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Conservation Effects Assessment Project (CEAP)-Cropland

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Effects of Conservation Practices on Phosphorus Loss from Farm Fields

A National Assessment Based on the 2003-06 CEAP Survey and APEX Modeling Databases

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The Conservation Effects Assessment Project (CEAP)—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and National Institute of Food and Agriculture (NIFA) [formerly known as Cooperative State Research, Education, and Extension Service (CSREES)] in 2002 as a means to analyze societal and environmental benefits gained from the 2002 Farm Bill's substantial increase in conservation program funding. The CEAP-1 survey was conducted on agricultural lands across the United States in 2003-06. The goals of CEAP-1 were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to assess the impacts and efficacy of various conservation practices on maintaining and improving soil and water quality at regional, national, and watershed scales.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.
- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazing Lands*, including rangeland, pastureland, and grazed forestland; and *Wildlife*.
- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are most effective and where they are needed within a watershed to achieve environmental goals.

CEAP-1 benchmark results, currently published for 12 watersheds, provide a scientific basis for interpreting conservation practice implementation impacts and identifying remaining conservation practice needs. These reports continue to inform decision-makers, policymakers, and the public on the environmental and societal benefits of conservation practice use. CEAP-2, the second national survey of agricultural lands across the United States, is currently underway, with sampling occurring in 2015 and 2016.

Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared for NRCS by Robert Kellogg on October 30, 2016.

Scope of This Report

The first CEAP national assessment was conducted using farmer survey data collected in 2003-06, where results were reported for Water Resource Regions that represented the major drainage basins in the United States. These reports were published by NRCS and are available on the Web at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/.

A second CEAP national assessment is underway and will produce an updated national assessment using farmer survey data collected in 2015-16. For this updated CEAP national assessment, newly defined CEAP production regions will serve as the basis for the assessment. The 12 CEAP production regions were derived specifically for use with the 2015-16 survey data to draw sharper distinctions among regions with respect to the prevalent land use, cropping systems, climate, soils characteristics, and, consequently, conservation practice use and effectiveness. The 12 regions are:

Region number	Region name
1	Northwest Coastal
2	California Coastal
3	Northwest Non-Coastal
4	Southwest Non-Coastal
5	Northern Plains
6	Southern Plains
7	North Central and Midwest
8	South Central
9	Lower Mississippi and Texas Gulf Coast
10	Northeast
11	East Central
12	Southeast Coastal Plain

The purpose of this report is to present the previously published 2003-06 results for the new CEAP production regions. The APEX modeling data for each of the 2003-06 CEAP sample points remain unchanged, as do the rules of analysis as presented in the 12 CEAP publications summarizing the 2003-06 findings by major drainage basins. ***The only change is that the 2003-06 CEAP sample points are aggregated into different groupings for this report*** and, consequently, the sample acreage weight for each sample point has been adjusted to reproduce the 2003 NRI acreage by cropping system for the 12 new CEAP production regions. (The 2003 NRI, an interim release of the national-level NRI results prior to the full 2007 NRI release, was the domain for the sample draw (i.e., sample frame) for the 2003-06 CEAP sample, and thus provides the foundation acreage estimates for the 2003-06 CEAP sample.)

Only the 2003-06 CEAP sample points used in the previously published CEAP reports could be incorporated into the revised assessment. The additional sample points for the “West” region—368 sample points—could not be used because the full set of APEX modeling results were not available. In addition, after assigning the remaining 18,323 sample points to the 12 new CEAP production regions, four of the new regions did not have enough 2003-06 sample points to support a regional representation. The four regions for which data summaries ***could not be presented*** are:

Region number	Region name
1	Northwest Coastal
2	California Coastal
4	Southwest Non-Coastal
8	South Central

The regional summary results reported herein represent what NRCS ***would have published*** based on the 2003-06 survey data and the associated APEX modeling data had 2003-06 results been summarized according to the new CEAP production regions. In the course of assessing the 2015-16 results, NRCS staff and collaborators will compare findings to the 2003-06 survey data, but will re-estimate APEX model results for the 2003-06 data using the most recent version of the APEX model and will incorporate additional upgrades in methods and refinements in ancillary datasets such as weather and soils to be as comparable as possible to methods and data used for assessing the 2015-16 results. Thus, those forthcoming results for 2003-06 will differ from findings reported herein.

Table of Contents

List of Figures

List of Tables

Summary of Findings

The purpose of this report is to assess how effective conservation practices are in reducing phosphorus loss from cultivated cropland acres. The 2003-06 CEAP farmer survey data and APEX simulation modeling results for cultivated cropland acres were used to make the assessment. Results for 2003-06 are available for 17,918 CEAP sample points, a subset of the National Resources Inventory (NRI) sample points. Regional results are summarized for eight newly defined CEAP production regions.

To what extent are conservation practices used to control phosphorus loss?

