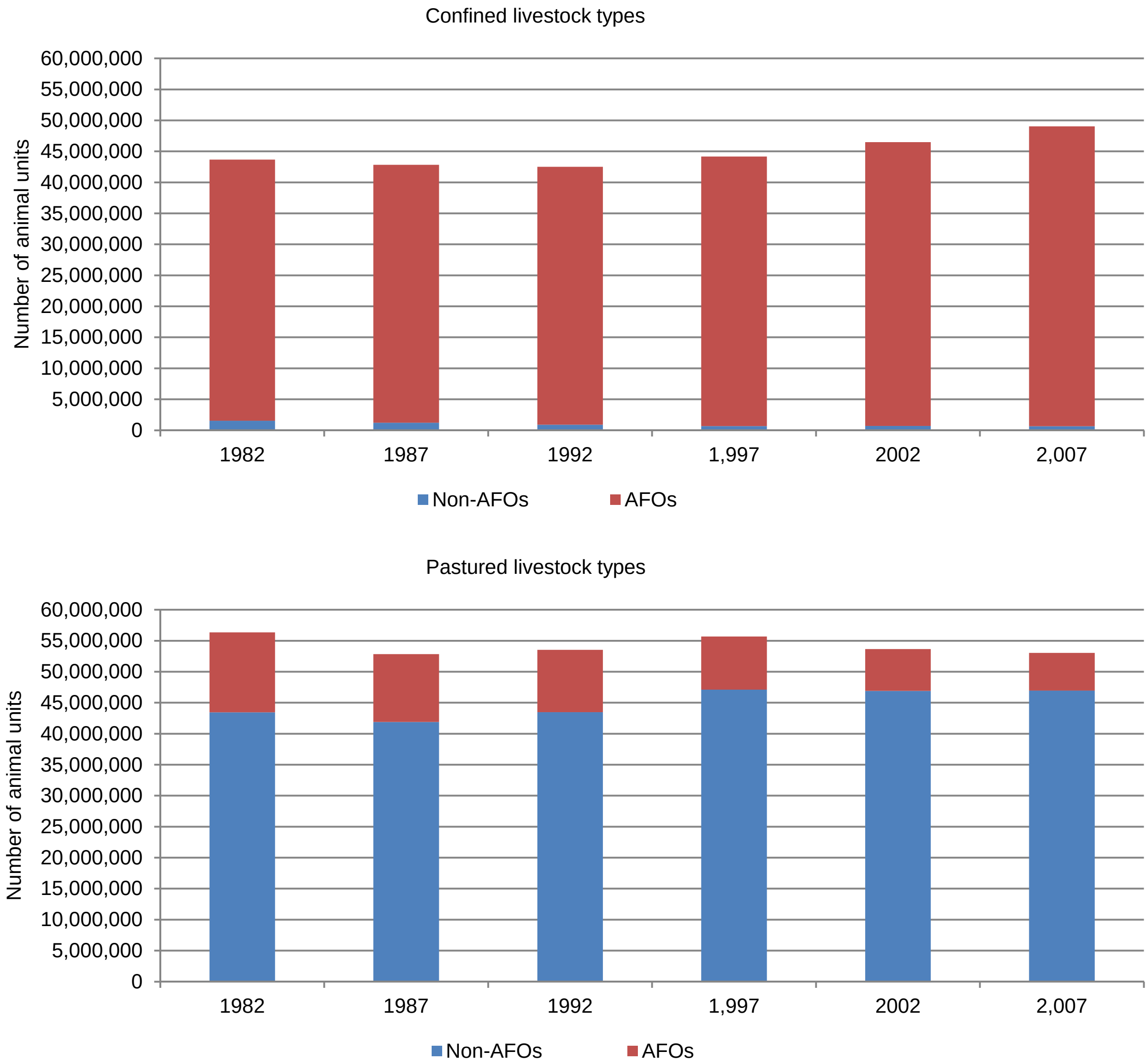
Figure 4. Number and percent of animal units on AFOs and non-AFOs





Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 5. Number of animal units for confined and pastured livestock types*

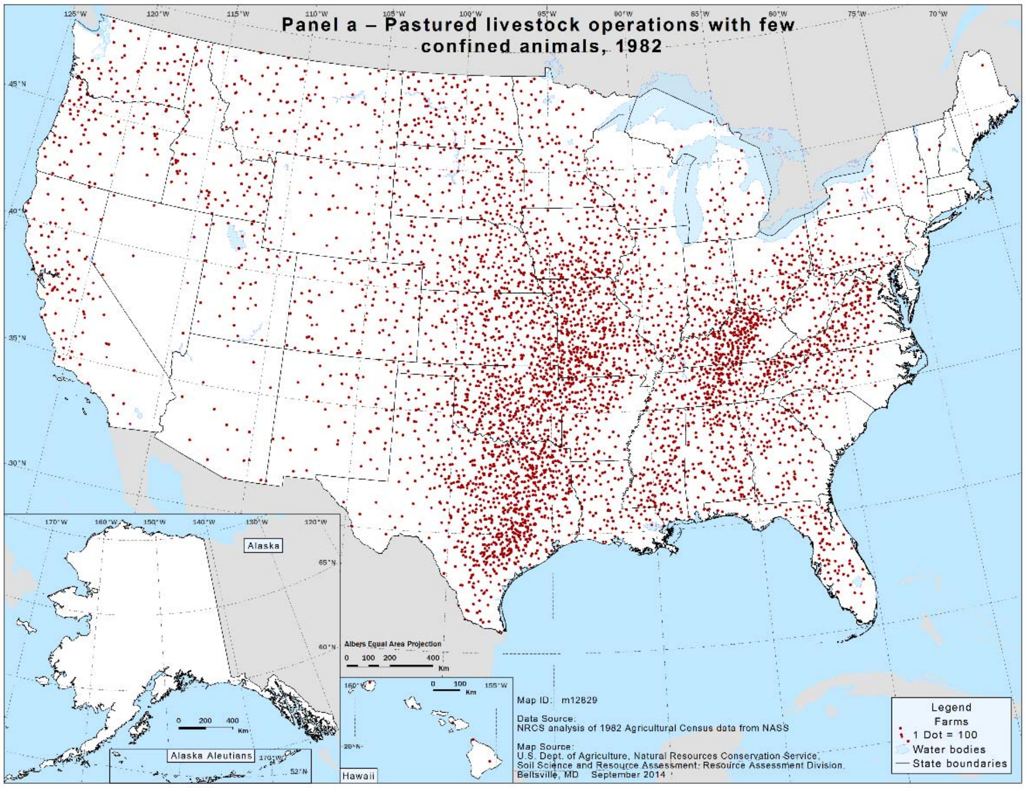


* Excludes AU for specialty livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

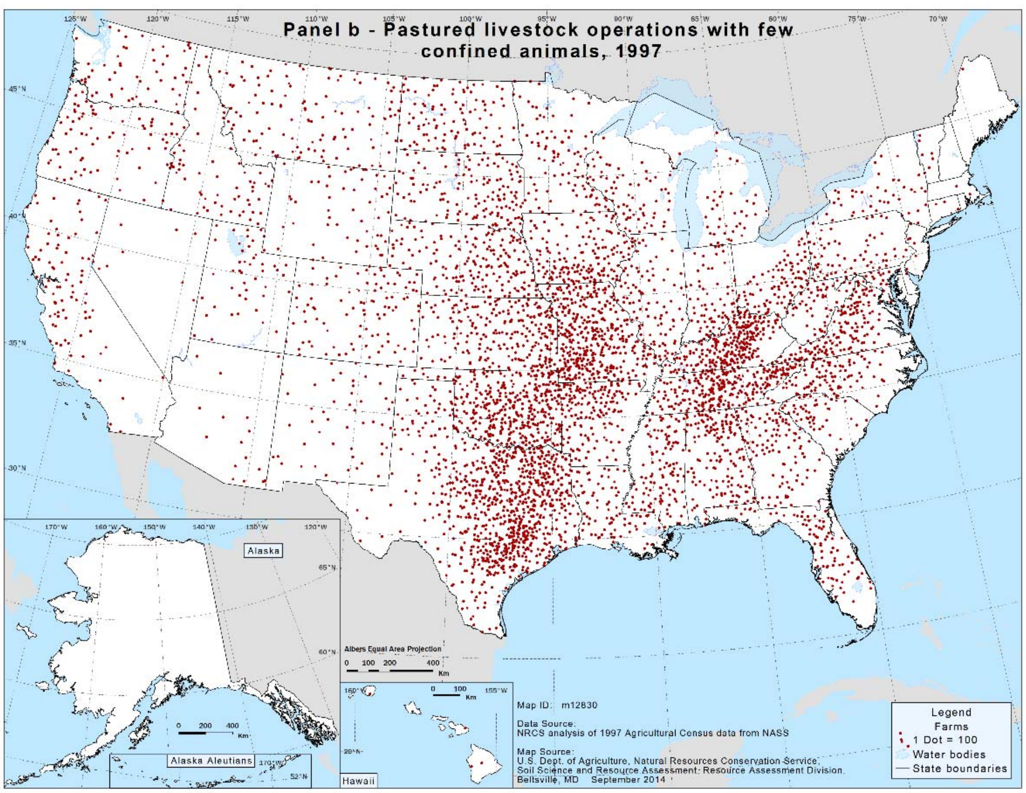
Map 3 presents the distribution of and change in the location of farms and ranches with pastured animals and few confined animals. Pastured animal operations were widely distributed across the Nation in 2007 (panel c) and have been over the study period (panel a, panel b). There are two broad areas with higher concentration of pastured animal operations; one band stretching from southern Iowa, through Missouri, Oklahoma, and East Texas and another band from northern Alabama through Tennessee and Kentucky.

Panels d to f illustrate the change in the location of operations and show little trend with a mix of declines and gains in operation numbers. Declines occurred in the West (except East Texas), Iowa, Illinois, Indiana, Mississippi, and Alabama. Increases occurred in East Texas and a region from Oklahoma eastward through Kentucky and Tennessee.

Map 3. County location of pastured livestock operations with few confined animals for 1982, 1997, and 2007 and change in the county location of pastured livestock operations with few confined animals for periods 1982-1997, 1997-2007, and 1982-2007

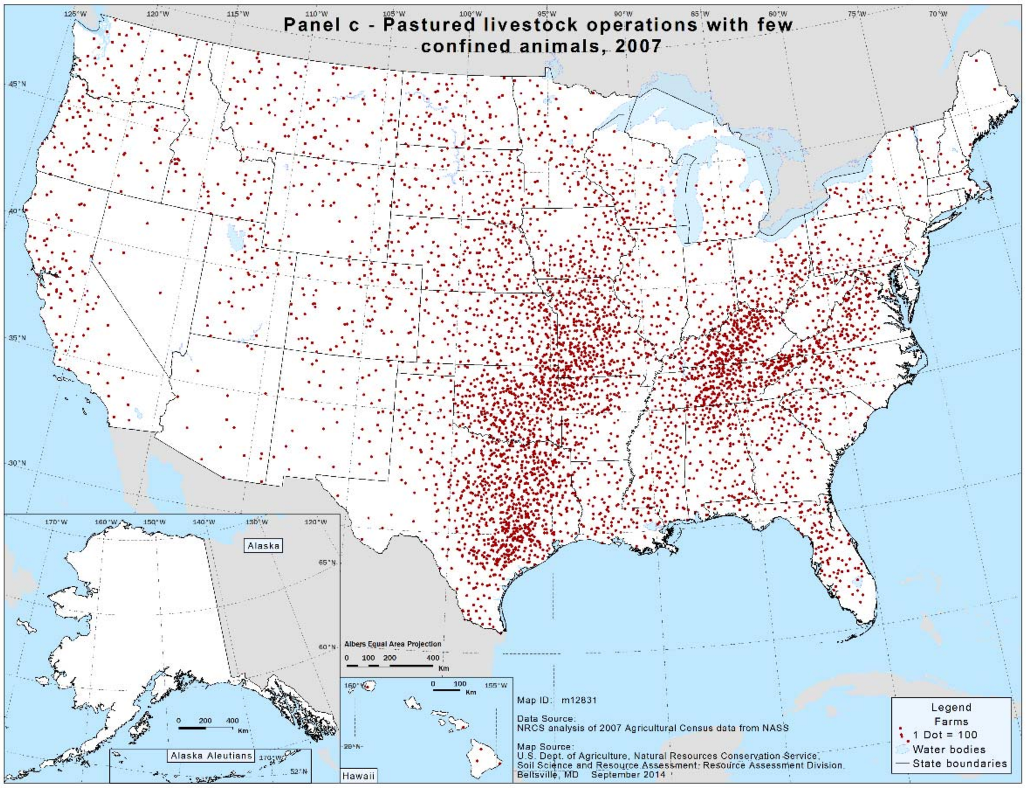


Legend: Dot = 100 farms
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

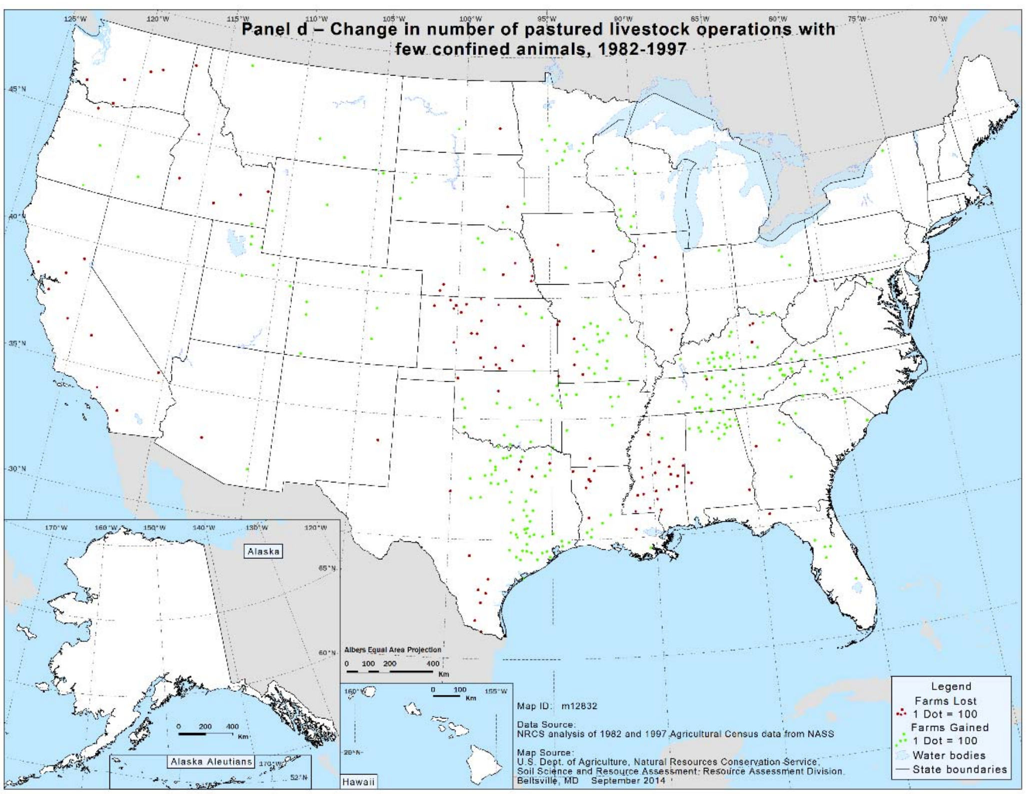


Legend: Dot = 100 farms
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 3. County location of pastured livestock operations with few confined animals for 1982, 1997, and 2007 and change in the county location of pastured livestock operations with few confined animals for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

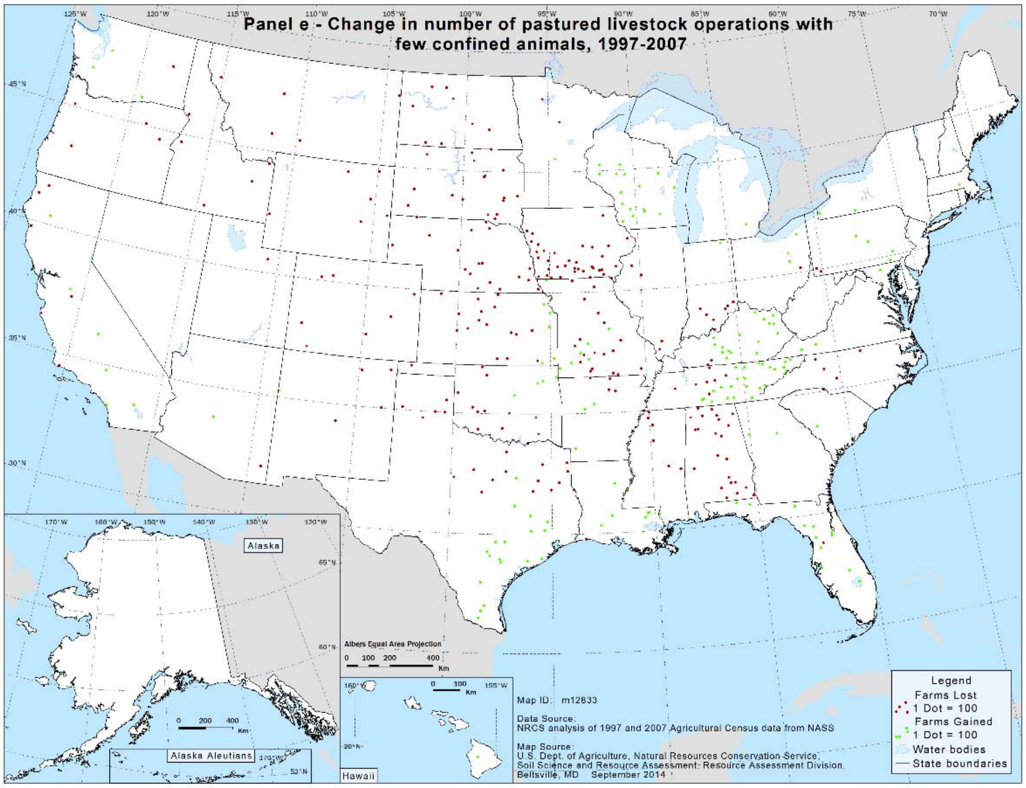


Legend: Dot = 100 farms
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

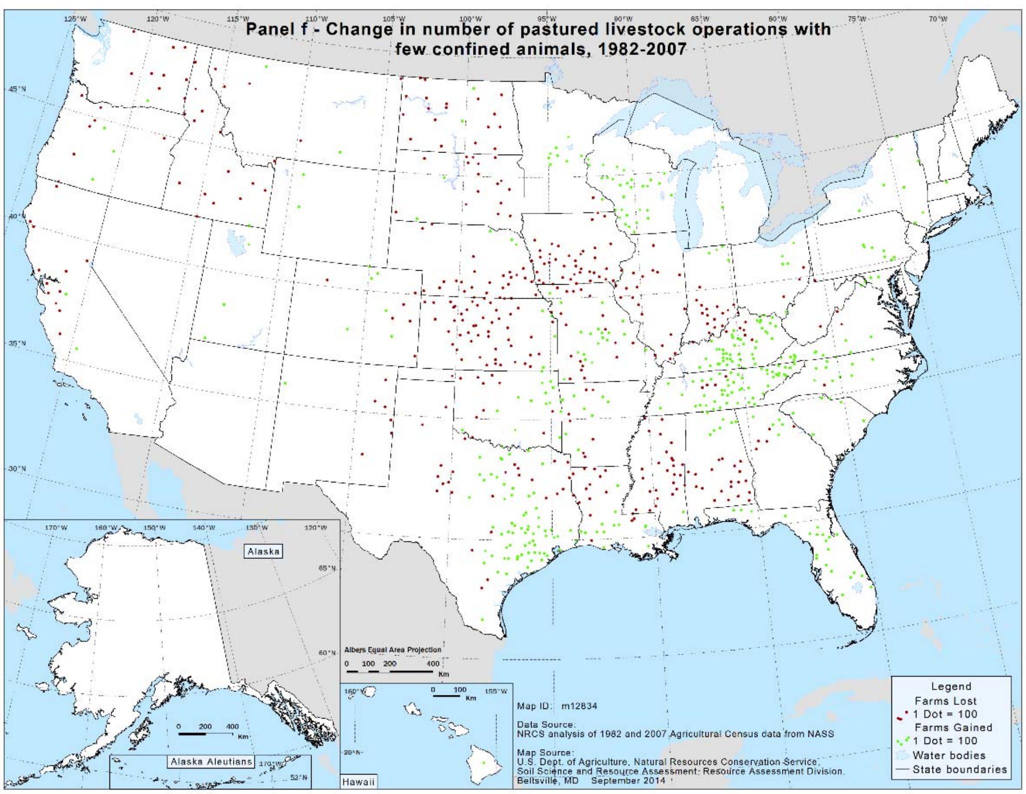


Legend: Green dot = 100 farm gain and red dot = 100 farm loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 3. County location of pastured livestock operations with few confined animals for 1982, 1997, and 2007 and change in the county location of pastured livestock operations with few confined animals for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 100 farm gain and red dot = 100 farm loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



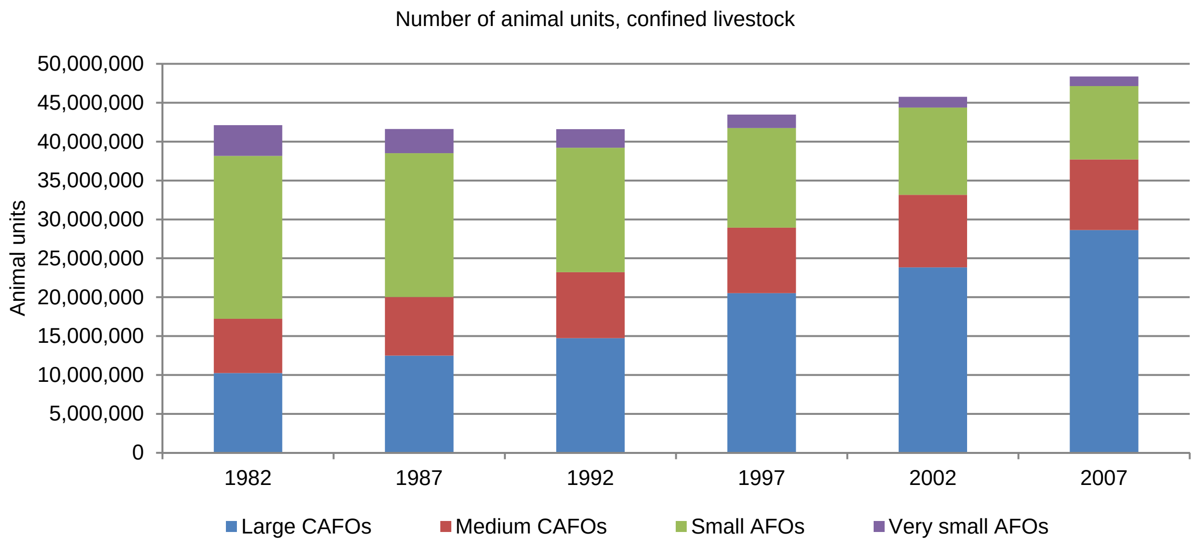
Legend: Green dot = 100 farm gain and red dot = 100 farm loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

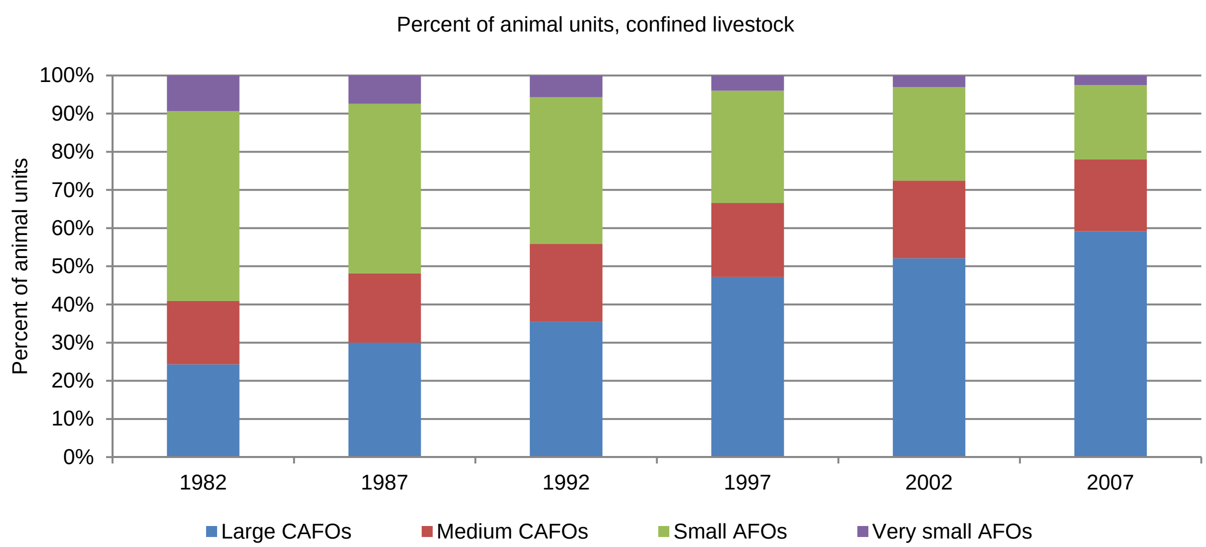
While the number of AFO farms has been steadily decreasing over time, the total number of animal units on AFOs has remained about the same (fig. 5). The total number of AUs on AFOs in 1982 was 55 million and the total in 2007 was 54 million.

The number of confined livestock on AFOs in 1982 was 42 million AU, compared to 48 million AU in 2007. The proportion of confined animal units on the large potential AFO-CAFOs increased dramatically as the number of large AFO-CAFOs increased. In 1982, 24 percent of the confined livestock AUs on AFOs were on the large AFO-CAFO farms (3,658 farms). In 2007, 59 percent of the confined livestock AUs on AFOs were on the large AFO-CAFOs (13,152 farms) (fig. 6). AUs on the small and very small AFOs decreased over time as the number of small and very small AFOs decreased.

The composition of AU by livestock type changed significantly over this time period, as shown in figure 7. Over these 25 years, poultry AU on AFOs increased 91 percent, swine AU increased 48 percent, and fattened cattle (including veal) AU increased 37 percent. The number of milk cow and confined pastured livestock types decreased by 14 percent and 31 percent, respectively. In 2007, fattened cattle and milk cows each represented about one-fourth of the confined livestock; swine represented 21 percent; poultry (chickens, turkeys, and ducks) represented 16 percent; and confined pastured livestock types represented 10 percent (fig. 7).

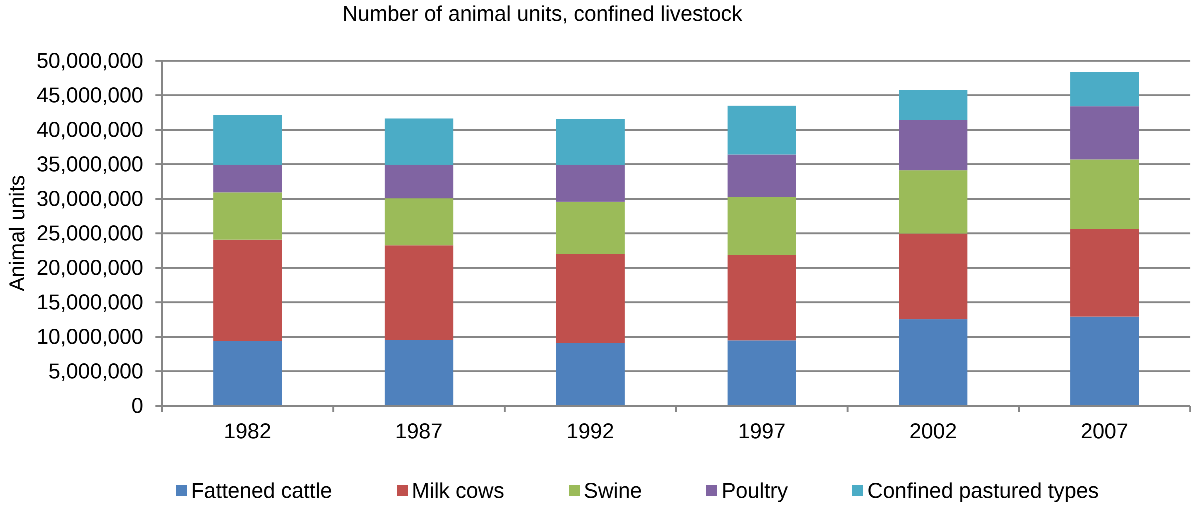
Figure 6. Number of animal units for confined livestock on AFOs*, by AFO farm type

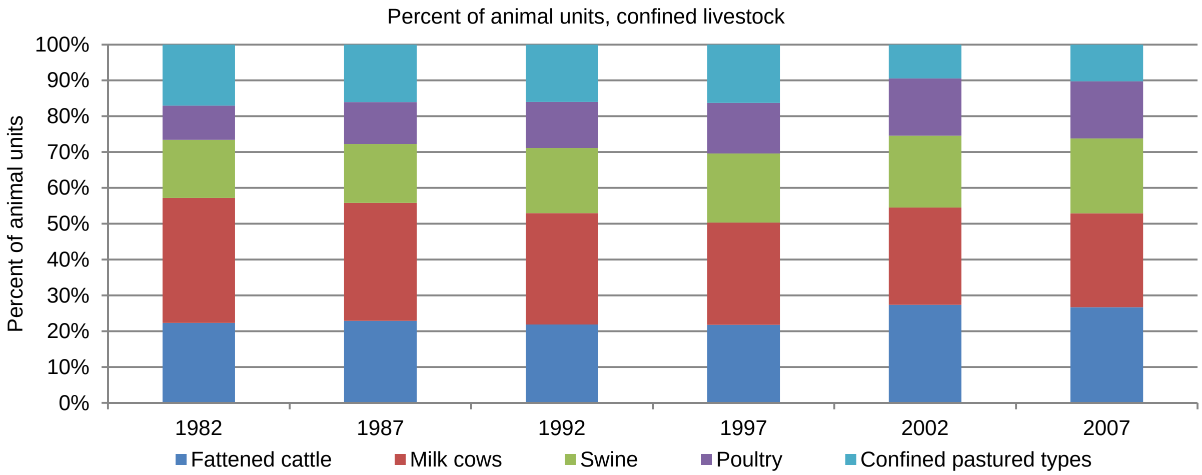




* Includes partially or wholly confined pastured livestock types
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases

Figure 7. Number of confined livestock on AFOs*, by livestock group



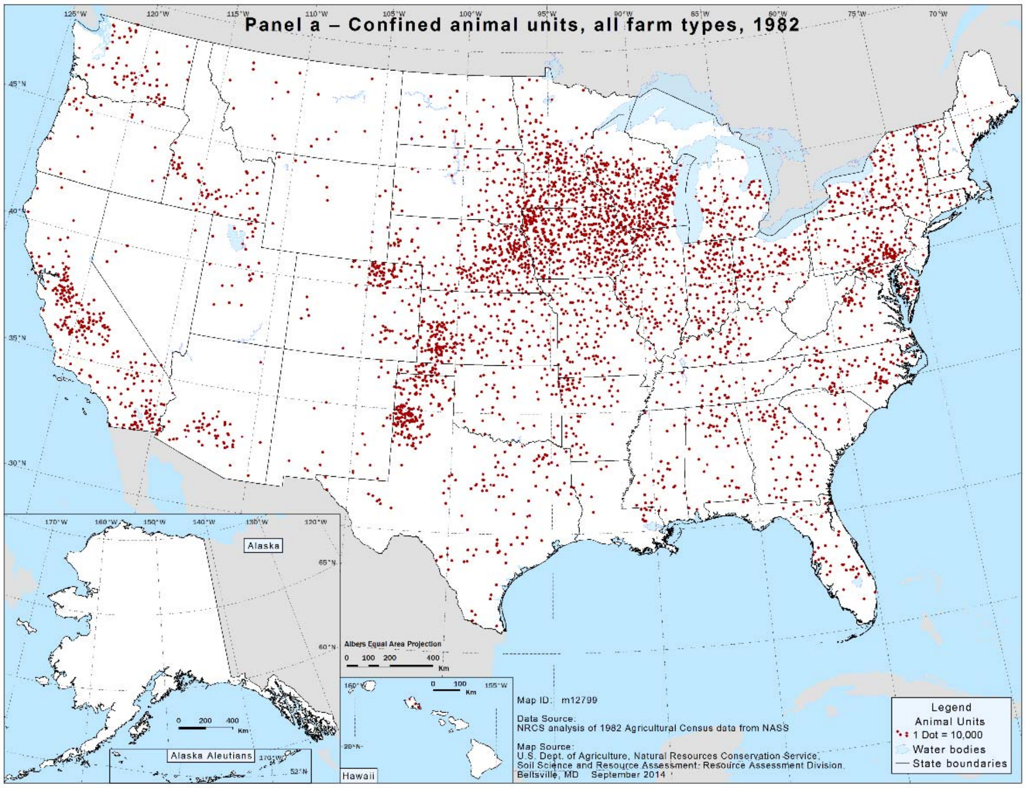


* Includes partially or wholly confined pastured livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

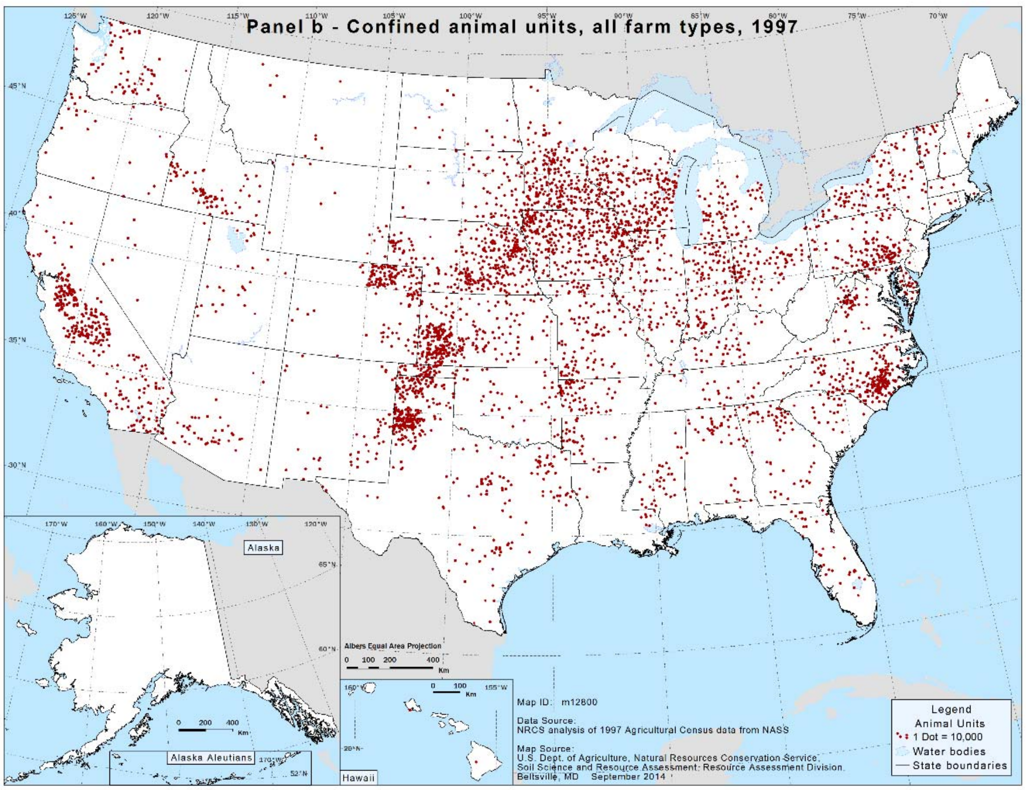
Map 4 presents the distribution and change in the location of confined animal units. The major trend observed in the distribution panels (a-c) is an increasing concentration of confined AU into tighter geographic clusters, especially from 1982 to 1997. In 2007 (panel c), confined AU are concentrated in California, North Carolina, states around the Chesapeake Bay, and in a band from the Texas Panhandle through western Kansas, Nebraska, Iowa into southern Minnesota and across Wisconsin. Panel f illustrates the change between 1982 and 2007 show increases in the number of confined animal units in central California, southern Idaho, western Arkansas, North Carolina, states around the Chesapeake Bay, and in a band from the Texas Panhandle through western Kansas, Nebraska, Iowa, and into southern Minnesota. Declines in the number of confined animal units occurred in southern California, New York, and from central Minnesota across Wisconsin. Most of the gains in North Carolina, Arkansas, Texas panhandle, western Kansas, and Nebraska occurred from 1982 to 1997, along with declines in Iowa, Wisconsin and central Minnesota. Gains over period from 1997 to 2007 (panel e) were significant in Iowa and southern Minnesota. Gains in Central California, southern Idaho, and North Carolina occurred in both periods (panels d, e, and f).

Map 5 presents the distribution and change in the location of pastured animal units. The location of pastured animals shows where the manure nutrients from non-confined animals would be most concentrated. There is a wide distribution of pastured AU across the nation exhibiting less concentration than farm numbers in map 3. Areas with relatively fewer farms in map 3 but higher concentrations of pastured AU indicate greater AU per operation. In general, the population of pastured livestock has not changed much over the 1982 to 2007 time period. There was a decline in the number of pastured AU (panel f) in the West (except Oklahoma and East Texas) and the central Corn Belt (Iowa and adjoining areas in Illinois, Wisconsin and Minnesota). There were increases in the number of pastured animals in a band from East Texas, through Oklahoma, Missouri, Arkansas, Tennessee and Kentucky. Some areas of gain in the 1982 to 1997 period (Texas panhandle, western Kansas, and western Nebraska) shown in panel d, had losses in 1997 to 2007, with a net decline over the entire 1982 to 2007 period.

Map 4. County location of confined animal units (AU) on all farm types* for 1982, 1997, and 2007 and change in the county location of confined animal units for periods 1982-1997, 1997-2007, and 1982-2007

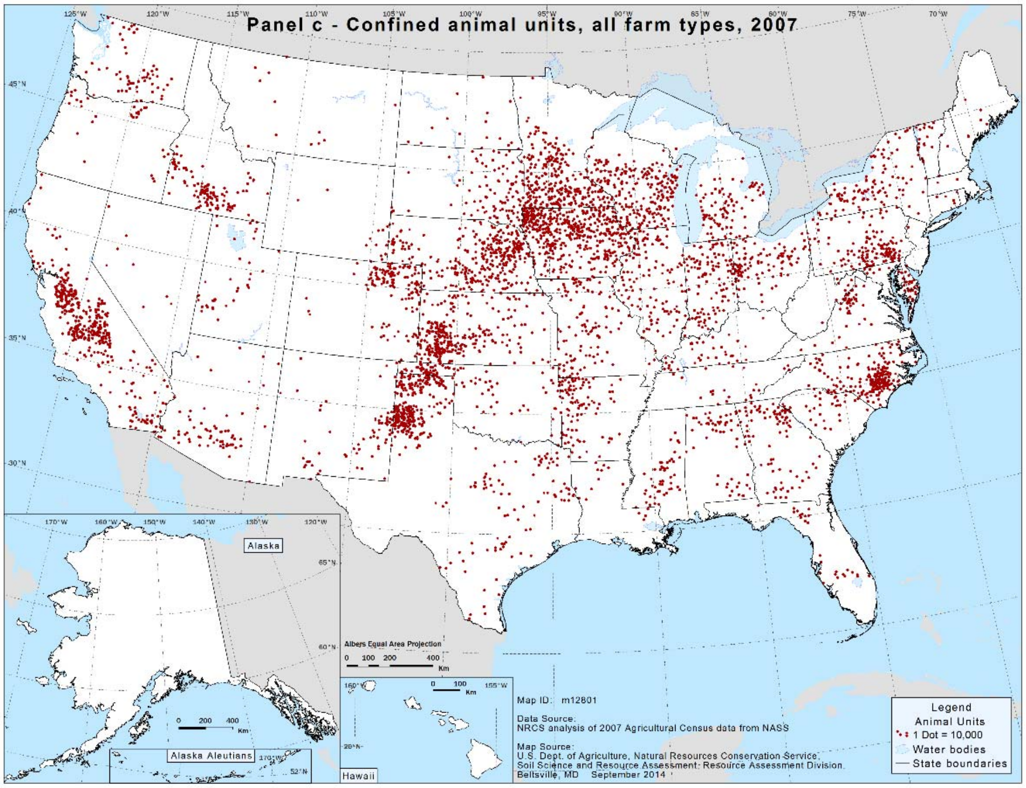


*Includes confined pastured livestock types
Legend: Dot = 10,000 AU
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

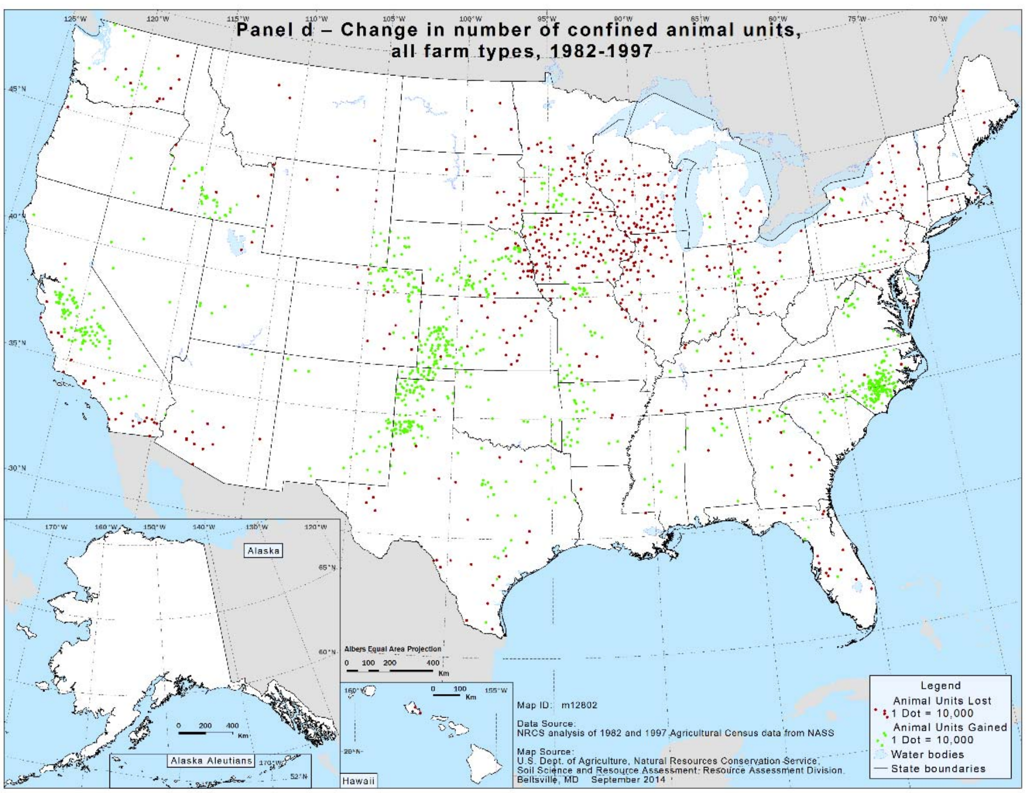


*Includes confined pastured livestock types
Legend: Dot = 10,000 AU
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 4. County location of confined animal units (AU) on all farm types* for 1982, 1997, and 2007 and change in the county location of confined animal units for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

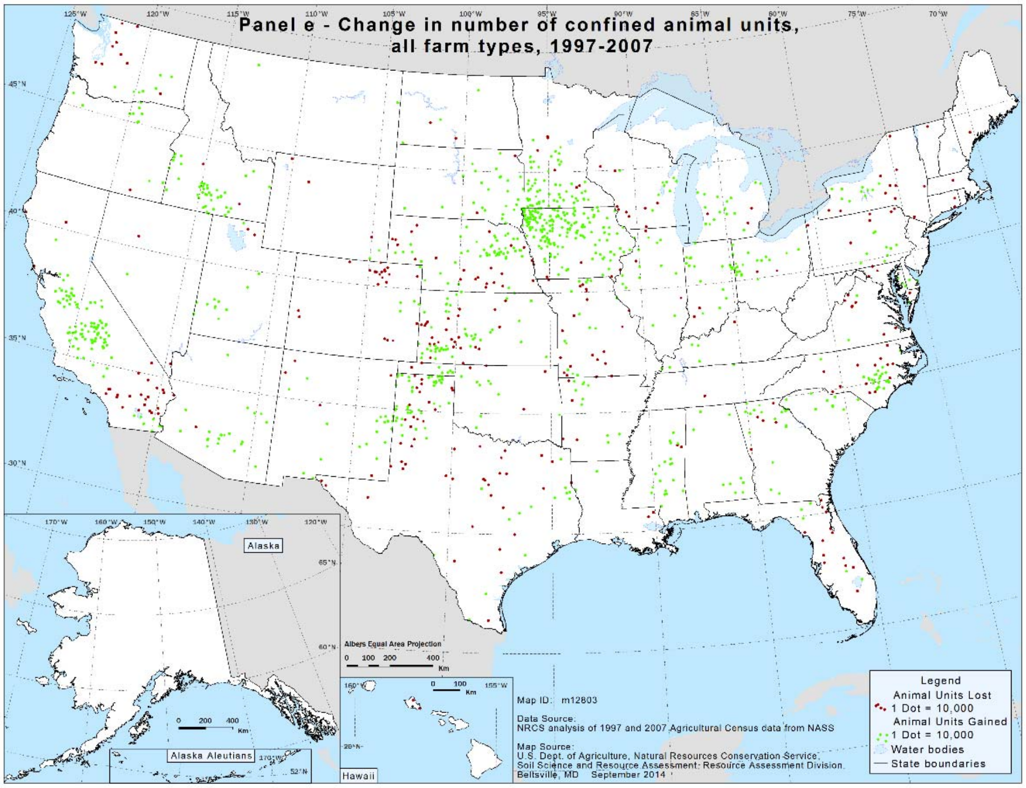


Includes confined pastured livestock types
Legend: Dot = 10,000 AU
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

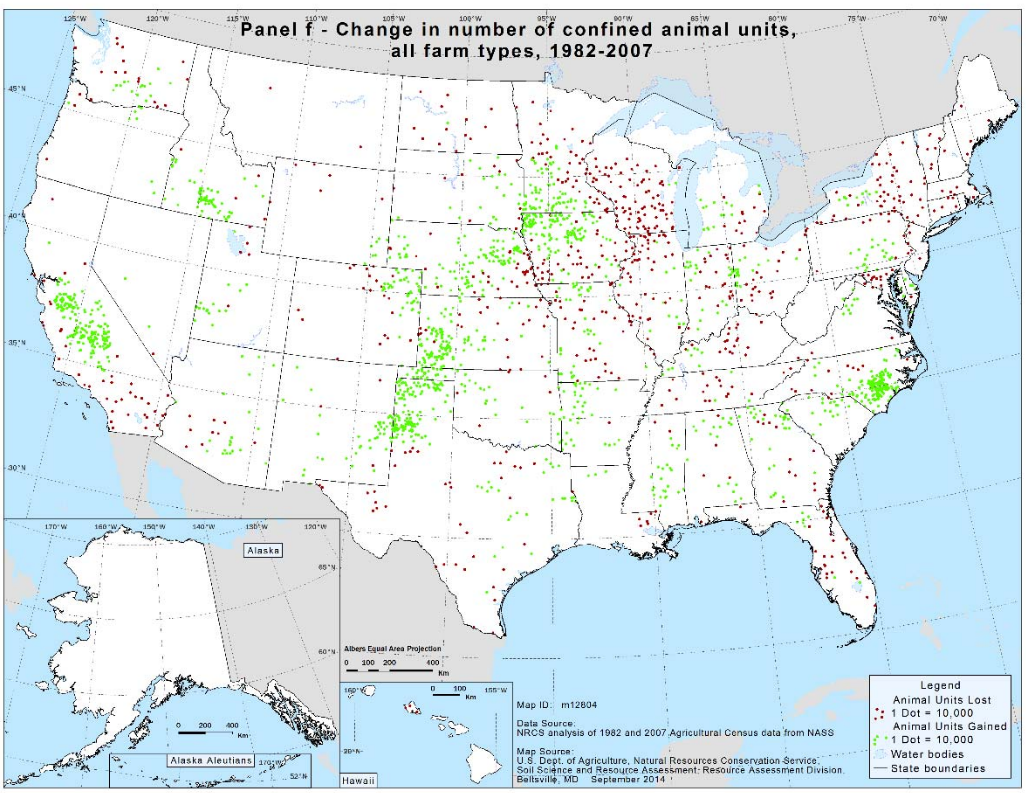


Includes confined pastured livestock types
Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 4. County location of confined animal units (AU) on all farm types* for 1982, 1997, and 2007 and change in the county location of confined animal units for periods 1982-1997, 1997-2007, and 1982-2007**—continued**