Effective control of phosphorus loss from farm fields typically consists of a combination of practices that:

- avoid or limit the potential for phosphorus losses by using appropriate phosphorus management practices on *all* crops in the rotation;
- control erosion and the movement of soil within the field; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

Erosion control practices include residue and tillage management (annual practices) and structural practices which, once implemented, are usually kept in place for several years. For all eight regions combined, 94 percent of cultivated cropland acres had some kind of practice use to control water erosion in 2003-06:

- 34 percent had one or more structural practice and some form of reduced tillage,
- 55 percent had some form of reduced tillage but no structural practices,
- 4 percent had one or more structural practice but no reduced tillage, and
- only 6 percent had no reduced tillage and no structural practices.

Phosphorus management practices address the rate, timing, and method of phosphorus application to promote crop growth. For all eight regions combined, the majority of acres met at least one of these three management practices in 2003-06:

- 64 percent of cropped acres met criteria for timing of phosphorus applications for all crops in the rotation, including both manure and commercial fertilizer applications, and another 7 percent of cropped acres did not have any phosphorus application;
- 61 percent of cropped acres met the criteria for the method of phosphorus application; and
- 47 percent of cropped acres met the criteria for the rate of phosphorus application.

However, only 30 percent of cropped acres met criteria for timing and method and rate. After accounting for the 7 percent of acres that did not receive phosphorus applications, about 63 percent of cropped acres did not fully meet the criteria for phosphorus management.

How much phosphorus loss is there on cultivated cropland acres?

About 16 percent of the phosphorus applied as commercial phosphorus and as manure, as represented in the APEX model simulations based on the 2003-06 survey data, was lost from the farm fields through various loss pathways. The mean of the average annual estimates of total phosphorus loss was 2.79 pounds per acre per year. The amount varied considerably, however, among cultivated cropland acres:

- 29 percent of cropped acres had annual average total phosphorus loss (all loss pathways) less than 1 pound per acre per year;
- 28 percent had total phosphorus loss between 1 and 2 pounds per acre per year;
- 23 percent had total phosphorus loss between 2 and 4 pounds per acre per year;
- 11 percent had total phosphorus loss between 4 and 7 pounds per acre per year; and
- 8 percent had total phosphorus loss greater than 7 pounds per acre per year.

Total phosphorus losses were highest for acres receiving manure. About 41 percent of cropped acres receiving manure had total phosphorus loss amounts greater than 4 pounds per acre per year, compared to 16 percent of cropped acres without manure. The average annual estimate of total phosphorus loss for acres receiving manure was 5.45 pounds per acre per year, over twice the average annual amount lost for acres not receiving manure.

The two regions with the largest average amount of total phosphorus loss (all loss pathways) are the same two regions that had the largest amount of phosphorus applied:

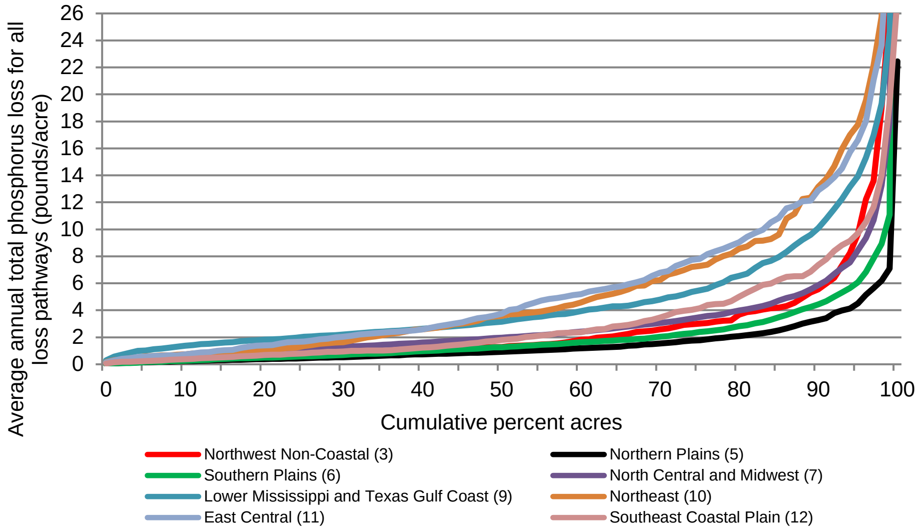
- the East Central (11) region, where the mean of the average annual total phosphorus loss is 5.91 pounds per acre per year, and
- the Northeast (10) region, where the mean of the average annual total phosphorus loss is 5.86 pounds per acre per year.

The relatively high yields in the North Central and Midwest (7), which has the most cultivated cropland acres of all eight regions, resulted in a relatively small proportion of the amount of phosphorus applied—14 percent—lost from farm fields. The average annual loss of total phosphorus in this region was 2.95 pounds per acre per year.