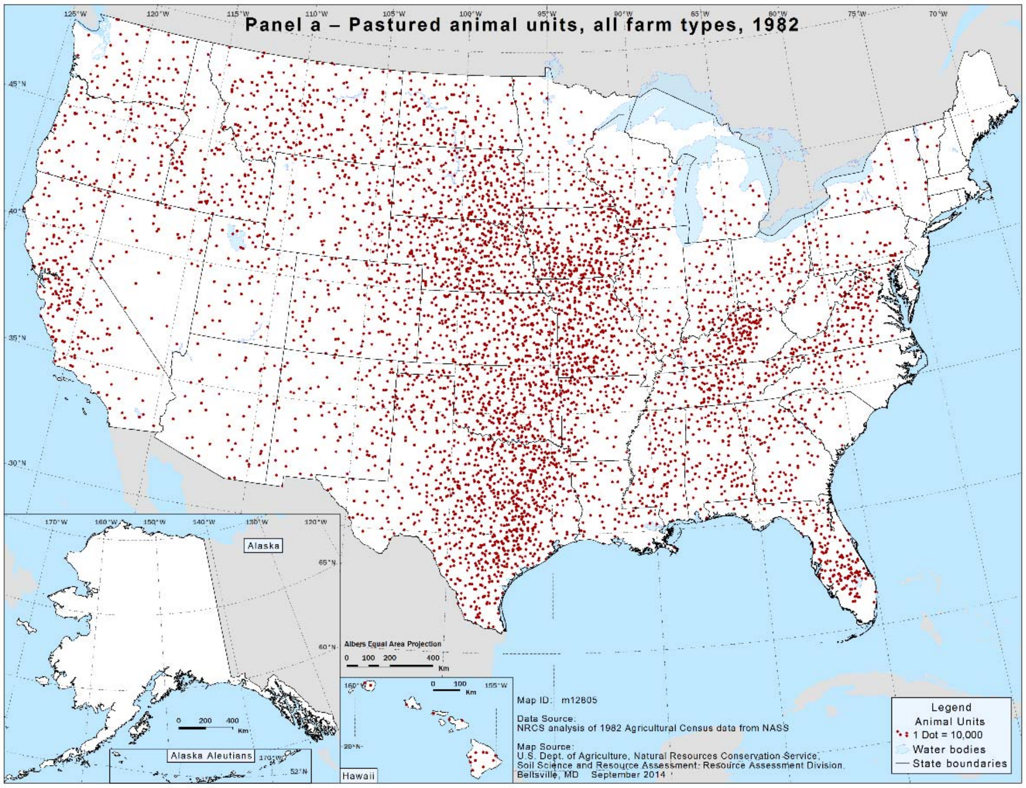


**Includes confined pastured livestock types*
Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS

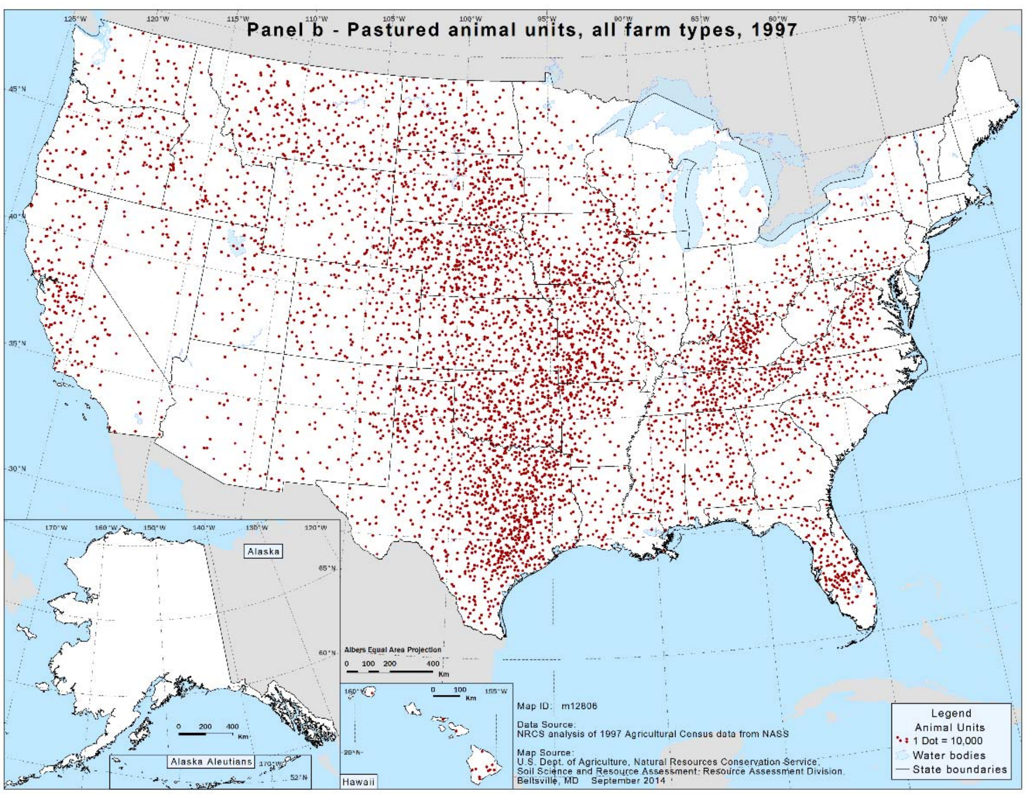


**Includes confined pastured livestock types*
Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Map 5. County location of pastured animal units (AU) on all farm types for 1982, 1997, and 2007 and change in the county location of pastured animal units for periods 1982-1997, 1997-2007, and 1982-2007

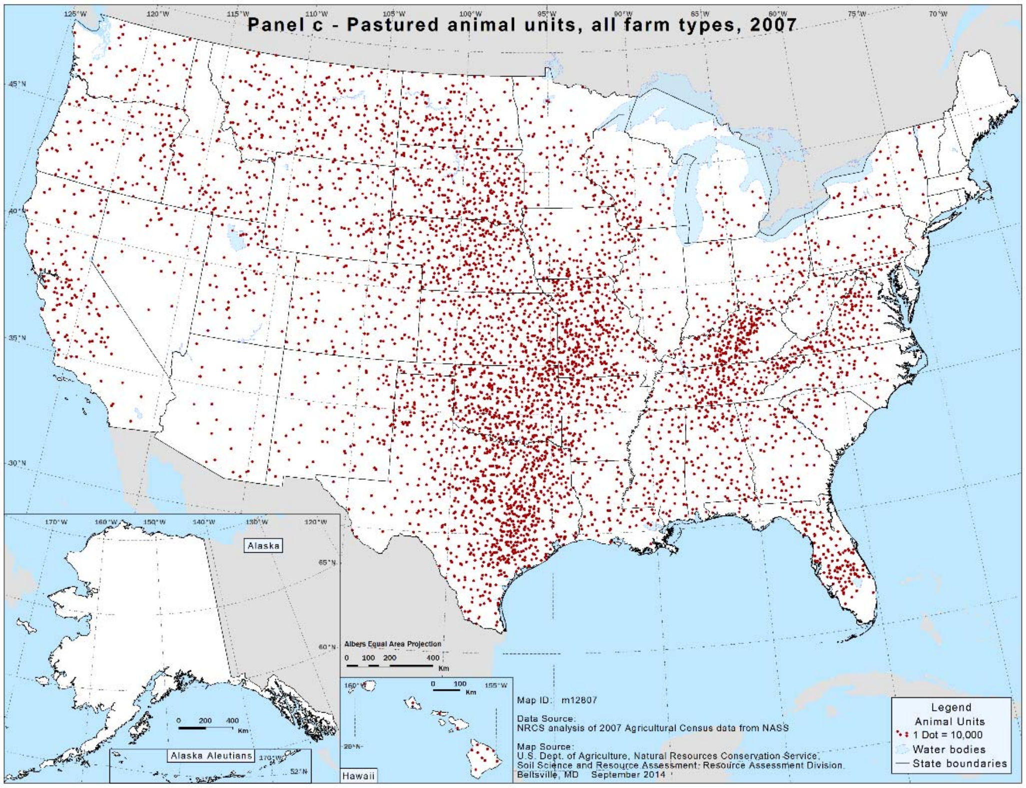


Legend: Dot = 10,000 AU
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

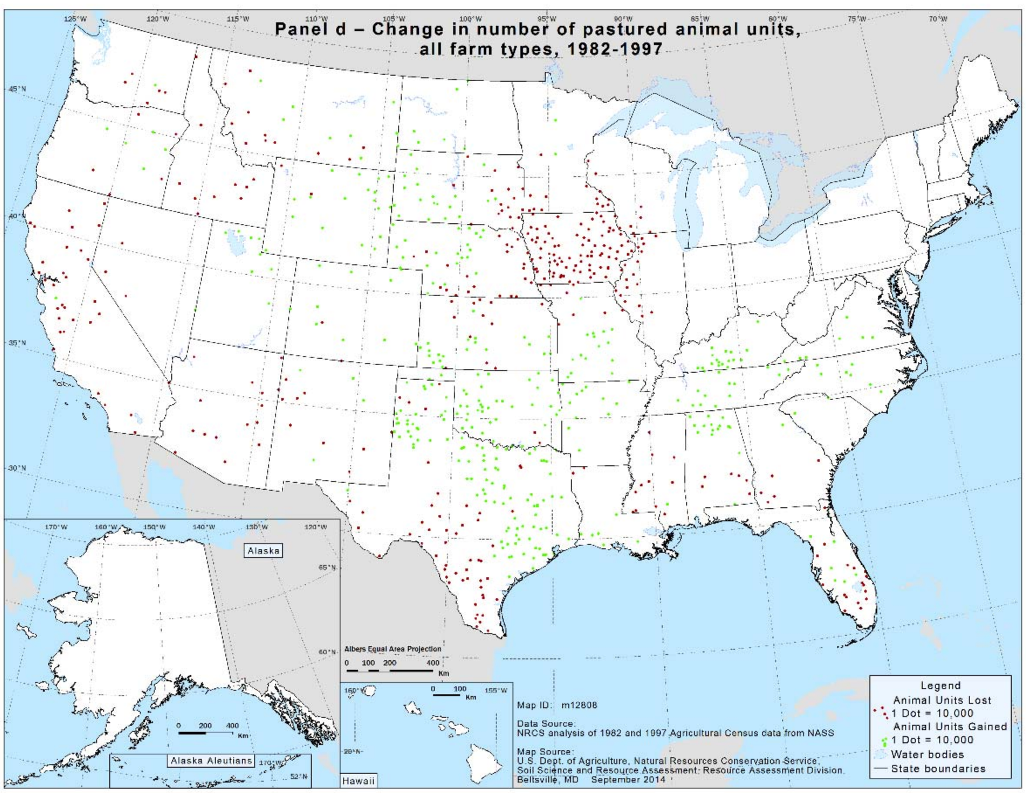


Legend: Dot = 10,000 AU
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 5. County location of pastured animal units (AU) on all farm types for 1982, 1997, and 2007 and change in the county location of pastured animal units for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

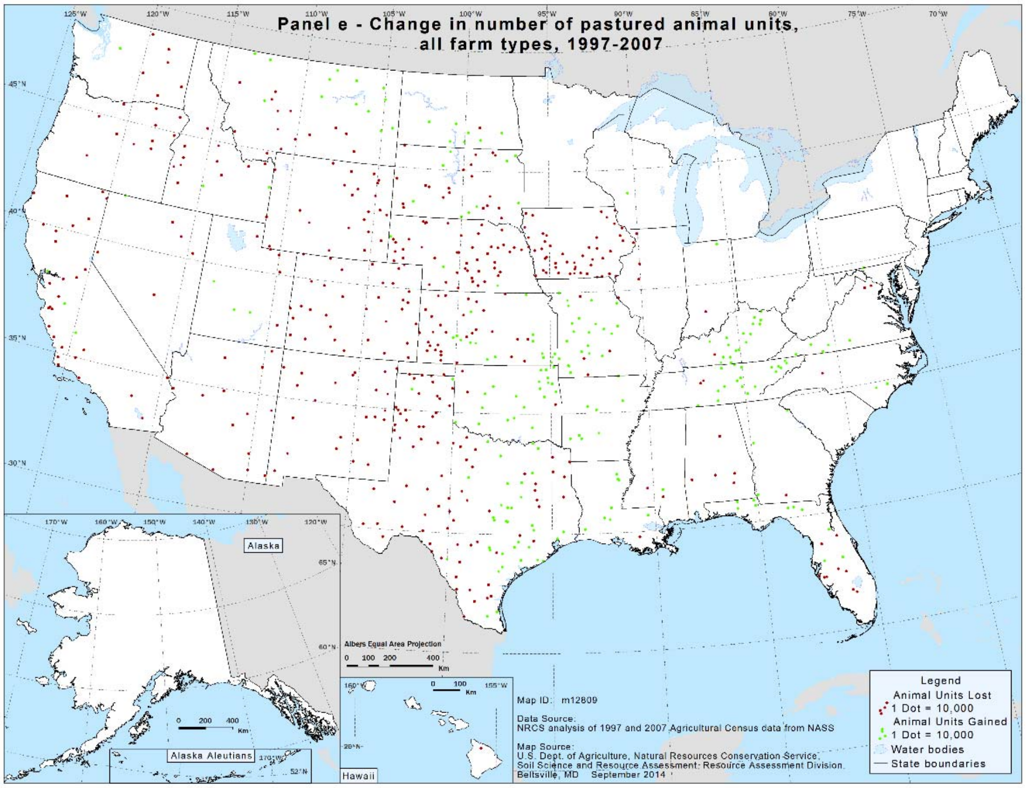


Legend: Dot = 10,000 AU
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

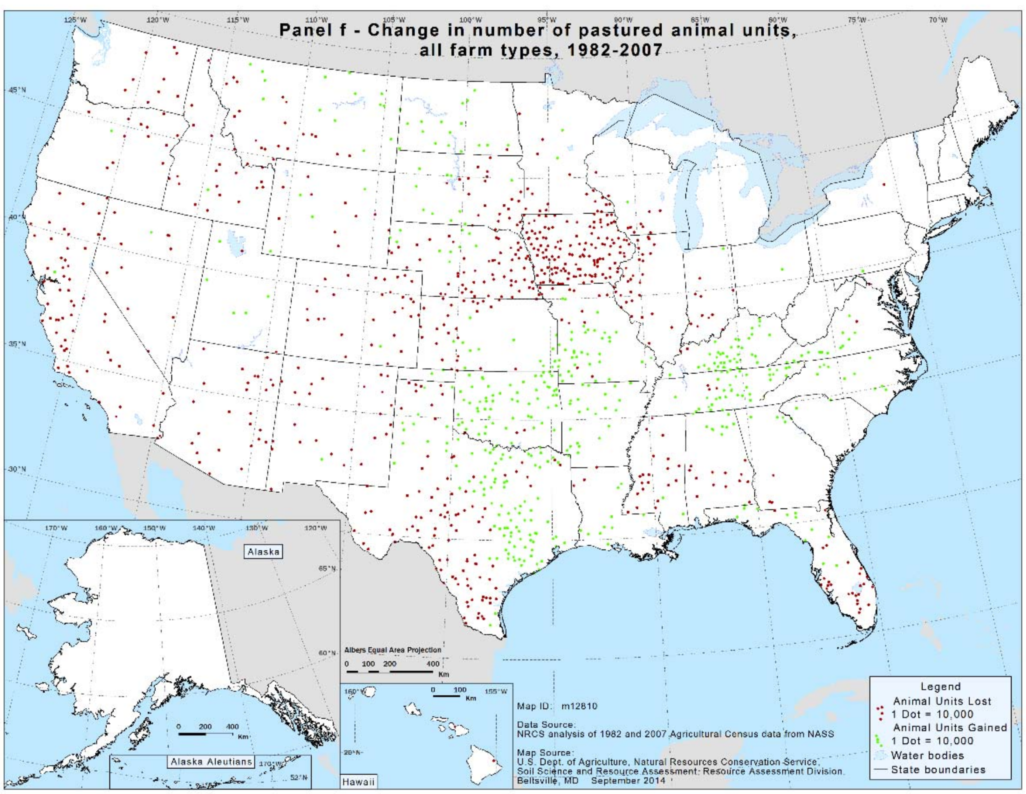


Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 5. County location of pastured animal units (AU) on all farm types for 1982, 1997, and 2007 and change in the county location of pastured animal units for periods 1982-1997, 1997-2007, and 1982-2007**—continued**



Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1997and 2007 Agricultural Census data from NASS



Legend: Green dot = 10,000 AU gain and red dot = 10,000 AU loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Manure and Manure Nutrients Produced by Livestock

Estimating the Quantity of Manure and Manure Nutrients

The amount of manure *as excreted* that is produced on a farm annually is calculated as the number of average annual AU times the amount of manure produced by an animal unit. Values include both urine and feces. Manure nitrogen and manure phosphorus *as excreted* were calculated by multiplying the tons of manure (wet weight) by standard values for the pounds of elemental nutrients per ton of manure (wet weight) *as excreted*. The quantity of manure and manure nutrients were estimated for confined livestock types and pastured livestock types. Estimates of manure and manure nutrients were not made for specialty livestock types, which make up less than 1 percent of total AUs.

The amount of manure and the amount of manure nutrients produced per animal varies among livestock types and from farm to farm depending on how much and how often the animals are fed, the quality, quantity, and nutrient content of feed and grazing materials, the extent to which the animals are held in confinement, and the extent to which animals are allowed access to grazing land.

A variety of data sources were used to obtain manure characteristics. Sources for 1982–97 are documented in Moffitt and Lander (1997) and Lander, Moffitt, and Alt (1998). Foremost among these sources is “Manure Production and Characteristics, Standard D384.1” published by the American Society of Agricultural Engineers in 1995 and updated in 2005 (ASABE, 2005; ASAE, 1995). The ASAE and ASABE standards provide estimates of manure characteristics, including the amount of nitrogen and phosphorus, for a variety of livestock types and ages. Information from these and other data sources was adapted to correspond to the livestock types and ages used in estimates for this study.

Coefficients used to calculate the quantity of manure and manure nutrients are presented in table 5. Manure characteristics can change over time (monthly as well as yearly) as production technologies, feed characteristics, and climatic factors vary. Manure characteristics for the period 1982–97 are the same as used in previous studies (USDA/NRCS, 2003). The 2002–07 parameters for confined livestock types were adjusted to reflect the updated manure characteristics published by ASABE (2005) and other sources. Separate estimates were derived for pastured livestock types that were assumed to be held primarily on grazing lands and those that were assumed to be partially confined. All measures of nitrogen and phosphorus in the table are in terms of *elemental nitrogen* and *elemental phosphorus*.

The ASABE 2005 effort evaluated manure characteristics from a feed supplement standpoint, and included studies with more comprehensive manure sampling regimes than was generally available in the 1995 ASAE effort. Most of the changes in manure characteristics between 1982–97 and 2002-07, shown in table 5, are relatively small, but some are substantial and represent changes in feeding regimes and genetics. The more notable changes include—

- an increase from 15.24 tons of manure per AU for milk cows to 20.34 tons per AU,
- an increase from 26.93 pounds of nitrogen per ton of manure (wet weight) for chicken layers to 36.97 pounds per ton,
- a decrease from 3.37 pounds of phosphorus per ton of manure (wet weight) for fattened cattle to 1.35 pounds per ton,
- an increase from 22.41 pounds of nitrogen per ton of manure (wet weight) for turkeys for breeding to 34.7 pounds per ton, and
- a significant increase in the pounds of nitrogen per ton of manure (wet weight) for hogs for slaughter.

These changes are responsible to some extent for sharp increases or decreases in estimates of manure nutrients for confined livestock types between 1997 and 2002. It is more likely, however, that the changes took place more gradually over a longer time period, and that the sharp increases and decreases in the estimates between 1997 and 2002 are exaggerated to some extent.

The quantity of manure at hauling weight was also estimated, assuming all manure was in solid form. The quantity of manure at hauling weight was used in part to identify AFOs. (See previous section.) For all livestock types except chicken broilers, ducks, and turkeys, the quantity of manure at hauling weight was assumed to be two times the oven dry weight of manure *as excreted*. For chicken broilers and ducks, it was assumed to be 1.3 times the oven dry weight of manure *as excreted*, and for turkeys it was assumed to be 1.5 times the oven dry weight of manure *as excreted*.[12]

[12] Oven dry weight is essentially equal to the total solids content of the *as excreted* manure.

Table 5. Coefficients used to calculate the quantity of manure and manure nutrients *as excreted*

Livestock category	Tons of manure per AU per year		Pounds of nitrogen/ton wet weight*	Pounds of phosphorus/ton wet weight*
	Wet weight	Oven-dry weight		
Confined livestock types 2002–2007				
Fattened cattle	11.7	0.94	11.08	1.35
Veal	11.1	0.28	6.60	1.32
Milk cows	20.34	2.64	12.92	2.30
Breeding hogs	5.38	0.54	13.38	4.01
Hogs for slaughter				
Finish only	12.2	1.46	15.9	2.62
Farrow to finish	13.5	1.62	17.85	2.80
Farrow to feeder	17.1	2.22	19.35	3.1
Farrow to wean	16.2	2.11	20.55	3.29
Nursery	16.2	2.11	20.4	3.27
Chickens, layers	11.39	2.85	36.97	11.69
Chickens, pullets	8.21	2.13	27.19	10.53
Chickens, broilers	15.97	4.15	21.87	6.31
Turkeys for breeding	7.47	1.94	34.7	9.64
Turkeys for slaughter	6.83	1.78	32.67	9.48
Ducks	18.4	4.8	19.60	6.8
Confined livestock types 1982–1997				
Fattened cattle	10.59	1.27	10.98	3.37
Veal	11.1	0.28	6.60	1.32
Milk cows	15.24	2.20	10.69	1.92
Breeding hogs	6.11	0.55	13.26	4.28
Hogs for slaughter	14.69	1.33	11.30	3.29
Chickens, layers	11.45	2.86	26.93	9.98
Chickens, pullets	8.32	2.08	27.20	10.53
Chickens, broilers	14.97	3.74	26.83	7.80
Turkeys for breeding	9.12	2.28	22.41	13.21
Turkeys for slaughter	8.18	2.04	30.36	11.83
Ducks	18.4	4.8	19.60	6.8
Partially confined pastured livestock types (all years)				
Beef calves	14.94	1.79	11.57	2.17
Beef heifers for replacement herds	18.72	2.25	6.73	1.54
Beef breeding herds (cows and bulls)	18.72	2.25	6.73	1.54
Beef stockers and grass-fed beef	18.72	2.25	6.73	1.54
Dairy calves	14.91	2.54	10.14	1.21
Dairy heifers for replacement herds	10.02	1.70	9.7	1.80
Dairy stockers and grass-fed beef	18.75	2.25	6.73	1.54
Horses, ponies, mules, burros, and donkeys	9.25	1.39	9.34	1.79
Sheep and goats	7.20	1.80	22.50	3.50
Pastured livestock types (all years)				
Beef calves, heifers, cows, bulls, stockers and grass-fed	11.7	1.8	12	5
Dairy calves, heifers, stockers, and grass-fed	11.7	1.8	12	5
Horses, ponies, mules, burros, and donkeys	9	2.6	12	2.7
Sheep and goats	7.2	1.8	22.5	3.5

* Amounts of nitrogen and phosphorus are in terms of elemental nitrogen and elemental phosphorus. Includes nitrogen and phosphorus in urine.

Manure and Manure Nutrients by Type of Livestock Farm

In 2007, livestock on farms in the US produced about 1.3 billion tons of manure, wet-weight *as excreted* (table 6). The AFO farm types produced the majority of the manure—59 percent of the total manure produced. Farms with pastured livestock operations with few confined livestock produced 38 percent. Only about 3 percent of the manure was produced on the three other types of non-AFO farms with livestock.

The amount of manure produced has increased only about 5 percent over the 25 years from 1982 to 2007 (fig. 8). The share of manure produced on AFOs has remained nearly constant at 56 to 59 percent over the 25-year period.

In 2007, livestock on farms in the US produced about 17.3 billion pounds of manure nitrogen and 4.9 billion pounds of manure phosphorus, *as excreted* (tables 7 and 8). The AFO farm types produced the majority of the manure nitrogen—62 percent (table 7), which is only slightly higher than AFO's share of the total quantity of manure produced. Farms with pastured livestock operations with few confined livestock produced 35 percent of the manure nitrogen.

AFO farm types produced 47 percent of the manure phosphorus in 2007 (table 8). Farms with pastured livestock operations with few confined livestock produced 49 percent. The higher share of phosphorus for non-AFOs reflects, in part, the higher manure phosphorus content of pastured livestock relative to most confined livestock types (table 5).

Over the 25-year period, manure nitrogen increased by 18 percent while manure phosphorus changed very little (less than 1 percent) (figs. 9 and 10). AFO's share of all manure nitrogen produced increased from 57 percent in 1982 to 62 percent in 2007, while AFO's share of manure phosphorus decreased slightly.

For confined livestock on AFOs, manure nitrogen increased by 50 percent over the 25 years (fig. 11). On the large potential AFO-CAFOs, manure nitrogen production nearly tripled over the 25 years, while manure nitrogen production for the small and very small AFOs decreased significantly. In 2007, 57 percent of the manure nitrogen produced by confined livestock on AFOs was on the large potential AFO-CAFOs (table 7).

The sharp increase in manure nitrogen between 1997 and 2002 is, in part, due to increases in confined livestock on AFOs, shown in figures 6 and 7. But it is likely that the magnitude of the increase is exaggerated by the revisions in the manure characteristics for 1982–97 versus 2002–07. As noted earlier, these changes most likely took place more gradually over a longer time period.

Over the 25 years, manure nitrogen increased 93 percent for poultry, 90 percent for swine, 53 percent for fattened cattle (including veal), and 39 percent for milk cows (fig. 12). Manure nitrogen decreased 32 percent for confined pastured livestock types. In 2007, milk cows accounted for about one-third of manure nitrogen for confined livestock on AFOs; poultry accounted for one-fourth; swine and fattened cattle each accounted for about 18 percent; and confined pastured livestock accounted for 6 percent (fig. 12).

Manure phosphorus increased 18 percent for confined livestock on AFOs over the 25 years (fig. 13), primarily due to the 15 percent increase in confined livestock AU on AFOs during this time period. On the large potential AFO-CAFOs, manure phosphorus production nearly doubled over the 25 years. Manure phosphorus production for the small and very small AFOs decreased significantly because of decreases in the number of farms and animal units. In 2007, 55 percent of the manure phosphorus produced by confined livestock on AFOs was on the large potential AFO-CAFOs (table 8).

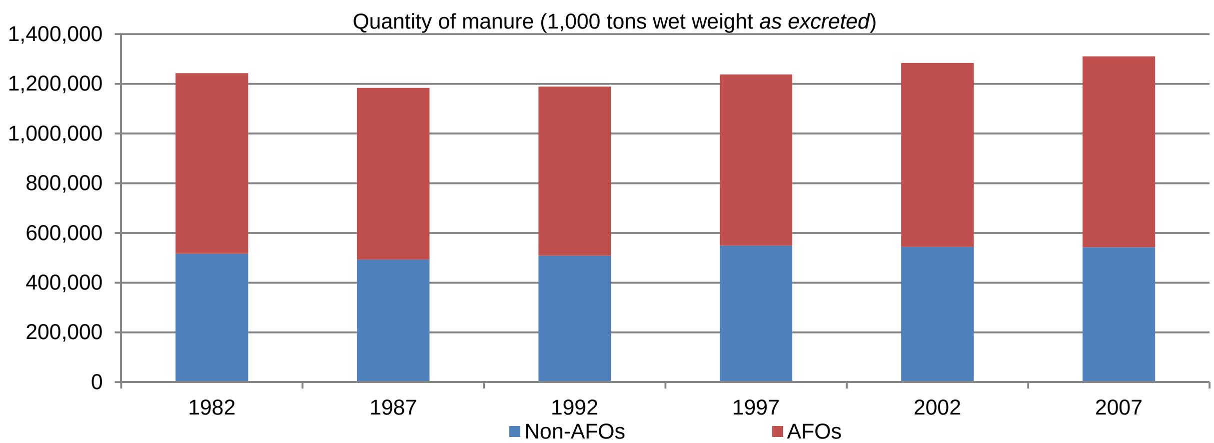
Over the 25 years, manure phosphorus increased 66 percent for poultry, 38 percent for milk cows, and 13 percent for swine (fig. 14). Manure phosphorus decreased 36 percent for confined pastured livestock types and 39 percent for fattened cattle (including veal). In 2007, poultry accounted for about 37 percent of manure phosphorus for confined livestock on AFOs; milk cows accounted for 30 percent; swine accounted for 16 percent; fattened cattle (including veal) accounted for 10 percent, and confined pastured livestock accounted for 6 percent (fig. 14).

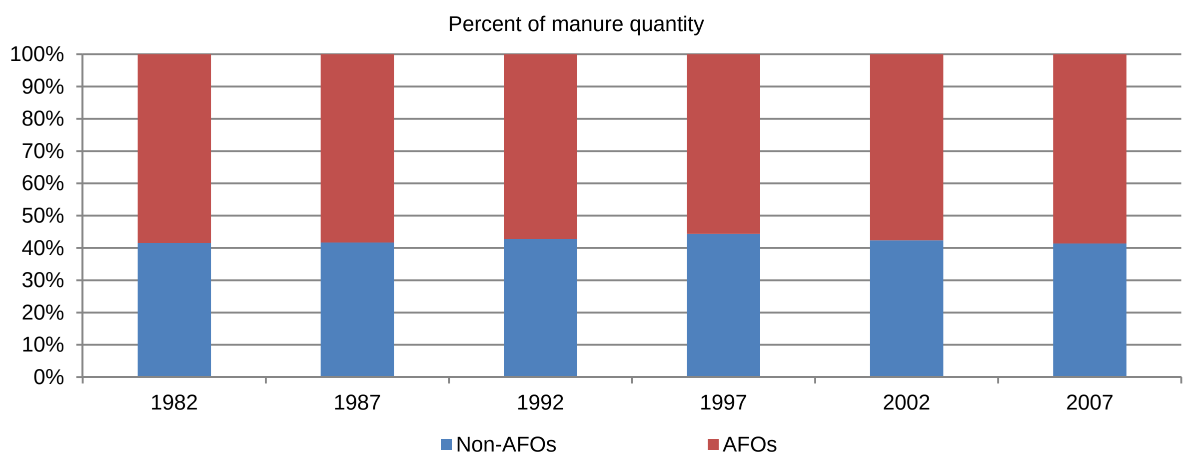
Table 6. Quantity of manure produced *as excreted* (wet weight) by livestock, all U.S., 2007

	Pastured livestock types*		Confined livestock types**		All livestock types***	
	1,000 Tons	Percent of total	1,000 Tons	Percent of total	1,000 Tons	Percent of total
Non-AFOs						
Farms without livestock	0	0	0	0	0	0
Farms with some livestock but not a livestock operation	2,303	<1	127	<1	2,430	<1
Very small livestock operations	38,142	6	6,205	1	44,347	3
Specialty livestock operations with few confined livestock	1,019	<1	7	<1	1,027	<1
Pastured livestock operations with few confined livestock	493,354	82	1,577	0	494,930	38
AFOs						
Very small AFOs	10,203	2	18,564	3	28,767	2
Small AFOs	34,205	6	162,763	23	196,968	15
Medium AFO-CAFOs	14,798	2	132,411	19	147,210	11
Large AFO-CAFOs	11,225	2	383,815	54	395,041	30
All non-AFOSs	534,818	88	7,916	1	542,734	41
All AFOs	70,431	12	697,554	99	767,985	59
Total	605,249	100	705,470	100	1,310,719	100

* Excludes partially or wholly confined pastured livestock types.
** Includes partially or wholly confined pastured livestock types.
*** Excludes specialty livestock types.

Figure 8. Amount and percent of manure *as excreted* on AFOs and non-AFOs





Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Table 7. Quantity of manure nitrogen produced *as excreted* by livestock, all U.S., 2007

	Pastured livestock types*		Confined livestock types**		All livestock types***	
	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total
Non-AFOs						
Farms without livestock	0	0	0	0	0	0
Farms with some livestock but not a livestock operation	29,290	<1	1,361	<1	30,651	<1
Very small livestock operations	475,777	6	65,577	1	541,358	3
Specialty livestock operations with few confined livestock	12,412	<1	88	<1	12,501	<1
Pastured livestock operations with few confined livestock	5,968,094	81	18,948	<1	5,987,043	35
AFOs						
Very small AFOs	123,363	2	183,596	2	306,959	2
Small AFOs	412,274	6	1,853,719	19	2,265,993	13
Medium AFO-CAFOs	178,603	2	2,131,032	21	2,309,634	13
Large AFO-CAFOs	135,386	2	5,663,590	57	5,798,976	34
All non-AFOSs	6,485,574	88	85,979	1	6,571,553	38
All AFOs	849,626	12	9,831,937	99	10,681,563	62
Total	7,335,200	100	9,917,916	100	17,253,117	100

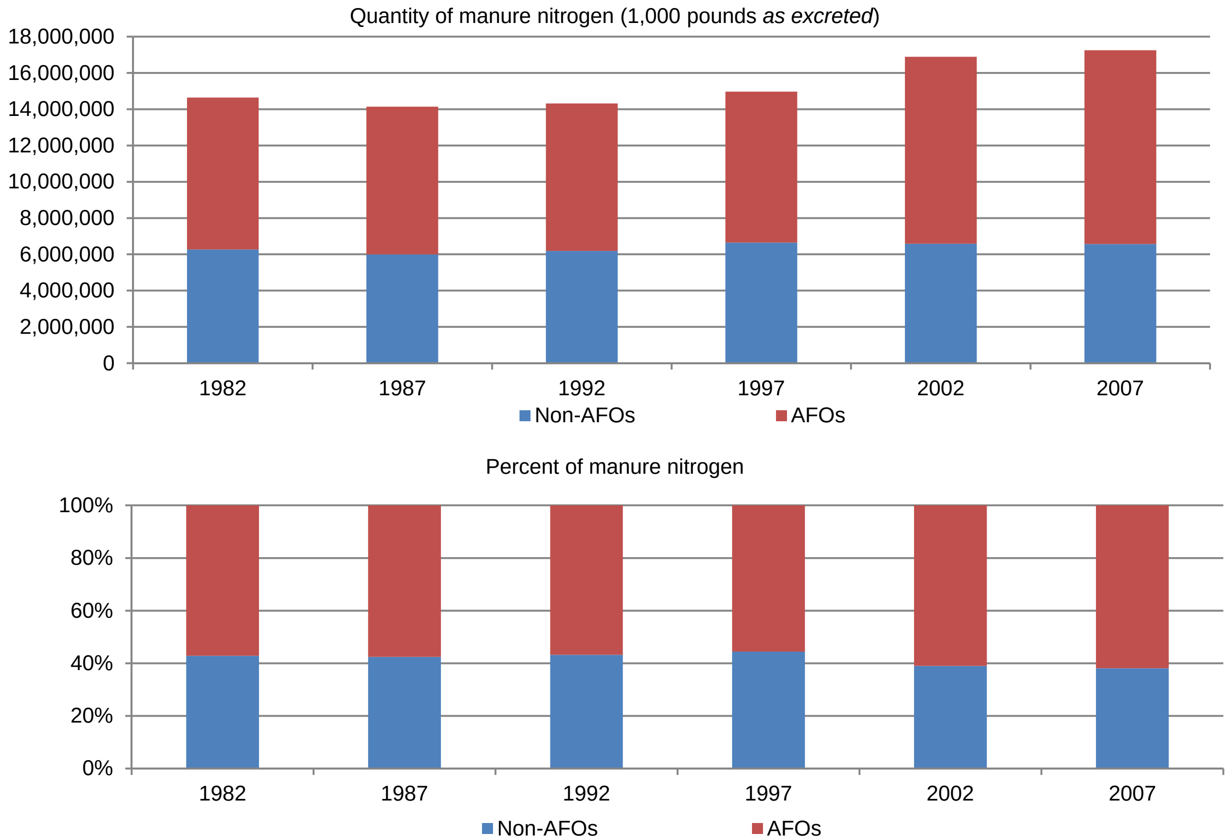
* Excludes partially or wholly confined pastured livestock types.
** Includes partially or wholly confined pastured livestock types.
*** Excludes specialty livestock types.

Table 8. Quantity of manure phosphorus produced *as excreted* by livestock, all U.S., 2007

	Pastured livestock types*		Confined livestock types**		All livestock types***	
	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total
Non-AFOs						
Farms without livestock	0	0	0	0	0	0
Farms with some livestock but not a livestock operation	9,307	<1	270	<1	9,577	<1
Very small livestock operations	162,395	6	12,813	1	175,209	4
Specialty livestock operations with few confined livestock	4,431	<1	18	<1	4,449	<1
Pastured livestock operations with few confined livestock	2,407,400	82	3,111	<1	2,410,511	49
AFOs						
Very small AFOs	49,737	2	36,474	2	86,211	2
Small AFOs	168,753	6	355,429	18	524,182	11
Medium AFO-CAFOs	73,396	3	472,594	24	545,990	11
Large AFO-CAFOs	55,798	2	1,095,231	55	1,151,028	23
All non-AFOSs	2,583,533	88	16,212	1	2,599,745	53
All AFOs	347,684	12	1,959,728	99	2,307,412	47
Total	2,931,217	100	1,975,940	100	4,907,157	100

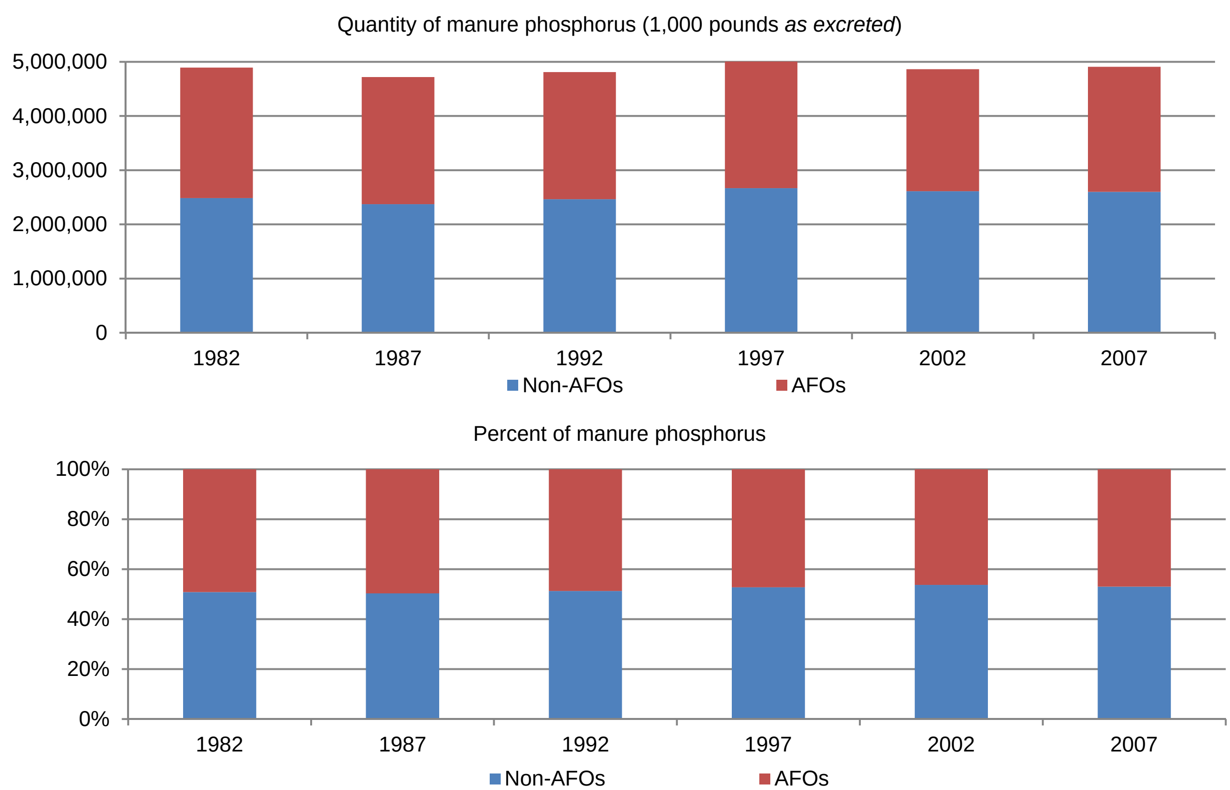
* Excludes partially or wholly confined pastured livestock types.
** Includes partially or wholly confined pastured livestock types.
*** Excludes specialty livestock types.

Figure 9. Amount and percent of manure nitrogen *as excreted* on AFOs and non-AFOs



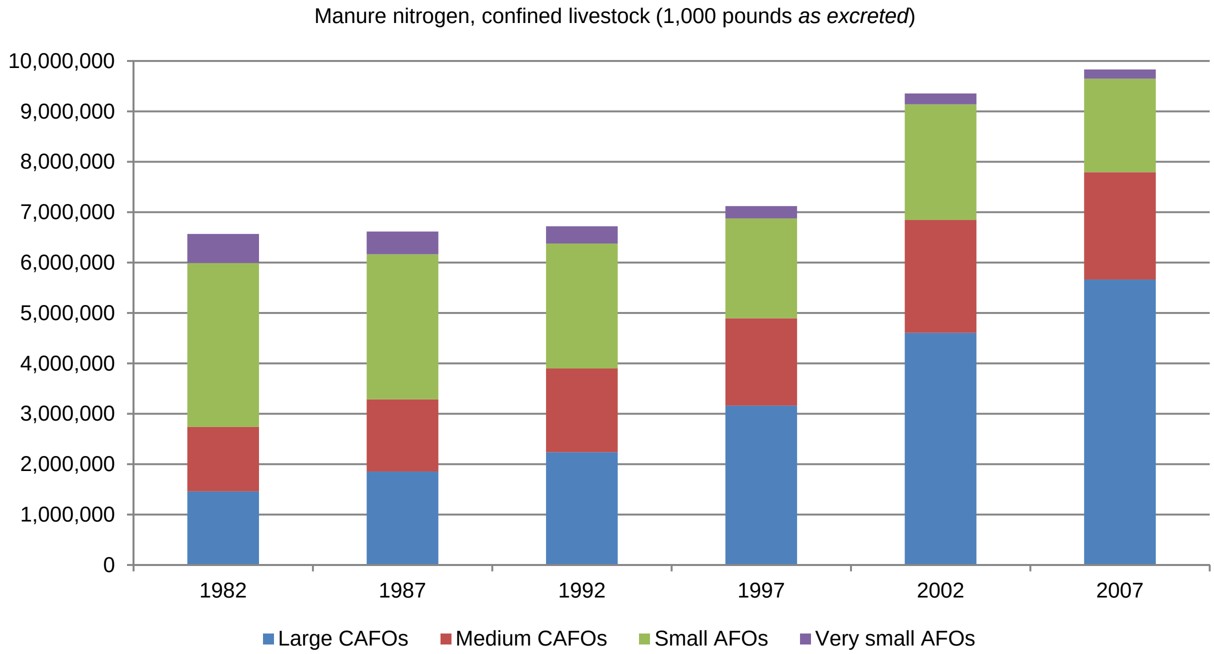
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

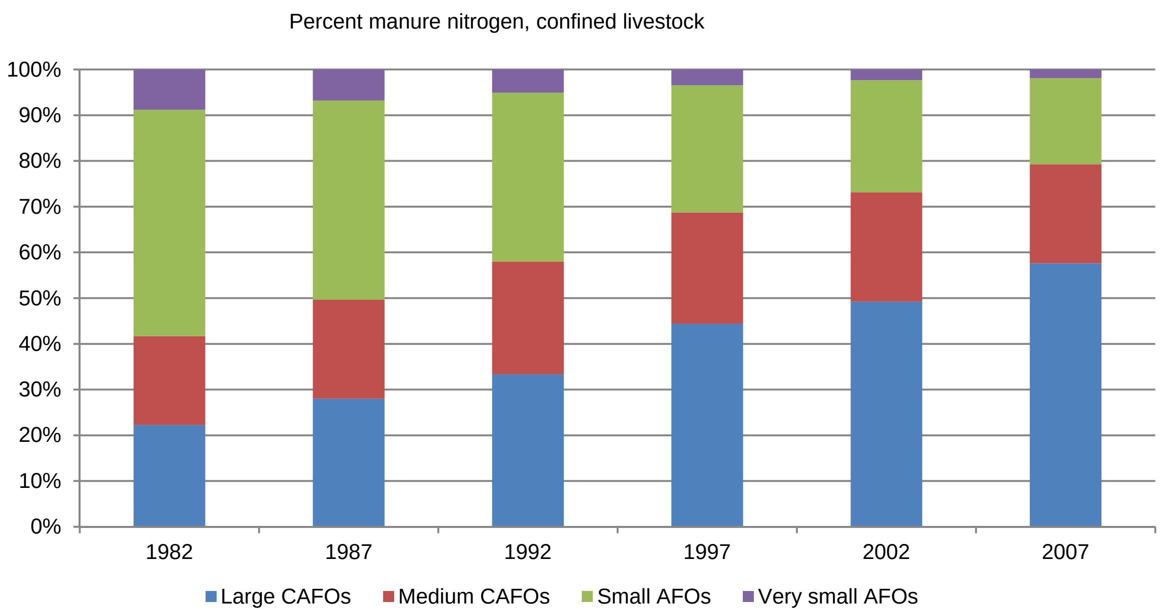
Figure 10. Amount and percent of manure phosphorus *as excreted* on AFOs and non-AFOs



Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

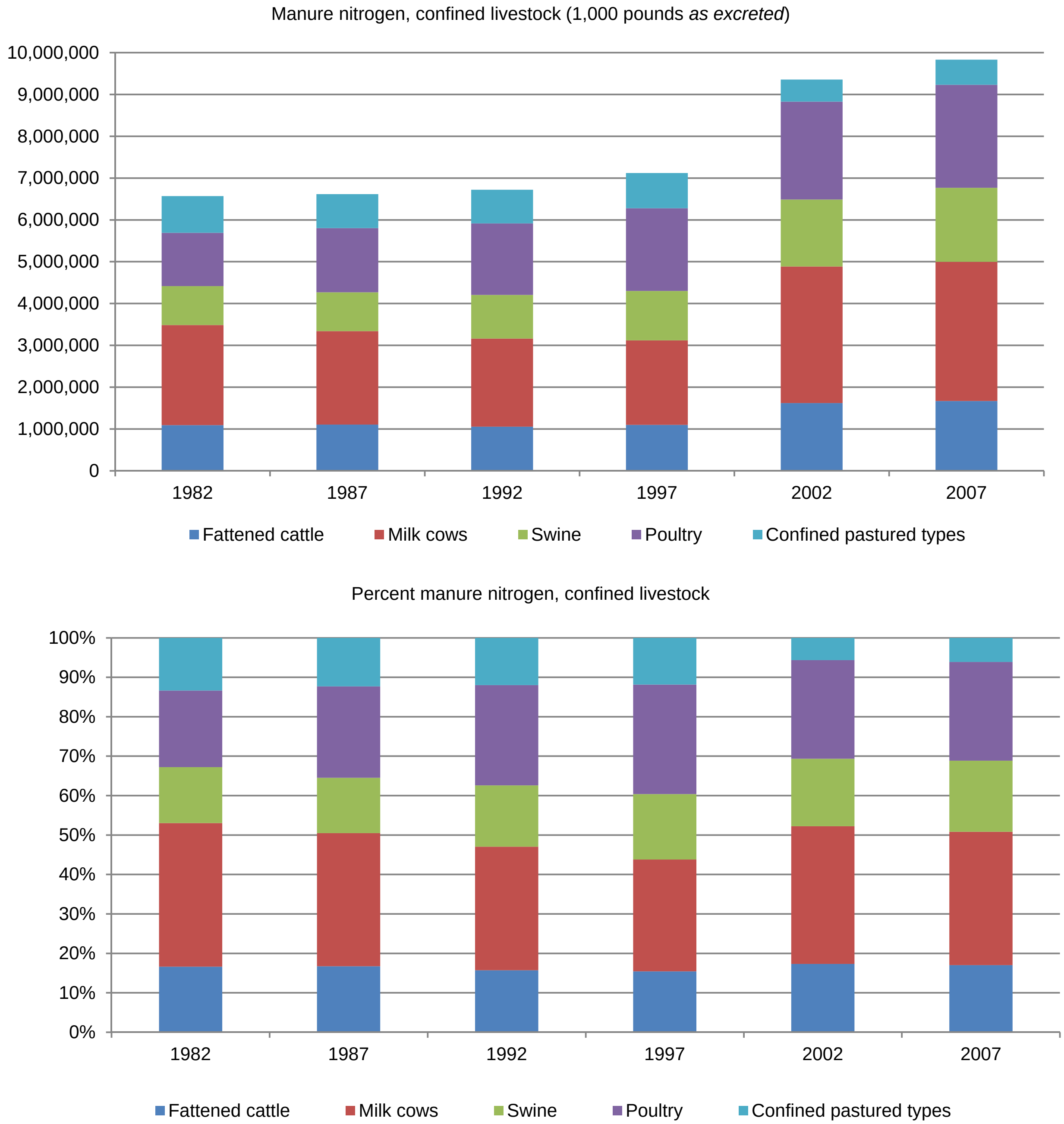
Figure 11. Amount and percent of manure nitrogen *as excreted* for confined livestock on AFOs*, by AFO farm type





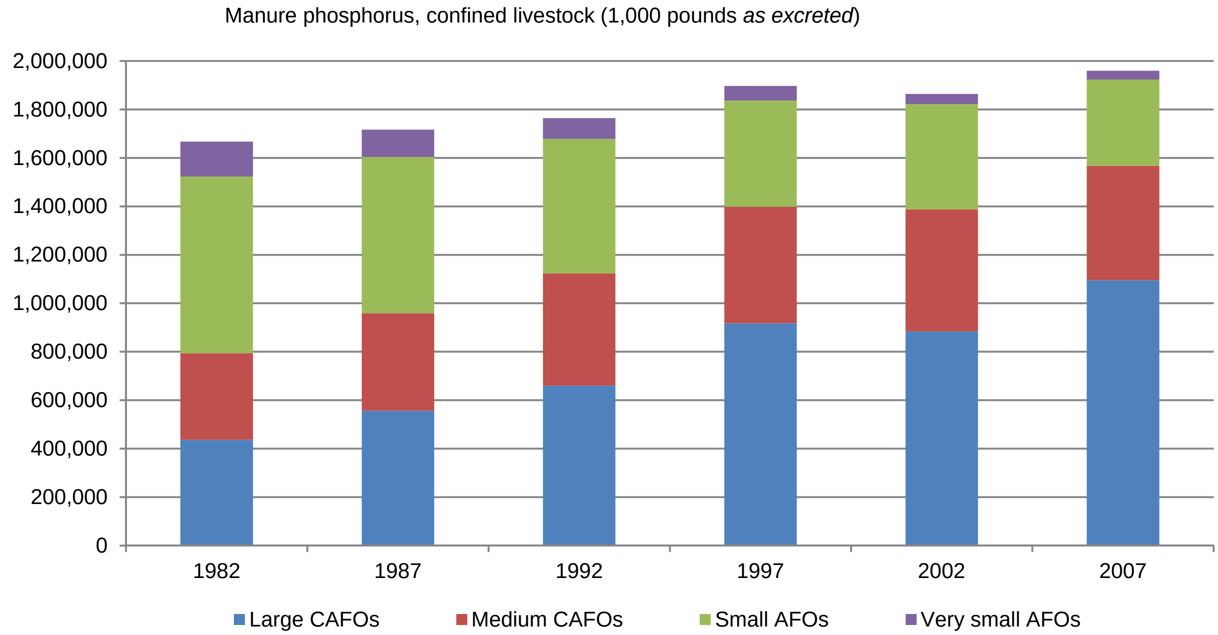
* Includes partially or wholly confined pastured livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

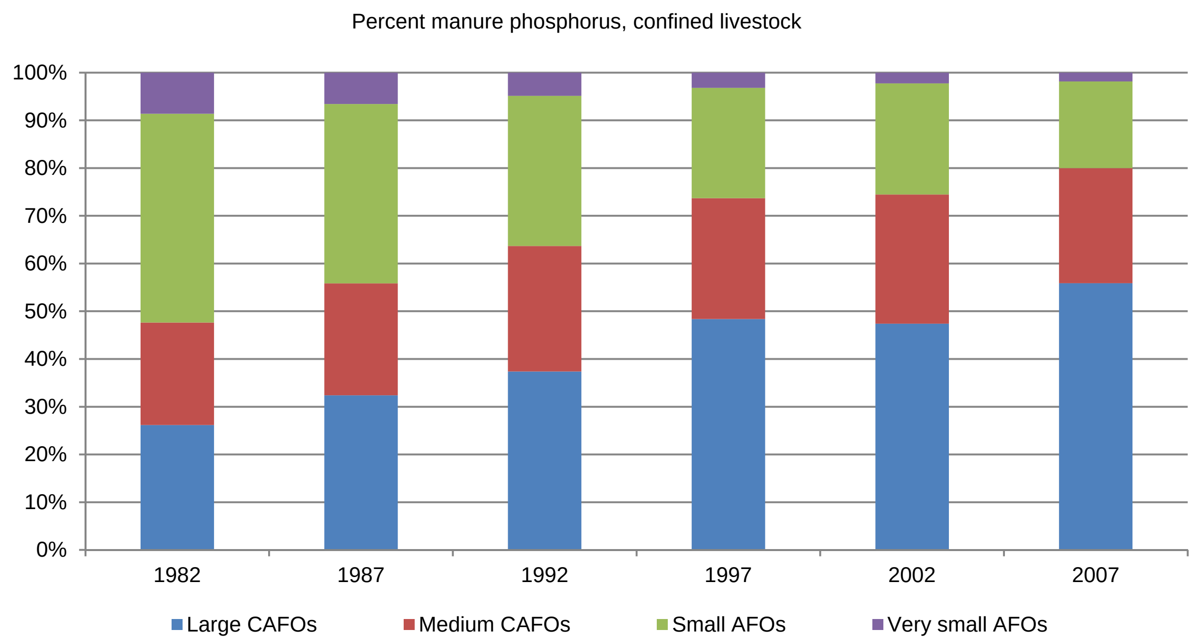
Figure 12. Amount and percent of manure nitrogen *as excreted* for confined livestock on AFOs*, by livestock group



* Includes partially or wholly confined pastured livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

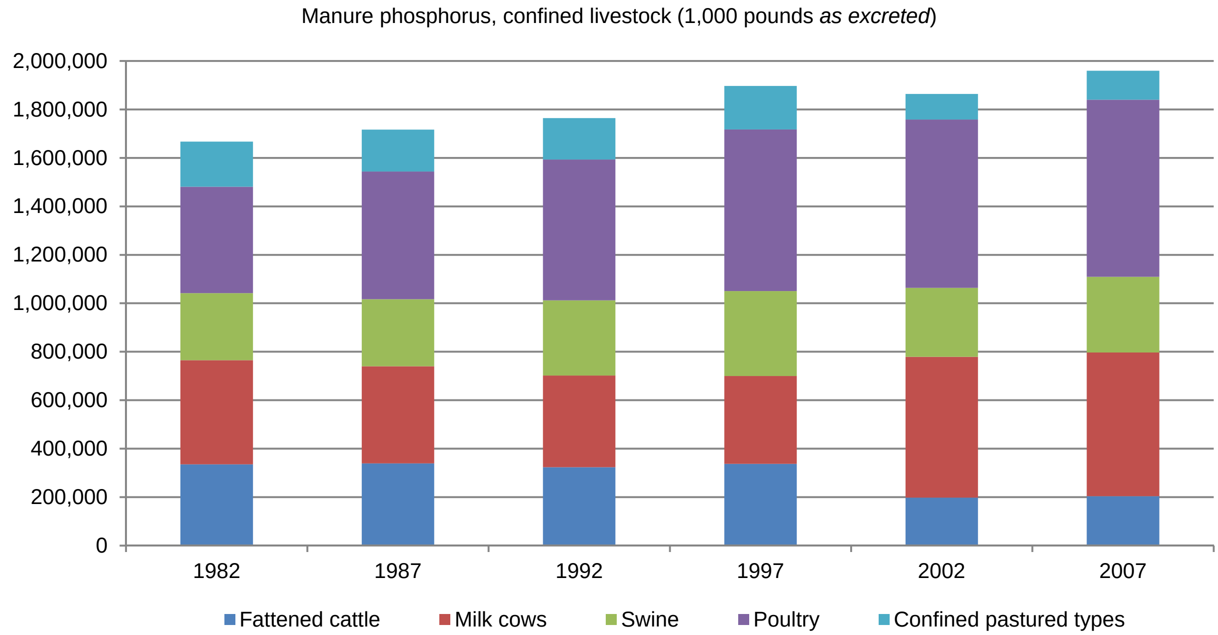
Figure 13. Amount and percent of manure phosphorus *as excreted* for confined livestock on AFOs*, by AFO farm type

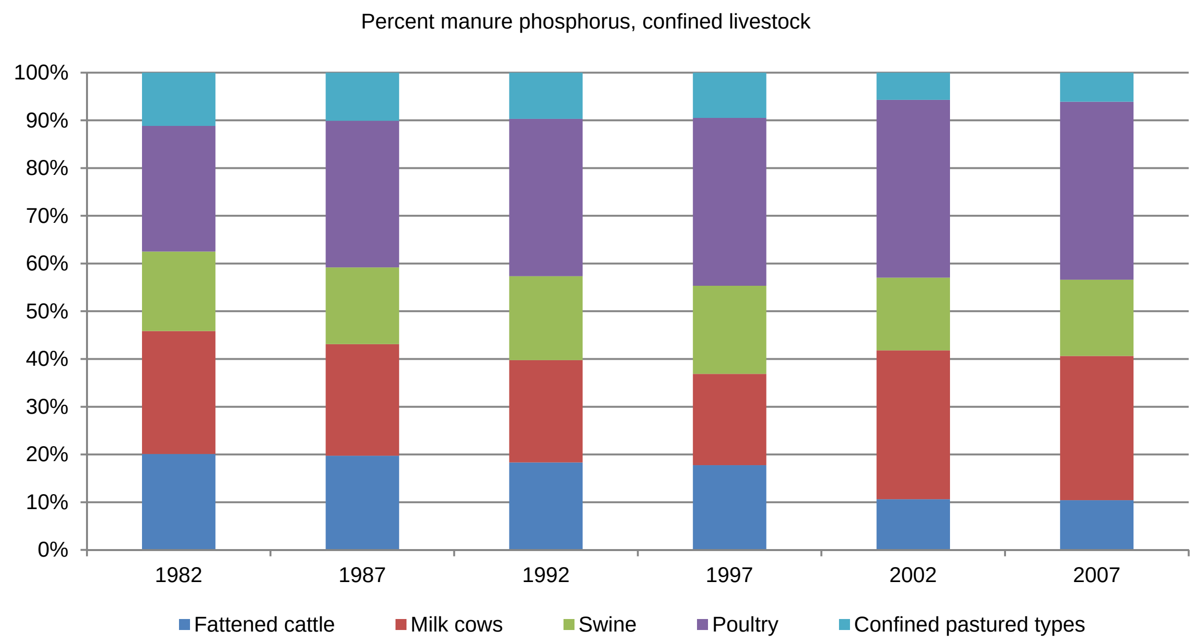




* Includes partially or wholly confined pastured livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 14. Amount and percent of manure phosphorus *as excreted* for confined livestock on AFOs*, by livestock group





* Includes partially or wholly confined pastured livestock types.
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Recoverable Manure

Estimating Recoverable Manure and Manure Nutrients

Livestock operations with animals held in confinement have "recoverable manure." Recoverable manure is the portion of manure that is routinely collected and removed from buildings and lots where livestock are held, and which would thus be available for land application or other use. As indicated earlier, AFOs have been defined for the purposes of this study to be livestock operations where management and disposal of manure would be expected based on the kind and number of livestock on the farm as reported in the Census of Agriculture.

It was assumed that all manure from confined livestock types on AFOs was potentially recoverable, as well as manure from pastured livestock types assumed to be confined because of limited or no grazing land available on the farm, as previously defined. On a dairy AFO with a few chickens for private use, for example, chicken manure as well as the manure from milk cows was treated as recoverable manure. Manure from pastured livestock that may be present on AFOs, such as horses or goats, was treated as non-recoverable, as long as a sufficient amount of grazing land was available on the farm.

The quantity of manure *as excreted* was multiplied by the recoverability factors presented in table 9 to obtain estimates of the quantities of recoverable manure for each AFO. Recoverability coefficients vary over time, region of the country, and by farm size so as to represent varying levels of manure handling and management. Larger farms would be expected to have more efficient manure management technologies in use. It is also expected that manure handling and management technologies have improved over time as older, less efficient operations are replaced by newer and better designed operations or upgraded with newer technologies.[13] The values presented in table 9 are *average* values using the strategy suggested by Van Dyne and Gilbertson (1978). More site-specific studies such as the one by Powell (2005) in Wisconsin will often find different values.

Manure recoverability factors for 1982-2007 were derived from recoverability factors used with the 1997 Census of Agriculture database in USDA/NRCS (2003). In that study, model farms were defined, each with a specific manure management and handling system for which a recoverability factor was estimated. Since these model farms were defined only for 1997, recoverability factors reported in USDA/NRCS (2003) were generalized by livestock type, region, and operation size to represent the most typical manure management and handling systems. USDA/NRCS (2003) also projected what recoverability factors would be based on all AFOs having Comprehensive Nutrient Management Plans (CNMPs).

Using these estimates, a time trend of recoverability factors was generated spanning from 1997 through 2017 under the assumption that all AFOs would have CNMPs fully implemented by 2017. Estimates of recoverability factors for specific years were made as follows.

- For 1997, recoverability factors were the same as was used in USDA/NRCS (2003) for the baseline, or "before CNMP" scenario. (See USDA/NRCS (2003), appendix B, table B3.)
- For 2017, recoverability factors were the same as used in USDA/NRCS (2003) for the "after CNMP" scenario.
- For 2002-2007, recoverability factors were increased according to the upward trend in CNMP implementation assumed for 1997 to 2017.
- For 1982-1992, recoverability factors were decreased relative to the 1997 estimates at half the rate of the 1997-2017 trend, representing a slower pace of CNMP implementation or practice adoption.

Recoverable manure nutrients are the nitrogen and phosphorus content of recoverable manure, adjusted for losses during collection, transfer, storage, and treatment. Recoverable manure nutrients are *not* adjusted for losses of nutrients during the land application process. The amount of manure nutrients that was recoverable was calculated using the coefficients in tables 5 and 10 as follows.

1. The quantities of recoverable manure were multiplied by the nutrient content of manure using coefficients presented in table 5 to obtain estimates of the quantities of manure nutrients.
2. Losses during collection, transfer, storage, and treatment, including nitrogen volatilization, were subtracted by multiplying the quantities of manure nutrients by the proportion of manure nutrients retained in the recoverable fraction, presented in table 10. It was assumed that chemical changes within the manure would not lead to phosphorus losses. Phosphorus losses primarily include incidental losses in manure handling and transfer.

One minus the proportion of nutrients retained in the recoverable fraction of manure represents nitrogen volatilization and other losses during collection, transfer, storage, and treatment. Losses will vary according to the type of manure handling, storage, and treatment system in use. Long term storage and treatment options tend to increase nitrogen losses. Retention estimates presented in table 10 represent manure management systems in common use for the bulk of the livestock populations and are the same as, or consistent with, nutrient loss estimates used in USDA-NRCS (2003).[14]

[13] For example, since 1997, most large operations have CAFO permits and over 35,000 Comprehensive Nutrient Management Plans (CNMPs) have been prepared.

[14] The phosphorus retention percentage for swine operations was adjusted upward to 90 percent under the assumption that the majority of lagoon sludge, which contains the bulk of the manure phosphorus in lagoon systems, is land applied when the lagoons are eventually emptied completely.

Table 9. Manure recoverability factors expressed as the percent of manure *as excreted* that is recoverable

Livestock type and region	Farm size group AUs	1982 %	1987 %	1992 %	1997 %	2002 %	2007 %	2012 %	2017 %
Milk Cows									
All	<35	43	44	45	45	46	48	49	50
North Central, Northeast	35-135	51	52	54	55	58	62	65	68
	135-270	50	52	54	56	60	63	67	71
	>270	47	49	52	54	59	64	70	75
Southeast	35-135	46	48	50	52	56	59	63	67
	>135	47	49	52	54	57	61	64	68
West	35-135	46	48	50	52	56	60	64	68
	135-270	47	49	52	54	59	64	69	74
	>270	54	56	58	60	64	68	71	75
Fattened Cattle									
All	<35	48	50	53	55	60	65	70	75
New England	>35	48	50	53	55	60	65	70	75
PA, NY, NJ	>35	54	56	58	60	64	68	72	76
Southeast	>35	52	54	57	59	64	69	74	78
Midwest	35-500	54	56	58	60	64	69	74	78
	>500	59	61	63	65	69	73	76	80
MT, WY, ND, MN	35-500	52	55	57	60	65	70	75	80
	>500	59	61	63	65	69	73	76	80
CO, KS, NE, SD	35-1,000	52	55	57	60	65	70	75	80
	>1,000	52	55	57	60	65	70	75	80
TX, OK, NM	35-1,000	52	55	57	60	65	70	75	80
	>1,000	52	55	57	60	65	70	75	80
West	35-500	52	55	57	60	65	70	75	80
	>500	52	55	57	60	65	70	75	80
Pastured Livestock Types Assumed To Be Confined									
Northeast	All	57	59	62	64	69	74	78	83
Midwest	All	59	61	63	65	69	73	78	82
Southeast	All	59	61	63	65	69	73	77	80
West	All	59	61	63	65	69	73	77	80
Veal									
All Regions	All	68	70	73	75	80	85	90	95
Broilers									
Northeast	All	66	69	72	75	81	87	93	98
Southeast	All	80	82	84	85	88	91	95	98
Northwest	All	66	69	72	75	81	87	93	98
Southwest	All	66	69	72	75	81	87	93	98
Layers									
All Regions	<35	67	70	72	75	80	85	90	95
Southeast	35-400	70	72	75	77	82	86	91	95
	>400	70	72	75	77	82	86	91	95
West	35-400	76	77	79	80	84	88	91	95
	>400	67	70	72	75	80	85	90	95
South Central	35-400	67	70	72	75	80	85	90	95
	>400	76	77	79	80	84	88	91	95
North Central & Northeast	35-400	81	82	84	85	87	90	92	95
	>400	81	82	84	85	87	90	92	95
Pullets									
North Central & Northeast	All	81	82	84	85	87	90	92	95
Southeast	All	76	77	79	80	84	88	91	95
West	All	76	77	79	80	84	88	91	95
South Central	All	76	77	79	80	84	88	91	95

Table 9. Manure recoverability factors expressed as the percent of manure *as excreted* that is recoverable**—continued**

Livestock type and region	Size group AUs	1982 %	1987 %	1992 %	1997 %	2002 %	2007 %	2012 %	2017 %
Turkeys									
All Regions	<35	42	43	44	45	46	47	49	50
East	>35	70	72	74	76	80	84	89	93
South Central	>35	74	76	78	80	84	89	94	98
North Central	>35	70	72	74	76	80	84	89	93
West w/o CA	>35	56	57	59	60	64	67	70	74
CA	>35	66	68	70	72	76	80	84	88
Ducks									
All regions	<35	42	43	44	45	46	47	49	50
	>35	74	76	78	80	80	80	84	89
Hogs for breeding									
All Regions	<35	50	50	50	50	50	50	50	50
North Central & Northeast	35-500	74	76	78	80	84	88	92	96
	>500	78	80	82	84	87	90	93	97
Southeast	35-100	73	74	75	76	78	81	83	85
	>100	80	82	83	85	88	91	94	97
West	35-500	70	71	72	73	75	78	80	83
	>500	78	80	81	83	86	90	94	97
Hogs for slaughter									
All Regions	<35	69	71	73	75	79	83	87	90
North Central & Northeast	35-500	69	70	72	73	76	79	82	95
	>500	75	77	79	81	85	89	93	97
Southeast	35-100	81	82	83	84	87	90	94	97
	>100	81	82	84	85	88	91	94	97
West	35-500	76	78	80	82	86	90	93	97
	>500	76	78	80	82	86	90	93	97

Note: Estimates for 1982-1992 and 2002-2007 were derived from recoverability estimates developed for 1997 in USDA-NRCS (2003). See text.

Table 10. Proportion of manure nutrients retained in recoverable fraction* for AFOs

Livestock category	Nitrogen	Phosphorus
Confined livestock types		
Fattened cattle	0.40	0.90
Veal	0.39	0.95
Milk cows	0.40	0.95
Breeding hogs	0.25	0.90
Hogs for slaughter, all types	0.25	0.90
Chickens, layers	0.69	0.85
Chickens, pullets	0.50	0.95
Chickens, broilers	0.60	0.95
Turkeys	0.53	0.95
Ducks	0.50	0.95
Pastured Livestock Types Assumed To Be Confined	0.30	0.90

* Losses include volatilization, denitrification, and spillage.

Recoverable Manure and Manure Nutrients by Type of AFO

In 2007, the amount of recoverable manure totaled 514 million tons, wet weight (equivalent to 71 million tons dry weight) (table 11). Over half of this amount (57 percent by wet weight, 54 percent by dry weight) was produced on large potential AFO-CAFOs. Only 2 percent of recoverable manure was produced on the very small AFOs. Small AFOs and medium potential AFO-CAFOs each accounted for about 20 percent (table 11).

The quantity of recoverable manure increased steadily from 328 million tons wet weight in 1982 to 514 million tons in 2007—an increase of 57 percent (fig. 15). Large potential AFO-CAFOs in 1982 accounted for only 22 percent of recoverable manure, while small AFOs accounted for 51 percent. The amount of recoverable manure on large potential AFO-CAFOs increased more than 4-fold by 2007, while the amount on small AFOs decreased by 34 percent and the amount on very small AFOs decreased by 59 percent.

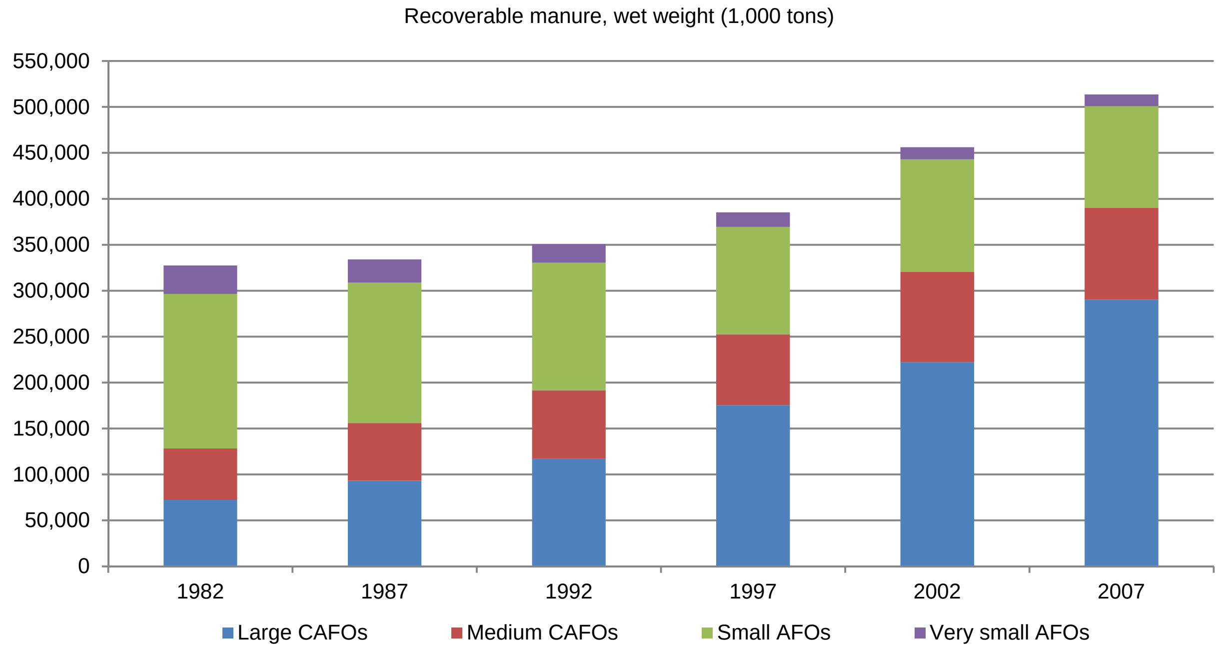
Overall, the amount of recoverable manure in 2007 was 74 percent of the total amount of manure (wet weight, *as excreted*) produced by confined livestock on AFOs (table 11). The amount of recoverable manure nitrogen was 32 percent and recoverable phosphorus was 72 percent. The remaining manure and manure nutrients on AFOs were categorized as non-recoverable. Relative to the total manure and manure nutrients produced on all farms by both pastured livestock and confined livestock, the recoverable portion represents 39 percent of the quantity of manure by wet weight, 18 percent of manure nitrogen, and 29 percent of manure phosphorus (table 11).

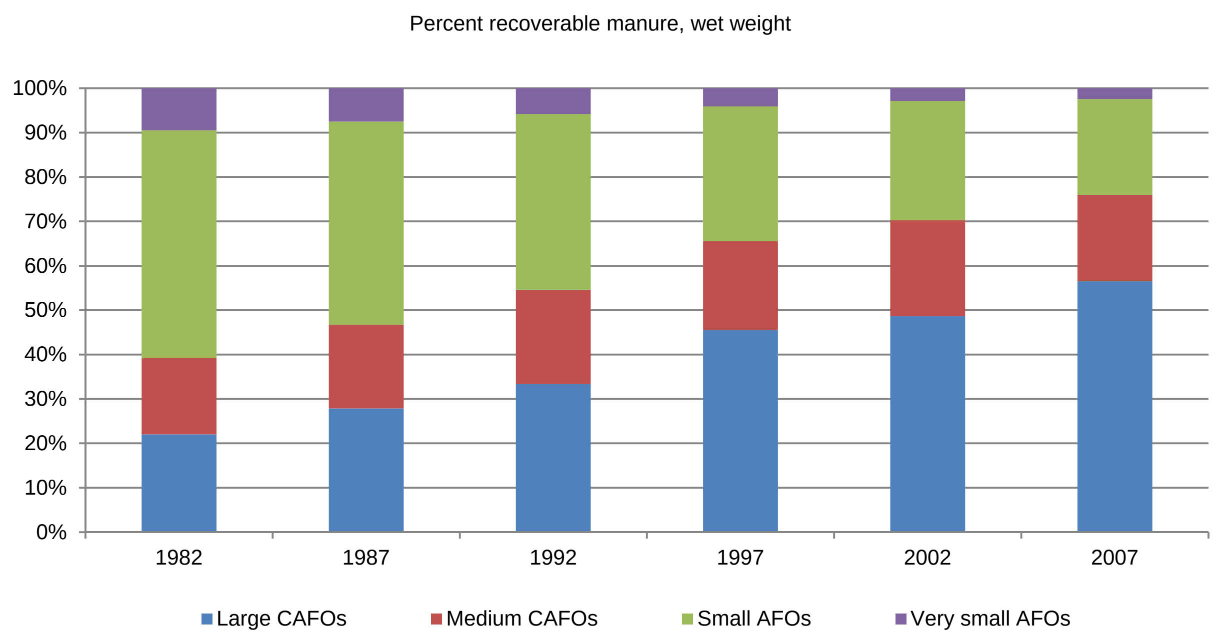
Map 6 presents the distribution and change in the estimated location of recoverable manure (dry weight equivalent) from confined animal units. The location of recoverable manure closely follows the location of confined animals shown in map 4. Recoverable manure is concentrated in regions of confined livestock production, and as was the case with animals, recoverable manure had become more concentrated over the observed period. The distribution of recoverable manure nutrients has not changed dramatically but has become more concentrated in the same general areas due to gains in the total recoverable quantity. The change in recoverable manure location from 1982 to 2007 (panel f) shows gains in most areas. There were a few areas of declines from 1982 to 2007 in southern California, eastern Nebraska, and eastern Minnesota, southern Wisconsin, northern Illinois, central Florida and central New York. However, there were regions of gain and loss in the quantity of recoverable manure shown for 1982 to 1997 (panel d) and 1997 -2007 (panel e) that partially or completely offset over the entire period from 1982-2007 (panel f). For example, Iowa had a decline in recoverable manure in the 1982-1997 period that was almost completely offset by gains in recoverable manure from 1997-2007 resulting in a general gain for most of the State for the overall 1982-2007 period (panel f).

Table 11. Quantity of recoverable manure and manure nutrients after adjusting for losses, all U.S., 2007

	Quantity of recoverable manure (wet weight)		Quantity of recoverable manure (dry weight)		Recoverable manure nitrogen		Recoverable manure phosphorus	
	1,000 tons	Percent of total	1,000 tons	Percent of total	1,000 pounds	Percent of total	1,000 pounds	Percent of total
AFOs								
Very small AFOs	12,702	2	1,586	2	44,634	1	22,815	2
Small AFOs	110,651	22	14,142	20	496,402	16	228,828	16
Medium AFO-CAFOs	100,060	19	16,624	23	782,747	25	358,885	25
Large AFO-CAFOs	290,302	57	38,503	54	1,834,458	58	806,144	57
Total	513,716	100	70,855	100	3,158,242	100	1,416,672	100
Recoverable manure as a percentage of total manure *as excreted* produced on all farms	39%	--	37%	--	18%	--	29%	--
Recoverable manure as a percentage of manure *as excreted* for confined livestock produced on all AFOs	74%	--	76%	--	32%	--	72%	--

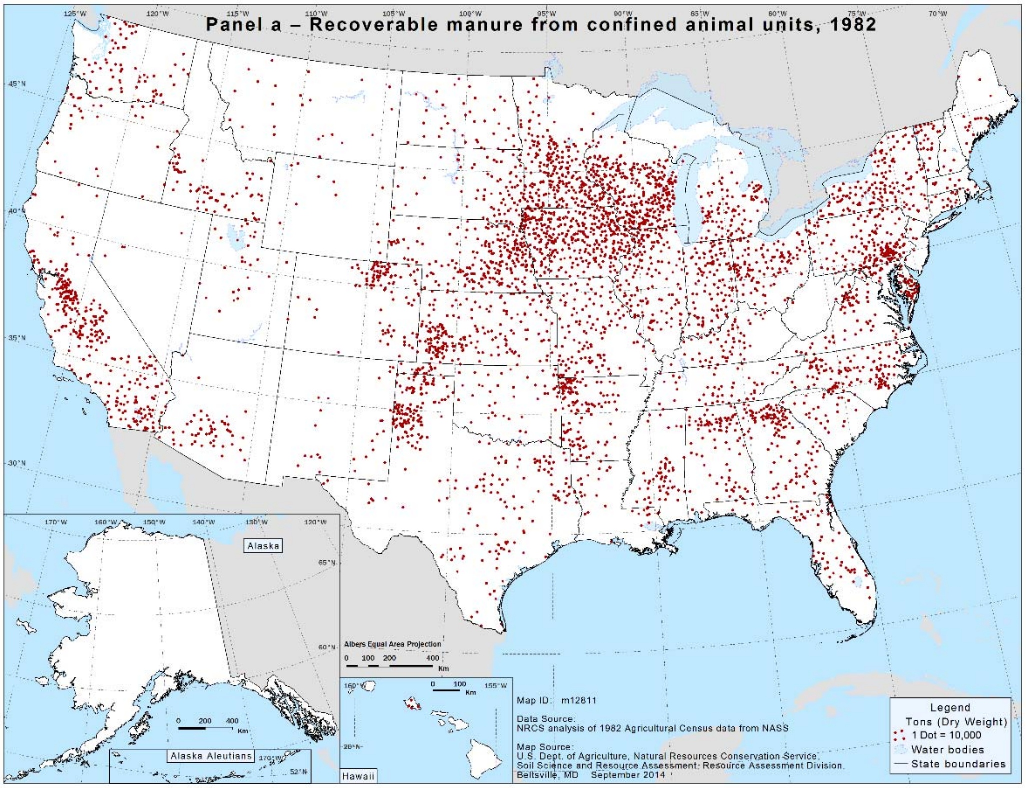
Figure 15. Amount and percent of recoverable manure (wet weight), by AFO farm type



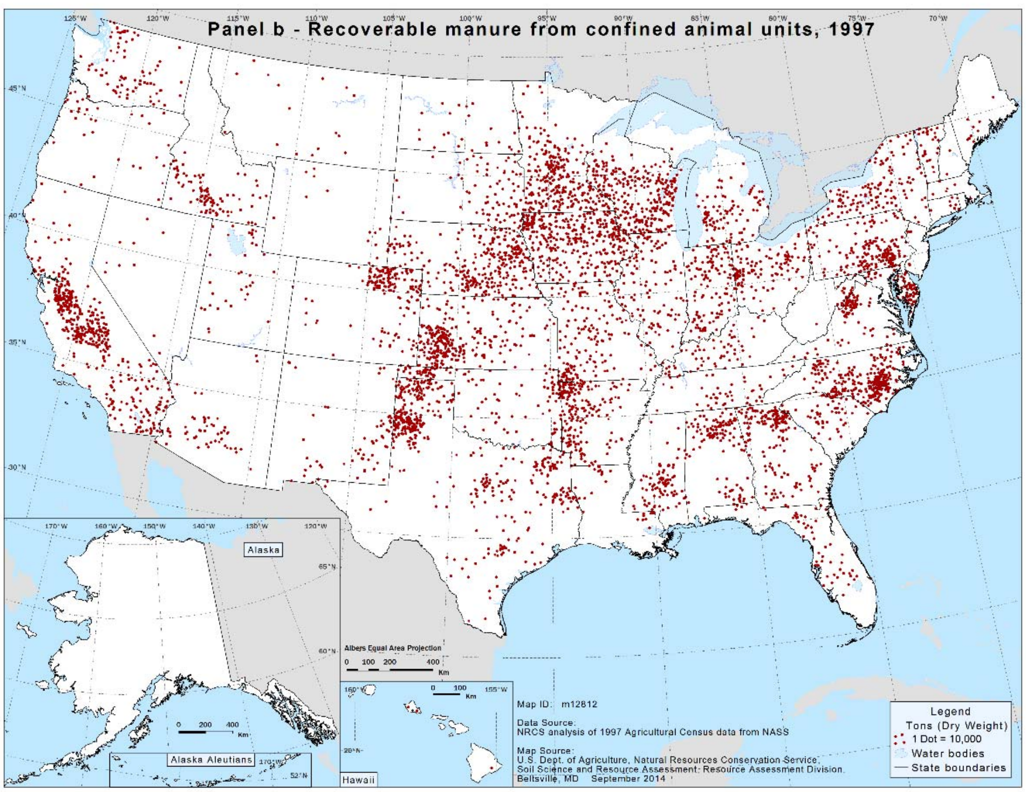


Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Map 6. County location of recoverable manure from confined animals for 1982, 1997, and 2007 and change in the county location of recoverable manure from confined animals 1982-1997, 1997-2007, and 1982-2007

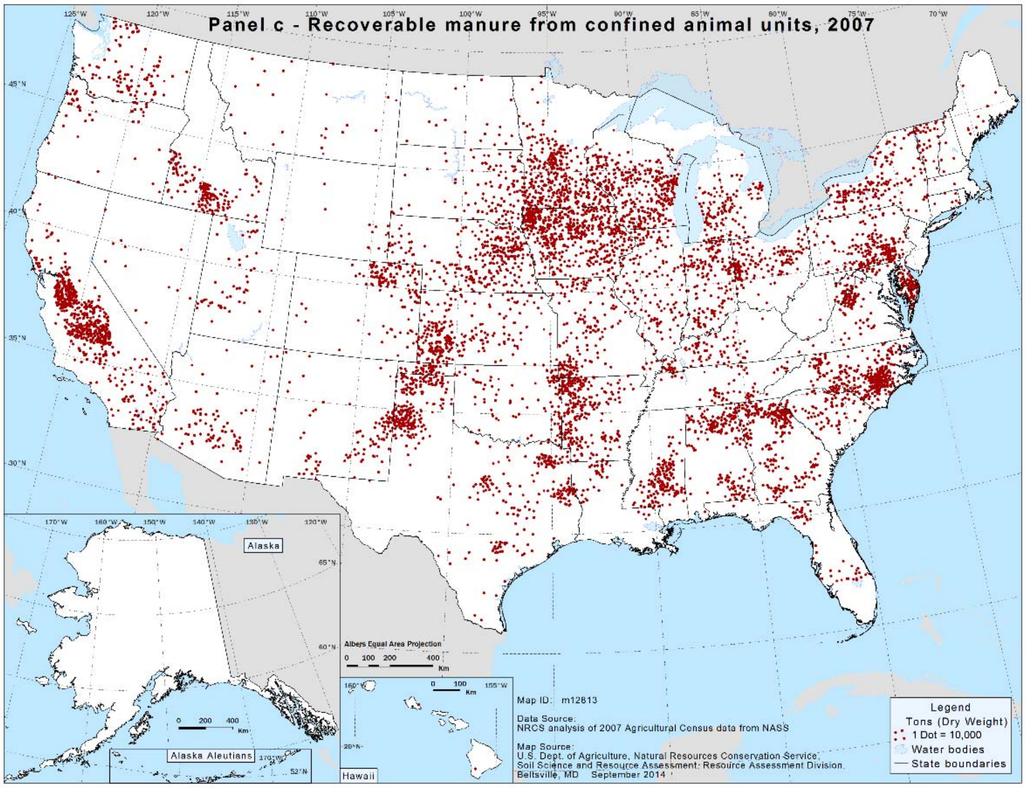


Legend: Dot = 10,000 tons (dry weight)
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

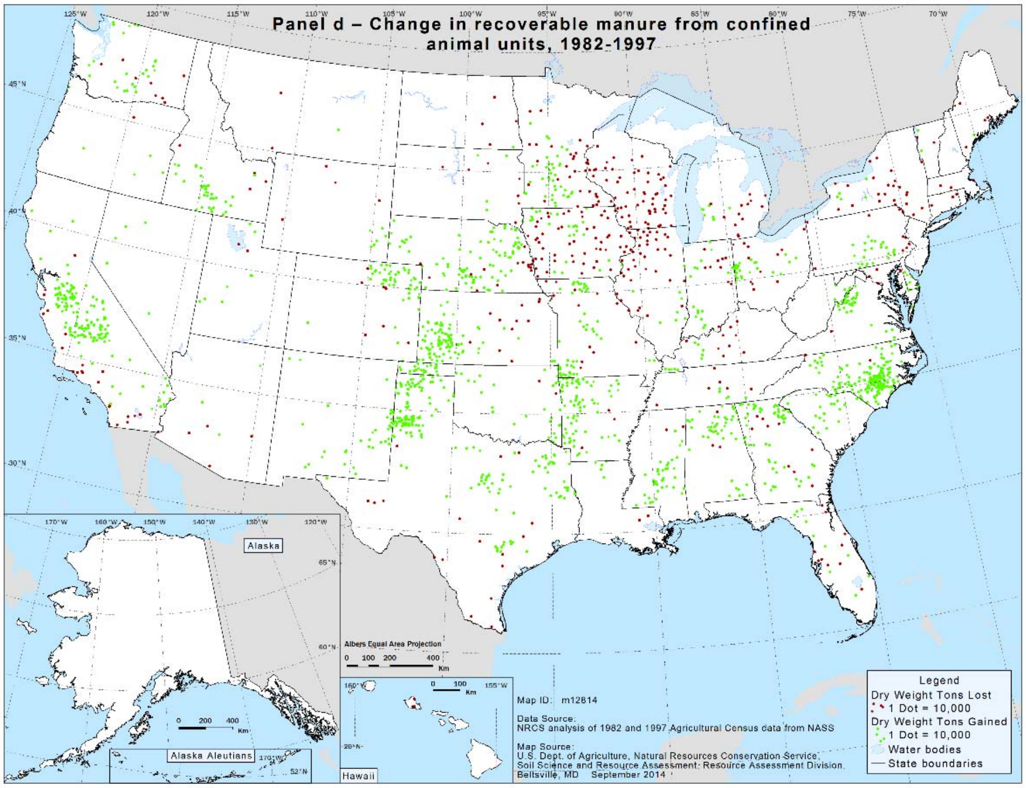


Legend: Dot = 10,000 tons (dry weight)
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 6. County location of recoverable manure from confined animals for 1982, 1997, and 2007 and change in the county location of recoverable manure from confined animals 1982-1997, 1997-2007, and 1982-2007—**continued**

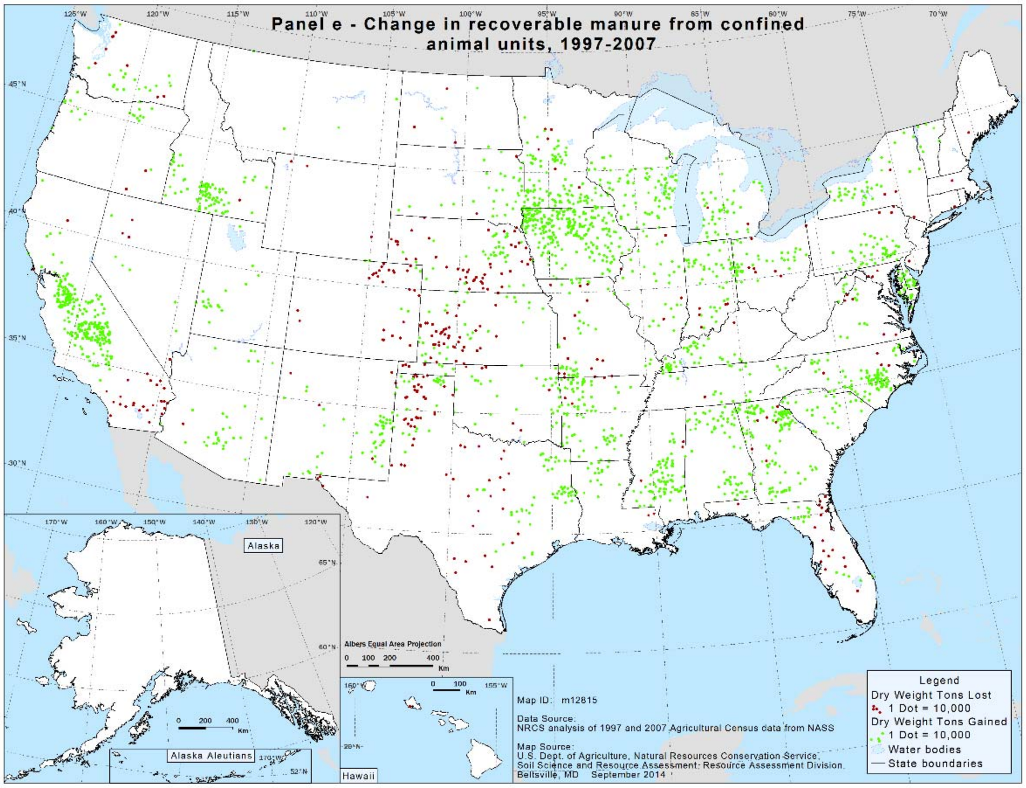


Legend: Dot = 10,000 tons (dry weight)
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

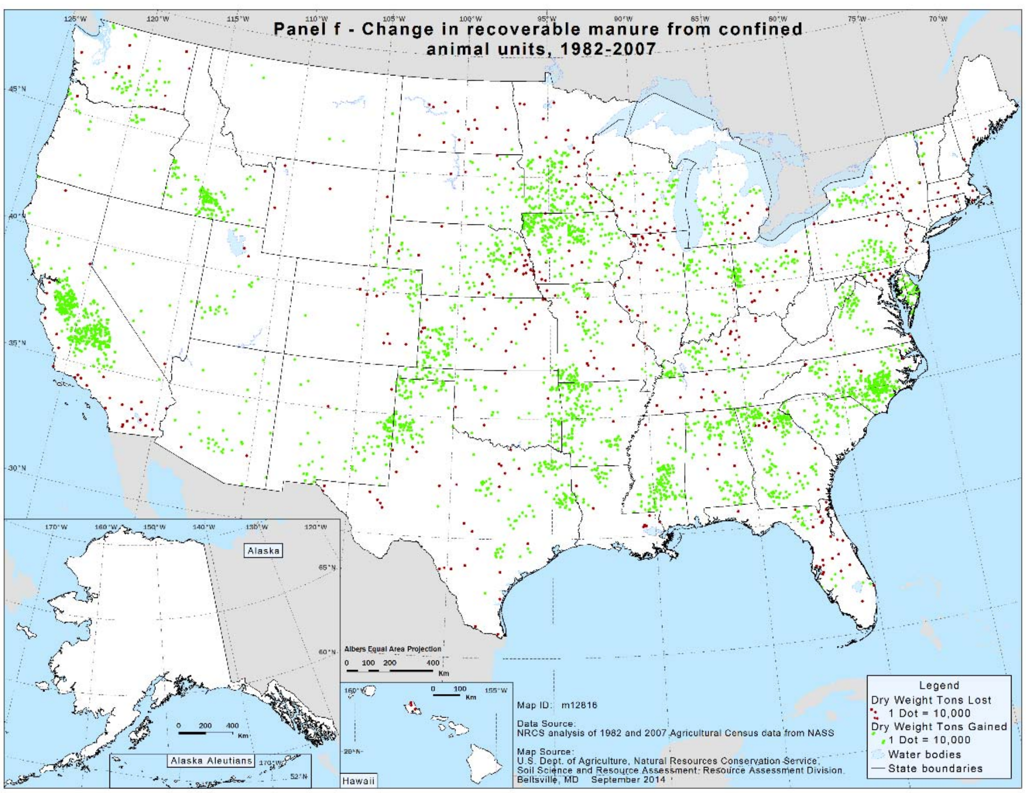


Legend: Green dot = 10,000 ton gain and red dot = 10,000 ton loss (dry weight).
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 6. County location of recoverable manure from confined animals for 1982, 1997, and 2007 and change in the county location of recoverable manure from confined animals 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 10,000 ton gain and red dot = 10,000 ton loss (dry weight).
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



Legend: Green dot = 10,000 ton gain and red dot = 10,000 ton loss (dry weight).
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

The amount of recoverable manure nitrogen totaled 3.2 billion pounds in 2007 (table 11 and fig.16), representing an increase of 98 percent relative to 1982. Large potential AFO-CAFOs accounted for 58 percent of the total, while medium potential AFO-CAFOs accounted for 25 percent, small AFOS accounted for 16 percent, and very small AFOs accounted for 1 percent. In 1982, large potential AFO-CAFOs accounted for 24 percent of the total, while medium potential AFO-CAFOs accounted for 23 percent, small AFOS accounted for 45 percent, and very small AFOs accounted for 8 percent.

The amount of recoverable manure phosphorus totaled 1.4 billion pounds in 2007 (table 11 and fig.17). Large potential AFO-CAFOs accounted for 57 percent of the total, while medium potential AFO-CAFOs accounted for 25 percent, small AFOS accounted for 16 percent, and very small AFOs accounted for 2 percent. The amount of recoverable manure phosphorus on large potential AFO-CAFOs increased 4-fold between 2002 and 2007, while the amount on small AFOs decreased by 41 percent and the amount on very small AFOs decreased 70 percent. The amount of recoverable manure phosphorus increased 53 percent over the 25 years.

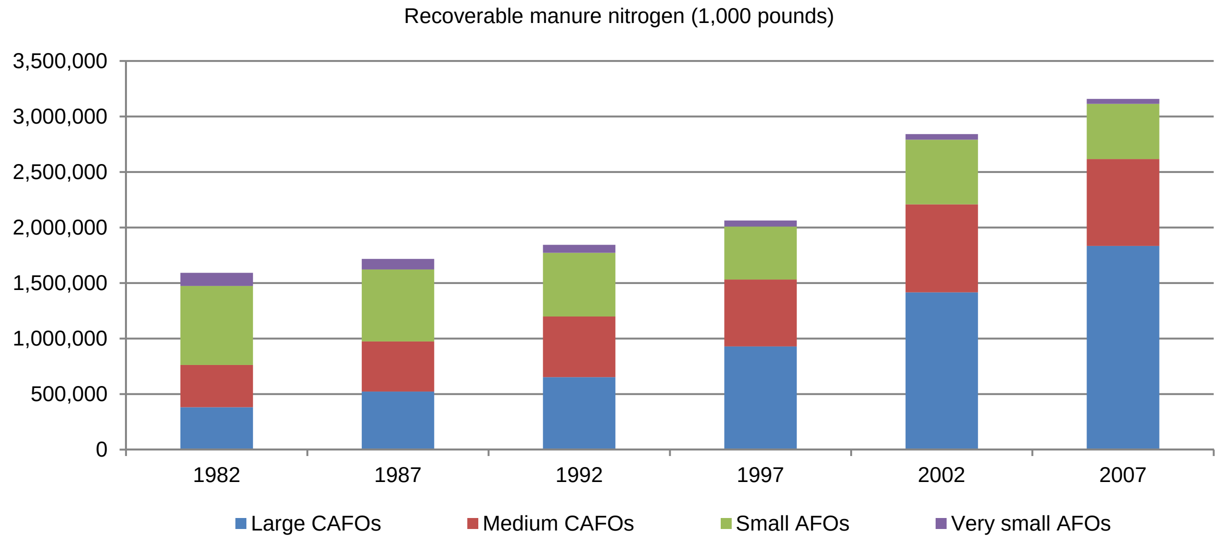
Poultry has the largest share of recoverable manure nitrogen, increasing from 36 percent of the total in 1982 to 42 percent in 2007 (fig. 18). Poultry accounted for only one-fourth of the manure nitrogen *as excreted* on AFOs in 2007 (fig. 12). Milk cows account for the second largest share of recoverable manure nitrogen, but the share decreases slightly over time from 30 percent of the total in 1982 to 27 percent in 2007 (fig. 18); in comparison, milk cows accounted for 39 percent of the manure nitrogen *as excreted* on AFOs in 2007 (fig. 12). Swine accounted for 12 percent of recoverable manure nitrogen and fattened cattle accounted for 15 percent with little change over time (fig. 18). Confined pastured livestock types have the smallest share of recoverable manure nitrogen, decreasing from 10 percent of the total in 1982 to 4 percent in 2007.

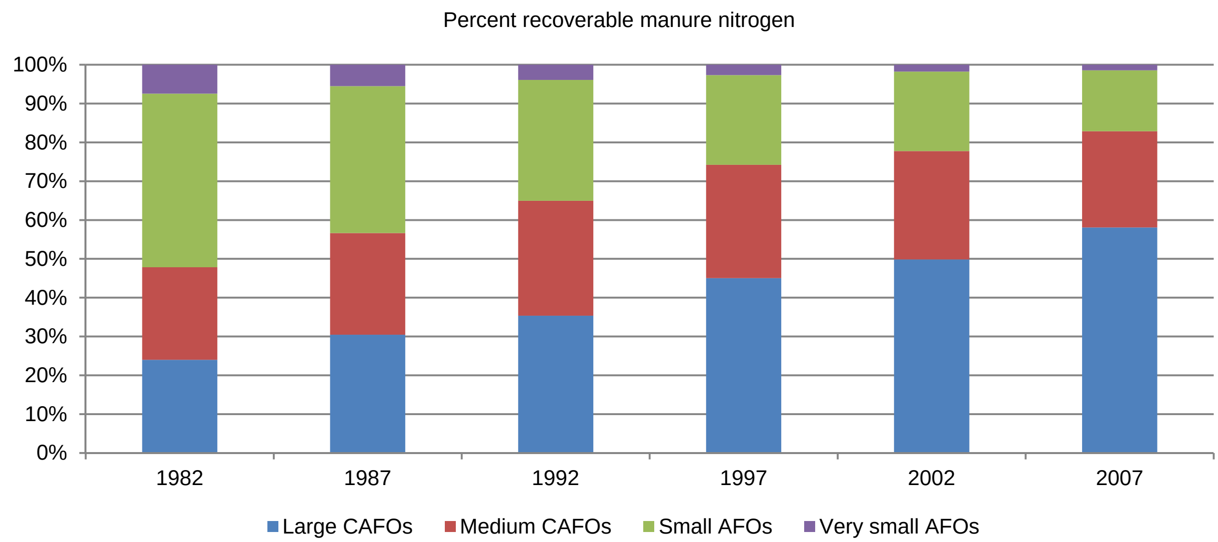
Over the 25 years, recoverable manure nitrogen increased 130 percent for poultry, 140 percent for swine, 105 percent for fattened cattle (including veal), and 82 percent for milk cows (fig. 18). Recoverable manure nitrogen decreased 15 percent for confined pastured livestock types.

Poultry also has the largest share of recoverable manure phosphorus, increasing from 32 percent of the total in 1982 to 42 percent in 2007 (fig. 19). Milk cows account for the second largest amount of recoverable manure phosphorus, with shares fluctuating from a low of 16 percent in 1997 to a high of 26 percent in 2002 and 2007. Swine accounted for 17 to 20 percent of recoverable manure phosphorus. Fattened cattle accounted for a decreasing share of 17 percent in 1982 to 9 percent in 2002 and 2007. Confined pastured livestock types have the smallest share of recoverable manure phosphorus, decreasing from 11 percent of the total in 1982 to 6 percent in 2007.

Over the 25 years, recoverable manure phosphorus increased 102 percent for poultry, 43 percent for swine, and 80 percent for milk cows (fig. 19). Recoverable manure phosphorus decreased 20 percent for confined pastured livestock types and decreased 18 percent for fattened cattle. Correspondingly, the share of the total, shown in figure 19, increased over the period for poultry and milk cows, held about constant for swine, and decreased for fattened cattle and confined pastured livestock types.

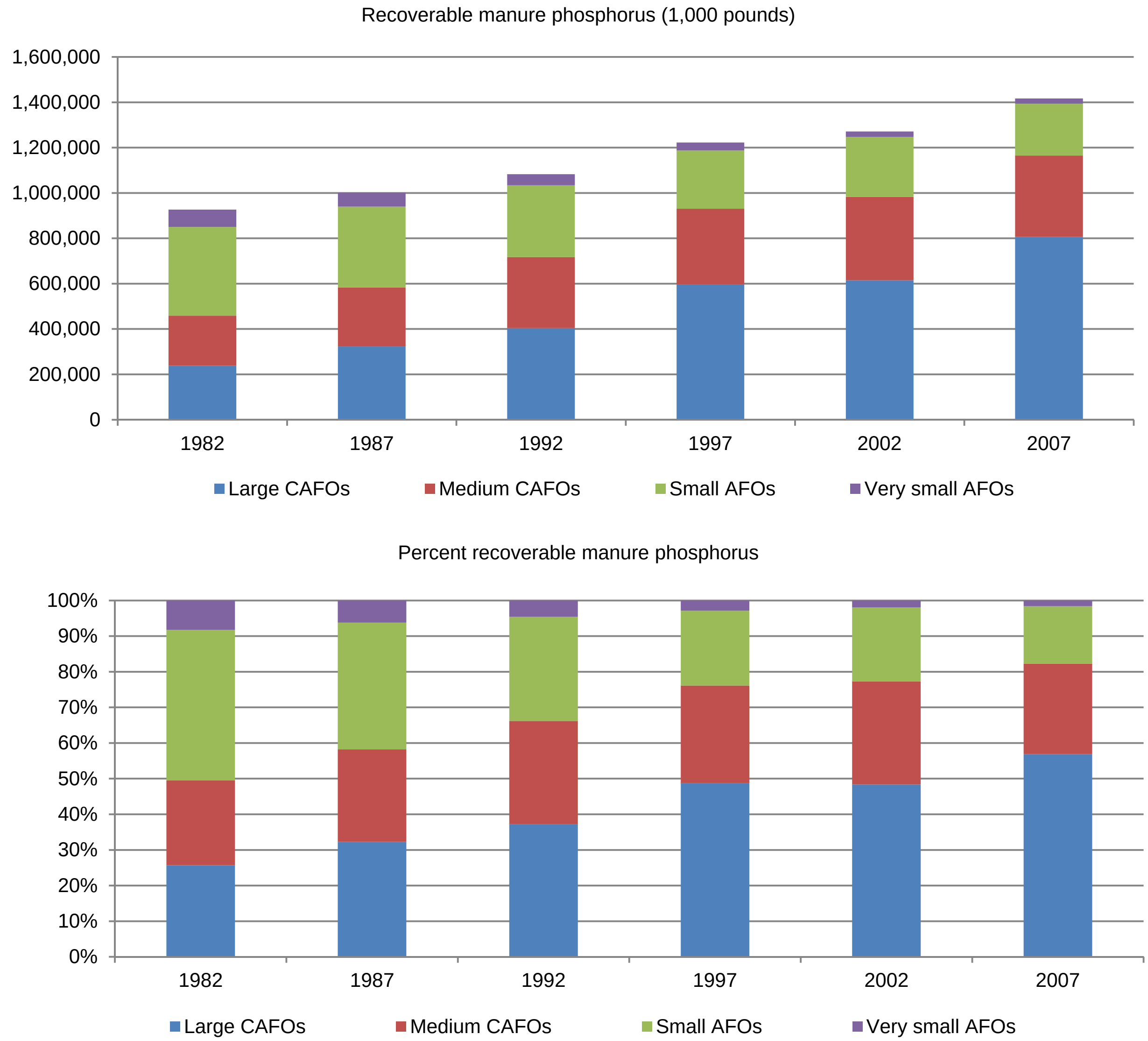
Figure 16. Amount and percent of recoverable manure nitrogen, by AFO farm type





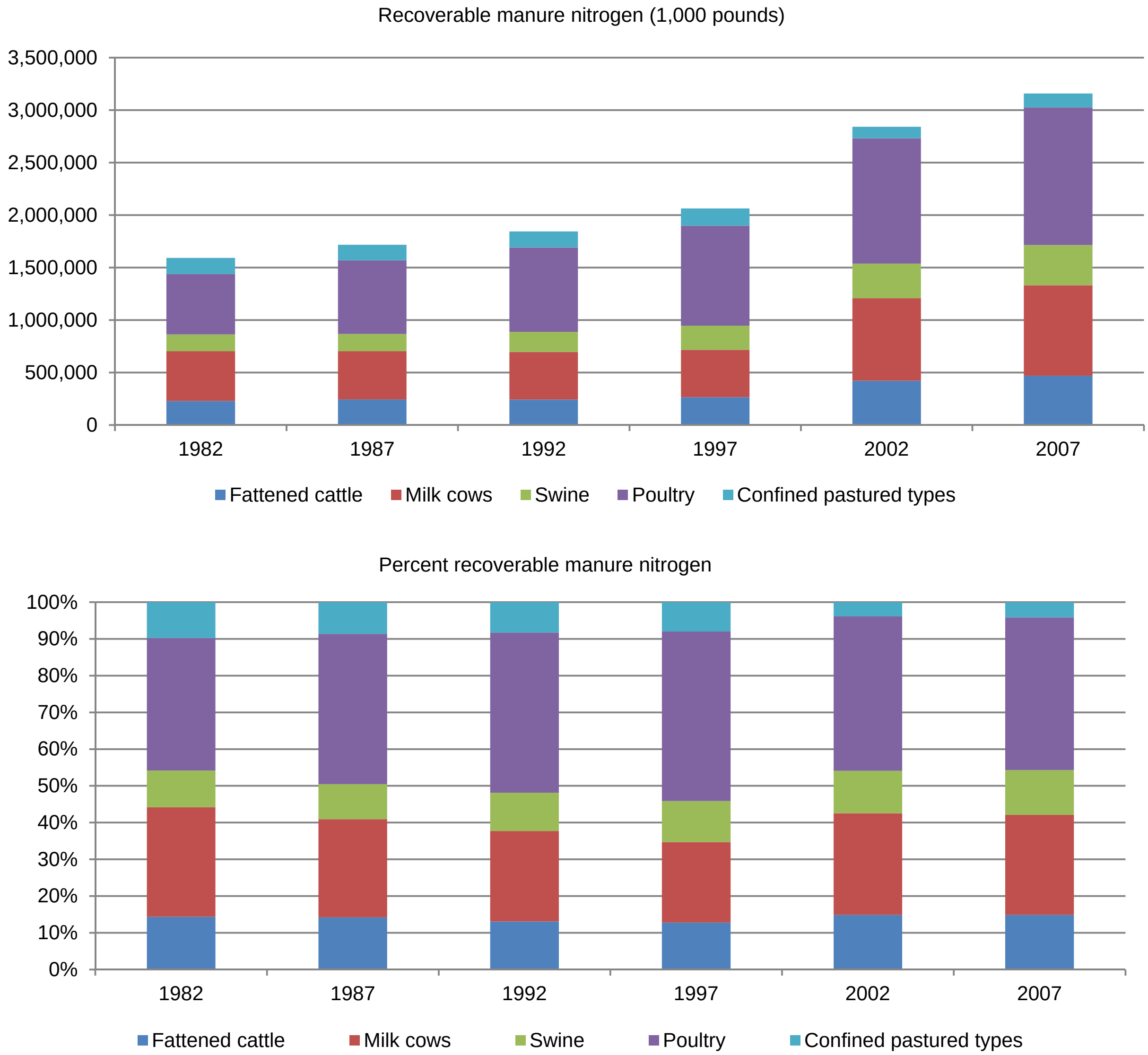
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 17. Amount and percent of recoverable manure phosphorus, by AFO farm type



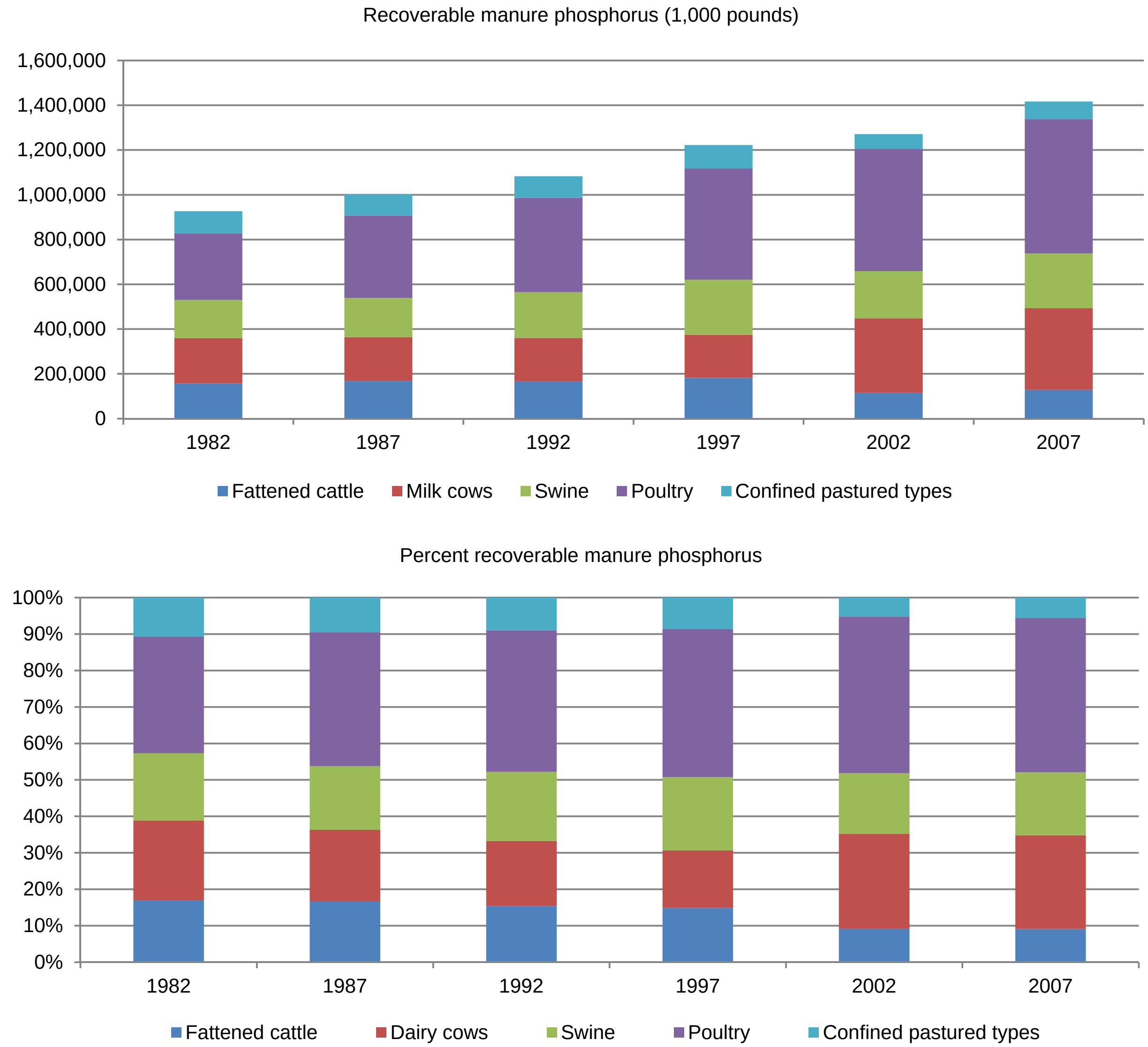
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 18. Amount and percent of recoverable manure nitrogen, by livestock group



Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 19. Amount and percent of recoverable manure phosphorus, by livestock group



Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Non-Recoverable Manure

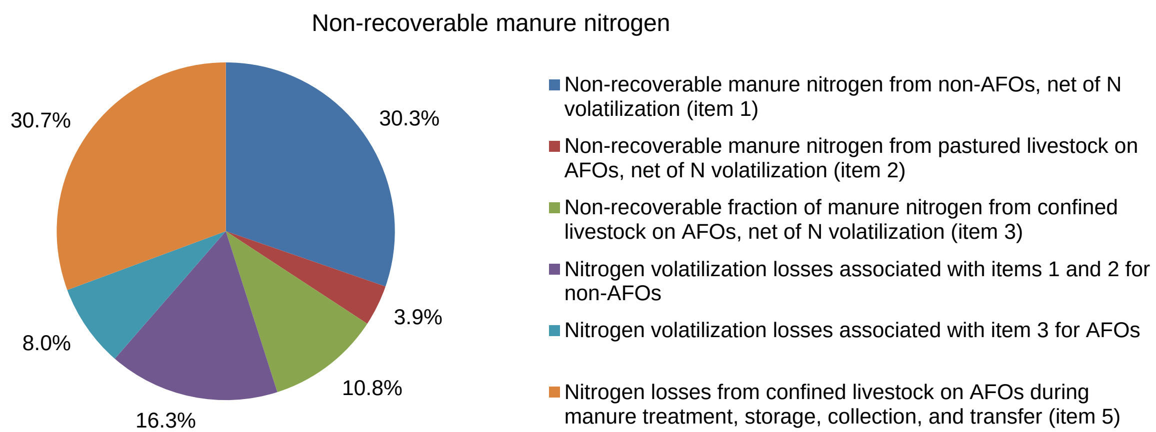
Estimating Non-Recoverable Manure and Manure Nutrients

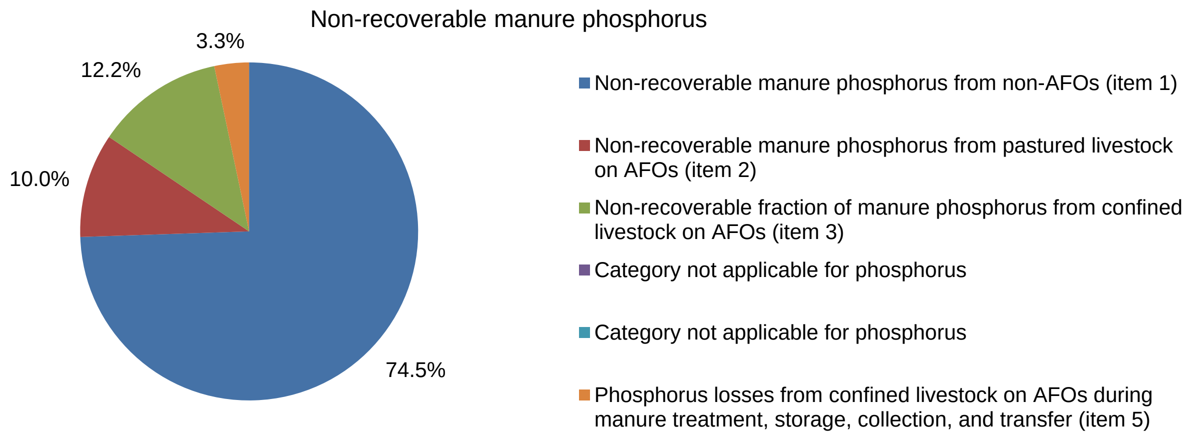
The difference between *as excreted* manure nutrients and recoverable manure nutrients can be broken down into the following components of non-recoverable manure nutrients.

1. Nutrients in manure *as excreted* for all livestock types on farms *not* identified in this study as AFOs, excluding nitrogen volatilization. Non-recoverable manure nutrients originate from all pastured and confined livestock types on these farms. It was assumed that 35 percent of the non-recoverable manure nitrogen *as excreted* would volatilize.
2. Nutrients in manure *as excreted* for all pastured livestock on AFOs, excluding nitrogen volatilization. It was assumed that 35 percent of the non-recoverable manure nitrogen *as excreted* would volatilize.
3. Manure nutrients in the non-recoverable fraction of manure from confined livestock on AFOs, excluding nitrogen volatilization. Nutrients in the non-recoverable fraction of manure from confined livestock on AFOs were estimated using the same nutrient content coefficients as used to estimate manure nutrients in the recoverable fraction (table 3).
4. Nitrogen volatilization losses associated with items 1, 2, and 3.
5. Nitrogen volatilization losses and other nutrient losses during manure treatment, storage, collection, and transfer of recoverable manure from confined livestock on AFOs. This also includes uncollected manure deposited on outside lots and walkways often associated with confined livestock operations.

These five sources of non-recoverable manure nutrients are calculated separately. Nutrients in manure *as excreted* for all livestock not on AFOs and all pastured livestock on AFOs (items 1 and 2 in the above list) were estimated by multiplying the quantity of manure *as excreted* (wet weight) times the nutrient content of manure *as excreted*. The nutrient content coefficients for each livestock type are shown in table 5. The nitrogen estimates for items 1, 2, and 3 were further adjusted to account for nitrogen lost to the atmosphere through volatilization, primarily as ammonia. The proportions of these 5 components of non-recoverable manure nutrients are shown in figure 20 for 2007.

Figure 20. Six components of non-recoverable manure nutrients for 2007





Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Non-Recoverable Manure and Manure Nutrients by Type of Livestock Farm

In 2007, the amount of non-recoverable manure totaled 797 million tons, wet weight (equivalent to 122.5 million tons dry weight) (table 12). Non-recoverable manure represented 61 percent of the total wet weight of manure *as excreted*. Most of this amount (62 percent) was produced on farms with pastured livestock operations and few confined livestock. About 32 percent was produced on AFOs, and the remaining 6 percent was produced on the small non-AFO farms.

The amount of non-recoverable manure nitrogen totaled 14.1 billion pounds in 2007 (table 12 and fig. 21), representing an increase of 8 percent relative to 1982. Slightly more than half of the non-recoverable manure nitrogen was produced on AFOs in most years and slightly less than half was produced on non-AFOs (fig. 21). Non-recoverable nitrogen increased 11 percent on AFOs over the 25 years, and increased 5 percent on non-AFOs.

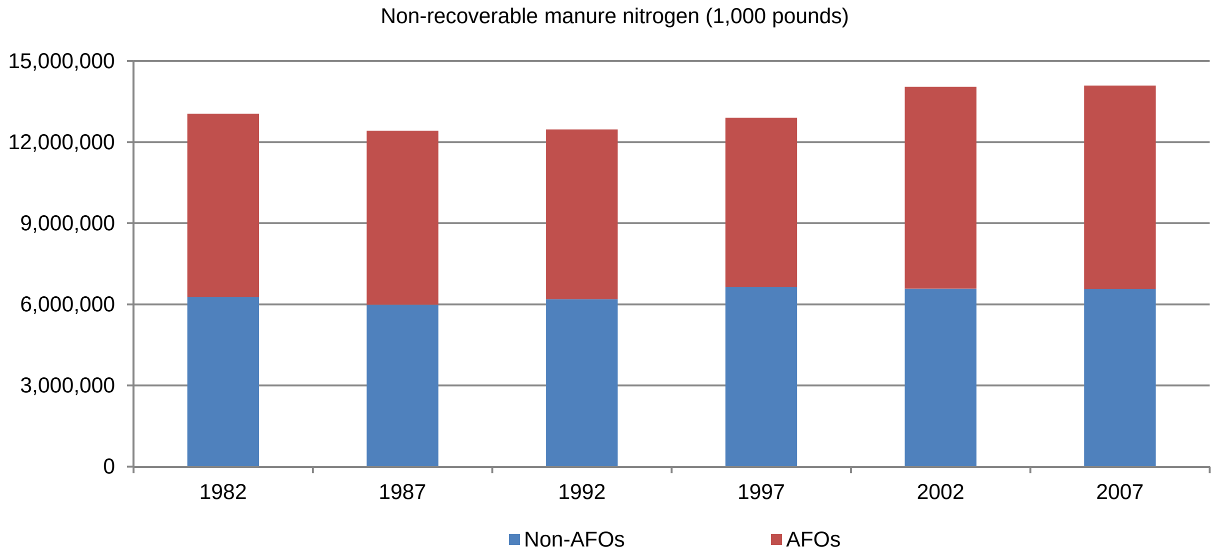
The amount of non-recoverable manure phosphorus totaled 3.5 billion pounds in 2007 (table 12 and fig. 22), compared to 4.0 billion pounds in 1982—an overall decrease of 12 percent. The amount of non-recoverable manure phosphorus increased a small amount on non-AFOs—5 percent—as pastured livestock AU increased slightly over the 25 years. For AFOs, however, non-recoverable manure phosphorus decreased 40 percent from 1982 to 2007 (fig. 22) as the number of pastured livestock AU decreased 53 percent. As shown in figure 20, non-recoverable manure phosphorus from pastured livestock represents about 40 percent of the total non-recoverable manure phosphorus on AFOs. Consequently, the large decrease in pastured livestock types on AFOs over the 25 years resulted in a significant decrease in non-recoverable manure phosphorus on AFOs from 1982 to 2007.

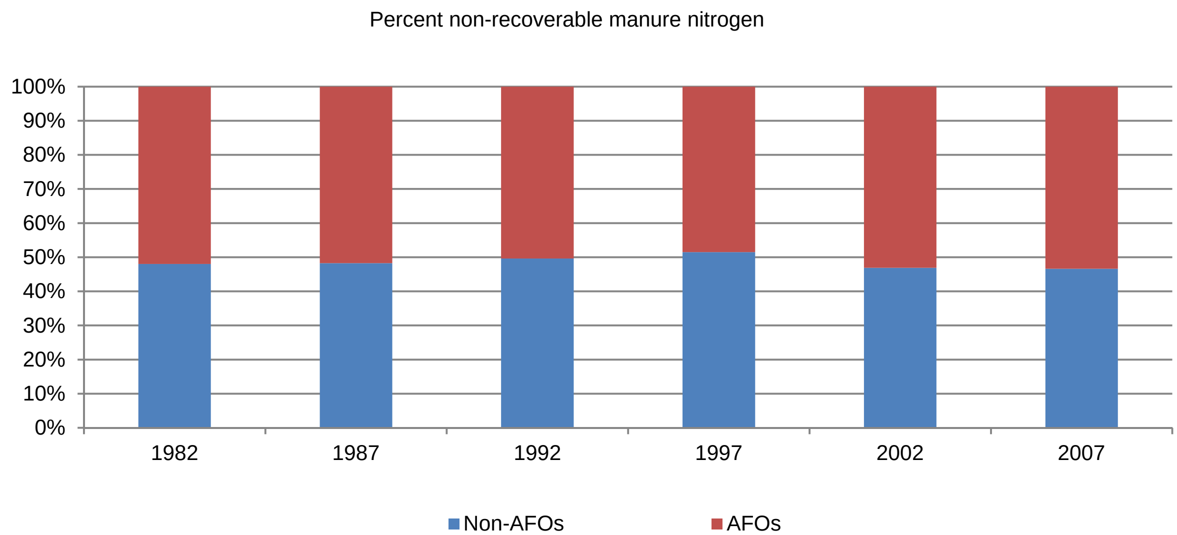
Table 12. Quantity of non-recoverable manure and manure nutrients *as excreted*, all U.S., 2007

	Quantity of non-recoverable manure (wet weight)		Quantity of non-recoverable manure (dry weight)		Non-recoverable manure nitrogen*		Non-recoverable manure phosphorus**	
	1,000 Tons	Percent of total	1,000 Tons	Percent of total	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total
Non-AFOs								
Farms without livestock	0	0	0	0	0	0	0	0
Farms with some livestock but not a livestock operation	2,430	<1	504	<1	30,651	<1	9,577	<1
Very small livestock operations	44,347	6	8,380	7	541,358	4	175,209	5
Specialty livestock operations with few confined livestock	1,027	<1	197	<1	12,501	<1	4,449	<1
Pastured livestock operations with few confined livestock	494,930	62	79,588	65	5,987,043	42	2,410,511	69
AFOs								
Very small AFOs	16,065	2	2,360	2	262,325	2	63,397	2
Small AFOs	86,317	11	11,885	10	1,769,591	13	295,354	8
Medium AFO-CAFOs	47,150	6	6,755	6	1,526,887	11	187,105	5
Large AFO-CAFOs	104,738	13	12,831	10	3,964,518	28	344,885	10
All non-AFOSs	542,734	68	88,669	72	6,571,553	47	2,599,745	74
All AFOs	254,269	32	33,831	28	7,523,322	53	890,740	26
Total	797,003	100	122,501	100	14,094,875	100	3,490,485	100

* Includes all components of non-recoverable nitrogen shown in figure 20, including nitrogen volatilization.
** Includes all component of non-recoverable phosphorus shown in figure 20.

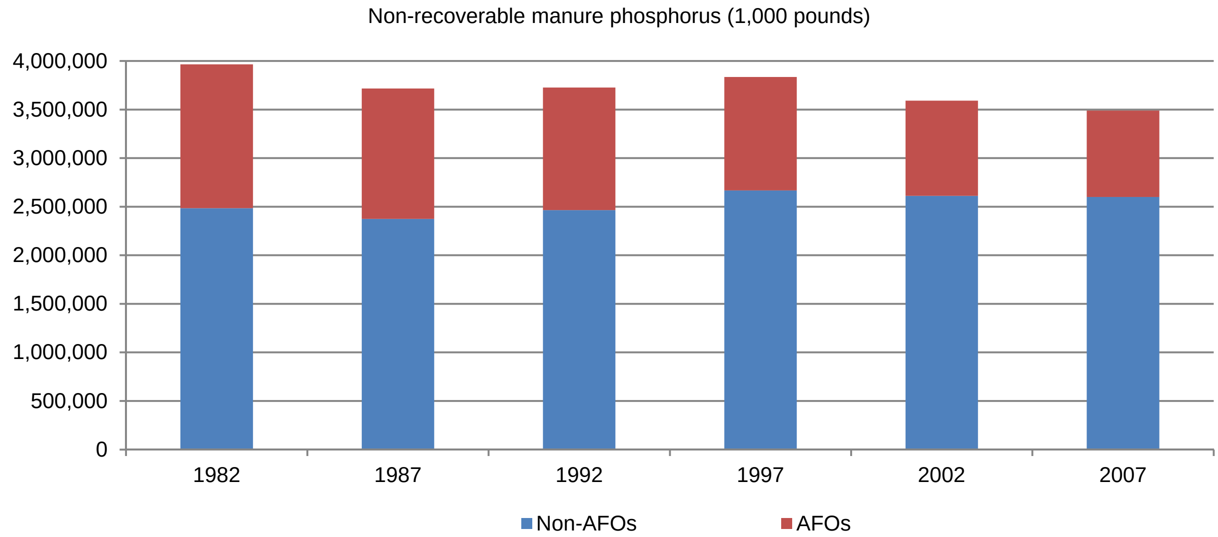
Figure 21. Amount and percent of non-recoverable manure nitrogen

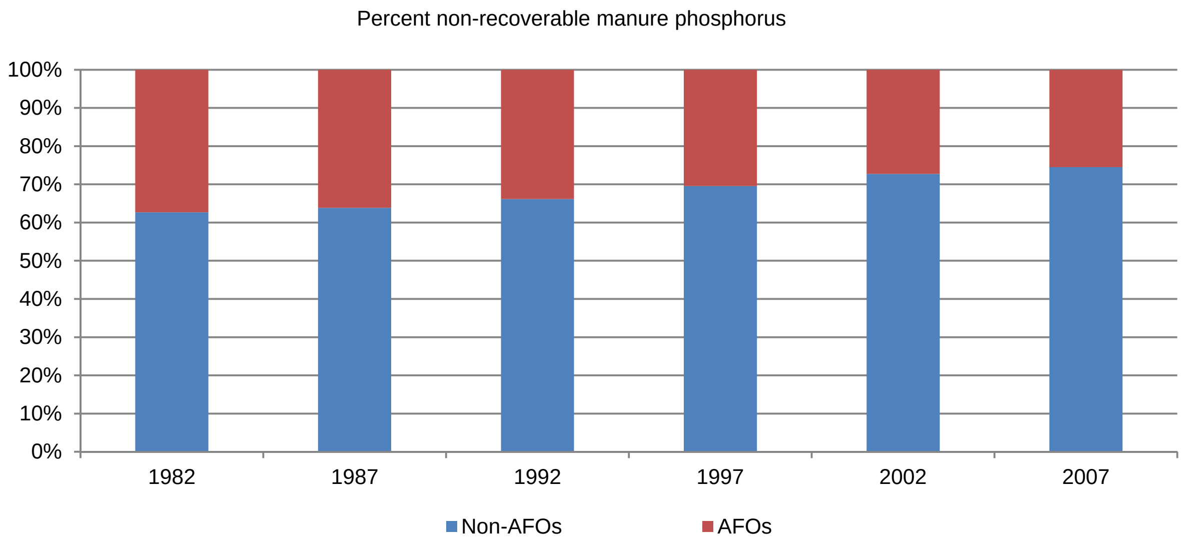




Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 22. Amount and percent of non-recoverable manure phosphorus





Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Box 2: How Estimates for 1982–97 Compare to Previous Estimates for These Years

This report updates a previous report published by the authors in 2000 (Kellogg et al., 2000). That report also included estimates of animal units, manure nutrients *as excreted*, and recoverable manure nutrients for 1982, 1987, 1992, and 1997 based on the Census of Agriculture databases. The current estimates use the same basic methodology but include refinements, including adjustments to manure characteristics and recoverability coefficients in some cases.

Animal Units

Current estimates of AU are about 4.1 to 4.5 million AU higher than previous estimates for 1982–97, as shown in the table below. Most of the differences are due to the additional livestock types included in the current estimates—veal, ducks, horses, ponies, mules, donkeys, sheep, and goats. When the same livestock types are compared, the current estimates are only 1 million AU or less higher than the previous estimates, which is a difference of about 1 percent or less.

Comparison of animal unit estimates

	Estimates from this report*				Estimates from Kellogg and others (2000)			
Livestock type	1982	1987	1992	1997	1982	1987	1992	1997
Fattened cattle	9,710,316	9,760,618	9,265,172	9,588,839	9,706,927	9,758,625	9,264,073	9,588,189
Milk cows	14,862,849	13,814,653	13,002,490	12,459,505	14,652,378	13,622,207	12,823,803	12,289,085
Swine	7,357,373	7,219,134	7,847,684	8,529,712	7,330,637	7,201,496	7,833,189	8,522,082
Poultry (excluding ducks)	4,043,126	4,873,610	5,359,830	6,129,089	4,032,844	4,867,275	5,353,545	6,122,411
Other cattle	60,346,102	56,125,291	57,039,896	59,613,004	59,897,784	55,758,084	56,662,498	58,787,447
Sub-total	96,319,766	91,793,306	92,515,072	96,320,148	95,620,570	91,207,687	91,937,108	95,309,214
Veal	30,091	54,090	55,613	58,444	0	0	0	0
Ducks	13,630	15,559	9,941	14,244	0	0	0	0
Horses, ponies, etc.	2,110,336	2,365,820	2,002,477	2,398,115	0	0	0	0
Sheep and goats	1,544,072	1,458,494	1,458,561	1,062,199	0	0	0	0
Sub-total	3,698,129	3,893,963	3,526,592	3,533,001	0	0	0	0
Total	100,017,895	95,687,269	96,041,664	99,853,150	95,620,570	91,207,687	91,937,108	95,309,214

* Excludes AU for specialty livestock types.

Manure nutrients

Current estimates of total manure nutrients, *as excreted*, are about 2 billion pounds higher for nitrogen and 1.2 billion pounds higher for phosphorus than previous estimates for 1982–97 (see table below). This is due in part to the increase in AU but is also due to refinements in the manure characteristics for pastured livestock types. As shown in table 5, manure characteristics for partially confined pastured livestock types differ from other pastured livestock types. For the estimates in Kellogg and others (2000), a single set of manure characteristics was used on all "other cattle," which differed somewhat from manure characteristics used in the current study.

Recoverable and non-recoverable manure nutrients

Current estimates of recoverable manure nutrients are lower than previous estimates for 1982–97, and current estimates of non-recoverable manure nutrients are higher than previous estimates for 1982–97, as shown in the table below. These estimates are affected by the differences in AU estimates and the differences in manure nutrient estimates, as discussed above. The lower current estimates of recoverable manure nutrients are also due to two changes in methods.

1. Recoverability coefficients for 1997 were revised for a study on the costs of CNMP adoption, published by NRCS in 2003 (USDA/NRCS, 2003). Separate recoverability estimates were made by region of the country, livestock type, and farm size. The estimates were derived by a team of experts working on the study, and are superior to the recoverability estimates used in Kellogg and others (2000). For the current study, these recoverability coefficients derived for 1997 were extended backward to 1982 and forward through 2007 as described in the text associated with table 9.
2. In the study by Kellogg and others (2000), a very low threshold was used to define confined livestock. In the current study, a higher threshold was used, thus reducing the number of small farms (and associated AU) that would be expected to have recoverable manure. This higher threshold resulted in a more reasonable estimate of AFOs as well as a more reasonable estimate of the non-recoverable portion of manure nutrients.

Comparison of manure nutrient estimates

	Estimates from this report, million pounds				Estimates from Kellogg and others (2000), million pounds			
	1982	1987	1992	1997	1982	1987	1992	1997
Manure nitrogen, as excreted	14,646	14,143	14,318	14,970	12,498	12,103	12,313	12,905
Manure phosphorus, as excreted	4,892	4,719	4,809	5,059	3,651	3,554	3,639	3,840
Recoverable manure nitrogen	1,592	1,718	1,844	2,063	2,205	2,310	2,390	2,583
Recoverable manure phosphorus	927	1,002	1,083	1,223	1,208	1,266	1,320	1,437
Non-recoverable manure nitrogen	13,054	12,425	12,474	12,906	10,293	9,793	9,923	10,322
Non-recoverable manure phosphorus	3,966	3,717	3,726	3,836	2,443	2,288	2,319	2,403

Assimilative Capacity of Cropland and Pastureland to Receive Manure Nutrients

Estimating Assimilative Capacity

Recycling manure nutrients by land-applying recoverable manure on cropland and pastureland is a long-standing agricultural practice that reduces the need to purchase commercial fertilizers and provides a cost-effective way to recycle accumulations of livestock manure generated by raising livestock in confinement. Land application of manure not only provides nutrients for crop growth but also enhances soil quality by increasing the organic carbon level in the soil. Over-application of manure nutrients, however, can cause nutrient levels in the soil to build up over time and may result in unacceptable losses of those nutrients from farm fields to surrounding environments through surface water runoff, wind erosion, and subsurface flows (drainage tiles and ditches, natural seeps, and groundwater return flow to rivers and streams).

Assimilative capacity (or land application capacity) is the amount of nutrients that could be applied to land available for application without building up nutrient levels in the soil over time. Estimates of acres by land use from the Census of Agriculture served as the basis for estimating assimilative capacity. The agricultural land base potentially available for manure application was assumed to include the area in harvested cropland, cropland used as pasture, and half of the permanent pasture acreage, as in Kellogg and others (2000). Cropland used as pasture is a specific land use category in the Census of Agriculture database. For cropland, the acreage considered is defined by the production of 21 crops: corn for grain, corn for silage, soybeans, sorghum for grain, sorghum for silage, cotton, barley, winter wheat, durum wheat, other spring wheat, oats, rye, rice, peanuts, sugar beets, tobacco, alfalfa hay, small grain hay, other tame hay (including sorghum hay), wild hay, and grass silage.[15]

Permanent pasture is not reported in the census, but was derived from acres of rangeland and pastureland combined (a land use category in the Census) and separate estimates of pastureland and rangeland acres by county as reported in the National Resources Inventory (NRI). The NRI was used to determine the percentage of pastureland and rangeland that is classified as pastureland in each county in each year. This percentage was then applied to the Census acres for pastureland and rangeland combined for each farm to estimate the acres of permanent pastureland on each farm. In the East, most of the pastureland and rangeland combined, as reported in the Census, was classified as permanent pastureland with this calculation, while few acres in the West were classified as permanent pastureland. It was assumed that half of the permanent pastureland would not be accessible by manure-spreading equipment because of location, terrain, or trees and other plant growth.

The assimilative capacity of cropland to receive manure nutrients without excessive accumulation of nutrients in the soil is estimated based on the amount of nitrogen and phosphorus taken up by the crop and removed with the yield at harvest. Crop yields for each farm were estimated by dividing total crop production (tons, pounds, bushels, or bales) by the number of acres harvested. The approach and assumptions are similar to how assimilative capacity was estimated in Kellogg and others (2000). The amounts of nutrients taken up and removed with the crop yield at harvest were obtained from the National Uptake and Removal Database (NURD), constructed and maintained by the International Plant Nutrition Institute (IPNI). Nutrient uptake and removal coefficients used to estimate assimilative capacity for the 21 crops are presented in table 13.[16]

In the calculation of assimilative capacity, estimates of the nutrient uptake and removal with crop yield were multiplied by an “efficiency factor” to account for the fact that some of the nutrients applied would be lost from the farm field with wind and water and would thus not be available for crop yield. The nitrogen efficiency factor is the ratio of applied nutrients to the amount of nutrients removed with the yield at harvest and is always greater than 1. These additional nutrients above and beyond nutrient removal with crop harvest are included in the assimilative capacity calculation because without them the reported crop yields could not have been attained. It is assumed that nutrients taken up in the non-harvested portion of the plant (i.e., crop residues) are recycled into the soil and thus are not included in derivation of the efficiency factor. The proportion of nitrogen lost is typically much higher than the proportion of phosphorus lost, however, the nitrogen losses will be reduced by incorporation into the soil profile at the time of application. The use of conservation practices (soil erosion control and nutrient management techniques) reduces these losses significantly, but cannot entirely eliminate them. Two levels of assimilative capacity for nitrogen were estimated representing two levels of conservation and nutrient management, as follows.

1. A nitrogen efficiency factor of 1.4, representing 70-percent efficiency in crop uptake and removal of applied nitrogen. For this estimate, 30 percent of the nitrogen applied is lost through volatilization, denitrification, runoff, leaching, or with wind erosion. An application-removal ratio for nitrogen of 1.4 has been traditionally considered an acceptable rate of application when the manure is not incorporated and nitrogen losses are not well

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[15] Kellogg and others (2000) also included potatoes and sweet potatoes. Production data on these two crops are no longer reported in the Census of Agriculture, so both crops were dropped from estimates for 1982–97 to provide consistency among the estimates across all years.

[16] NURD presents information from research reports on the uptake and removal of crops conducted in each state at www.globalmaize.org/NURD/. Jerry Lemunyon, Natural Resources Conservation Service, Fort Worth, TX, extracted estimates from NURD that would be representative of crops throughout the United States. These representative estimates are presented in table 7. They differ somewhat from estimates used in Kellogg and others (2000).

controlled by conservation practices, and was used by Kellogg and others (2000) to estimate assimilative capacity for nitrogen. [17]

2. A nitrogen efficiency factor of 1.2, representing 83 percent efficiency in crop uptake and removal of applied nitrogen. This rate of application was used in the Conservation Effects Assessment Project (CEAP) simulations of full nutrient management, and is agronomically feasible when accompanied by the appropriate application timing and method and soil erosion control practices where needed.

The assimilative capacity estimate for phosphorus was based on an application-removal ratio of 1.05 for crops, representing a 95-percent efficiency in crop uptake and removal of applied phosphorus.[18]

The assimilative capacity for permanent pastureland could not be established based on crop uptake and removal since pasture grasses are not harvested in the manner of field crops. (The grass crop is "harvested" in the form of grazing livestock.) Thus, nitrogen and phosphorus rates of application for pastureland were set at levels expected to provide the nutrients necessary for good levels of grass production assuming the pastureland is being grazed and accounting for the additional manure nutrients contributed by the grazing animals. For nitrogen, the rate was 75 pounds of nitrogen per acre for cropland used as pasture and 30 pounds per acre for permanent pastureland. The lower rate for permanent pastureland reflects the generally lower productivity associated with permanent pastureland as compared to cropland used as pastureland. The phosphorus rate was set at approximately equivalent levels after adjusting for the ratio of phosphorus to nitrogen in beef cattle manure. The phosphorus rate was 28 pounds of phosphorus per acre for cropland used as pasture and 11 pounds per acre for permanent pastureland.

Separate estimates of assimilative capacity were made for each of these scenarios for each farm. The estimate of assimilative capacity for nitrogen is thus the total amount of manure nitrogen that could be applied to cropland and pastureland on each farm according to the two nitrogen application scenarios defined above. The estimate of assimilative capacity for phosphorus is the total amount of manure phosphorus that could be applied to cropland and pastureland on each farm according to the phosphorus application assumption defined above.

These estimates of assimilative capacity are theoretical endpoints under specific and somewhat ideal conditions. For example, it is unlikely that all of the acres for the 21 crops would be available for manure application. Some landowners would not be willing to accept manure applications, and other acres would not be used because of environmental reasons, such as acres with high levels of soil erosion or acres with high levels of soil phosphorus resulting from previous over-application of manure or fertilizers. The production data reflect actual yields in each year, determined in large part by prevailing weather conditions. Moreover, the assumptions governing the rate of manure applications are idealistic in that it is assumed that losses of nitrogen from farm fields are controlled to the assumed levels of 70-percent efficiency or 83-percent efficiency through appropriate conservation and management practices on each field so that reported crop yields could be maintained.

The hallmark of these estimates is that they are made using the same assumptions about land availability and nutrient efficiency factors from year to year. Year-to-year differences in assimilative capacity estimates are thus attributable only to changes in crop yields and changes in acres harvested.

[17] Kellogg and others, 2000, estimated assimilative capacity for two scenarios, one assuming 70 percent efficiency in crop uptake and removal of applied nitrogen and another assuming 100 percent efficiency in crop uptake and removal of applied phosphorus. Assimilative capacity was not reported in NRCS/USDA (2003).

[18] This estimate of assimilative capacity for manure phosphorus would be possible only if additional nitrogen fertilizer was made available so that the crop yields represented by the production data could be attained.

Table 13. Nutrient uptake and removal coefficients for 21 crops used to estimate assimilative capacity for all years

Crop	Per-acre yield unit	Pounds of nutrients per yield unit	
		Nitrogen	Phosphorus
Corn for grain	Bushels	0.84	0.18
Corn for silage	Tons	8.43	1.60
Soybeans	Bushels	3.60	0.31
Sorghum for grain	Bushels	0.84	0.18
Sorghum for silage	Tons	9.00	1.57
Cotton (lint and seed)	500 pound bales	12.31	2.42
Barley	Bushels	0.94	0.18
Winter wheat	Bushels	1.10	0.22
Durum wheat	Bushels	1.50	0.22
Other spring wheat	Bushels	1.50	0.22
Oats	Bushels	0.70	0.15
Rye for grain	Bushels	1.20	0.18
Rice	100 pound bags	1.27	0.29
Peanuts for nuts (with pods)	Pounds	0.040	0.003
Sugar beets for sugar	Tons	3.32	0.69
Tobacco	Pounds	0.040	0.004
Alfalfa hay	Tons	52.31	5.45
Small grain hay	Tons	25.60	4.48
Other tame hay, including sorghum hay	Tons	37.53	6.44
Wild hay	Tons	36.00	5.24
Grass silage	Tons	14.80	2.10

Capacity of Cropland and Pastureland to Receive Manure Nutrients by Type of Livestock Farm

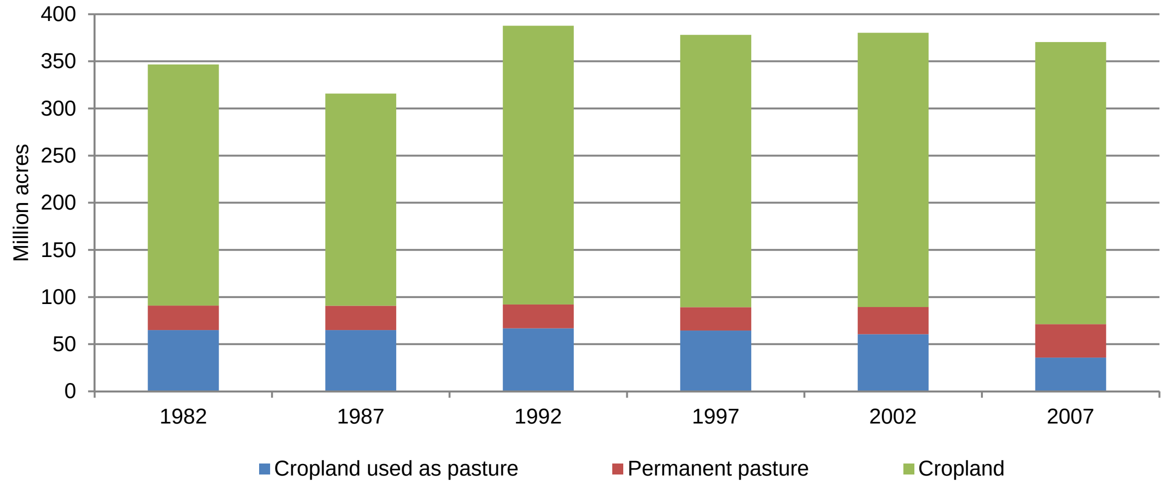
The land assumed to be available for manure application totaled 370 million acres in 2007, with 10 percent cropland used as pasture, 9 percent permanent pasture, and 81 percent cropland acres (fig. 23). Acres of cropland used as pasture were higher in years prior to 2007, ranging from 61 to 67 million acres during 1982–2002, compared to only 36 million acres in 2007. Acres of cropland fluctuated over the 25 years, ranging from a low of 225 million in 1987 to a high of 299 million in 2007. Permanent pasture acres ranged from 25 to 26 million throughout 1982-1997 and then increased to 29 and 35 million acres in 2002 and 2007, respectively.

In 2007, most acres assumed to be available for manure application were about evenly divided among farms with no livestock (41 percent) and other non-AFOs with livestock but few confined livestock types (42 percent). The remainder—17 percent—were acres on farms designated as AFOs in this study (fig. 24). In the earlier years, however, more acres were available on AFOs and fewer acres were available on farms with no livestock.

Acres assumed to be available for manure application on AFOs decreased from 109 million in 1982 to 65 million in 2007, representing a 40-percent decrease. The decline in land on AFOs is attributable to the increased specialization of livestock production which separates the land-intensive crop production from the animal production, especially on large AFO-CAFOs.

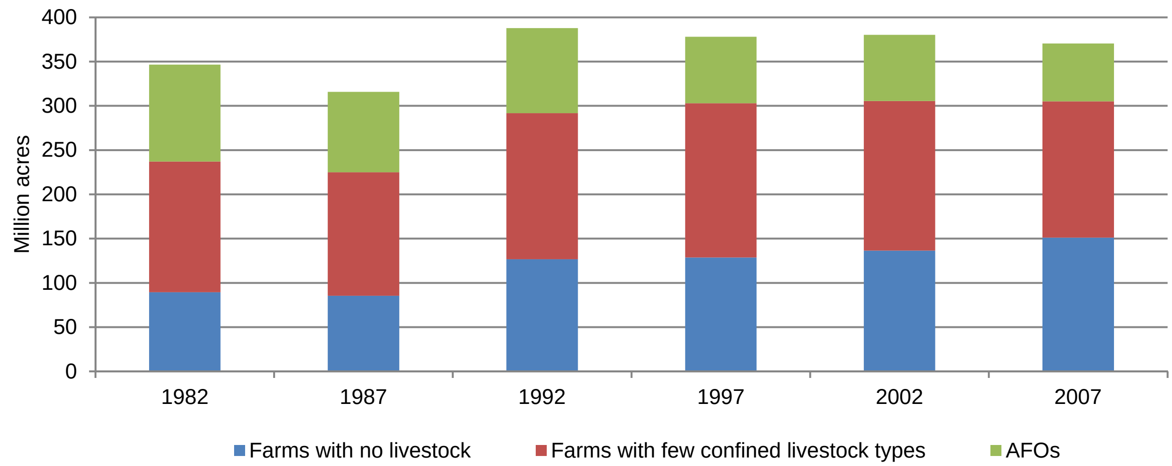
In 2007, the assimilative capacity for land application of manure nitrogen, assuming a nitrogen use efficiency factor of 1.4, totaled 47.5 million pounds (table 14). Only 22 percent of this capacity was on AFOs, compared to 47 percent on farms with no livestock and 24 percent on farms with pastured livestock but few confined livestock. Assimilative capacity increased over the 25 years from 37 million pounds in 1982 to 47 million pounds in 2007, in part because of a 7-percent increase in acres assumed to be available for manure applications and in part due to increases in crop yields (fig. 25).

Figure 23. Cropland and pastureland acres assumed to be available for manure application in the estimation of manure nutrient assimilative capacity



Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 24. Cropland and pastureland acres assumed to be available for manure application in the estimation of manure nutrient assimilative capacity, by farm type



Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 25. Potential to apply manure nitrogen on cropland and pastureland (assimilative capacity) assuming a 1.4 efficiency factor

Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

The assimilative capacity is less when assumptions are changed to represent better management of manure applications, such as appropriate times, methods, and rates of nitrogen application (table 14 and fig. 26). The assimilative capacity for land application of manure nitrogen under the assumption of a nitrogen use efficiency factor of 1.2 totaled 41.3 million pounds in 2007. Trends in assimilative capacity over the 25 years were similar to those with the higher nitrogen use efficiency factor.

Under the assumptions of a nitrogen use efficiency factor of 1.4 or 1.2, representing two levels of nutrient management, there would still be some acres where phosphorus would be over-applied if repeated applications were made year after year on the same acres. A phosphorus-based approach to manure application would apply manure at even lower rates but would assure that phosphorus levels would not build up in soils with repeated applications. The assimilative capacity for land application of manure phosphorus with a phosphorus use efficiency factor of 1.05 represents this kind of phosphorus based approach, where all but 5 percent of the amount applied would be available for crop uptake and growth.

Under the assumption of a phosphorus-based approach, the assimilative capacity for manure application totaled 6.6 million pounds of phosphorus in 2007 (table 14). About 20 percent of this capacity was on AFOs, slightly less than for nitrogen-based applications. This compares to 42 percent on farms with no livestock, slightly less than for nitrogen-based applications, and 30 percent on farms with pastured livestock but few confined livestock, slightly more than for nitrogen-based applications. Assimilative capacity increased over the 25 years from 5.7 million pounds in 1982 to 6.6 million pounds in 2007 (fig. 27).

Map 7 presents the distribution and change in the estimated location of the capacity of cropland to assimilate recoverable manure nutrients through land application, assuming a 1.4 nitrogen efficiency factor (70 percent efficiency in uptake). (Note that mapping at a 1.2 nitrogen efficiency factor would have changed the number of dots in the maps but not the location.) Nitrogen assimilative capacity coincides with the location of cropland, especially cropland with high per-acre nitrogen requirements, for example corn for grain or silage (panels a-c). In general, there was an expansion into the Northern Plains in the available assimilative capacity from 1982 to 1997 (panel d). The period from 1997 to 2007 exhibited assimilative capacity growth in in the Northern Plains and across the central Corn Belt (panel e). The increase in assimilative capacity was due in part to an increase in corn acres in the Northern Plains and more concentrated corn production in the Corn Belt to meet high demands for corn. The increase in per-acre corn yield of 33 percent from 1982 to 2007 would have increased the per acre nitrogen demand even with no increase in corn acres. The combination of shifting crops, increasing acres and increasing yields resulted in a significant increase in manure nitrogen assimilative capacity (panel f).

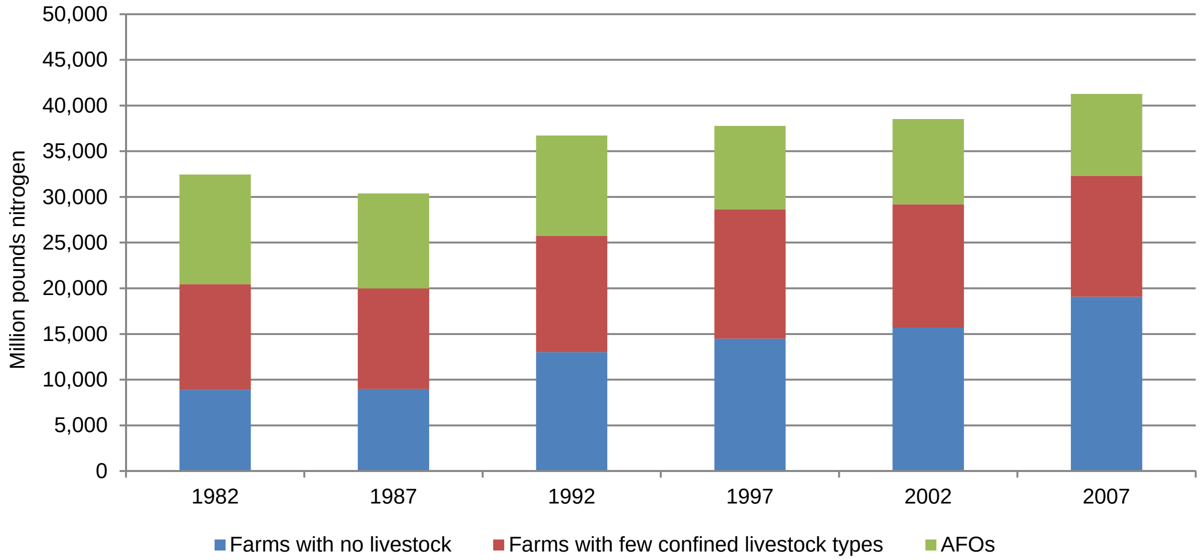
Table 14. Capacity of cropland and pastureland to assimilate manure nutrients,* all U.S., 2007

	Assimilative capacity for nitrogen assuming a 1.4 efficiency factor		Assimilative capacity for nitrogen assuming a 1.2 efficiency factor		Assimilative capacity for phosphorus assuming a 1.05 efficiency factor	
	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total	1,000 Pounds	Percent of total
Non-AFOs						
Farms without livestock	22,127,984	47	19,074,068	46	2,791,091	42
Farms with some livestock but not a livestock operation	570,196	1	498,037	1	83,304	1
Very small livestock operations	2,836,224	6	2,485,914	6	430,727	7
Specialty livestock operations with few confined livestock	67,190	<1	60,536	<1	13,415	<1
Pastured livestock operations with few confined livestock	11,515,958	24	10,184,861	25	1,940,967	30
AFOs						
Very small AFOs	1,459,764	3	1,257,261	3	177,180	3
Small AFOs	5,177,029	11	4,458,437	11	642,728	10
Medium AFO-CAFOs	2,148,784	4	1,850,674	4	274,370	4
Large AFO-CAFOs	1,625,776	3	1,398,647	3	207,569	3
All non-AFOSs	37,117,552	78	32,303,415	78	5,259,505	80
All AFOs	10,411,353	22	8,965,019	22	1,301,847	20
Total	47,528,906	100	41,268,434	100	6,561,352	100

* The assimilative capacity estimate does not account for current levels of phosphorus or nitrogen in the soil. The assumption is that the soil is depleted of phosphorus and nitrogen and therefore the assimilative capacity is equal to the amount taken up and removed with the yield at harvest plus the amount of applied nutrients that would likely be lost from the farm field and not be available for crop growth. See text.

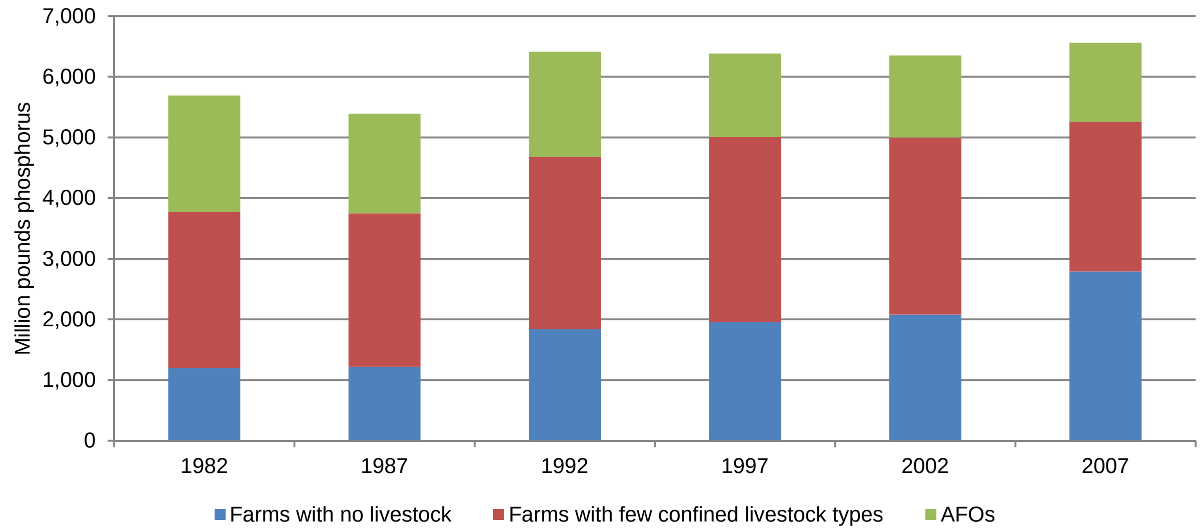
Note: For these calculations, it was assumed that all acres of cropland and cropland used as pasture on all farms were available for manure application, including all acres on AFOs. For permanent pasture, it was assumed that 50 percent of the acres would be available for manure application on all farms. These assumptions are the same as those assumed by Kellogg and others (2000), but differ from those used in the next section to estimate farm-level excess manure.

Figure 26. Potential to apply manure nitrogen on cropland and pastureland (assimilative capacity) assuming a 1.2 efficiency factor



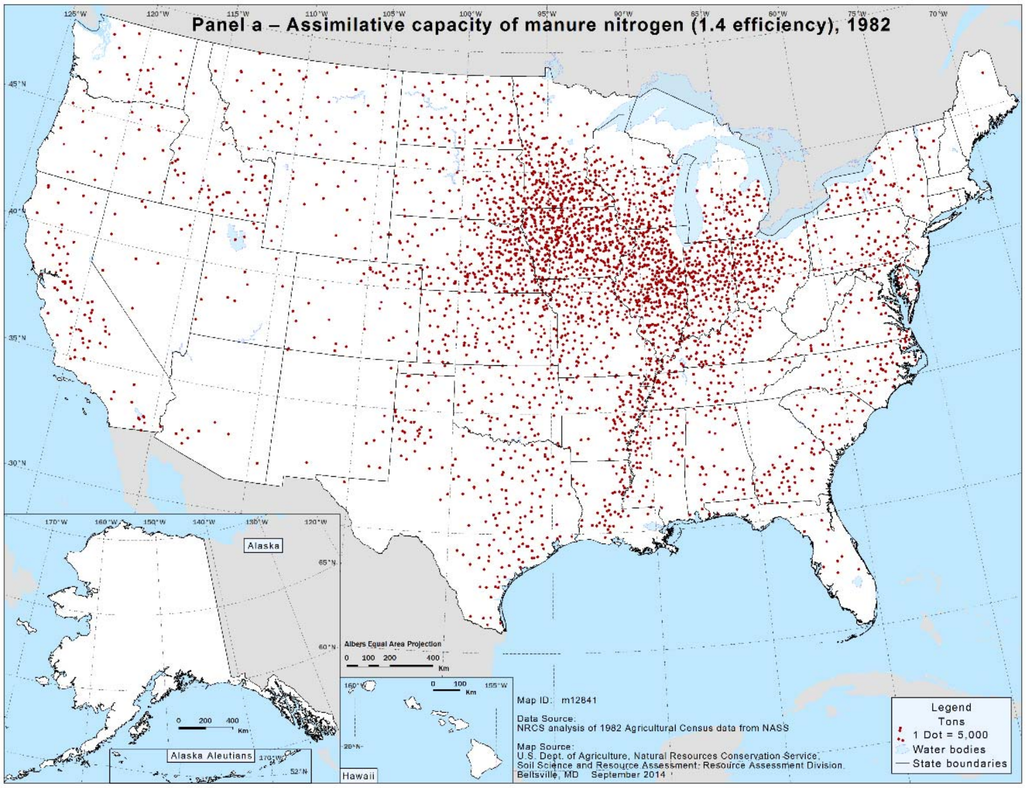
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 27. Potential to apply manure phosphorus on cropland and pastureland (assimilative capacity) assuming a 1.05 efficiency factor

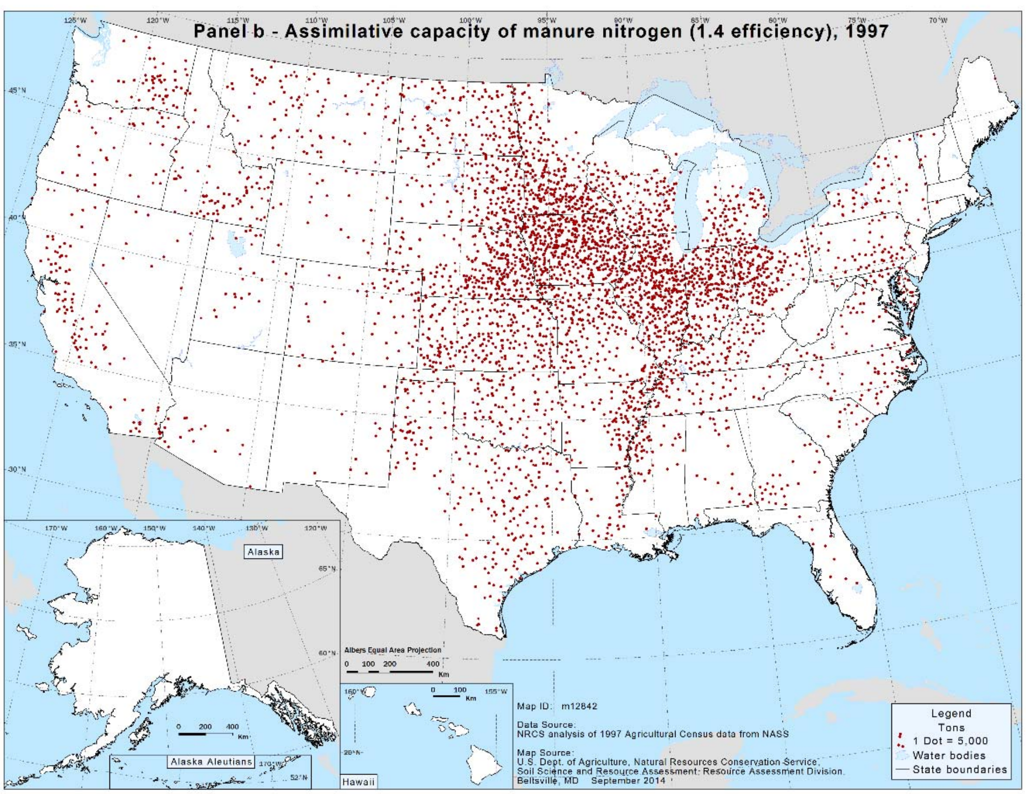


Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Map 7. County location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for 1982, 1997, and 2007 and change in the county location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for periods 1982-1997, 1997-2007, and 1982-2007

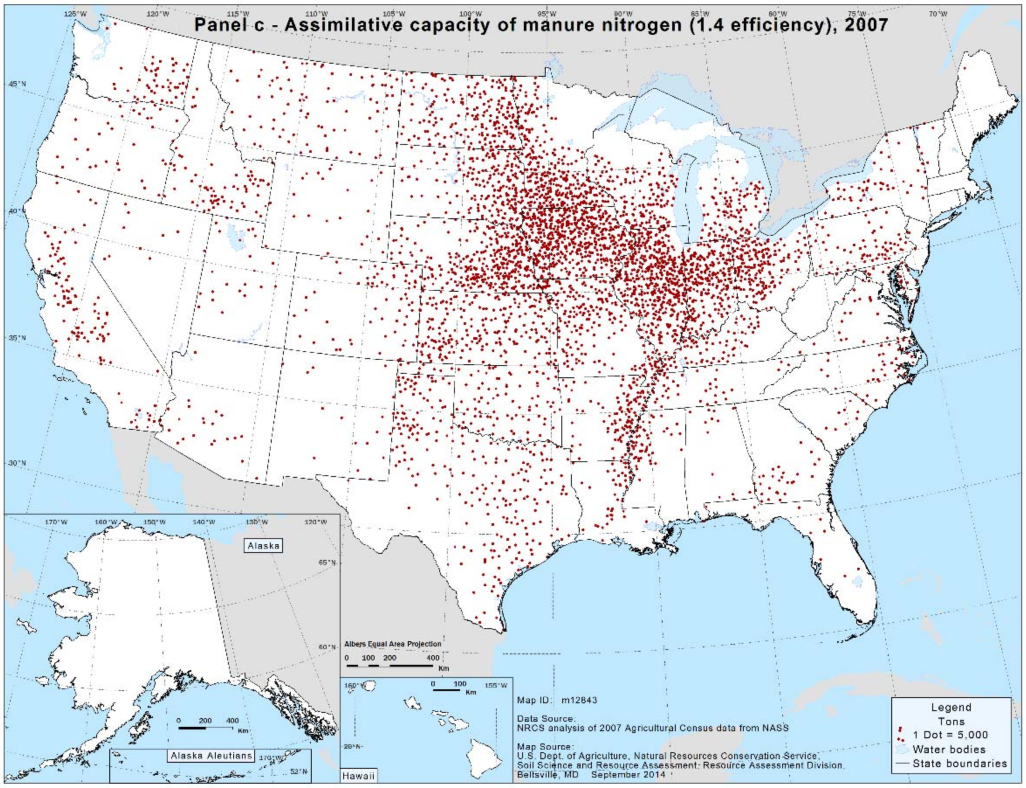


Legend: Dot = 5,000 tons
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

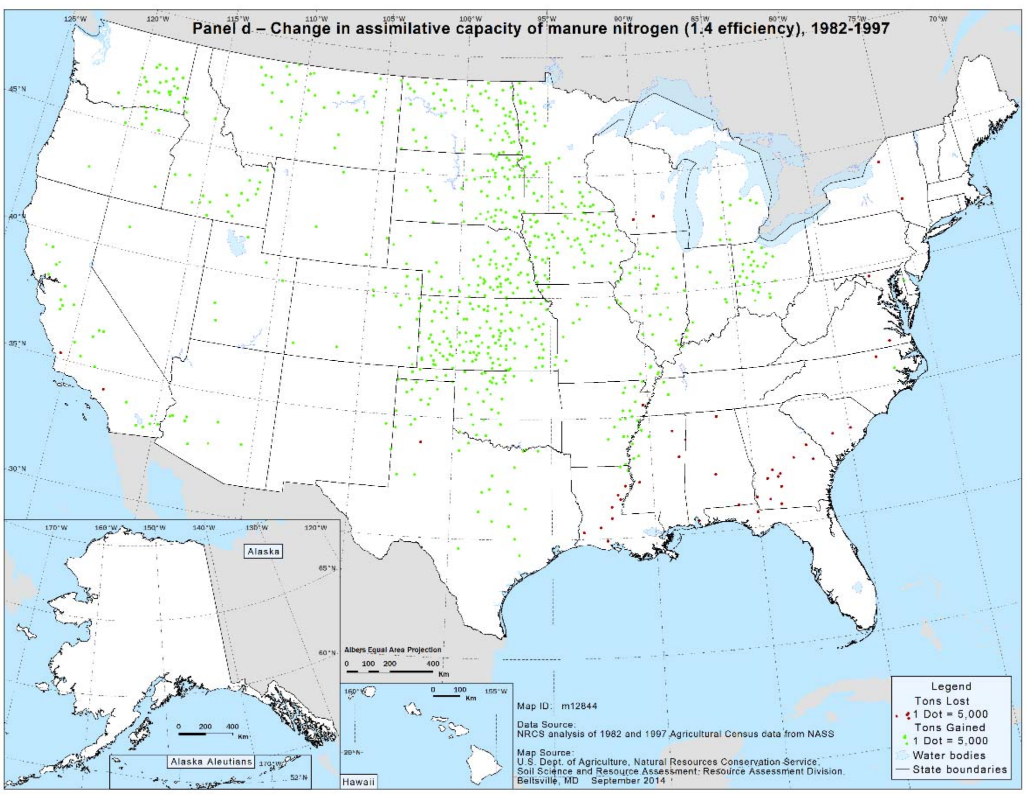


Legend: Dot = 5,000 tons
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 7. County location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for 1982, 1997, and 2007 and change in the county location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

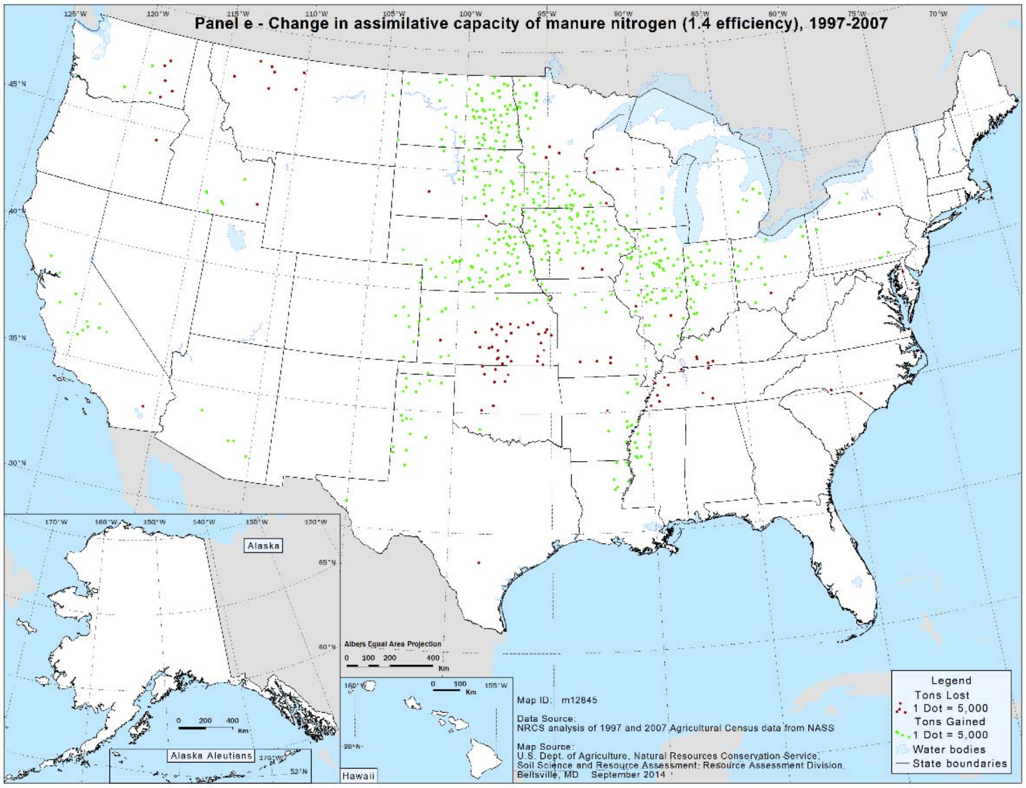


Legend: Dot = 5,000 tons
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

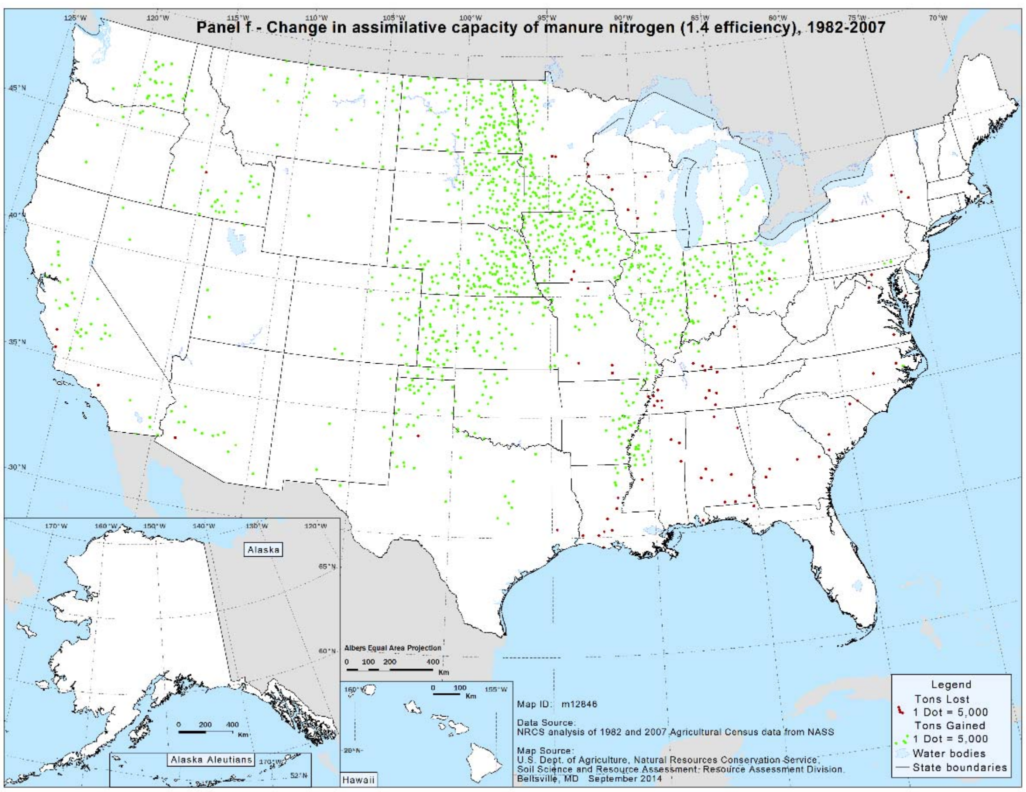


Legend: Green dot = 5,000 tons gain and Red dot = 5,000 tons loss
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 7. County location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for 1982, 1997, and 2007 and change in the county location of manure nitrogen assimilative capacity at a 1.4 efficiency factor for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 5,000 tons gain and Red dot = 5,000 tons loss
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



Legend: Green dot = 5,000 tons gain and Red dot = 5,000 tons loss
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Excess Manure and Manure Nutrients

Estimating the Quantity of Excess Manure and Manure Nutrients

"Excess" manure nutrients occur when the quantity of recoverable manure nutrients exceeds the assimilative capacity of cropland and pastureland to receive manure nutrients under the assumption that the goal is to recycle all recoverable manure nutrients using land application. "Farm-level excess manure nutrients" and "county-level excess manure nutrients" were estimated in Kellogg and others (2000) using estimates of assimilative capacity similar to those presented in the previous section of this report (but with different coefficients in some cases). Farm-level excess manure nutrients were the amount of recoverable manure nutrients that exceeded the assimilative capacity on farms with livestock. County-level excess manure nutrients were the amount of farm-level excess nutrients in excess of the remaining assimilative capacity on all farms within the county, including any unused assimilative capacity on farms with livestock.

Farm-level and county-level excess manure and excess manure nutrients are also estimated in this study, but using a different methodology from that used in Kellogg and others (2000). Excess manure nutrients are estimated in this study by simulating the land application of manure using methods similar to those used in NRCS/USDA (2003) to estimate the number of acres that would receive manure both "before" and "after" full implementation of Comprehensive Nutrient Management Plans[19] (CNMPs). In the simulation, manure is first applied on the land available on AFOs on a crop-by-crop basis. The simulation is conducted individually for each AFO using data on recoverable manure and crops grown specific to each individual farm. When available land on AFOs was insufficient for land application of the full amount of recoverable manure produced on the farm, the "*farm-level excess recoverable manure*" was made available for off-farm land application. Off-farm applications are simulated for available land on non-AFO farms within the county using data on crops grown on non-AFO farms.[20] If there was insufficient land within a county–where a "county" is the proxy for a manure distribution area–for off-farm land application of the farm-level excess manure, the remaining manure was designated as "*county-level excess manure*."

The land application simulation was used to estimate the number of on-farm and off-farm acres that would receive manure in each Census year from 1982 through 2007 such that the amount of recoverable manure nutrients produced in each year would be recycled as much as possible using land application. Allocation of the amount of manure applied to each crop was based on nitrogen uptake and removal coefficients. The amount of manure phosphorus applied was calculated based on the proportion of phosphorus to nitrogen in the manure available for application, which varies by livestock type as shown in table 5. Coefficients for the amount of nitrogen removed from the field at harvest with the crop yield were the same as those used to estimate assimilative capacity in the previous section, presented in table 13. The simulation rules for pastureland application were also the same as those used to estimate assimilative capacity—75 pounds per acre of manure nitrogen was applied to cropland used as pasture and 28 pounds per acre for permanent pastureland. These rules for pastureland were used for both on-farm and off-farm applications and for all years. As was done for the calculations of assimilative capacity, it was assumed that half of the permanent pastureland would not be accessible by manure spreading equipment because of location, terrain, or trees and other plant growth.

The simulation required the following assumptions:

1. The amount of manure nitrogen applied relative to the uptake and removal of nitrogen with the crop yield, with separate assumptions for on-farm and off-farm applications and for different years to represent gradual adoption and implementation of CNMPs.
2. The land available for manure application, with separate assumptions for on-farm land application of manure on AFOs and for off-farm application on non-AFOs.
3. The priority order in which crops would receive manure applications on AFOs (for calculation of farm-level excess) and non-AFOs (for calculation of county-level excess).

Farm-Level Excess

Assumptions for Simulation of On-Farm Manure Applications (AFOs)

The model simulation first allocates manure to the cropland and pastureland acres on AFOs, tracking the amounts of manure remaining. Simulation of manure application on AFOs depends on the amount of recoverable manure nitrogen produced on the farm, the acres harvested and available for manure application, the amount of nutrients removed by the crop at harvest, and the manure nitrogen application rate criteria. The acres receiving manure, the average quantity of manure applied, and the average manure nitrogen and manure phosphorus application rates were estimated for each crop and pastureland category on AFOs using the model simulation of land application of manure.

Assumptions for manure nitrogen application rates. The manure nitrogen rates varied from 1982 through 2007 to represent an ongoing implementation of CNMPs. CNMPs include provisions for on-farm application of manure so as to minimize nutrient losses to the environment and maximize crop uptake by managing the rate of application, method of application, and timing of application. It was assumed that for 1982–1992 the nitrogen application-uptake ratio used in

[19] Comprehensive Nutrient Management Plans (CNMPs) are conservation plans unique to livestock operations. These plans document practices and strategies adopted by livestock operations to address natural resource concerns related to soil erosion, livestock manure and disposal of organic by-products.

[20] AFOs without farm-level excess manure have acres that could be available for off-farm applications from other AFOs. However, the land application simulation model did not allow manure applications on any of these remaining AFO acres that did not receive manure from on-farm sources. Off-farm applications to available acres on other AFOs is not a universally accepted practice because of the potential for the spread of disease between farms, although it occurs to some extent in some regions of the country.

NRCS/USDA (2003) to simulate a "before CNMP" scenario would apply—2.5. The nitrogen application-uptake ratio was lowered for each subsequent Census year to simulate gradual adoption and implementation of CNMP provisions. It was further assumed that full adoption and implementation would occur by 2017, at which time the nitrogen application-uptake ratio would be about 1.2, which was used in the Conservation Effects Assessment Project (CEAP) to simulate full nutrient management. The application-uptake ratio was thus set as follows for cropland acres on AFOs:

- 2.5 for 1982–92,
- 2.2 for 1997,
- 1.9 for 2002, and
- 1.6 for 2007.

Assumptions for land availability. Acres available for manure application were assumed to be higher for AFOs than for other farms because of the need to dispose of manure. It was also assumed, however, that some on-farm cropland and pastureland would be unsuitable for land application because of environmental constraints, such as high erosion rates or phosphorus application limitations due to past manure or fertilizer applications. The extent to which acres would not be available because of phosphorus limitations and/or soil erosion is not known and likely varies around the country. Indications are, however, that some portion of acres on AFOs have received too much phosphorus over the years and, through State regulations or sound nutrient management practices, are not available for manure applications in any given year. An analysis of about 1,000 CEAP sample points in the Mid-Atlantic region by Moffitt and others (2012) indicated that, although phosphorus-index characteristics varied from State to State, there was generally a good correlation between high phosphorus-index ratings and high phosphorus loss. A phosphorus-index rating indicates that some restrictions would apply for additional manure applications. The analysis indicated that about 15 to 20 percent of the acres in the region would be expected to be unavailable for additional manure applications. Based on this finding and advice from agronomists working with farmers on manure applications, an estimate of 20 percent was assumed for 2007. Fewer acres would have been unavailable for land application of manure in previous years. Thus, the availability of cropland and pastureland for on-farm land application was set as follows—95 percent for 1982–92, 90 percent for 1997, 85 percent for 2002, and 80 percent for 2007.

Priority order for crops. The model allocates manure to crops according to a priority order established by agronomists and other agricultural specialists, with the highest priority for feed and forage crops. In the model simulation, the highest priority crop present on the farm is the first to receive manure; the rate of application is determined by the crop-specific rate criteria as discussed previously. If there are insufficient acres of the first priority crop to assimilate all of the manure produced on the farm, the model allocates manure to the next priority crop. This allocation process is repeated for each of the 21 crops and two pastureland categories on the farm or until all of the manure has been allocated.

The priority order for crops and pastureland on AFOs receiving manure is as follows:

1. corn for silage	9. cropland used as pasture	17. rye
2. sorghum for silage	10. permanent pasture	18. oats
3. corn for grain	11. alfalfa hay	19. soybeans
4. sorghum for grain	12. cotton	20. sugar beets
5. small grain hay	13. winter wheat	21. rice
6. other tame hay	14. barley	22. peanuts
7. wild hay	15. durum wheat	23. tobacco
8. grass silage	16. other spring wheat	

The Census does not identify the double-cropped acreage. Where double cropping occurs, it is assumed that each crop would potentially be available for manure application, which may result in more than one manure application per field in the manure application simulation.

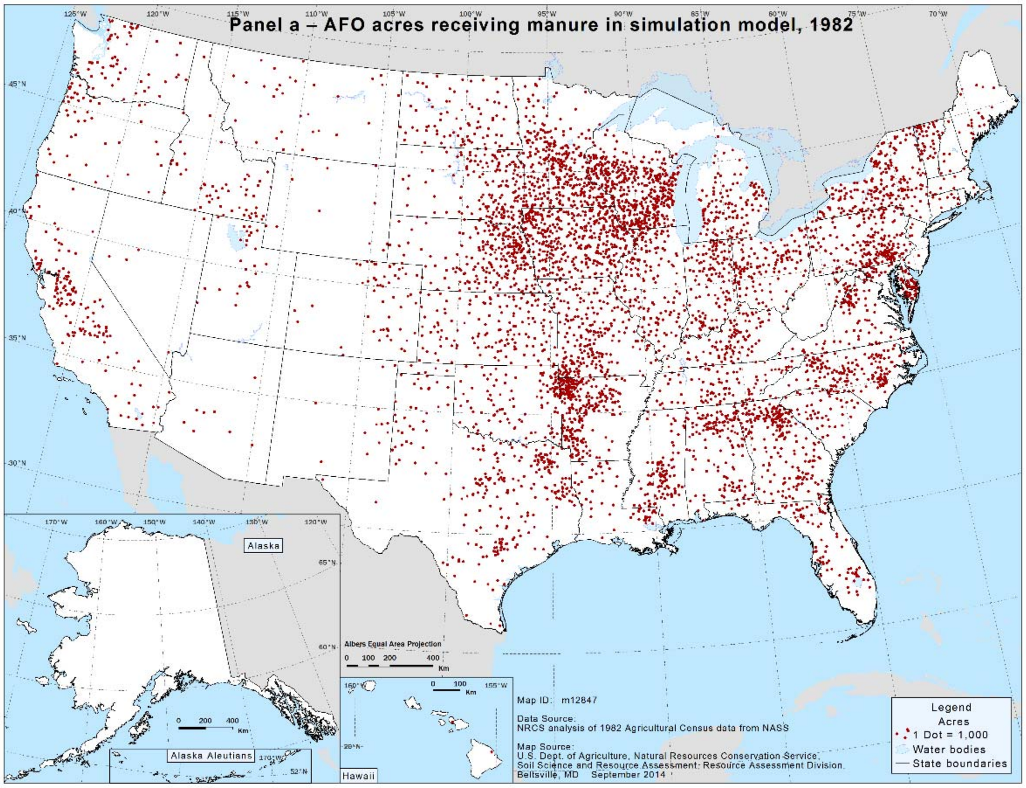
The order in which crops receive manure on AFOs does not matter in cases where all available land is utilized for manure application and there is farm-level excess manure. On other AFOs, however, the priority order in which crops receive manure determines the total number of acres that receive manure. Crops that take up high amounts of nitrogen, such as corn and other feed crops, will require fewer acres for land application than crops that use less nitrogen.[21]

AFO Acres Receiving Manure in Simulation Model

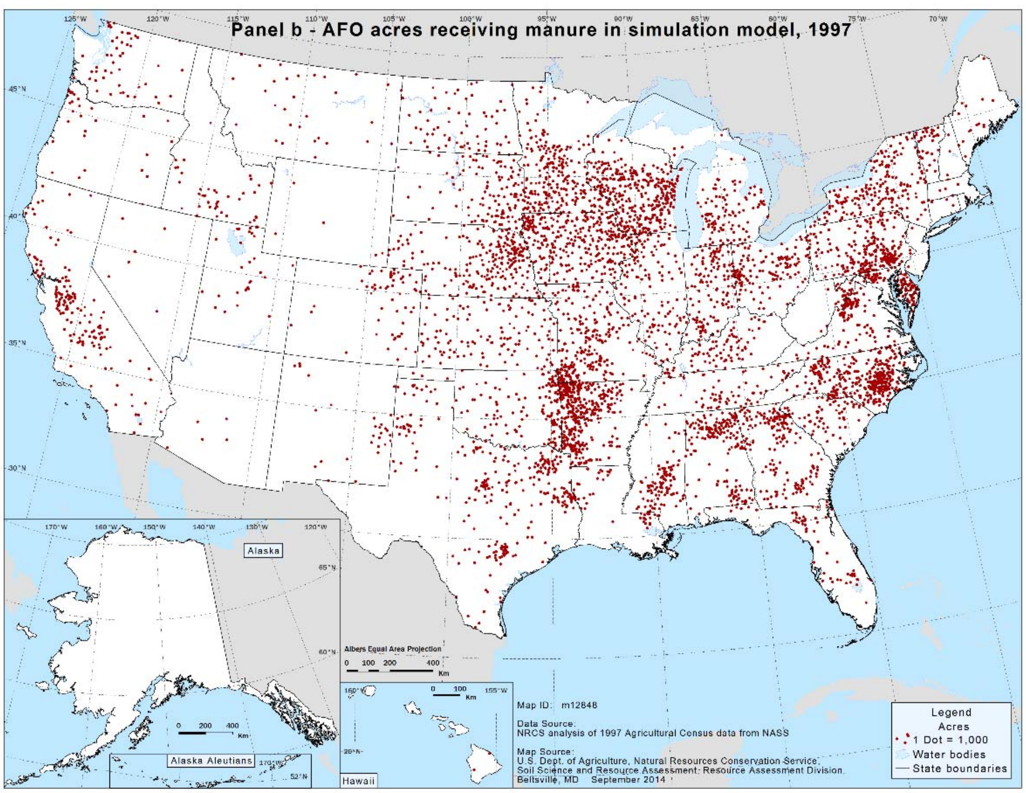
Map 8 presents the distribution and change in the AFO acres receiving manure estimated by the simulation model. The location of AFO acres receiving manure is in many ways a combination of the recoverable manure described in map 6 and the assimilative capacity described in map 7; in order to have manure applied both the manure and the land must be present. The location of acres receiving manure (panels a-c), reflects the location of cropland through assimilative capacity and the location of AFOs through recoverable manure. Over the 1982 to 1997 time period in panel d, the acres receiving manure declined over the Midwest and Florida and increased in areas of Oklahoma, Arkansas, North Carolina, and states around the Chesapeake Bay. The areas with increases are some of the same areas with increases in recoverable manure. Over the 1997-2007 time period, shown in panel e, some of the areas reverse compared to the previous period, with increases in the Midwest and declines in Oklahoma, Arkansas, and North Carolina. Panel f shows a significant increase in the acres receiving manure in the simulation model over the 1982-2007 time period. Proceeding through the panels of map 8 shows the need for increased land application of the greater levels of recoverable manure quantities from AFOs and the simulation model's attempt to apply that manure to the farms of origin. The panels also show the difficulty in predicting where the manure may be land-applied as acres receive and then are not available to receive manure in patterns difficult to predict without a farm-level model.

[21] This priority order for crops was also used for simulation of off-farm manure applications, where the order is even more important. In the off-farm simulation, only a few counties use all the available off-farm land for manure application and generate county-level excess manure nutrients. In all other counties, the priority crop order can have a significant impact on the number of acres required to land-apply all available manure nutrients.

Map 8. County location of AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007

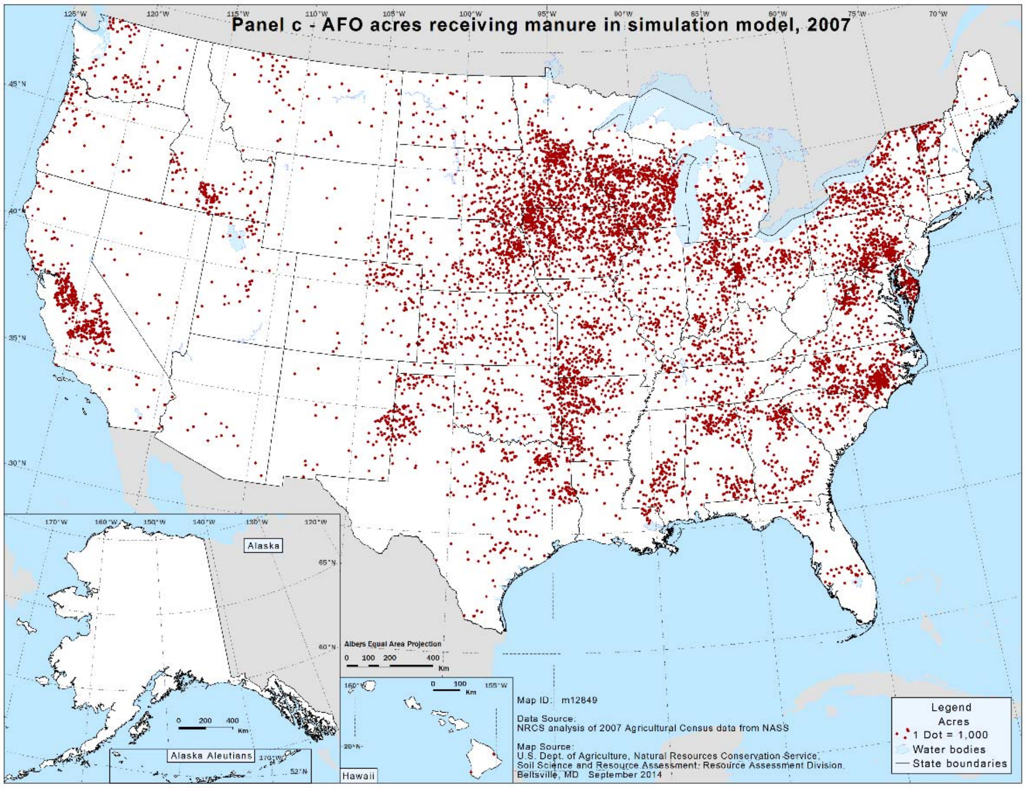


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

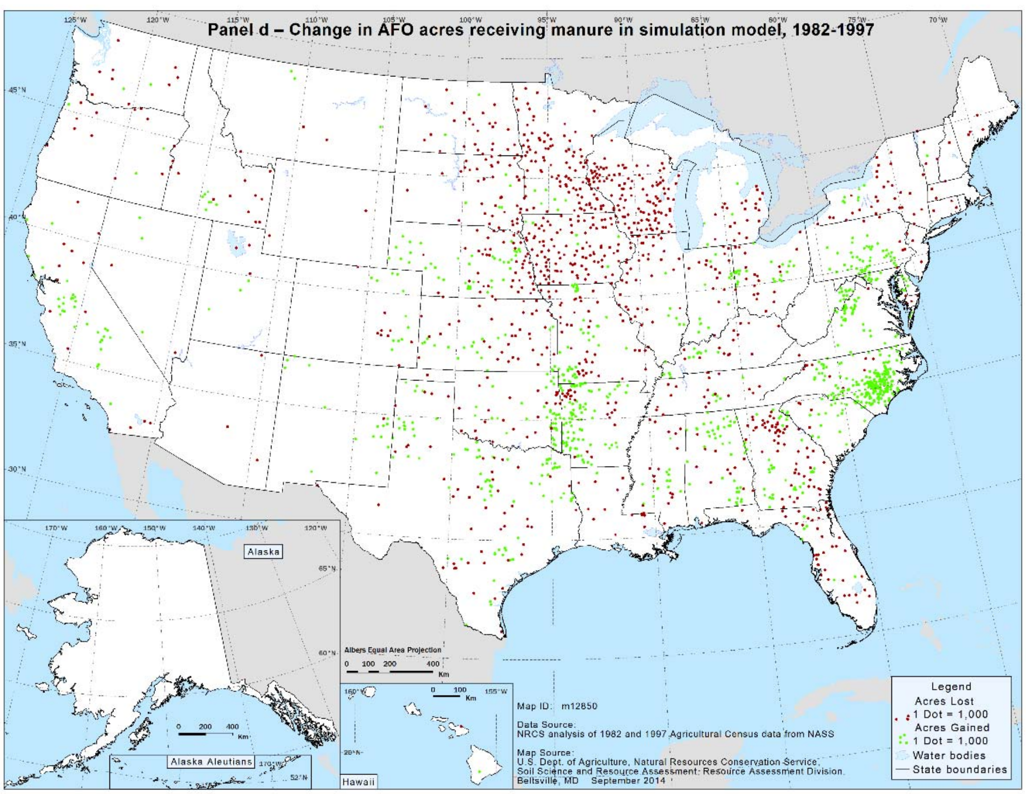


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 8. County location of AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

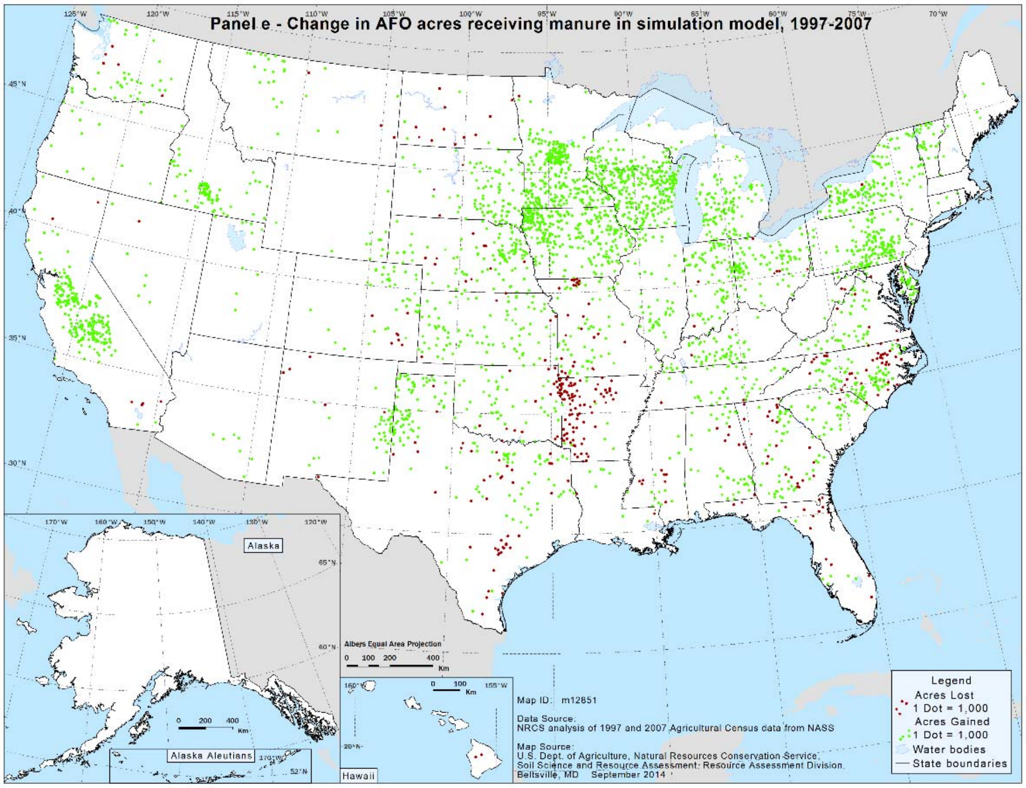


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

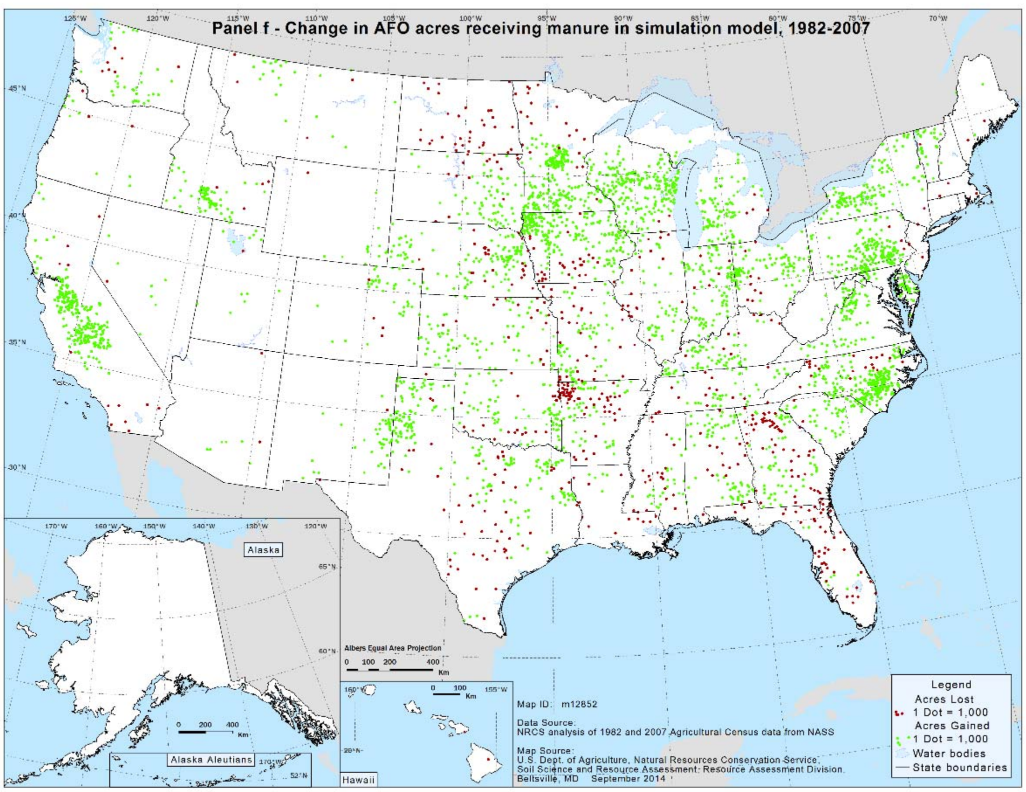


Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 8. County location of AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Farm-Level Excess Manure and Manure Nutrients by Type of AFO

Under the assumptions of the simulation model for land application of manure, there were about 61,000 of the 190,000 AFOs in 2007 that could not land-apply all of the manure produced on the farm (table 15)—32 percent of AFOs. This included 65 percent of all large potential AFO-CAFOs and 55 percent of all medium potential AFO-CAFOs. Only 20 percent of the small AFOs had farm-level excess manure. Thus, more of the small AFOs have more land available for application relative to the amount of manure produced than the larger AFOs (table 15).

The total number of AFOs with farm-level excess manure has decreased dramatically since 1982 (fig. 28). The number of very small and small AFOs with farm-level excess manure has decreased, while the number of potential AFO-CAFOs with farm-level excess manure has increased, especially the large potential AFO-CAFOs. This is consistent with the trend in number of AFOs shown in figure 3.

In 2007, these 61,000 farms had about 1.85 billion pounds of farm-level excess manure nitrogen and 829 million pounds of excess manure phosphorus, equal to 59 percent of the total recoverable manure nutrients produced on the farms (table 15). The bulk of the farm level excess manure nutrients were on the large potential AFO-CAFOs—70 percent of the farm-level excess manure nitrogen and 68 percent of the farm-level excess phosphorus. The medium potential AFO-CAFOS had 24 percent of the farm-level excess manure nitrogen and 25 percent of the farm-level excess phosphorus. Only a small proportion of the excess manure was from the small and very small AFOs.

Overall, about 8 million acres on AFOs received manure applications in the simulation in 2007 (table 15). All the available land on 32 percent of the AFO's was used, as those farms had farm-level excess manure that required exporting off-farm for land application or other uses. The remaining 68 percent of AFO's had additional on-farm unused capacity for land application of manure that totaled about 44 million acres. Use of this land for manure application would have meant that manure from one AFO would have been applied to a portion of the acres on a neighboring or nearby AFO. As noted earlier in this section (footnote 20), this was not allowed in the land application simulation model because of bio-security concerns (spread of disease).[22] On the 13,152 large AFO-CAFOs in 2007, however, where 58 percent of the recoverable manure nitrogen and 70 percent of the farm-level excess manure nitrogen originates, only 4.3 million on-farm cropland and pastureland acres did not receive manure in the model simulation. About 38 percent of the cropland and pastureland on these farms received manure in the model simulation and 65 percent of these farms utilized all available land and needed to export additional manure off-farm (table 15).
The amount of farm-level excess manure nitrogen and phosphorus appears to be on the rise (figs. 29 and 30). Based on the results of the model simulation for each of the six Census years, the amounts of farm level nitrogen and phosphorus have doubled over the 25-year period. This is due to the increase in the number and size of potential AFO-CAFOs, as the amount of farm-level excess manure nutrients on small and very small AFOs has decreased over the 25 years (figs. 29 and 30).

Map 9 presents the distribution and change in the location of AFOs with farm-level excess manure estimated by the simulation model. Farm-level excess manure on AFOs implies that the manure and associated nutrients will need to move off the source AFO to be land-applied or be used in another commercial use. Panels a-c show an increasing concentration of farms with excess farm-level manure in areas with large numbers of potential medium and large AFO-CAFOs. The change maps (panels d-f) exhibit a mixed trend with most area of the Nation seeing a decrease in the numbers of farms with excess manure. This largely reflects the trend of decreasing numbers of AFOs over the 1982-2007 time period, most of which are small AFOs. There are some regions with increases, especially in Arizona and New Mexico, eastern North Carolina, around the Chesapeake Bay, and in pockets from Iowa southward to the Gulf. The areas of increases generally correspond to increases in the numbers of large farms, except for the increase in Arizona and New Mexico, which in large part was due to the change in the manner farms were reported on the Navajo Nation.[23]

Map 10 presents the *quantity* of manure nitrogen associated with the farm numbers shown in map 9. The farm–level excess manure nitrogen quantities represent manure nitrogen production less the assimilative capacity of the farm. Farm-level excess does not imply that manure nutrients are being mismanaged. It only means the manure needs to leave the production farm for land application. Farm-level excess is significant because if land-applied, another landowner becomes involved in the decision process. The distribution maps (panels a-c) show an increase in the quantity of farm-level excess manure over time and a definite trend toward concentration of farm-level excess nitrogen into many of the same areas with potential medium and large AFO-CAFOs. However, there is not a one-to-one association between farms and quantity as shown by visually comparing the farm-level excess nitrogen with the number of potential medium and large AFO-CAFOs in the Texas Panhandle, where the relatively few farms are either large, have little land to apply manure nutrients, or both. (In the case of Texas cattle feedlots, it is both.) The change panels (d-f) in map 10 present a strong pattern of almost uninterrupted increases in farm-level excess nutrients. While the trend for increases in farm-level excess manure is to be expected given the growth in AUs on potential Medium and Large AFO-CAFOs, the almost uninterrupted increase (all green dots with few red dots) is a stronger trend than seen on other mapped variables where there tends to be a regional mix of increase and decrease.

[22] To the extent that cropland and pastureland on one AFO is used for land application of manure from another AFO, estimates of excess manure reported are overstated. The authors believe that, while this will happen to some extent in some areas, it is generally a practice that the vast majority of livestock operations avoid, especially the larger operations that are the source of the bulk of the farm-level excess manure.

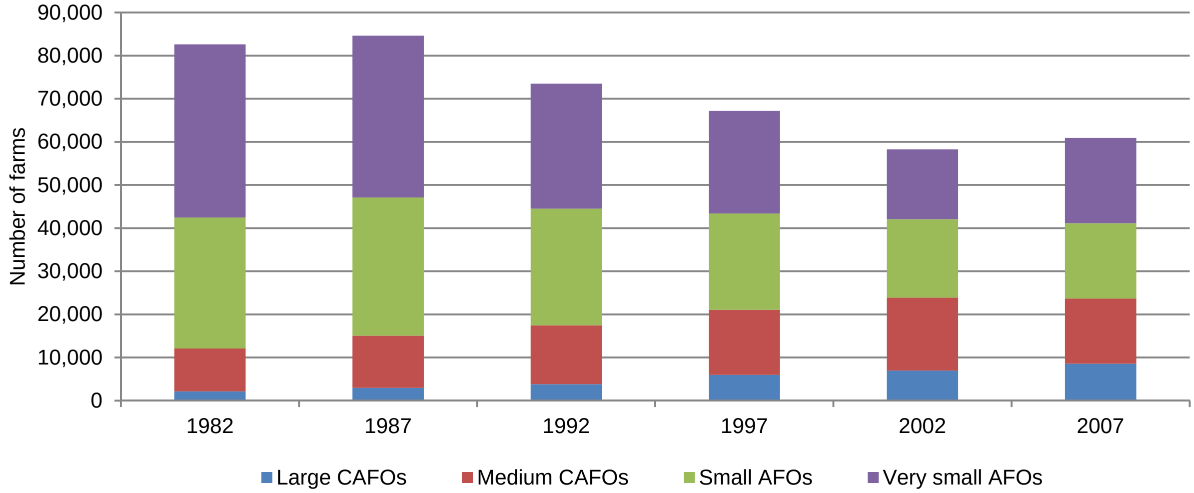
[23] In 2007, producers in the Navajo Nation reported as individual operations rather than one large operation for the Nation.

Table 15. Farm-level excess manure nutrients on AFOs and related estimates, all U.S., 2007

	Very small AFOs	Small AFOs	Medium AFO-CAFOs	Large AFO-CAFOs	All AFOs
Number of AFOs (from table 4)	61,051	88,312	27,409	13,152	189,924
Number of AFOs with farm-level excess manure*	19,800	17,470	15,116	8,543	60,929
Percent	32%	20%	55%	65%	32%
Recoverable manure nitrogen (million pounds) (from table 11)	45	496	783	1,834	3,158
Farm-level excess nitrogen (million pounds)	14	101	437	1,302	1,854
Percent	31%	20%	56%	71%	59%
Recoverable manure phosphorus (million pounds) (from table 11)	23	229	359	806	1,417
Farm-level excess phosphorus (million pounds)	7	50	205	567	829
Percent	30%	22%	57%	70%	59%
Acres on AFOs (1,000s)**					
Cropland and pasture	9,913	34,015	12,620	8,696	65,244
Pasture only (cropland used as pasture and half of permanent pasture)	861	3,012	1,268	686	5,827
Cropland only (acres of the 21 crops included in simulation)	9,052	31,004	11,351	8,010	59,417
Acres available for manure application on AFOs (1,000s) under the assumptions of the model					
Cropland and pasture	7,930	27,212	10,096	6,957	52,195
Pasture only (cropland used as pasture and half of permanent pasture)	689	2,409	1,015	549	4,661
Cropland only (acres of the 21 crops included in simulation)	7,242	24,803	9,081	6,408	47,534
Acres receiving manure on AFOs under assumptions of the model (1,000s)					
Cropland and pasture	355	2,846	2,217	2,653	8,071
Pasture only (cropland used as pasture and half of permanent pasture)	56	293	366	282	997
Cropland only (acres of the 21 crops included in simulation)	299	2,553	1,851	2,370	7,073
Percent of available cropland and pasture land on AFOs that received manure under the assumptions of the model	4%	10%	22%	38%	15%
Assimilative capacity for manure nitrogen assuming the rate and acreage constraints used in the simulation (million pounds)					
Cropland and pasture	1,330	4,717	1,958	1,483	9,489
Pasture only (cropland used as pasture and half of permanent pasture)	33	116	49	28	225
Cropland only (acres of the 21 crops included in simulation)	1,297	4,602	1,910	1,455	9,263
Manure nitrogen applied under the assumptions of the model (used assimilative capacity) (million pounds)					
Cropland and pasture	31	396	346	532	1,305
Pasture only (cropland used as pasture and half of permanent pasture)	2	14	18	15	48
Cropland only (acres of the 21 crops included in simulation)	28	382	329	517	1,256
Percent of assimilative capacity for manure nitrogen used under the assumptions of the model, cropland and pasture on AFOs	2%	8%	18%	36%	14%
Manure phosphorus applied under the assumptions of the model (million pounds)					
Cropland and pasture	15	179	154	239	588
Pasture only (cropland used as pasture and half of permanent pasture)	1	6	8	7	22
Cropland only (acres of the 21 crops included in simulation)	14	173	146	233	566

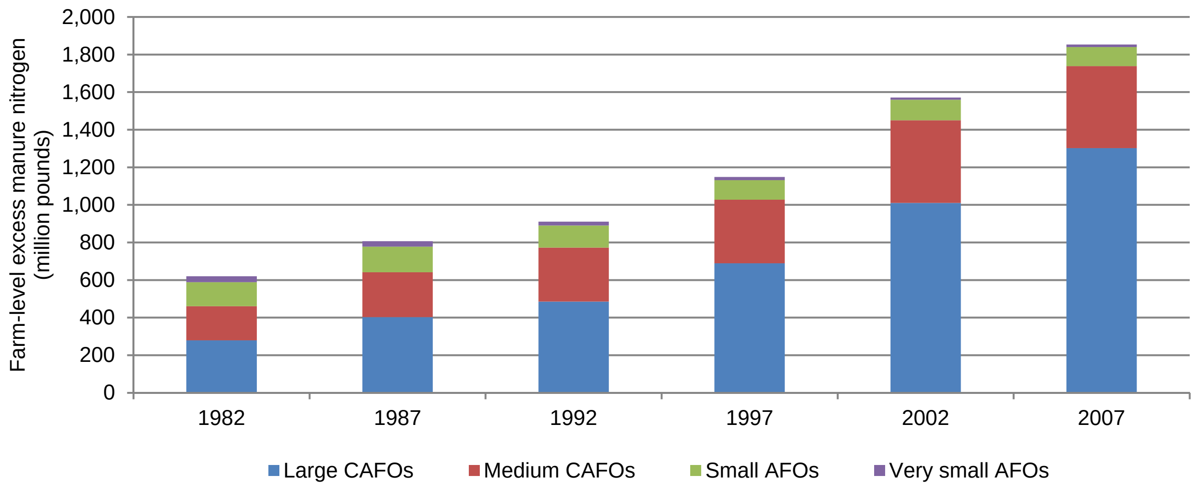
* Excludes farms with less than 100 pounds of farm-level excess manure nitrogen.
** Equal to the acres shown in figure 24 for AFOs in 2007.

Figure 28. Number of AFOs with farm-level excess manure, by AFO farm type



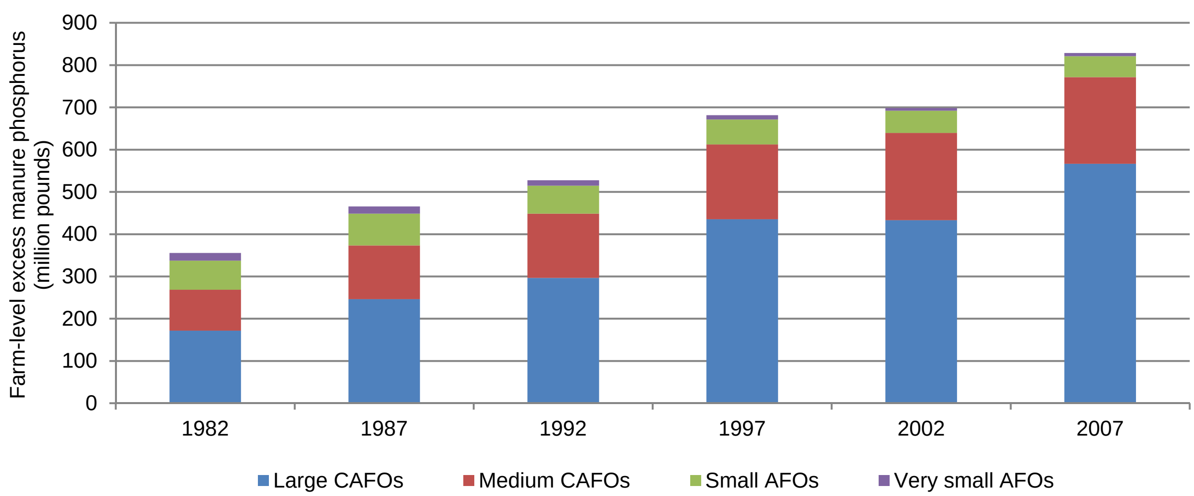
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 29. Farm-level excess manure nitrogen, by AFO farm type



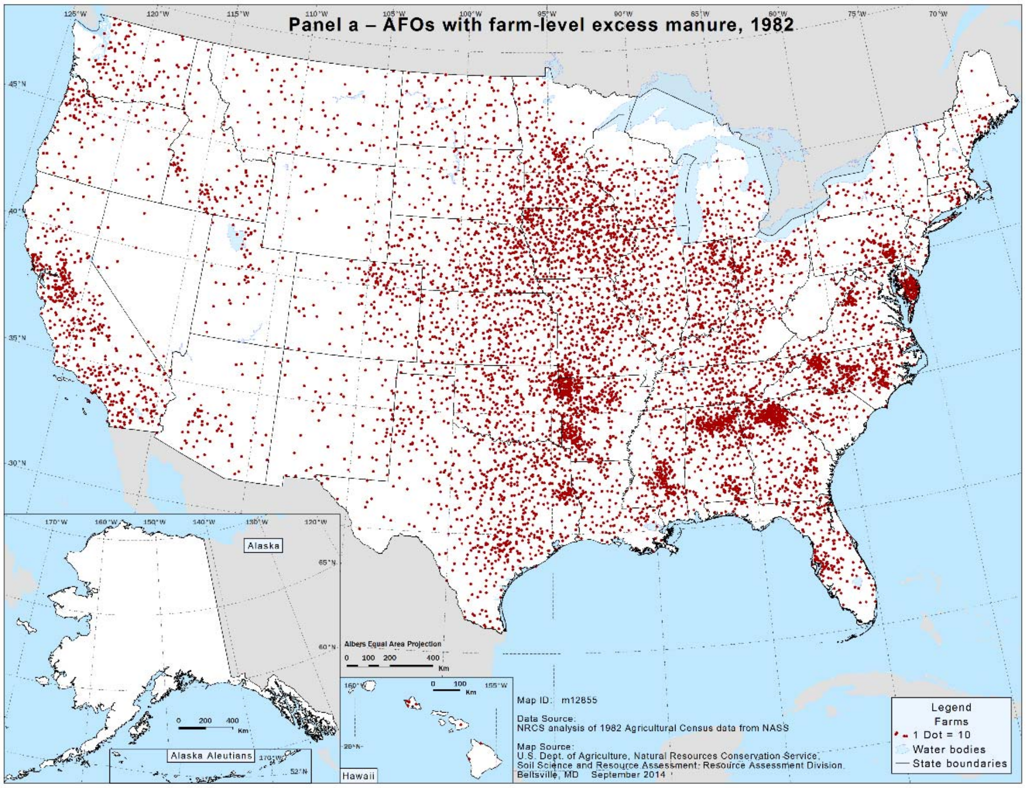
Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Figure 30. Farm-level excess manure phosphorus, by AFO farm type

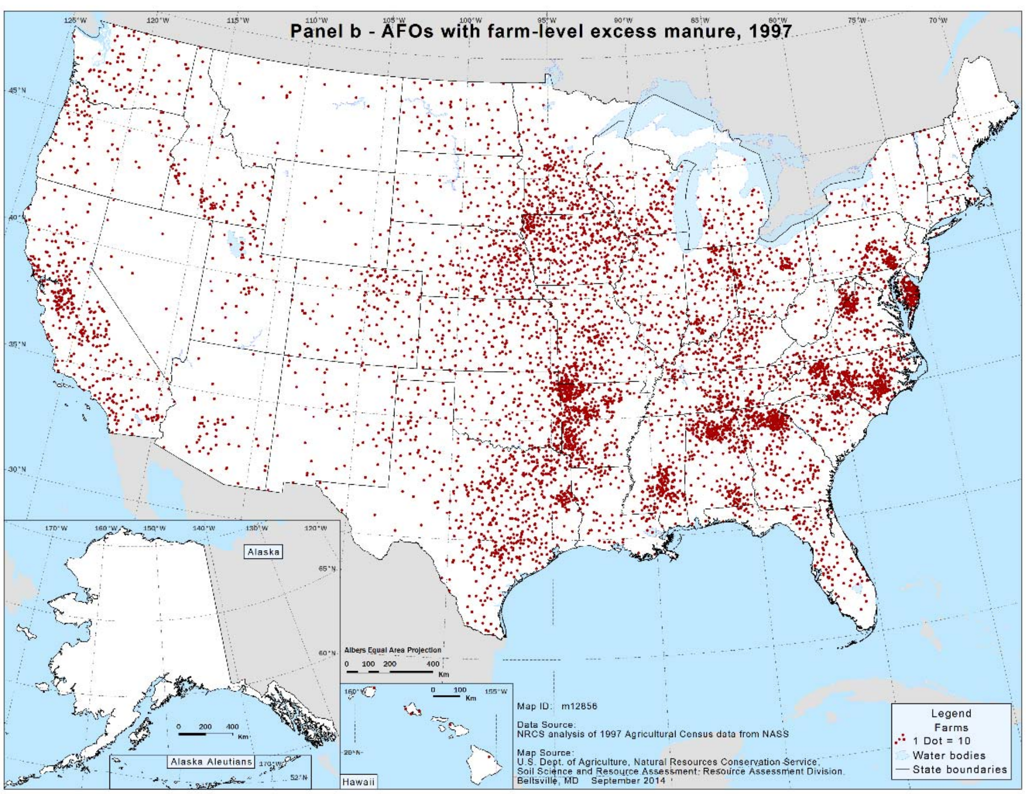


Note: See appendix B for data by census year.
Source: NRCS analysis of 1982-2007 Census of Agriculture databases.

Map 9. County location of AFOs with farm-level excess manure* for 1982, 1997, and 2007 and change in the county location of AFOs with farm-level excess manure* for periods 1982-1997, 1997-2007, and 1982-2007

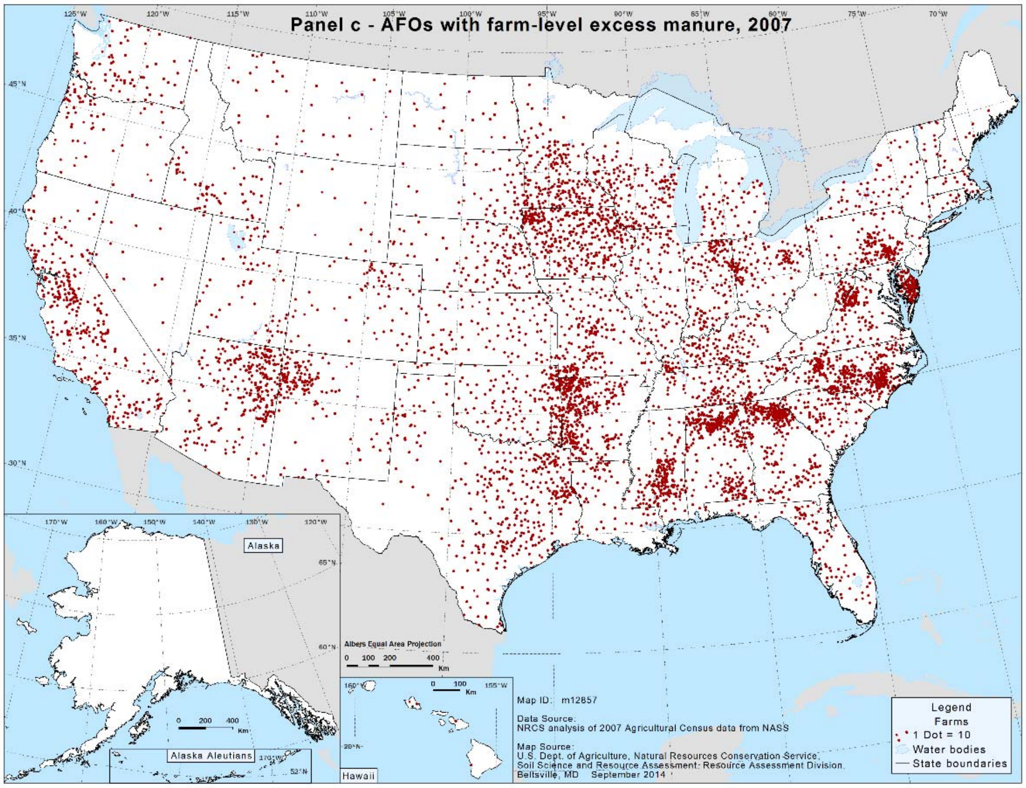


Legend: Dot = 10 farms
Excludes farms with less than 100 pounds of excess manure.
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

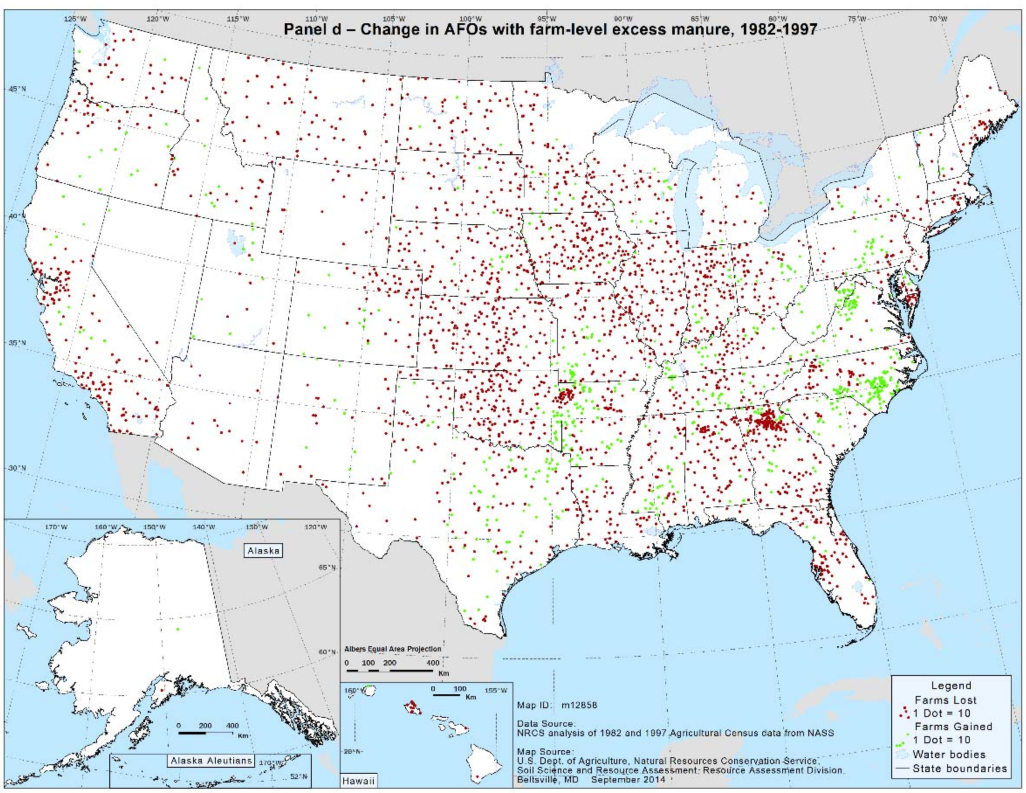


Legend: Dot = 10 farms
Excludes farms with less than 100 pounds of excess manure.
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 9. County location of AFOs with farm-level excess manure* for 1982, 1997, and 2007 and change in the county location of AFOs with farm-level excess manure* for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

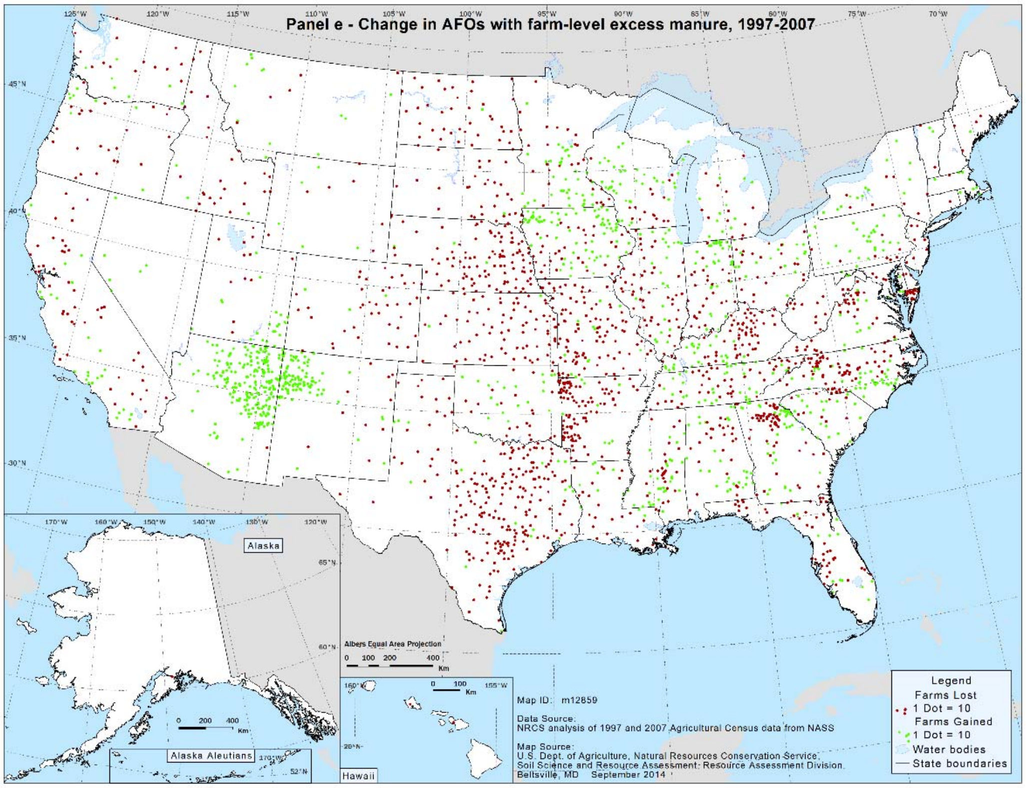


Legend: Dot = 10 farms
**Excludes farms with less than 100 pounds of excess manure.*
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

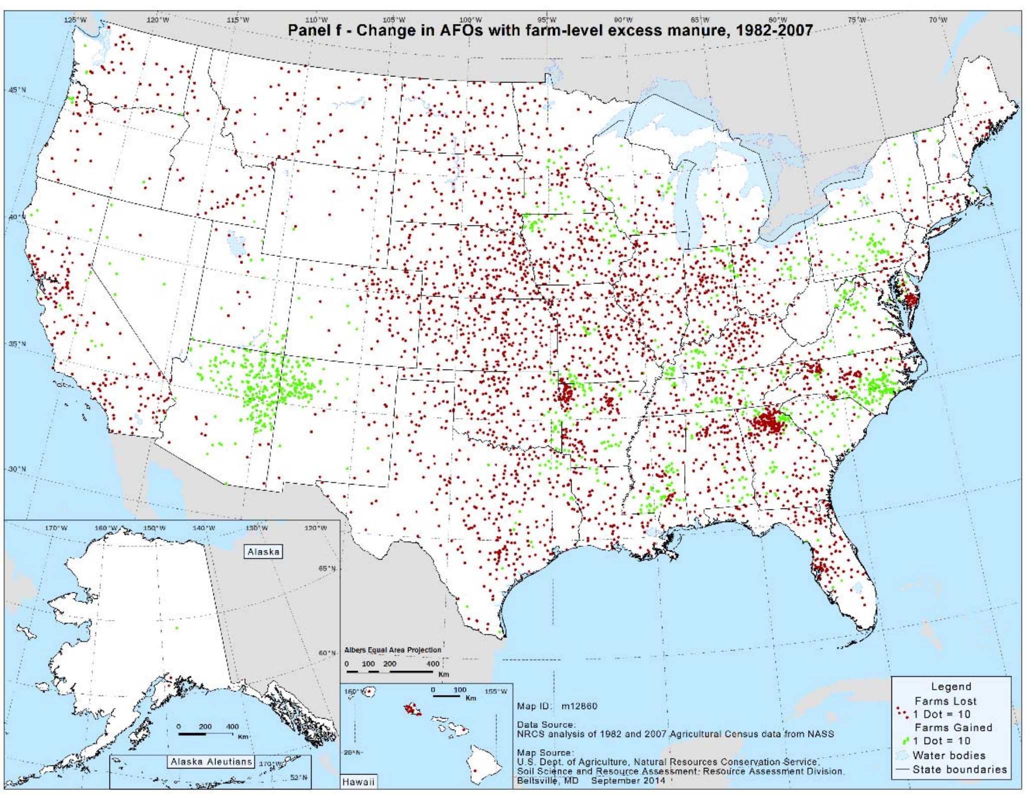


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
**Excludes farms with less than 100 pounds of excess manure.*
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 9. County location of AFOs with farm-level excess manure* for 1982, 1997, and 2007 and change in the county location of AFOs with farm-level excess manure* for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

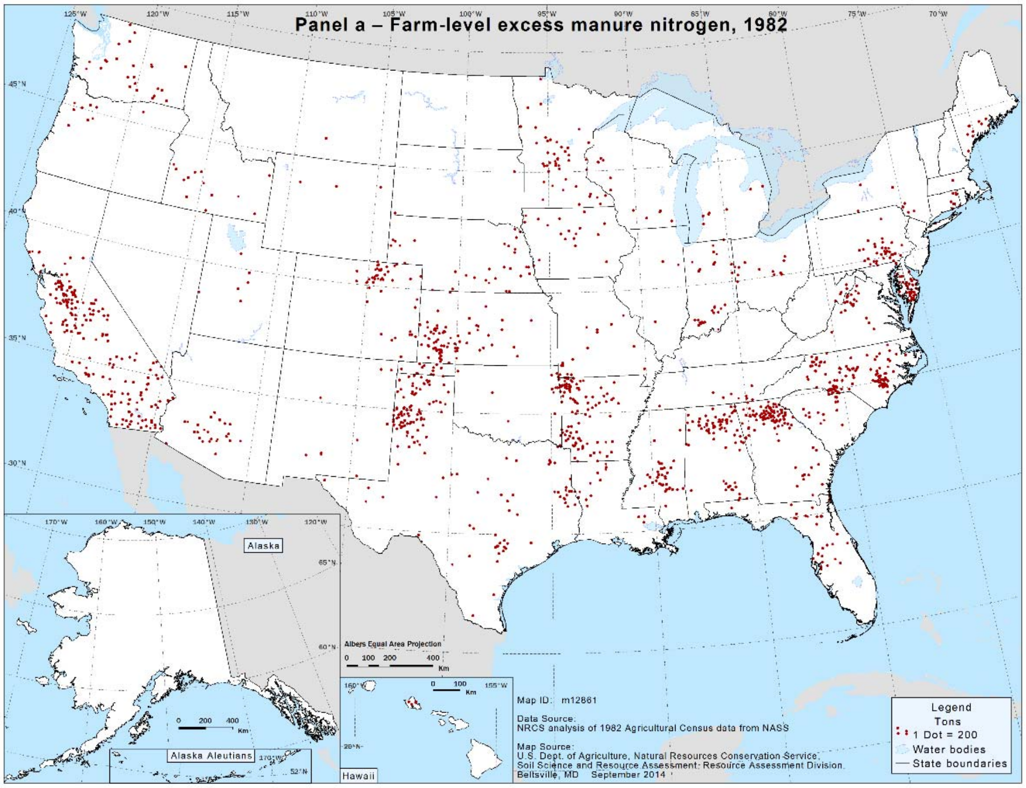


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
**Excludes farms with less than 100 pounds of excess manure.*
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS

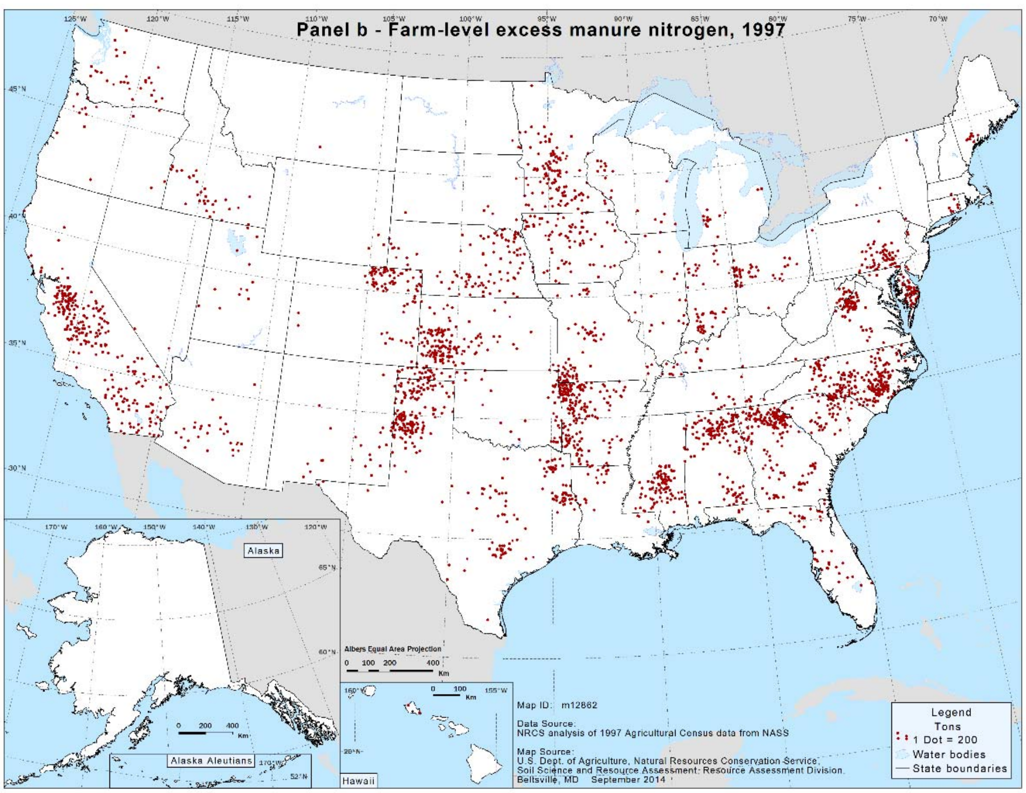


Legend: Green dot = 10 farm gain and red dot = 10 farm loss.
**Excludes farms with less than 100 pounds of excess manure.*
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 10. County location of farm-level excess manure nitrogen for 1982, 1997, and 2007 and change in the county location of farm-level excess manure nitrogen for periods 1982-1997, 1997-2007, and 1982-2007

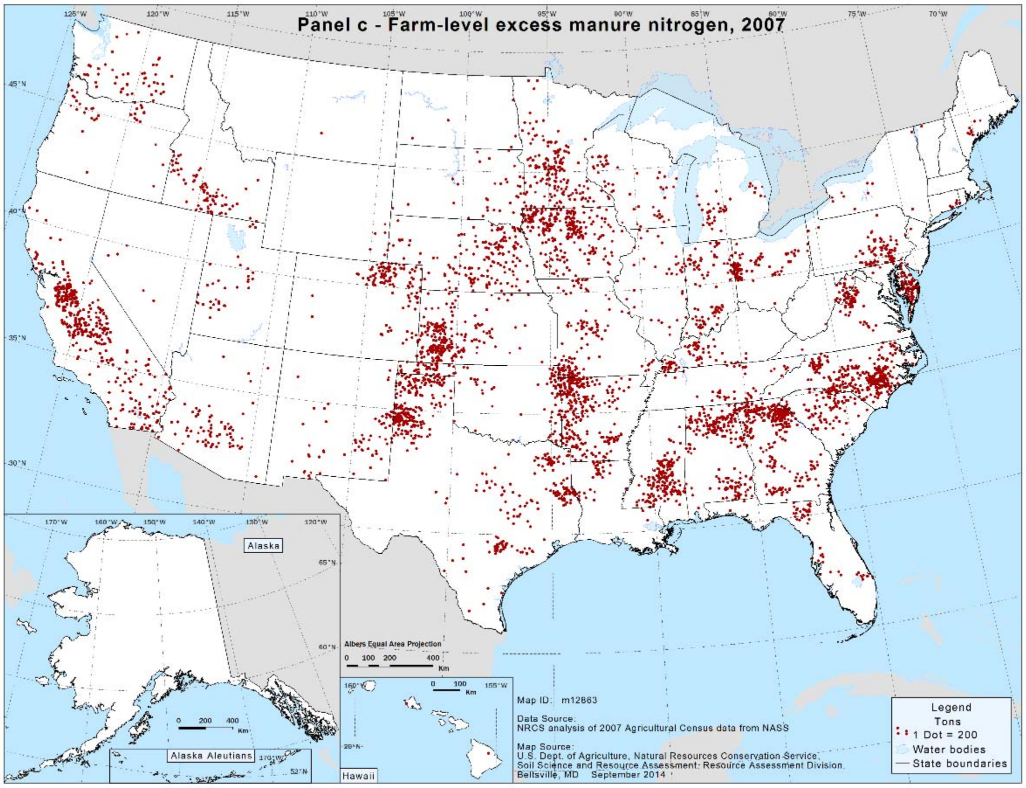


Legend: Dot = 200 tons.
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

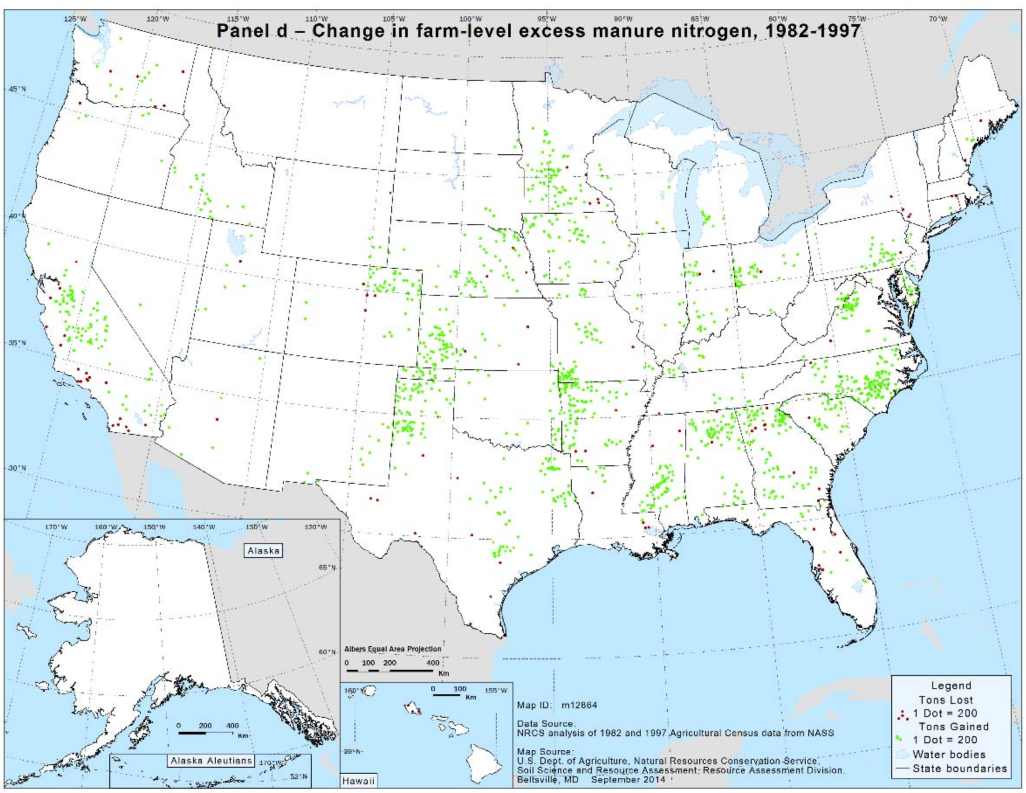


Legend: Dot = 200 tons.
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 10. County location of farm-level excess manure nitrogen for 1982, 1997, and 2007 and change in the county location of farm-level excess manure nitrogen for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

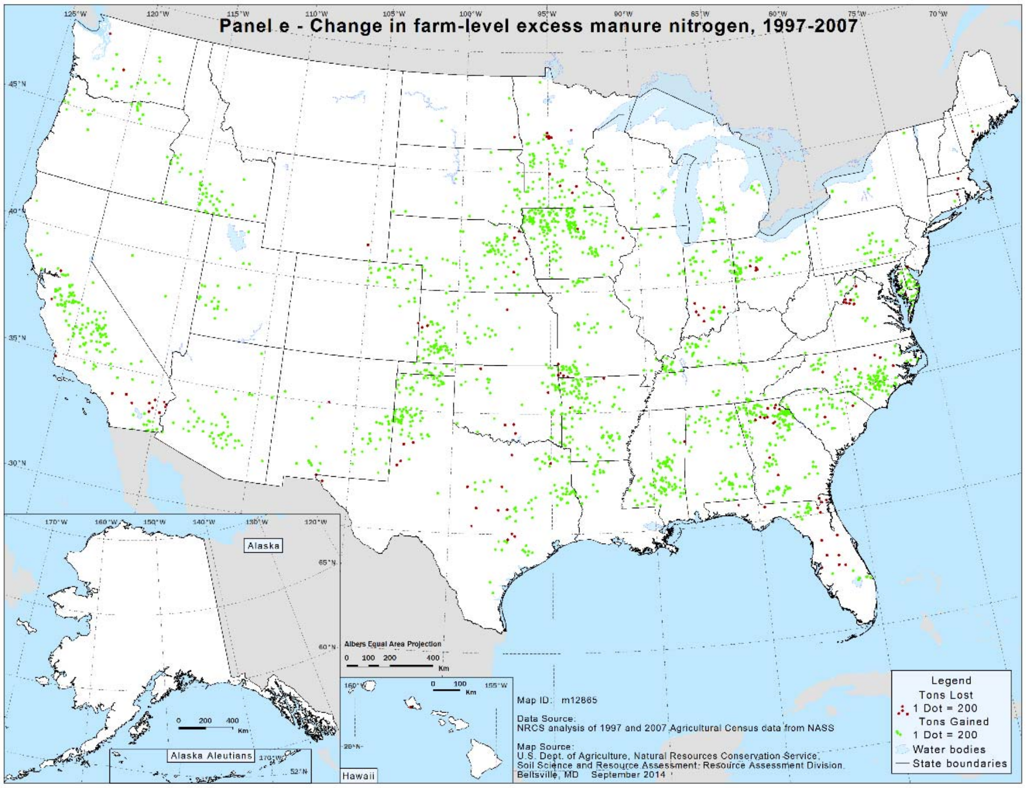


Legend: Dot = 200 tons.
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

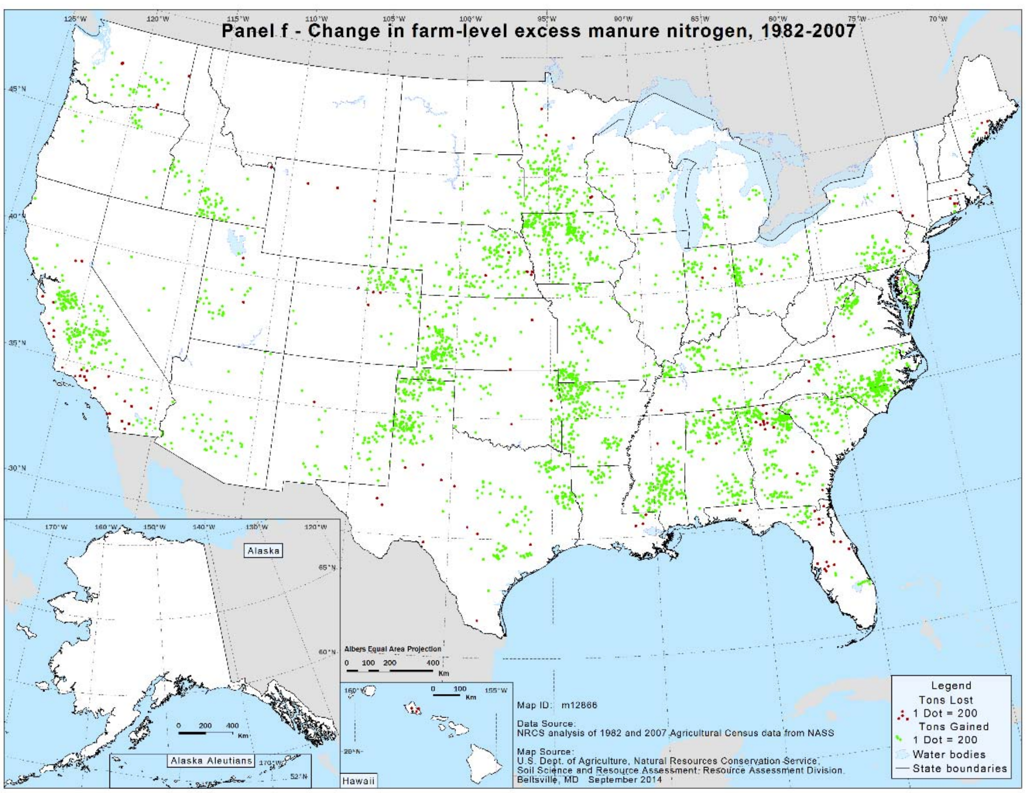


Legend: Green dot = 200 ton gain and red dot = 200 ton loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 10. County location of farm-level excess manure nitrogen for 1982, 1997, and 2007 and change in the county location of farm-level excess manure nitrogen for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 200 ton gain and red dot = 200 ton loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS

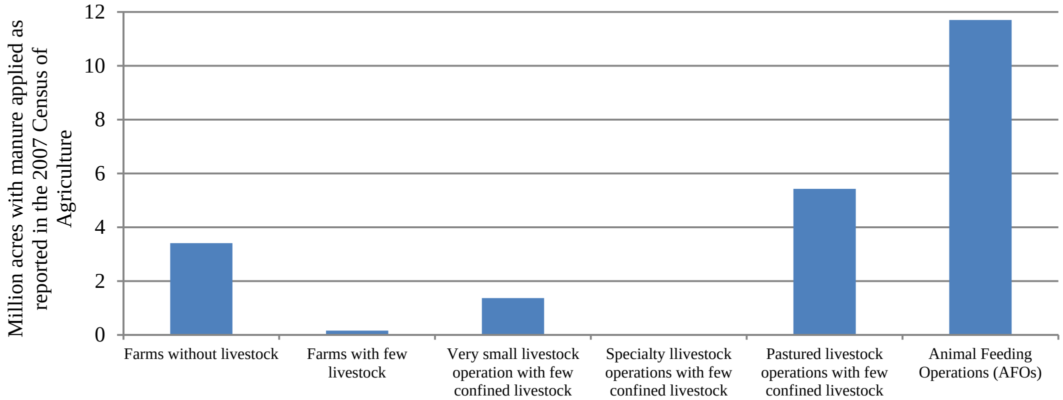


Legend: Green dot = 200 ton gain and red dot = 200 ton loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

Box 3: Comparison of Estimate of Acres Receiving Manure Based on the Model Simulation to Values Reported in the 2007 Census of Agriculture

In 2007, the Census of Agriculture survey asked all farmers to record the number of acres of "cropland and pastureland on which animal manure was applied" on the operation. Additional information on the manure applications was **not** requested, such as which crops received the manure or whether the manure was generated on the farm or off the farm. The question was included in the long form of the survey in previous years, but only a small percentage of farms were asked to complete the long version in those years. In 2007, however, all farms were asked to complete the long version of the survey. Thus, this comparison can only be reliably made for the year 2007, and is limited in scope.

The Census found that 22.1 million acres of pastureland and cropland received manure in 2007. About half (53 percent) of these acres were on farm types that met criteria used in this report for animal feeding operations (AFOs), while the rest was applied on non-AFO farm types, as shown in the figure below.



Using the land application simulation model, this study estimated that 19.1 million acres received manure, about 3 million fewer acres than reported in the Census. The simulation model estimate was reasonably close to the census value for non-AFOs (see table below), indicating that the level of off-farm land application was estimated fairly closely by the model.

Acres with Manure Applied in 2007

	AFOs	Non-AFOs	Total
Million acres reported in Census of Agriculture	11.698	10.398	22.096
Million acres estimated with land application simulation model	8.071	10.992	19.063
Difference (Census minus estimate)	3.627	-0.594	3.033

For AFOs, however, the land application simulation model under-estimates the acres receiving manure by 3.6 million acres. The largest under-estimate by the land simulation model was for small AFOs (2.5 million acres), followed by medium AFO-CAFOs (0.9 million acres). The land simulation model estimated the number of acres receiving manure on large AFO-CAFOs fairly closely, 2.6 million acres versus 2.4 million acres as reported in the 2007 Census of Agriculture.

It is not possible to identify the specific reasons for the under-estimates by the land application model for small and medium AFOs. Possibilities include under-estimation of the amount of recoverable manure generated on the farms, under-estimation of the amount of land available for application of manure on AFOs (including the potential for application of manure from other AFOs), and over-estimation of the on-farm application rates.

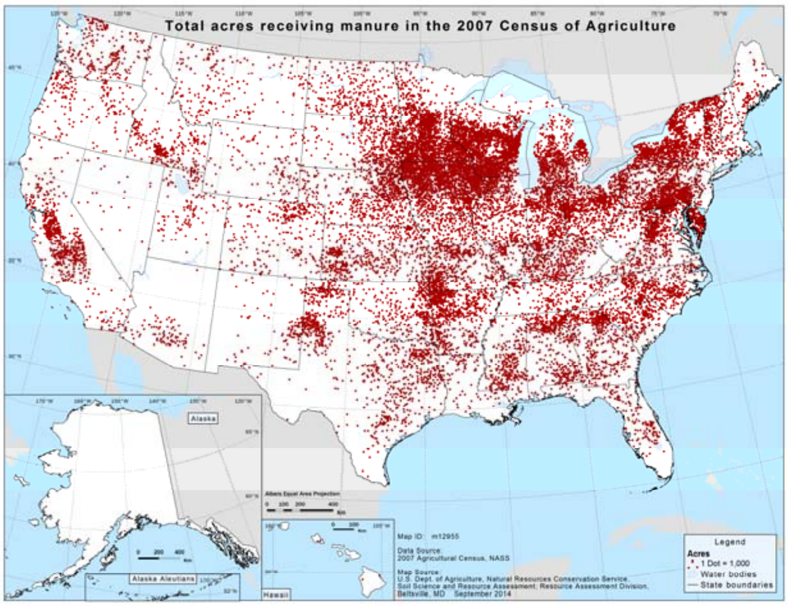
Acres on AFOs with Manure Applied in 2007

	Very small AFOs	Small AFOs	Medium AFO-CAFOs	Large AFO-CAFOs	Total
Million acres reported in Census of Agriculture	0.773	5.366	3.152	2.407	11.698
Million acres estimated with land application simulation model	0.355	2.846	2.217	2.653	8.071
Difference (Census minus estimate)	0.418	2.520	0.935	-0.246	3.627

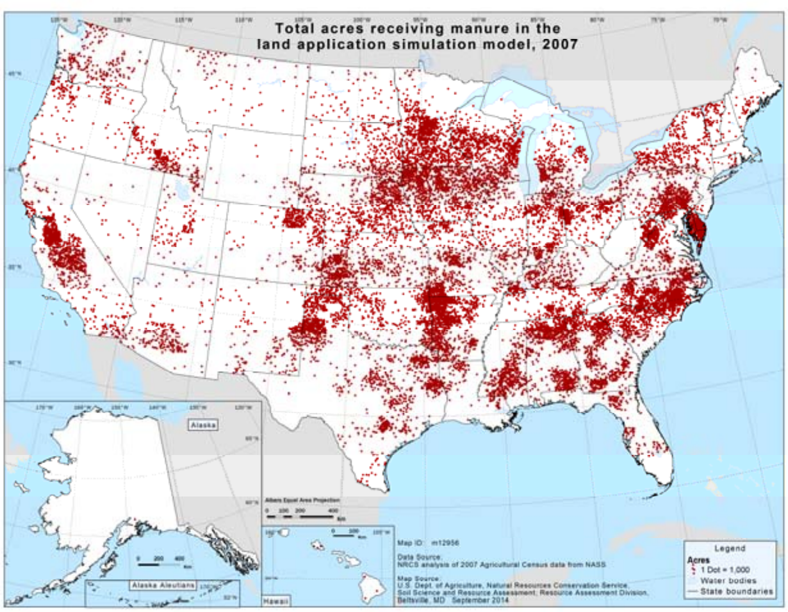
Box 3: Comparison of Estimate of Acres Receiving Manure Based on the Model Simulation to Values Reported in the 2007 Census of Agriculture--Continued

Spatially, the comparison of actual to simulated acres is acceptable, but not perfect. The box maps below show that the areas of concentrated livestock are well represented both in the actual and the simulated acres and the centers of most manure application are the same. A visual comparison indicates that the model under-represents acres receiving manure in areas where confined livestock are less concentrated on the landscape, especially in the Corn Belt. (This supports the finding that the small *AFOs* are the largest under-estimate group given their concentration in the Corn Belt as shown with map 2 earlier in the document.) There was a better match in areas with larger livestock operations where demand for land for manure application is highest.

Box 3 Map. County location of acres receiving manure as reported in the 2007 Census of Agriculture and as estimated by the land application simulation model for 2007



Legend: Dot = 1,000 acres
Source: 2007 Agricultural Census data from NASS



Legend: Dot = 1,000 acres
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

County-Level Excess

Assumptions for Simulation of Off-Farm Manure Applications

The simulation model allocates the farm-level excess manure to crop and pasture acres on farms not designated as AFOs. The first step in simulating off-farm land application of manure is to aggregate farm-level excess manure and crop and pastureland acres for non-AFOs to the county level. *Thus, each county is treated as one large farm for the allocation of the remaining manure*. The priority order for crops and pastureland was the same as that used for AFOs. Assumptions about land availability and the nitrogen application rules differed, however.

The model simulation of land application of manure was used to estimate the off-farm acres receiving manure and the average manure nitrogen and manure phosphorus application rates for each crop and pastureland in each county.

Assumptions for land availability[24]. It was assumed that land availability for manure application on farms receiving manure would be less than that assumed for farms producing manure (AFOs) because of phosphorus application limitations as well as unwillingness by landowners to accept manure.[25] It was assumed that *half* of the cropland acres and *one-fourth* of the pastureland acres on manure receiving farms would be available for manure application in the land application simulation.

It was also assumed that land on AFOs that did not receive manure would *not* be eligible to receive manure from other AFOs. This is cropland and pastureland on AFOs without farm-level excess manure.

Assumptions for manure nitrogen application rates. Manure nitrogen rates for off-farm application were set lower than those for AFOs because operators would likely manage manure resources better to enhance crop growth, rather than use land application as a convenient means of manure disposal. As was done for AFOs, rates for off-farm applications were reduced in the simulations from higher rates in 1982-92 to lower rates in 2002 and 2007 to represent ongoing adoption and implementation of Nutrient Management Plans[26] (NMPs). The application-uptake ratio was set as follows for cropland acres for off-farm manure application: 2.0 for 1982–92, 1.9 for 1997, 1.6 for 2002, and 1.4 for 2007.

Non-AFO Acres Receiving Manure in Simulation Model

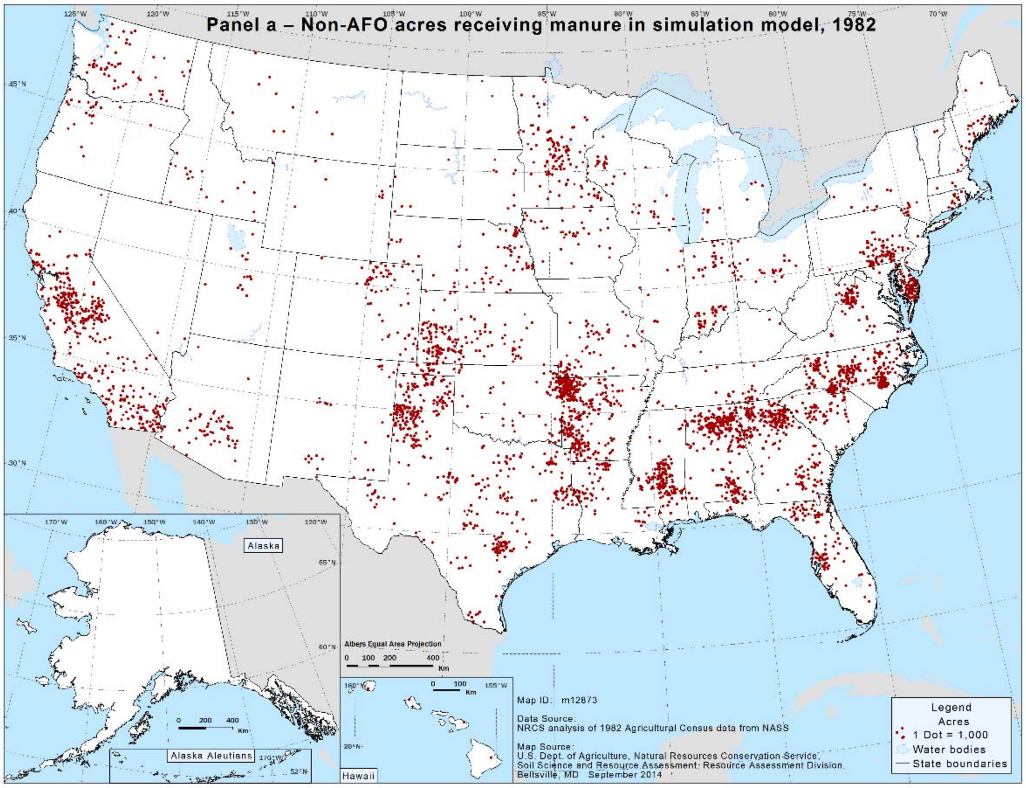
Map 11 presents the distribution and change in the non-AFO acres receiving manure estimated by the process described in the simulation model. This map shows movement of manure off AFO operations with recoverable manure in excess of source-farm assimilative capacity to other (non-AFO) farms in the county. The simulation model considered only the land area of non-AFO farms in the county (shown in this map) as a proxy for farms near the AFO to minimize transportation costs. In actuality, application of recoverable manure will not be limited by county boundaries. A more correct interpretation is that the map describes the acres needed for land application of manure off the source-AFO shown in map 10, yet near the AFO. The location of non-AFO acres receiving manure in panels a (1982) closely follow the location of recoverable manure except in the Midwest. This is an indication of large numbers of animals relative to farm size across the southern tier of the Nation, from California to North Carolina and around the Chesapeake Bay. By 2007, the characteristics of AFOs in the Midwest changed and panel c shows the need to move manure off the source-AFOs in the Midwest as well. The change in acres on non-AFOs receiving manure in the simulation model (panels d-f) were almost all gains in acres, consistent with the increasing concentration of confined animals on farms and the need for AFOs to find off-farm opportunities for land application of manure. Reductions in the non-AFO's receiving manure are in some cases, driven by the supply of available manure as is the case in southern California where the decline in non-AFOs receiving manure is consistent with the decline in farms with excess manure (map 9) and the decline in confined animal units (map 4).

[24] These assumptions differ from the land availability assumptions used to estimate nitrogen and phosphorus assimilative capacity in the previous section and reported in table 14.

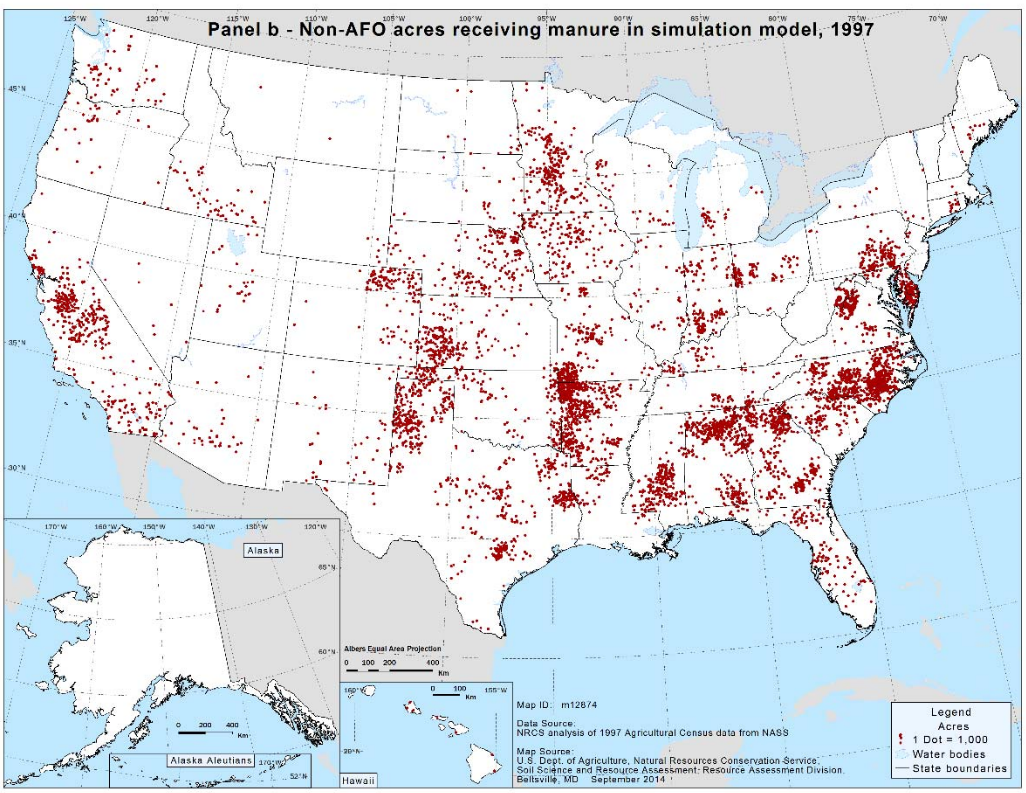
[25] A similar assumption was used by NRCS/USDA (2003) to simulate off-farm manure application. Reasons could include odor or other undesirable aspects; timing problems related to climate or crop stage; strong preference for commercial fertilizers so as to better control rate, timing, and method of application; soil phosphorus levels at or near threshold limits; or other environmental concerns.

[26] Nutrient Management Plans for non-AFO operations include organic and commercial fertilizer and plant residues. Manure is one potential source of nutrients. For operations without recoverable manure, the nutrient management plans drop the term "Comprehensive" in the title.

Map 11. County location of non-AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of Non-AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007

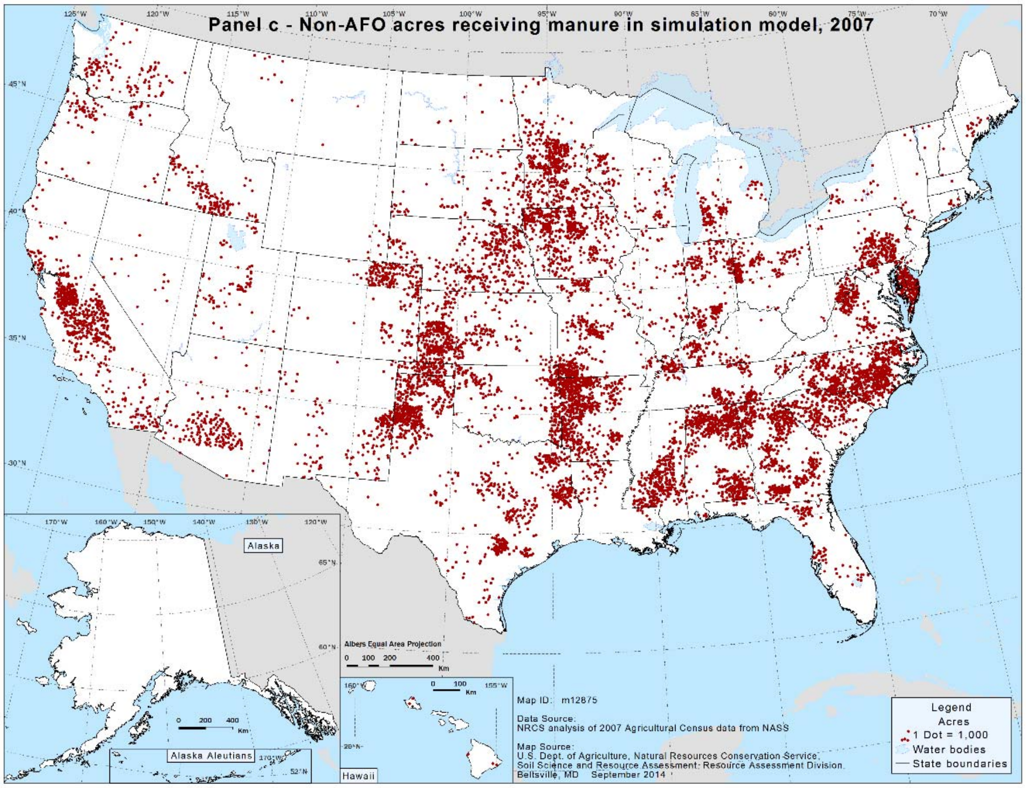


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

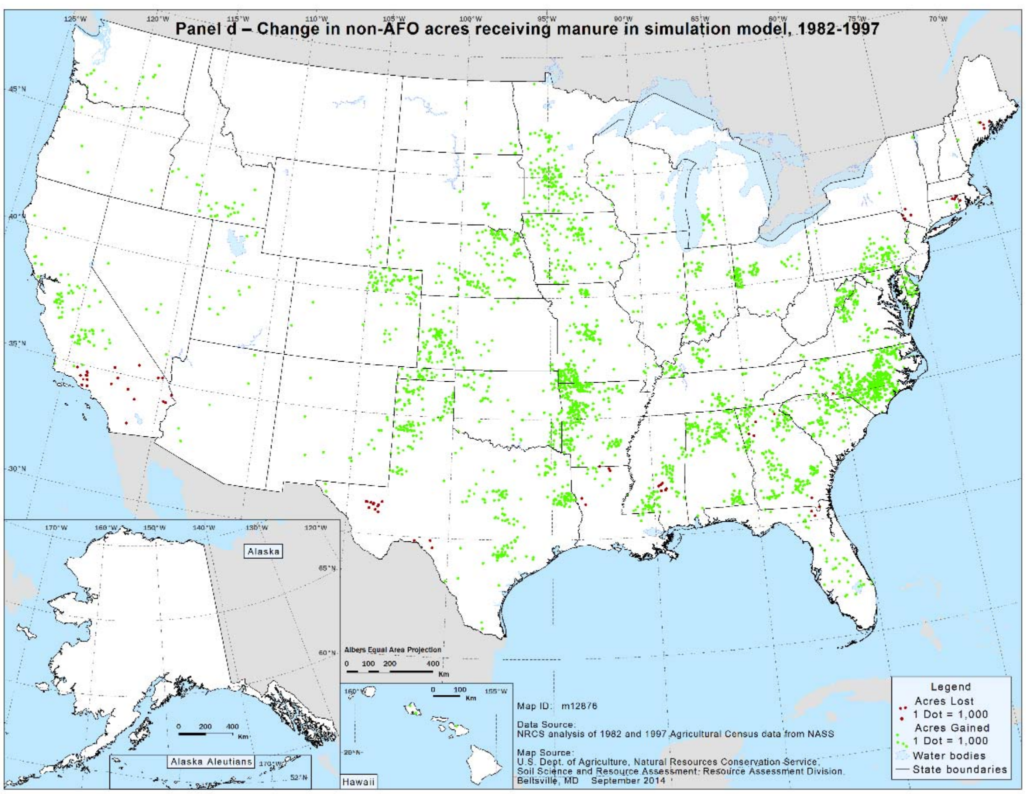


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 11. County location of non-AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of non-AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

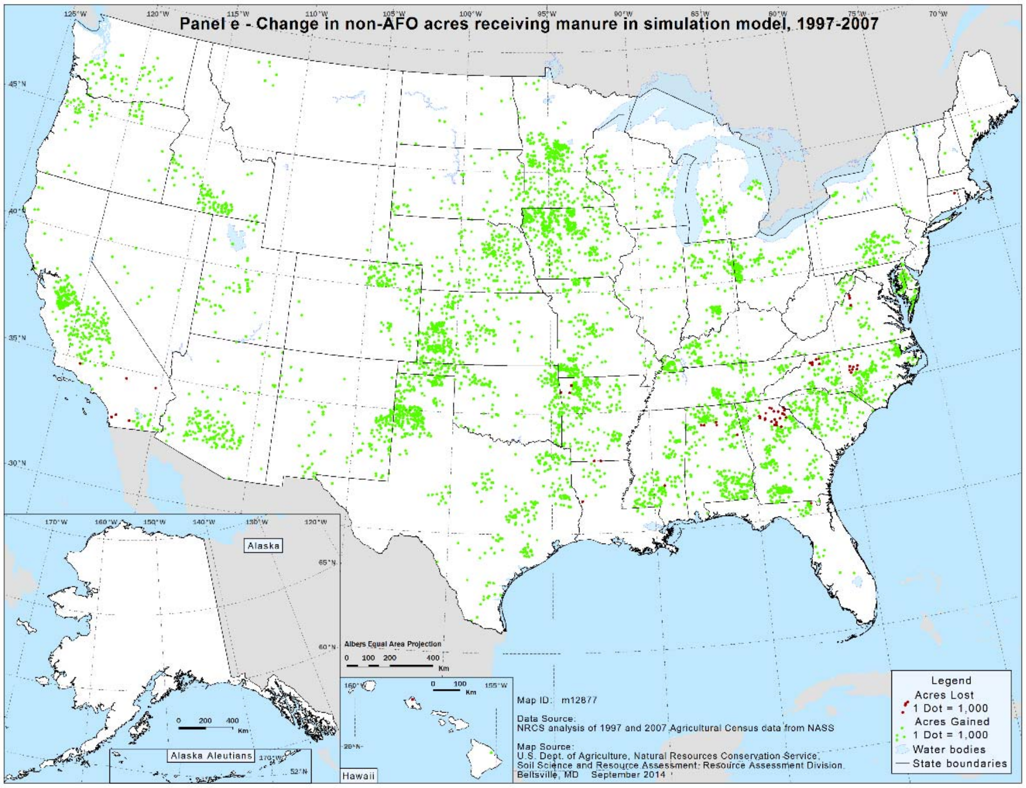


Legend: Dot = 1,000 acres
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

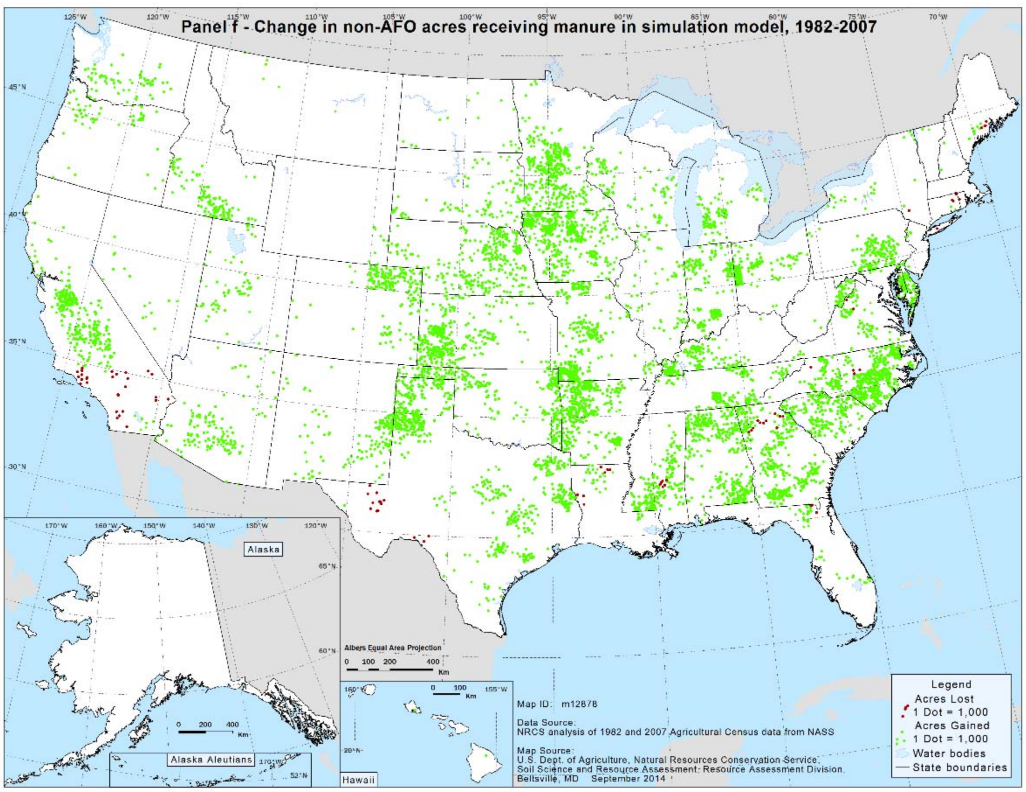


Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 11. County location of non-AFO acres receiving manure in the simulation model for 1982, 1997, and 2007 and change in the county location of non-AFO acres receiving manure in the simulation model for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



Legend: Green dot = 1,000 acres gain and red dot = 1,000 acres loss.
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

County-Level Excess Manure and Manure Nutrients

In most counties, sufficient acreage exists for off-farm land application of manure to exhaust the supply of farm-level excess manure produced in the county (table 16). In some counties, however, manure production exceeds the assimilative capacity of the acres available for manure application under the assumptions of the model simulation. This excess manure is categorized as *county-level excess manure*.

The presumption is that either this manure is presently being transported to areas outside of the county for application, is being used for purposes other than land application, is being applied to lands not considered in this analysis, such as available land on AFOs with no excess manure, or is held in storage temporarily. Lagoons, for example, accumulate manure nutrients as the solids settle to the bottom and the liquid is pumped off for land application. These solids are retained in the lagoon sometimes for many years before being cleaned out and applied to the land. In addition, manure is sometimes allowed to "stack up" for long periods of time in arid regions of the country, and is not removed for land application every year. It is also possible that some of this county-level excess manure, as measured by the simulation model, is actually land applied but at rates higher than simulated.

In 2007, about 1.5 billion of the 1.8 billion pounds of farm-level excess manure nitrogen was applied to non-AFOs, according to the model simulation, leaving 332 million pounds of county-level excess manure nitrogen (table 16). The phosphorus associated with the excess manure totaled 156 million pounds of county-level excess manure phosphorus. In 2007, there were 179 counties (of the 3,076 counties included in the Census of Agriculture database in 2007) with county-level excess manure. The number of counties with county-level excess manure has been steadily increasing since 1982, when there were only 48 counties with county-level excess manure (table 16 and fig. 31).

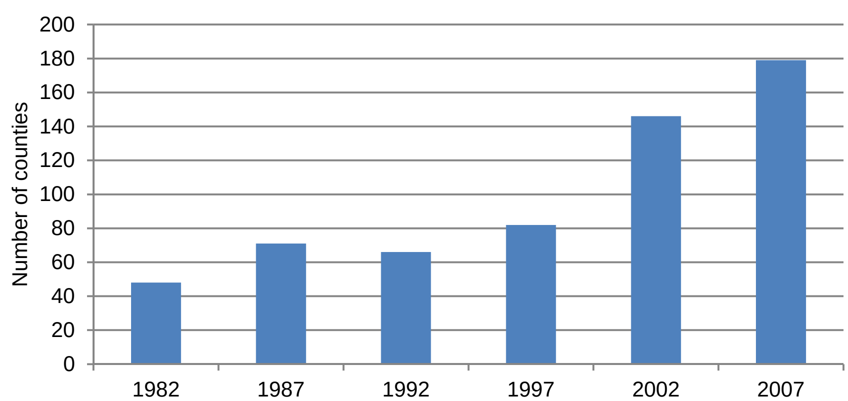
Map 12 presents the distribution and change in the location of county-level excess manure nitrogen as estimated by the simulation model after considering the assimilative capacity of the available land on the farm of production *and* in the county. As discussed earlier, the land available in the county is a proxy for nearby lands that might be available for manure production. Overall, only a few areas of the country are shown to have county-level excess manure, but these areas have been increasing over time. The distribution of county-level excess in 1982 (panel a) shows a few clusters of excess manure in southern California, Alabama, Georgia, and North Carolina. The quantity of county-level excess manure nitrogen in 1997 (panel b) adds a few more clusters of excess in Arkansas, Mississippi, and Virginia. And finally by 2007 (panel c), the quantity of county-level excess manure nitrogen and the areas with county-level excess increase even more. The change panels (d-f) describe an almost uninterrupted increase in county-level excess manure nitrogen, except for some small areas of southern California, and isolated pockets of Georgia, Florida, and New York. Of significance is the lack of county-level excess in the Corn Belt and Plains, regions with significant farm-level excess shown in map 11. In these regions, there is sufficient capacity on non-AFO farms to assimilate the recoverable manure produced on AFOs.

Table 16. County-level excess manure nutrients

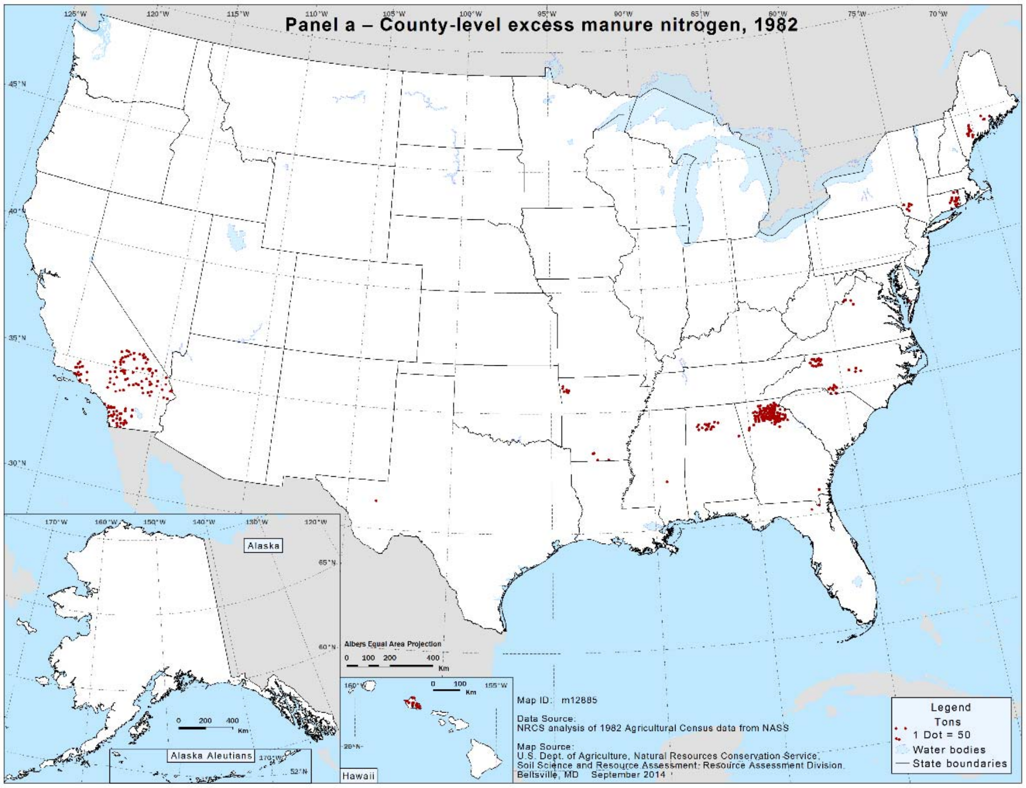
	1982	1987	1992	1997	2002	2007
Number of non-AFOs (manure receiving farms)	1,769,568	1,689,964	1,592,377	1,652,057	1,907,742	2,014,868
Acres available for manure application on non-AFOs under assumptions of the model (1,000s)						
Cropland and pasture	118,585	112,480	145,850	151,487	152,759	152,610
Pasture only (cropland used as pasture and half of permanent pasture)	35,981	36,969	38,638	39,293	40,063	32,680
Cropland only (acres of the 21 crops included in simulation)	82,603	75,511	107,212	112,194	112,696	119,930
Acres receiving manure on non-AFOs under assumptions of the model (1,000s)						
Cropland and pasture	3,899	5,046	5,052	6,327	9,977	10,992
Pasture only (cropland used as pasture and half of permanent pasture)	664	914	801	910	1,355	1,187
Cropland only (acres of the 21 crops included in simulation)	3,234	4,131	4,251	5,417	8,622	9,806
Percent of available cropland and pasture land on non-AFOs that received manure under the assumptions of the model	3%	4%	3%	4%	7%	7%
Farm-level excess manure nitrogen (million pounds) (from table 15)	620	806	911	1,149	1,572	1,854
Manure nitrogen applied to non-AFOs under assumptions of the model (million pounds)	577	725	831	1,049	1,332	1,522
County-level excess manure nitrogen (million pounds)	43	82	81	100	239	332
Farm-level excess manure phosphorus (million pounds) (from table 15)	355	465	528	681	699	829
Manure phosphorus applied to non-AFOs under assumptions of the model (million pounds)	335	425	487	630	586	672
County-level excess manure phosphorus (million pounds)	20	41	41	51	112	156
Number of counties with county-level excess manure*	48	71	66	82	146	179

* Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.

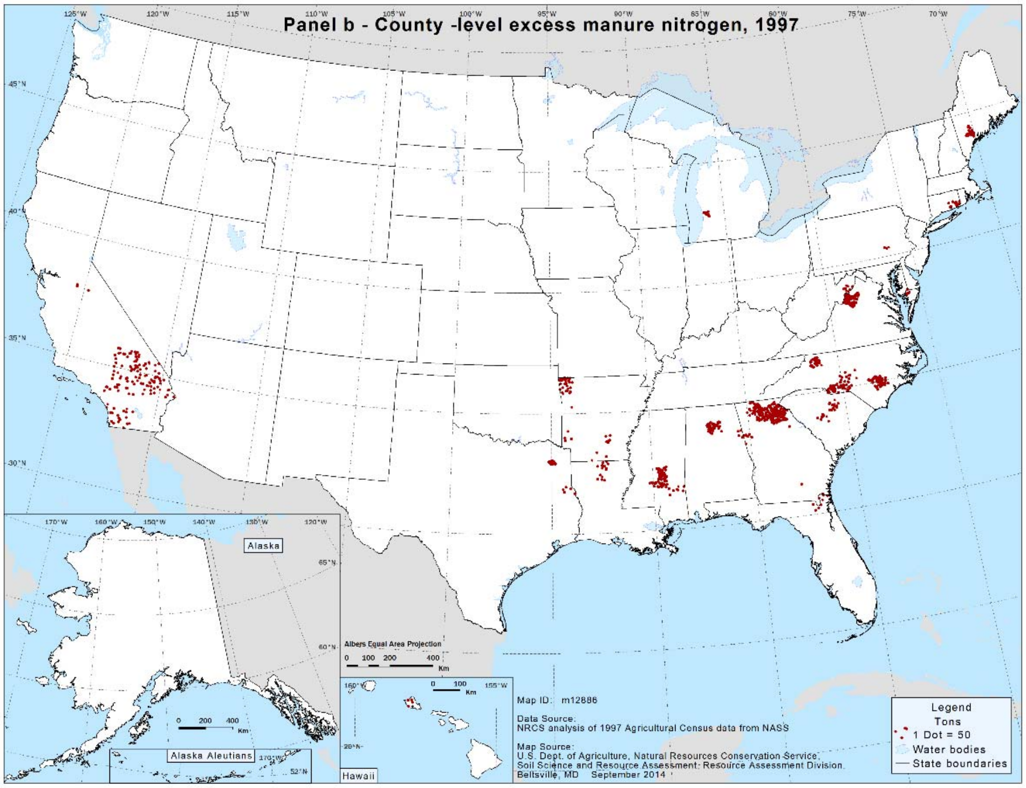
Figure 31. Number of counties with county-level excess manure under the assumptions of the simulation model



Map 12. Location of county-level excess manure nitrogen* for 1982, 1997, and 2007 and change in the location of county-level excess manure nitrogen* for periods 1982-1997, 1997-2007, and 1982-2007

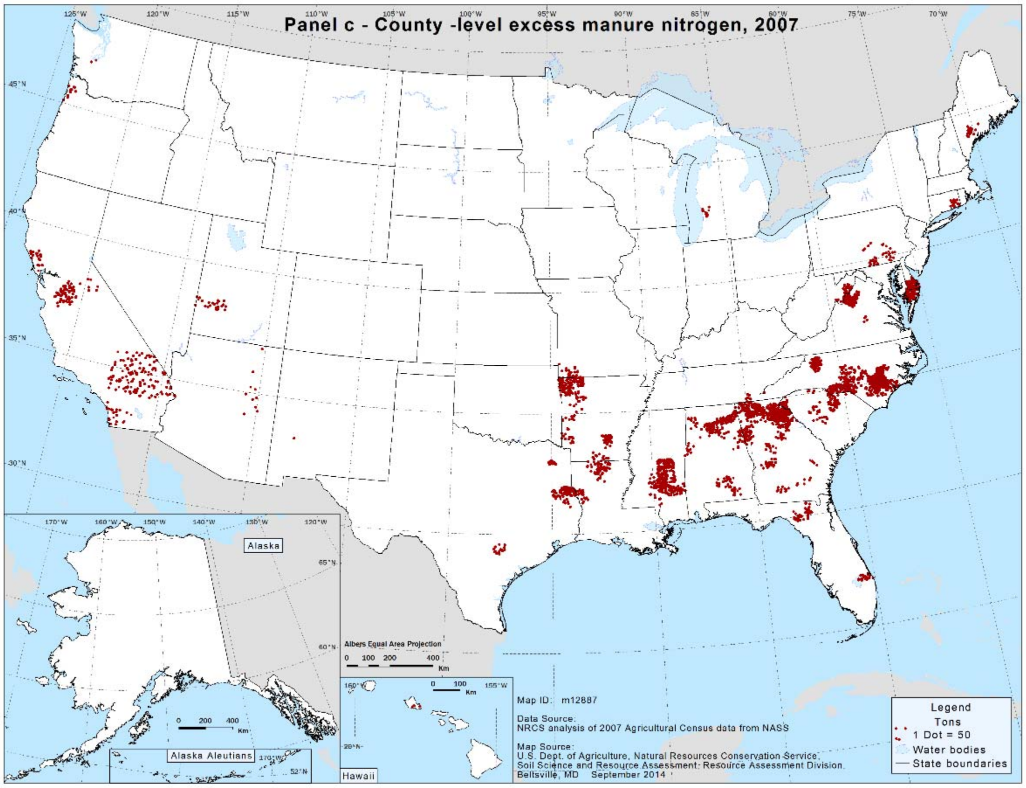


Legend: Panel a-c dot = 50 tons.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 1982 Agricultural Census data from NASS

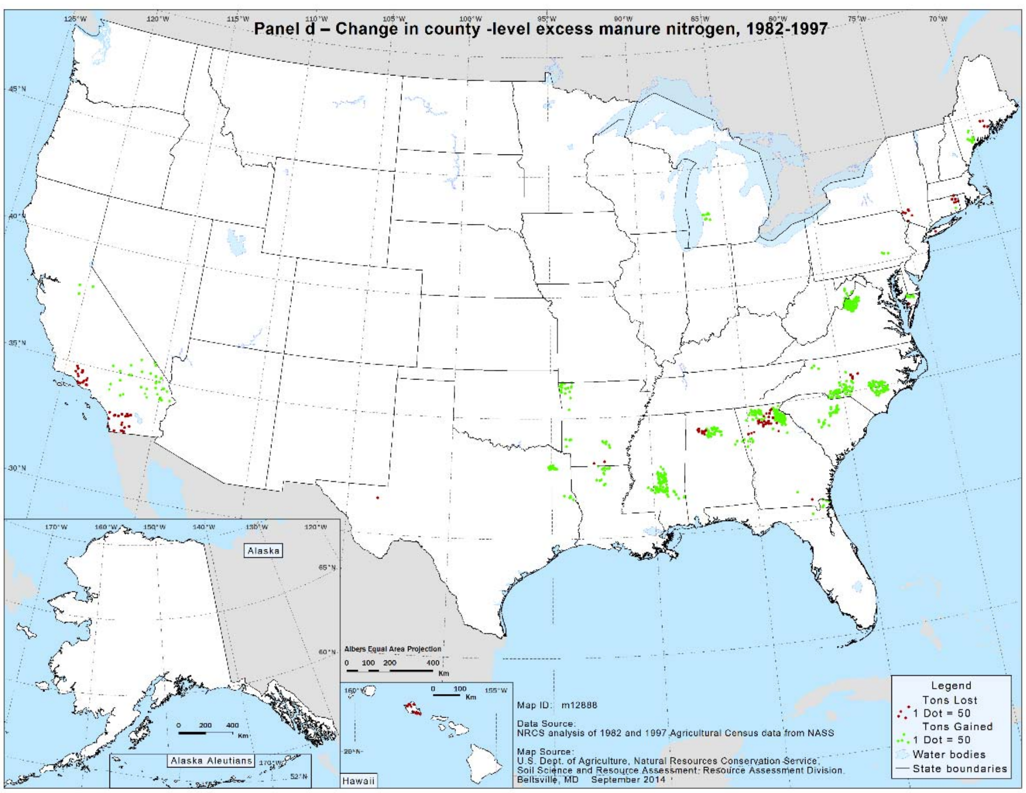


Legend: Panel a-c dot = 50 tons.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 1997 Agricultural Census data from NASS

Map 12. Location of county-level excess manure nitrogen* for 1982, 1997, and 2007 and change in the location of county-level excess manure nitrogen* for periods 1982-1997, 1997-2007, and 1982-2007—**continued**

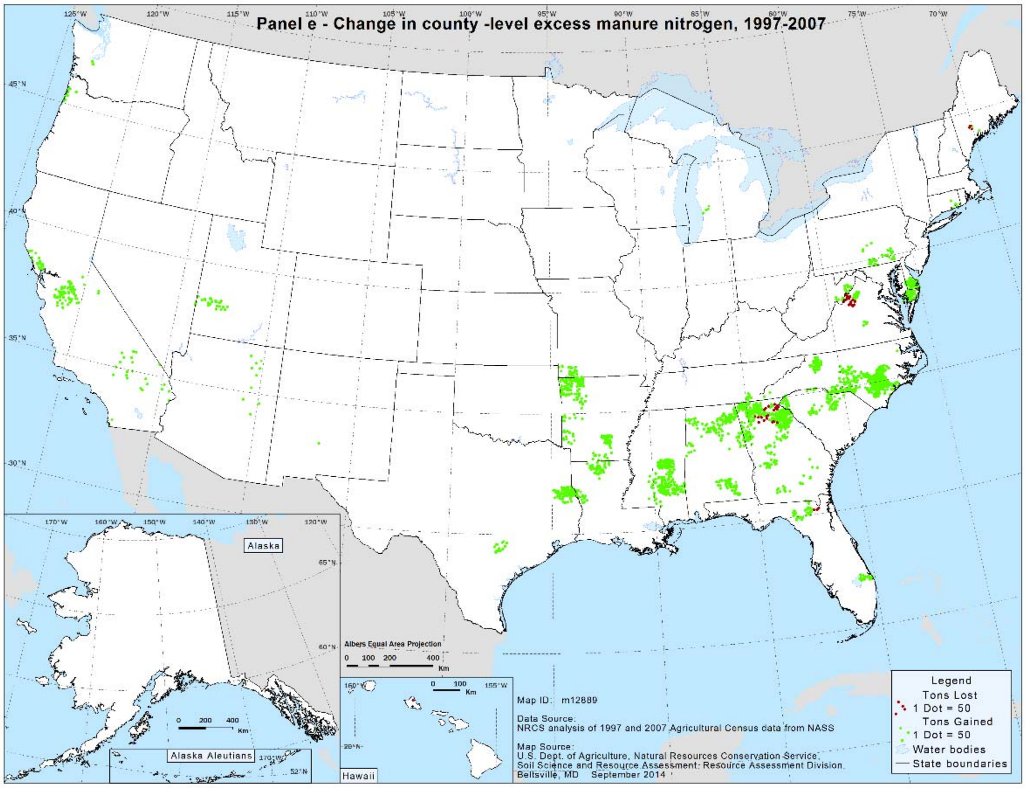


Legend: Panel a-c dot = 50 tons.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 2007 Agricultural Census data from NASS

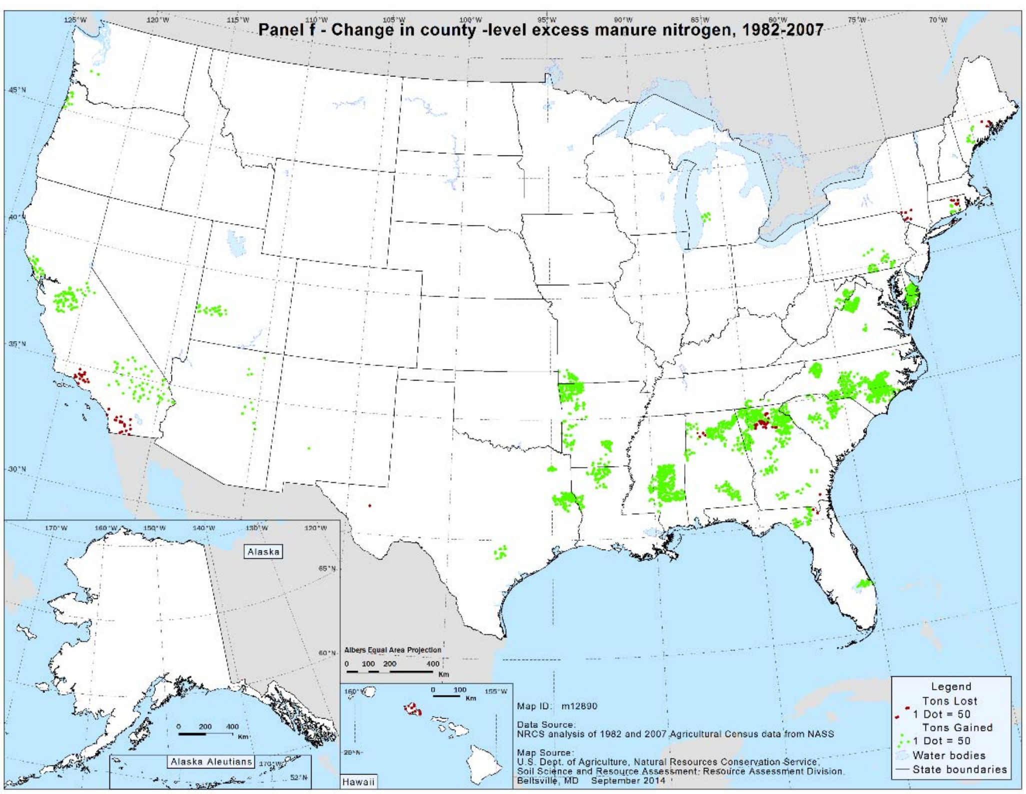


Legend: Green dot = 50 ton gain and red dot = 50 ton loss.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 1982 and 1997 Agricultural Census data from NASS

Map 12. Location of county-level excess manure nitrogen* for 1982, 1997, and 2007 and change in the location of county-level excess manure nitrogen* for periods 1982-1997, 1997-2007, and 1982-2007—**continued**



Legend: Green dot = 50 ton gain and red dot = 50 ton loss.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 1997 and 2007 Agricultural Census data from NASS



Legend: Green dot = 50 ton gain and red dot = 50 ton loss.
**Excludes counties with less than 2,000 pounds of county-level excess manure nitrogen.*
Source: NRCS analysis of the 1982 and 2007 Agricultural Census data from NASS

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Appendix A: Documentation of Average Weights for Livestock and Poultry[27]

The basic building block of the estimation process is an animal unit (AU). An animal unit represents 1,000 pounds of live animal weight and serves as a common unit for aggregating over different types of livestock. Since the Census of Agriculture does not list the average weights of livestock and poultry reported, it was necessary to develop average weights for each livestock and poultry category used in this report.

Average weights of confined livestock types can vary over time depending on markets and production technologies. Average weights for 1982–97 are the same as those reported in Kellogg et al. (2000), which were based on USDA/NRCS (1992), ASAE (1995), and other sources. Average weights for 2002–07 were based on ASABE Standards revised and published in 2005 (ASABE, 2005) and other recent sources. These sources did not include data on all of the specific livestock types and ages of animals for which Census of Agriculture data were available, so in several cases the published values were adapted to conform to the type and size of animal for which head counts were available or could be derived. Average weights used in this study can be derived from the animals per AU in tables 1 through 3 in the main body of the report.

An important aspect of the animal unit calculation is the amount of time that an animal is assumed to be on the farm during the year. For fattened cattle, hogs for slaughter, and poultry other than breeding stock, it was assumed that the animals were raised in multiple cycles per year, resulting in continuous production throughout the year. For the various cattle categories (calves, heifers, stockers), the animal unit calculation was based on the proportion of the year that the animals were in the specified category. Animal units for breeding stock and chicken layers were estimated based only on end-of-year inventory. For these categories, it was assumed that the animal was present throughout the year or that there was continuous replacement.

Average weights were derived to represent general production practices across the Nation for all operations, both large and small. For any specific part of the country, farm size, or time period, prevailing practices could result in different values for these parameters. For example, industry sources indicate that the time in a confined setting for fattened cattle ranges from 60 to 200 days with a typical range of 120 to180 days. A value of 2.5 cycles (146 days) was selected to estimate fattened cattle animal units for all operations. Similar information was evaluated to set these parameters for other livestock categories. Moffitt and Lander (1997) discuss factors to be evaluated when selecting a national data set.

The number of animals per animal unit values for 1982–97 were first published in NRCS's Status and Trends document (USDA, 1994), and confirmed with similar information prepared by Sweeten (1992). The actual documentation for each of the values in the 1982–97 animals per animal unit data set is no longer available, but where values can be confirmed from known sources, those references will be identified. One data source used to determine the average weights for many of the pastured livestock types is no longer available as will be discussed later. In addition, weights for some of the livestock types were not readily identifiable in the common literature and a more circular path was taken to identify values as will be noted below.

Confined Livestock Types

Fattened Cattle

References from the 1982–97 period indicate a weight range of 800 to 1,000 pounds, with Barker (1990) and ASAE (1995) both recognizing an average weight in the 800s. For this analysis, we used 875 pounds, or 1.14 animals per animal unit. The more recent ASABE D384.1 lists fattened beef in the lot at an average of 445 kilograms or 980 pounds for 1.02 animals per animal unit. ASABE D384.1 (2005) lists a typical 'feedlot' stay of approximately 150 days, or 2.5 cycles per year. Feedlot stays range from 60 to 180 days depending on market and climate conditions.

Veal calves

Veal is a term used to describe four distinct groups of calves raised for meat. Bob veal is a unique U.S. variety, consisting of calves that are marketed a few days after birth at approximately 150 pounds. Formula-fed or milk-fed veal calves are the most common and are raised from birth on a nutritionally complete milk-based formula. A typical growth cycle is approximately 18-plus weeks for the heavier veal. Non-formula-fed (red or grain-fed) veal calves are raised on hay, grain, or other solid ration in addition to milk. This group is often marketed as calves rather than veal; calves are older and heavier by some 200 pounds. The final group is rose veal found mainly in the United Kingdom, so named because of the color of the meat. Rose veal calves are raised to strict standards of Britain's Freedom Food Program, and are marketed at 35 weeks of age. Rose veal occupies a rather small but steady niche market in the U.S.

Farms with veal as reported in the Census of Agriculture could be any one of these four groups, but from veal manure characteristics in other literature the majority are the formula-fed veal. There are some differences in the literature as to the market weight of formula-fed veal which impacts the average weight to be applied to Census of Agriculture numbers. The Cattlemen's Beef Board site (Cattlemen's Beef Board, 2008) references a market weight of 450 to 500 pounds (average of 225 to 250 pounds using an assumed straight line growth rate). A Web site from the American Veal Association (http://www.americanveal.com/VEAL_WHITE_PAPER_R1-0706.pdf) references veal growing to 500 pounds or 250 pounds average. A North Carolina State University reference

[27] This appendix was prepared by co-author David C. Moffitt.

(Shaffer and Cleveland, 2008) notes a 200-pound average weight or 400 pounds at market. The American Society of Agricultural and Biological Engineers suggests in its standard on manure characteristics (ASABE, 2005) an average weight of veal of 118 kilograms or roughly 260 pounds. It appears that the range of average weights for veal is 200 to 260 pounds. It also appears that most of the higher average weights are from the most recent documents, so using a consensus number of 225 pounds for the 'average' veal calf is appropriate. Thus, there will be 4.4 veal calves per animal unit. The same value is used for both the 1982–97 and 2002–07 periods.

For heavier veal calves (250 pound average weight) an 18-plus week growth cycle was used in this study (Wikipedia, 2008). Lighter weight veal calves would have a shorter growth cycle. ASABE 384.1 (2005) suggests a 1- to 2-pound-per-day weight gain, so a 200-pound veal calf could have an approximate life cycle of 13 weeks. A 3½-month or 15-week growth cycle is used in this study, which is in the midrange of the average weight of veal calves.

Milk Cows

Typically, lactating cows weigh between 1,200 and 1,500 pounds, with values of 1,370 pounds (ASABE, 2005) to 1,400 pounds (Barker, 1990) most common. A weight of 1,370 pounds, or 0.73 animal per animal unit, was used for both the 1982–97 and 2002–07 periods.

Breeding Hogs

The average weight used for the period 1982-1997 was 375 pounds or 175 kilograms, which represents a breeding sow after lactation (ASABE, 2005 and Barker, 1990). The current ASAE practice (ASABE, 2005) shows the average weight of a sow at 195 kilograms or approximately 430 pounds. Kansas State University (Sulabo et al., 2006) estimates that boars range from 300 to 650 pounds. Even though there are few boars, the average weight for breeding hogs was used as 440 pounds or 2.27 animals per animal unit.

Hogs for Slaughter

In Kellogg et al. (2000), NRCS recognized two categories of swine, "Breeding Hogs" and "Hogs for Slaughter." These designations were consistent with information available from the 1997 Agricultural Survey (USDA, 1997). Hogs for slaughter were listed as 9.09 animals per AU, or 110 pounds average weight. It was assumed that Hogs for Slaughter were considered farrow to finish, and that producers would raise two cycles per year. Other literature from the 1990s typically listed swine with an average weight of 135 pounds (Barker, 1990) (ASAE, 1995). The difference results from assumptions about rate of growth. NRCS in Kellogg et al. (2000) and elsewhere has assumed a straight line growth, whereas assuming a rapid initial growth and a slower later growth results in a higher average weight.

In the 2002 Agricultural Census (USDA, 2002) and again in 2007, the categories provided were "Farrow to Wean," "Farrow to Finish," "Finish Only," "Farrow to Feeder," "Nursery," and "Other." Providing information on animals per animal unit and number of cycles per year becomes more complex. The literature often disagrees on the weight breakdown between the different age groups, but considering ASABE (2005), Dhuyvetter et al. (2007), and an Economic Research Service report (USDA, 2008), table A1 summarizes the consensus animals per animal unit and cycles per year.

Table A1. Animals per 1,000-pound animal unit and annual production cycles

Age Group	Wt In	Wt Out	Ave Wt	Animal/AU	Cycles/Year
Farrow to Wean		13	7	143	17 days + clean-up, Use 18.25 cycles
Farrow to Finish		260	135	7.4	6 Months, Use 2 cycles
Finish Only	40	260	150	6.7	4 ½ months + clean-up, Use 2.6 Cycles
Farrow to Feeder		40	20	50	Six weeks + clean-up, Use 8 Cycles
Nursery	13	40	27	37.04	3 ½ weeks + clean-up, Use 13 Cycles

Chicken Layers

ASAE (1995) and other references list the average weight of layers as 4 pounds, or 250 animals per animal unit as used for the 1982–97 data. More recent data from many sources such as Jacob (2011) discuss the typical layer as beginning production about 3 pounds (ASABE, 2005), continuing to grow till about 4 pounds, then decreasing with weight as they age. We used an average of 3.4 pounds, or 293 animals per animal unit.

Chicken Pullets

Husbandry practices for pullets have changed little in the past few decades. Often, the term pullet is used to reflect young laying hens (actually in production), which also complicates documentation. The typical pullet operation (Jacob, 2011) provides birds at 15 to 20 weeks that are ready to begin laying, but are often held until replacement hens are required. Many references such as ASAE (1995) list pullet and layer weights as the same, but using 350 animals per animal unit reflects an overall smaller bird and a 22- to 26-week cycle (US Poultry and Egg Association, 2000). A 23-week cycle was used in this study.

Chicken Broilers

Barker (1990) and ASAE (1995) list an average broiler weight of 2 pounds. In our previous reports covering the 1982-1997 period we used a 10-percent heavier bird at harvest, or an average weight of 2.2 pounds. The documentation for the heavier weight is no longer available, but most likely was from industry sources. The more recent ASAE reference (ASABE, 2005) provides a harvest weight of 2.36 kg or 5.2 pounds, for an average weight of 2.6 pounds used for the period 2002-2007. The higher harvest weight in the recent period supports a trend to heavier birds at harvest which further supports the somewhat heavier average weight used in the earlier period.

There has always been uncertainty as to the number of broiler cycles per year. Industry (US Poultry and Egg Association, 2000) estimates are five to seven cycles per year. There are reports of 7-plus cycles per year with the industry's best producers, but these reports are not typical. ASABE (2005) estimates an approximate 7-week growth cycle. The number of cycles is also influenced by the markets identified for the birds with "fast food cut" having a shorter cycle than "tray pack" birds which is shorter than "roasters." With time for a partial litter clean-out between cycles and at least one major clean-out a year, six cycles per year was used in this study.

Turkeys for Breeding

Barker (1990) lists breeder turkeys at 20 pounds average weight. The U.S. Poultry and Egg Association (2000) confirms that value as still valid. Twenty pounds average weight is 50 animals per animal unit used for both the 1982–97 and 2002–07 periods.

Turkeys for Slaughter

Barker (1990) and ASAE (1995) both show average weight of slaughter turkeys at 15 pounds, or 67 animals per animal unit used for the 1982–97 period. The more recent ASABE data (ASABE, 2005) lists a harvest weight of approximately 15.5 kilograms or an average weight of almost 16.5 pounds, or 59 animals per animal unit used for the 2002–07 period. The number of cycles per year for turkeys for slaughter has always been an estimate. ASABE (ASABE, 2005) indicates a typical growth cycle of 18-20 weeks, which would point to 2.5 to 3 cycles per year. The U.S. Poultry and Egg Association (2000) estimated that a typical operation would consist of approximately two cycles per year, with one cycle aimed at supplying turkeys for fall and winter holidays. Two cycles per year were used in our analysis.

Ducks

There are few data on ducks. The 2005 ASABE reference lists ducks at a harvest weight of approximately 3.2 kilograms, or an average weight of 3.5 pounds used for both the 1982–97 and the 2002–07 periods. The 2005 ASABE reference lists a cycle length of approximately 6 weeks. A case could be made for seven or even eight cycles per year, but the consensus (US Poultry and Egg, 2000) is that the duck industry allows more time to elapse between cycles. An estimate of six cycles per year was used for this analysis.

Pastured Livestock Types

Nationally applicable data on pastured animals are rarely available. Since pasturing is often limited by climate and growing season, animal husbandry varies widely across the country. One of the major references used for the average weights of pastured livestock was a 2001 online database that was an update of Barker (1990), and this reference is no longer available.

Beef and Dairy Calves

This is one of the categories included in the 2001 revised Barker publication. This source has a category for 'calves' on grass which comes close to matching an average weight of 250 pounds and a 24-week cycle, which was used in our study.

Beef and Dairy Heifers

Heifer categories are relatively hard to document because during much of their life before being bred, they are raised much like other pastured livestock categories. Gamroth (2008) suggested that as heifers approach breeding age they are separated out for five months. His suggestion was an average weight of 875 pounds for beef heifers and 950 pounds for dairy heifers. ASABE (2005) suggests 420 kilograms or approximately 925 pounds average weights for 'heifers' without designating beef or dairy. In this study Gamroth's recommendations were used.

Beef Breeding Herd

Barker (1990) and ASAE (1995) suggest beef breeders at 1,000 pounds average weight or 1 animal per animal unit.

Beef and Dairy Stockers

In Barker's original data set (1990), he suggested an average weight for stockers at 550 pounds or 1.8 animals per animal unit. While not identical to the value used in this study (1.73 animals per animal unit – 580 pounds average weight), the older value supports the value used here.

Horses and Ponies

Barker (1990) and the 1995 ASAE data documented horses at 1,000 pounds. More recent publications such as the 2005 ASABE data list horses at an average weight of 500 kilograms or 1,100 pounds which translates to 0.9 animal per animal unit used in this study. Ponies by definition are smaller animals, and in the Agricultural Census are not listed separately from horses. Assuming the percent of ponies compared to horses is small, no adjustment to average weight was made to account for ponies.

Mules, Burros, and Donkeys

There is a wide diversity in the size and weights of mules, burros, and donkeys. Most sources recognize the burro and donkey as the same animal (burro is Spanish for donkey), so the discussion that follows will only discuss mules and donkeys. The 2002 Census of Agriculture (USDA, 2002) does not differentiate between donkeys and mules, so we must assume the numbers are split equally between the two.

Mules are the larger of the two animals averaging 600 to 900 pounds, but there are 1,000 pound mules (Wikipedia, 2008). Donkeys are smaller, seldom larger than 600 pounds, and one source (Alberta Agriculture and Rural Development, 1990) suggests a 450-pound average. Assuming a 750-pound mule and 450-pound burro/donkey, the average weight would be 600 pounds. Both mules and donkeys have a mortality rate of greater than 10 percent (Wikipedia, 2008). Assuming 12-percent mortality and three years to maturity, the average weight would be 560 pounds.

Sheep and Goats

The category of 'sheep' includes both mature sheep and lambs. Barker (1990) suggests average weights of 160 pounds for mature sheep, 60 pounds for lambs, and 140 pounds for goats. Considering a weight of 3:1.5 for sheep versus lambs, and a small number of goats (in comparison), an average weight of 125 pounds seems appropriate.

Specialty Livestock Types

In addition to the normally recognized livestock and poultry categories, there are a number of specialized species also listed in the 2002 Agricultural Census (USDA, 2002). These include mink, bison, deer, elk, llamas, and rabbits. Also included in the poultry category are emu, geese, ostrich, pheasant, squab, and quail.

There is limited information available in regards to specialty livestock. Enough information was developed from an extensive literature search to develop a table of average weights for each species and the number of production cycles. These are shown in table A2. A description for each species follows, documenting the assumptions used in our study.

Large animals such as bison, deer, elk, and others present a special problem because they live longer and the Census of Agriculture makes no distinction regarding age breakdowns as it does, for example, for cattle. The assumption is made that the reported farm numbers include all levels of maturity. Without definite trends in production, it was assumed that animal mortality and birth rate are approximately equal, so an adjustment was made where appropriate to account for younger animals (not yet mature) in the herd numbers.

Table A2. Characteristics for specialty livestock types

Animal Species	Average Weight Pounds	Production Cycles
Mink	2.1	1
Bison	1,230	1
Deer	210	1
Elk	600	1
Llama	320	1
Rabbits	4.9	3.5
Emu	100	1
Geese	8	2
Ostrich	185	1
Pheasant	1.6	1 – 3*
Quail	0.17	4**
Pigeon or Squab	0.8	6

*Theoretically there could be three production cycles per year. More realistically with the majority of sales geared to fall hunting, many producers will have only one large production cycle

**Coturnix quail mature in six to eight weeks, where the more common quail mature in twelve weeks or more

Mink

There is a great deal of anecdotal information on the internet relating to mink, but little recent technical data. The best available information is from 1966 (Adair et al, 1966), but probably still appropriate. Mink are raised in confinement and produce one litter per year. They reach full size in six or seven months and are harvested in late fall and early winter as their winter fur is at its best. There appears to be no weight gain in the period between maturity and harvest. Males weigh upwards of 2,000 grams at maturity with females somewhat smaller at 1,100 grams.

A reasonable understanding of the Census data indicates the sales are the harvested mink and the inventory would be the breeding stock. However, Adair et al. (1966) indicate that litter size varies from three to five kits per female. Assuming three kits per litter (allows for some mortality) and total sales plus inventory of 3,600,000 animals, it would appear that some of the inventory could still be harvested. In spite of what appears to be a discrepancy, we made the assumption that sales are the harvested kits and inventory is breeding stock, primarily females. Assuming an equal split in kits at maturity between male and female, we use an average weight of 775 grams. We also assume breeding stock at constant average weight of 1,200 grams to account for some males. Average weight for mink at 60 percent harvest and 40 percent breeding stock, would thus be 945 grams or 2.1 pounds.

Bison

Bison, or the common misnomer, buffalo, is often viewed as a leaner, healthier form of bovine meat (Koch et al, 1995). As such, they occupy a small but steady niche market in the United States. Bison in captivity have very similar traits to bison raised in the wild, except that those in the wild tend to have a markedly shorter life (USDI, 2005), although 15- to 20-year-old animals are still common in the wild. At birth, a bison calf will weigh 40 to 50 pounds (NBA, 2008b). Bison bulls are estimated to weigh up to 2,000 pounds, with cows weighing 800 to 1,100 pounds. Yearlings of both sexes are estimated to weigh 500 to 700 pounds (Koch et al, 1995). Other sources confirm the cow weights but place bulls over three years of age at 1,600 to 1,700 pounds (Haigh and Gates, 1995).

Bull bison marked for meat production are harvested at 18 to 30 months of age, at a weight of approximately 1,150 pounds (NBA, 2008a). After 30 months of age, the meat is no longer considered to be prime. The 2002 Agricultural Census (USDA, 2002) indicates an end-of-year inventory of approximately 231,000 and approximately 57,000 bison sales in 2002. The National Bison Association indicates 30,000 bison were slaughtered in 2004 which was twice the number slaughtered in 2000 (NBA, 2008b). We estimate that roughly 22,000 bison were slaughtered in 2002. It would appear that almost 35,000 of the bison sold in 2002 would be considered as part of the inventory numbers reported in the 2002. Total inventory including slaughtered bison would be approximately 255,000 animals, which corresponds to the industry statistic of a stable captive population of 270,000 (NBA, 2008b).

A strict average weight for bulls would be 1,600 to 2,000 pounds or 1,800 pounds on average, and for cows 800 to 1,100 pounds or 950 pounds on average. Assuming an equal distribution of bulls and cows, a calculated average weight would be 1,375 pounds. With approximately 20 percent of the bulls harvested each year at approximately 2 years of age and 1,000 pounds, the average weight of bull is reduced to 1,580 pounds and the national average would be 1,265 pounds not considering mortality of the herds. Considering 5 percent mortality (inventory numbers reflect replacement bulls and cows) and a three-year growth to full maturity, the average weight is 1,230 pounds.

Deer

There are a wide variety of deer grown commercially in the United States. The most common are Red and Fallow Deer. Average weight of mature Red Deer is reported at 240 pounds for hinds (females) and 550 pounds for stags (males). Red Deer reach maturity in 24 to 30 months. Fallow Deer are considerably smaller with does weighing 110 pounds and bucks averaging 220 pounds. Fallow Deer reach maturity in the same length of time as the Red Deer (Altizio and Westendorf, 2002).

There are a number of farms producing venison from better known varieties of deer such as Whitetails and Mule Deer. These deer vary widely in average weights across the country, generally heavier in the East and Midwest than they are in the West and Southwest. The literature does not contain a great deal of information as to average weights for those grown in captivity. Most all studies providing average weights were based on check station weights of field dressed deer using a conversion of 1.4 to convert to live weight (Deer and Elk Farmers Discussion Forum, 2008). It is difficult putting an average weight on Whitetails and Mule Deer due to this lack of information, but Hefflefinger in his book. *Deer of the Southwest* (Hefflefinger, 2006), suggests an upper limit for bucks would be 175 pounds, and 105 pounds for does. Knowing the deer in the Southwest are lighter than those in the East or Midwest, there's reason to believe these are reasonable approximations of national averages.

The 2002 Agricultural Census (USDA, 2002) lists a national inventory of almost 290,000 animals and 43,000 animals sold, or some 15 percent. There are not any break-down of national deer sales, but the Pennsylvania Deer farmer's Association does describe the type of sales typical to deer farms (Shepstone Management Company, 2007). Breeding services are most common, and lethal sales such as hunting and venison are far behind. A 15-percent harvest per year was assumed, with inventory numbers reflecting mature and replacement animals.

The Census results do not specify deer varieties, so one must make assumptions knowing the predominant varieties for deer grown in captivity are the Red and Fallow Deer as cited above. Assuming a 60-40 split between the predominant two varieties and other deer, and assuming the Red and Fallow Deer are evenly divided, the average weight of male deer would be about 300 pounds and female would be about 150 pounds. If we assumed a 70-30 split and kept the same equal distribution between Red Deer and Fallow Deer, the average weight would be 154 pounds for does and hinds and 320 pounds for bucks and stags. It seemed appropriate to use the 60-40 split until other information becomes available. Assuming an equal split between male and female, the average weight would be 225 pounds. Allowing for 15 percent replacement stock and two years until maturity would reduce the average weight to 210 pounds.

Elk

Raising elk as part of a commercial enterprise is a relatively recent development in the United States, but has been practiced in Europe and elsewhere for decades. Up until the 1960's the only elk raised were for zoos and other exhibits. In 1990 the North American Elk Breeders Association was formed, and marked the real start of the United States commercial elk industry (Forrest, 2004) (NAEBA, 2008). Like commercial elk farms, the raising of elk for their meat is relatively new in the United States, and 75 percent of the elk meat consumed in the US is imported – primarily from New Zealand (Altizio and Westendorf, 2002). There are no numbers available to indicate the number of confined elk slaughtered for meat or other uses. The major product from the raising of elk is the "velvet" or soft antler that is harvested before the antler calcifies and becomes hard. The velvet is said to have a wide variety of medicinal purposes, and there is an expanding market in Asia as well as a niche market here in the US among baby-boomers (Forrest, 2004). However, the velvet market fluctuates widely, and an expanding meat market is thought to be the long term foundation of the commercial elk industry (Deer and Elk Farmers Discussion Forum, 2008).

Elk are hardy and live upwards of 15 years or more in confinement (Forrest, 2004). Much of the literature reports average weights of mature cows (4 to 5 years) at 550 to 600 pounds, and 800 to 1,100 pounds for mature bulls (more than 7 years old) (Forrest, 2004). Other literature (Altizio and Westendorf, 2002) reports averages of 500 pounds for cows and a maximum of 850 pounds for bulls, again for mature animals, but no specifics provided on age. An industry source (Deer and Elk Farmers Discussion Forum, 2008) also reports similar variability, especially for bulls. One contributor reports a fair average weight for bulls would be 625 pounds, the reasoning being that the heavier averages are for older, more mature bulls, whereas the most plentiful bulls are younger and significantly lighter. It is reasonable to accept a lighter weight for a national average that would reflect the fact that the older mature animals are heavier, and that as a group do weigh in the 850 to 1,000 pound range, but this does not include the lighter stock. Considering the variability of weights in the literature as well the comments of elk farmers, we chose to use an average weight of 500 pounds for cows and 700 pounds for bulls. This would reflect the long life at maturity and approximately 20 percent at all stages less than maturity. Assuming an equal split between male and female, the average weight per elk would be 600 pounds.

Llama

Llamas are commercially grown in the United States for fiber or live sales. There are four types of lama (the genus name is spelled with one 'l'), with llamas and alpacas being the most common (Gegner, 2000). There is no reason to assume operators included all the lama types as llama, although some may have done so. The 2002 Agricultural Census lists llama inventory at approximately 145,000 animals (USDA, 2002). This contrasts with the Gegner reference that lists the llama number at 'over 200,000' with an additional 20,000 alpacas. Interestingly enough, another reference (Altizio and Westendorf, 1998) states the llama population is 125,000 with 25,000 alpacas, which closely approximates the 2002 Agricultural Census (USDA 2002) numbers. Gegner lists the average llama weight as 250 to 450 pounds with an expected life of 15 to 25 years. There is no explanation for the range, although male-female differences most likely enter into the range. Average weight would be 350 pounds, and allowing 15 percent young stock, the average weight would be 320 pounds.

Rabbit

Rabbits are normally grouped into four categories by size: dwarf (2–3 pounds), medium (4.5–7 pounds), meat rabbits (8–12 pounds), and giants (up to 25 pounds) (Waldo, 2009). The most numerous are the meat rabbits (Waldo, 2009). As with the category ‘Mules, Burros, and Donkeys,’ the 2002 Agriculture Census provides no help in assigning average weights. A median value for average weight would be 13 to 14 pounds, but since the meat rabbits are the most numerous, and the giants are probably relatively uncommon, it is reasonable to accept an average weight at maturity of 10 pounds, which is the mid-range of meat rabbits.

The Crusader Team (2007) provides a fairly complete insight into rabbit farming, and the discussion that follows is from that source. Rabbits mature at 16 to 20 weeks of age, depending on the sex. Does normally produce eight litters of ‘kittens’ per year and wean some 40 offspring. Weaning takes place in four to five weeks when the ‘kittens’ are a little over a pound, and slaughter takes place at roughly 13 to 15 weeks of age when the rabbit weighs seven pounds.

The 2002 Census of Agriculture (USDA, 2002) estimates roughly 400,000 rabbits in inventory and 900,000 in sales, which is some 25 percent less than in 1997. If we assume that 10 percent of the sales are for pets and breeding stock and would be reflected in inventory numbers, this leaves approximately 1,200,000 rabbits. Of this number, some are breeding stock or pets and allowed to reach maturity (ten pounds from discussion above), and the remainder slaughtered at seven pounds. Penn State (PSU, 1994) estimates rabbit sales for meat at eight to ten million pounds annually. The actual weight of meat sold would be less due to losses in slaughter. Assuming that the 25 percent decrease in rabbit population from the ‘90s also applies to meat sales and using an average weight of 7 pounds at slaughter, the sales for meat in 2002 would be approximately 950,000 rabbits with an average weight during their life cycle of 3.5 pounds. The remainder of the rabbits will be mature at an average weight of 10 pounds. The average weight for the entire population would be 4.9 pounds.

Emu

Emus are the second largest bird in a group known as ratites, which also includes ostrich and rhea. Emus typically mature in a year and weigh between 90 and 140 pounds (Gegner, 2001). From what limited sources are available, slaughter for meat and oil takes place also at twelve months. Assume a life cycle average weight of 65 pounds. The 2002 Census of Agriculture (USDA, 2002) lists approximately 50,000 emus in inventory and annual sales of another 15,000 birds.

The Emu industry is transitioning away from a strictly breeding industry to one dominated by product sales such as meat and oils (Gegner, 2001). The females produce eggs during a season that lasts from October to April. We do not know the percent sales that are breeders and those that are slaughtered, nor does there appear to be anything other than anecdotal information on national sales. Assuming the sales are primarily for slaughter, their average weight would be 65 pounds. Emu in inventory would include young hatched during 2002 and not ready for market (most likely the number shown as sales this year), and the remainder as adult birds at 130 pounds. Weighted average weight would be 100 pounds.

Geese

Geese production in 2001 was approximately 200,000 birds, up 25 percent from 2000, but still less than demand (USDA, 2002; Business Network, 2002). An adult goose’s weight varies by breed and sex. Mature males range from 15 to 22 pounds, while females weigh between 10 and 20 pounds (FAO, 1998). Assuming a mid-range value for each sex, and an equal distribution between sexes, the average goose would weigh approximately 17 pounds. This is not entirely correct, because in a breeding situation there would most likely be fewer males than females, but better data are unavailable.

Geese for slaughter range from eight pounds for goslings to the more common 12 to 14 pounds for ‘young’ goose. More mature geese (most likely spent breeders) are not slaughtered for table use except as processed food (USDA, 2006). Geese are most commonly raised inside for up to six weeks, then mainly outside for an additional 14 to 20 weeks (USDA, 2006). We assume two production cycles per year.

Average weights for slaughter would be somewhere between eight and fourteen pounds, so assume a midrange of 11 pounds, or 5.5 pounds average during the production cycle. The ratio of breeders to slaughter is not readily available, but geese are known as difficult to reproduce (FAO, 1998) so it is reasonable to assume that breeding stock makes up 20 percent of the flock. Weighting the average weight between 80 percent for slaughter and 20 percent for breeding yields an average of 8 pounds.

Ostrich

Ostriches are large flightless birds in the same group as emu and rhea, but much larger. Average weight of a male ostrich approaches 225 pounds and females are slightly smaller (Gegner, 2001). Slaughter is usually around 18 to 24 months of age when the ostrich weighs approximately 200 pounds (Shanawaney, 2004). It would seem there is little distinction between the mature weight and harvest weight in these more recent publications, but one older publication from North Dakota estimated the weight range of the adult ostrich as 150 to 330 pounds (Sell, 1993) which could indicate a little higher average weight. Discounting the North Dakota reference, the average weight of an adult ostrich would be 210 pounds.

The 2002 Census of Agriculture (USDA, 2002) lists an inventory of 20,000 with annual sales of 16,000 birds. However, Gegner (2001) notes that until recent years only limited sales were going to products such as meat and leather with the majority of sales being used to build the breeding herds. He went on to note that sales for ostrich products were on the rise in the United States. With no definitive information to the contrary, assume that half of the sales were for slaughter, and 8,000 young birds are reflected in the inventory. With the ostrich approaching 100 pounds in the first year (Sell, 1993), a weighted average weight would be 185 pounds.

Pheasant

There is little recent literature on commercial pheasant production outside of a few anecdotal pieces. What literature that is available indicates there are three primary markets for pheasants: sale of chicks to game farms or those who raise pheasants for game farms, direct sales of adult pheasants to game farms, and the sale of adults for slaughter (Leute, 2007). The 2002 Census of Agriculture (USDA, 2002) shows an inventory of 2.2 million birds and sales of $7.2 million. In the sales category there undoubtedly is some double counting of chicks sold to growers who then sold to game farms, but the literature does not provide a number. Leute (2007) does note that the sale of chicks was very profitable, but only a small part of total sales were for resale with most sales directly to game farms. For this estimate, we ignore the resale possibility.

Pheasants reach maturity in approximately 15 weeks with sales for meat at 16 to 18 weeks. Males weigh 3 to 3.5 pounds and females 2.5 to 3 pounds (Noll, 1988). Birds sold to game farms are most likely sold at 13 to 14 weeks. Theoretically pheasants could be produced in three life cycles each year, but since over half of the sales are to game farms for fall hunting (Leute, 2007), there are most likely many farms with only one large production cycle with breeding stock held year round.

Average weights assuming an equal split between sexes for sales would be 3.0 pounds, and life cycle weight of 1.5 pounds. Assuming half the inventory (1 million birds as breeding stock at 2.9 pounds to account for more hens than cocks) the weighted average weight for pheasants would be 1.6 pounds.

Quail

Unlike pheasant, there is some definitive literature as to commercial quail production. The 2002 Census of Agriculture (USDA, 2002) lists almost 5 million birds in inventory and $20 million in sales. The two well-known varieties of quail are the bobwhite and scale quail. Both reach maturity in about 12 weeks and maximize their growth at 26 weeks (Applegate, 1997). While there are undoubtedly geographical differences in quail size and growth rates due to climatic factors, there is little in the literature other than the Applegate paper. The discussion that follows is based on his findings.

Applegate sampled fall quail captures and noted an average weight of 199 grams at 24 weeks for scale quail and 166 grams for bobwhite. He believed the bobwhite capture was unrepresentative of the population as a whole due to other literature that showed over a series of studies an average weight for bobwhite at 190 grams. He could account for the difference by noting his capture contained a proportion of juvenile birds. Assuming an average weight of 199 grams for scale quail and 190 grams for bobwhite with an equal split between the two, the average weight at 24 weeks would be 195 grams or 0.4 pound.

Lesser known, but still common in the Southwestern United States, is the Gambel's quail (Williams, 2008). Like the bobwhite and scale quails, the Gambel's quail weighs about 6 ounces or slightly less than 0.4 pound.

Fah (2005) and others point out that even though the bobwhite, Gambel's, and scale quail are better known and do well in commercial facilities, commercial quail production largely favors the coturnix (Pharaoh or Japanese) quail because of its rapid growth and hardy nature. The female coturnix is heavier than the male, with the average of the two approximately five ounces or 0.3 pound.

No definitive information was found to proportion the quail Census numbers between the different varieties. Assuming 2/3 coturnix quail and 1/3 others such as bobwhite, scale, and Gambel's, the weighted average adult would be 0.33 pound or a lifecycle average weight of 0.17 pound.

Pigeon and Squab

Squab is a young pigeon not allowed to reach maturity. References agree that squabs are ready for slaughter at 25 to 30 days, and depending on the reference, from 0.9 to 1.5 pounds (Bolla, 2007), or 1.25 to 1.4 pounds (Bokhari, 2002). An average value of 1.25 pounds live weight at slaughter seems appropriate with a life cycle average weight of 0.65 pounds. Breeding pairs weigh between 24 to 30 ounces with an average of 27 ounces or 1.7 pounds.

Pigeons normally lay two eggs that hatch in 17 days, and as the squab is removed from the nest, reproduction begins again. Normally a pair of pigeons will produce 12 squabs a year in six production cycles (Bokhari, 2002). The 2002 Census of Agriculture (USDA, 2002) lists inventory of 450,000 birds and sales of 1,150,000 birds. If we apply Bokhari's ratio to sales, breeding adults could number approximately 200,000 with the remainder of inventory being squab not yet reaching market size. Weighting the squab and breeders gives an average weight of 0.8 pound.

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Appendix B: Estimates by Census Year of Selected Variables Derived from the 1982–2007 Census of Agriculture Databases

Table B-1. Number of farms and animal units

	1982	1987	1992	1997	2002	2007
Number of farms (1,000 farms)						
Non-AFOs						
Farms without livestock	576.3	566.7	564.8	596.8	684.2	762.6
Farms with some livestock but not a livestock operation	80.2	65.5	58.7	60.3	96.6	101.5
Very small livestock operations	602.5	567.1	474.1	471.3	598.7	642.9
Specialty livestock operations with few confined livestock	1.0	1.5	1.7	1.7	3.3	3.2
Pastured livestock operations with few confined livestock	509.5	489.2	493.0	522.0	525.0	504.7
All non-AFOs	1,769.6	1,690.0	1,592.4	1,652.1	1,907.7	2,014.9
AFOs						
Very small AFOs	188.3	147.6	113.5	84.3	68.7	61.1
Small AFOs	253.2	216.8	180.3	134.4	111.0	88.3
Medium AFO-CAFOs	26.2	28.8	32.9	31.7	30.8	27.4
Large AFO-CAFOs	3.7	4.7	6.3	9.4	10.8	13.2
All AFOs	471.4	397.8	332.9	259.8	221.2	189.9
All farms	2,241.0	2,087.8	1,925.3	1,911.9	2,129.0	2,204.8
Animal units for pastured livestock types (1,000 AU)						
Non-AFOs	43,458	41,900	43,477	47,111	46,899	46,957
AFOs	12,896	10,946	10,061	8,571	6,765	6,085
All farms	56,354	52,846	53,538	55,682	53,664	53,042
Animal units for confined livestock types (1,000 AU)						
Non-AFOs	1,541	1,215	905	688	711	665
AFOs						
Very small AFOs	3,947	3,102	2,383	1,732	1,383	1,220
Small AFOs	20,941	18,491	15,991	12,805	11,227	9,437
Medium AFO-CAFOs	6,983	7,550	8,495	8,423	9,317	9,074
Large AFO-CAFOs	10,251	12,484	14,730	20,523	23,844	28,640
All AFOs	42,122	41,627	41,599	43,483	45,771	48,371
AFOs						
Fattened cattle	9,412	9,530	9,099	9,473	12,533	12,928
Milk cows	14,681	13,712	12,928	12,405	12,428	12,665
Swine	6,825	6,825	7,558	8,400	9,163	10,109
Poultry	4,027	4,870	5,358	6,134	7,318	7,702
Confined pastured livestock types	7,177	6,689	6,656	7,071	4,329	4,966
All farms	43,663	42,841	42,504	44,171	46,482	49,036

Table B-2. Quantity of manure and manure nutrients *as excreted*

	1982	1987	1992	1997	2002	2007
Quantity of manure *as excreted* (1,000 tons wet weight)						
Non-AFOs	516,453	493,274	508,766	549,258	543,867	542,734
AFOs	726,354	690,725	680,235	688,664	740,206	767,985
All farms	1,242,807	1,183,999	1,189,001	1,237,922	1,284,073	1,310,719
Manure nitrogen *as excreted* (million pounds)						
Non-AFOs	6,271	5,995	6,188	6,648	6,586	6,572
AFOs	8,375	8,148	8,130	8,322	10,302	10,682
All farms	14,646	14,143	14,318	14,970	16,888	17,253
AFOs, confined livestock types*						
Very small AFOs	578	449	341	246	218	184
Small AFOs	3,253	2,881	2,479	1,981	2,293	1,854
Medium AFO-CAFOs	1,277	1,432	1,661	1,732	2,241	2,131
Large AFO-CAFOs	1,462	1,853	2,239	3,162	4,606	5,664
All AFOs	6,569	6,615	6,721	7,122	9,358	9,832
AFOs						
Fattened cattle	1,093	1,106	1,056	1,099	1,621	1,671
Milk cows	2,392	2,234	2,106	2,021	3,266	3,328
Swine	932	928	1,044	1,181	1,602	1,770
Poultry	1,275	1,534	1,709	1,977	2,340	2,463
Confined pastured livestock types	877	813	806	843	530	600
Manure phosphorus *as excreted* (million pounds)						
Non-AFOs	2,485	2,374	2,466	2,668	2,612	2,600
AFOs	2,407	2,345	2,344	2,391	2,251	2,307
All farms	4,892	4,719	4,809	5,059	4,863	4,907
AFOs, confined livestock types*						
Very small AFOs	144	113	86	60	42	36
Small AFOs	729	645	554	439	434	355
Medium AFO-CAFOs	358	403	464	480	504	473
Large AFO-CAFOs	436	556	660	918	884	1,095
All AFOs	1,667	1,717	1,765	1,897	1,864	1,960
AFOs						
Fattened cattle	335	339	324	337	198	204
Milk cows	430	401	378	363	581	593
Swine	277	276	310	350	284	313
Poultry	439	527	581	667	695	731
Confined pastured livestock types	186	173	171	180	106	120

* Includes partially or wholly confined pastured livestock types.

Table B-3. Recoverable manure and manure nutrients

	1982	1987	1992	1997	2002	2007
Quantity of recoverable manure (1,000 tons wet weight)						
Very small AFOs	31,064	25,120	20,415	15,873	13,212	12,702
Small AFOs	168,200	152,944	138,795	116,774	122,339	110,651
Medium AFO-CAFOs	56,039	62,928	74,653	77,222	98,369	100,060
Large AFO-CAFOs	72,199	93,053	116,956	175,433	222,296	290,302
All AFOs	327,502	334,046	350,820	385,302	456,216	513,716
Recoverable manure nitrogen (1,000 pounds)						
Very small AFOs	118,637	94,862	72,268	54,905	49,946	44,634
Small AFOs	712,048	649,571	573,730	476,964	581,509	496,402
Medium AFO-CAFOs	379,613	450,113	546,313	602,512	793,847	782,747
Large AFO-CAFOs	381,976	522,957	651,984	928,768	1,415,731	1,834,458
All AFOs	1,592,273	1,717,503	1,844,296	2,063,148	2,841,032	3,158,242
Fattened cattle	228,393	243,455	241,424	263,954	421,343	468,609
Milk cows	474,582	459,566	454,271	452,181	786,106	861,899
Swine	159,768	163,439	191,893	230,130	329,707	383,920
Poultry	574,337	702,327	804,397	952,492	1,194,229	1,312,330
Confined pastured livestock types	155,194	148,716	152,311	164,391	109,648	131,483
Recoverable manure phosphorus (1,000 pounds)						
Very small AFOs	76,692	62,358	49,049	35,060	24,500	22,815
Small AFOs	390,840	356,198	317,007	256,976	264,584	228,828
Medium AFO-CAFOs	221,137	260,392	313,139	334,845	367,366	358,885
Large AFO-CAFOs	238,042	323,032	403,966	595,792	615,086	806,144
All AFOs	926,710	1,001,981	1,083,162	1,222,673	1,271,536	1,416,672
Fattened cattle	157,603	167,903	166,485	182,025	115,865	128,930
Milk cows	202,441	196,036	193,777	192,886	332,361	364,406
Swine	170,821	174,887	205,063	245,670	211,031	244,662
Poultry	296,959	368,110	420,802	496,870	546,344	599,985
Confined pastured livestock types	98,887	95,044	97,035	105,223	65,935	78,689

* Includes partially or wholly confined pastured livestock types.

Table B-4. Non-Recoverable manure, assimilative capacity, AFOs with excess manure, and excess manure nutrients

	1982	1987	1992	1997	2002	2007
Non-recoverable manure nitrogen (million pounds)						
Non-AFOs	6,271	5,995	6,188	6,648	6,586	6,572
AFOs	6,783	6,430	6,286	6,258	7,461	7,523
All farms	13,054	12,425	12,474	12,906	14,047	14,095
Non-recoverable manure phosphorus (million pounds)						
Non-AFOs	2,485	2,374	2,466	2,668	2,612	2,600
AFOs	1,481	1,343	1,260	1,168	980	891
All farms	3,966	3,717	3,726	3,836	3,591	3,490
Assimilative capacity (million pounds)						
Assimilative capacity for nitrogen assuming a 1.4 efficiency factor						
Farms without livestock	10,292	10,413	15,101	16,823	18,262	22,128
Farms with few confined livestock types	12,827	12,137	14,104	15,780	14,997	14,990
AFOs	13,799	11,957	12,682	10,533	10,794	10,411
All farms	36,918	34,507	41,886	43,137	44,053	47,529
Assimilative capacity for nitrogen assuming a 1.2 efficiency factor						
Farms without livestock	8,877	8,981	13,015	14,486	15,713	19,074
Farms with few confined livestock types	11,579	11,002	12,709	14,164	13,485	13,229
AFOs	11,999	10,401	11,005	9,125	9,331	8,965
All farms	32,455	30,383	36,729	37,774	38,529	41,268
Assimilative capacity for phosphorus assuming a 1.05 efficiency factor						
Farms without livestock	1,199	1,219	1,839	1,959	2,079	2,791
Farms with few confined livestock types	2,576	2,529	2,841	3,045	2,921	2,468
AFOs	1,918	1,641	1,732	1,379	1,352	1,302
All farms	5,693	5,390	6,412	6,383	6,352	6,561
Number of AFOs with farm-level excess manure						
Very small AFOs	40,159	37,525	28,983	23,774	16,203	19,800
Small AFOs	30,370	32,044	27,043	22,329	18,207	17,470
Medium AFO-CAFOs	9,960	12,088	13,649	15,121	16,886	15,116
Large AFO-CAFOs	2,132	2,968	3,828	5,947	6,981	8,543
All AFOs	82,621	84,625	73,503	67,171	58,277	60,929
Farm-level excess manure nitrogen (million pounds)						
Very small AFOs	32	29	21	17	12	14
Small AFOs	127	136	117	104	109	101
Medium AFO-CAFOs	182	238	288	338	440	437
Large AFO-CAFOs	279	403	485	689	1,010	1,302
All AFOs	620	806	911	1,149	1,572	1,854
Farm-level excess manure phosphorus (million pounds)						
Very small AFOs	18	17	13	10	6	7
Small AFOs	69	75	66	59	53	50
Medium AFO-CAFOs	97	127	152	177	206	205
Large AFO-CAFOs	172	246	297	436	433	567
All AFOs	355	465	528	681	699	829