Most cultivated cropland acres in the three westernmost regions—the Northwest Non-Coastal (3) region, the Northern Plains (5) region, and the Southern Plains (6) region—have, relative to the other five regions, the smallest amounts of total phosphorus lost (all loss pathways) from farm fields.

The regional cumulative distributions of phosphorus loss estimates shown in the figure below illustrate the extent to which losses vary among the eight production regions, after accounting for the benefits of conservation practices in use in 2003-06.

Comparison of cumulative acre distributions of average annual amount of total phosphorus loss (all loss pathways) for CEAP sample points in eight production regions.



The principal phosphorus loss pathways differed by region, reflecting differences in precipitation and surface water runoff. The principal loss pathway in the three westernmost regions, where wind erosion rates are high, was phosphorus lost with windborne sediment. Soluble phosphorus lost to surface water, which includes phosphorus dissolved in surface water runoff and water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, was the principal loss pathway in the Southeast Coastal Plain (12) region, and was an important loss pathway in all but the three westernmost regions. In three regions, over half of the total phosphorus lost from farm fields was phosphorus lost with waterborne sediment—the Northeast (10) region, the Lower Mississippi and Texas Gulf Coast (9) region, and the East Central (11) region. Phosphorus lost with waterborne sediment was an important secondary loss pathway in the North Central and Midwest (7) region, the Southeast Coastal Plain (12) region, and the Northwest Non-Coastal (3) region.

Amounts of total phosphorus lost to surface water at the edge of the field greater than 4 pounds per acre per year are generally considered to be unacceptable and require additional conservation treatment. (Total phosphorus lost to surface water includes the amount of soluble phosphorus dissolved in surface water runoff and water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps as well as the amount of phosphorus attached to sediment and lost from fields with waterborne sediment. It excludes phosphorus lost with windborne sediment.)

Overall, about 13 percent of all cultivated cropland acres in the eight regions—totaling 38 million acres—have average annual estimates of total phosphorus lost to surface water greater than 4 pounds per acre per year. About two-thirds of these acres are concentrated in two regions:

- the North Central and Midwest (7) region, where 16 percent of cropped acres (18.4 million acres) had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year, and
- the Lower Mississippi and Texas Gulf Coast (9) region, where 35 percent of cropped acres (7.5 million acres) had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year.

Three other regions had a high percentage of cropped acres with excessive phosphorus loss rates:

- the Northeast (10) region, with 43 percent of cropped acres,
- the East Central (11) region, with 49 percent of cropped acres, and
- the Southeast Coastal Plain (12), with 25 percent of cropped acres.

Together, these three regions account for 27 percent of the cropped acres with excessive levels of total phosphorus lost to surface water. The remaining three regions each accounted for less than 3 percent.

To what extent do conservation practices reduce phosphorus loss?

According to the model simulations, the use of conservation practices has reduced total phosphorus loss (all loss pathways) by an average annual amount of 2.35 pounds per acre per year, representing a 46-percent reduction. Reductions in total phosphorus loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. About 15 percent of the cropped acres had reductions in losses of more than 4 pounds per acre per year; these are the acres that were treated the most. In contrast, about 28 percent of the cropped acres had reductions in losses between 0 and 1 pound per acre per year, representing the least treated acres. Another 7 percent of cropped acres had negative reductions, indicating that phosphorus losses increased slightly for those acres resulting from tradeoffs in the benefits of conservation practice use for wind and water erosion.

The average annual reduction for all cropped acres in all eight regions combined was, for the three principal loss pathways:

- 0.85 pounds per acre per year for phosphorus lost with windborne sediment, a 51-percent reduction relative to the results for the no-practice scenario;
- 0.50 pounds per acre per year for soluble phosphorus lost to surface water, a 36-percent reduction; and
- 0.99 pounds per acre per year for phosphorus lost with waterborne sediment, a 49-percent reduction.

Conservation practices were most effective in reducing phosphorus losses in different regions depending on the loss pathway. For phosphorus lost with windborne sediment, conservation practices were most effective in the three westernmost regions, where wind erosion is the principal loss pathway for phosphorus loss. The largest reductions were in the Northern Plains (5) region, where the average annual reduction in phosphorus lost with windborne sediment was 2.05 pounds per acre per year, representing a 63-percent reduction. Average annual reductions in phosphorus lost with windborne sediment were greater than 1 pound per acre per year for 70 percent of the cropped acres, and greater than 3 pounds per acre per year for 21 percent of the cropped acres, far more than any other region.

Conservation practices were the most effective in controlling soluble phosphorus lost to surface water in the Lower Mississippi and Texas Gulf Coast (9) region, where the average annual reduction in soluble phosphorus lost to surface water was 1.94 pounds per acre per year, representing a 48-percent reduction. In this region, average annual reductions in soluble phosphorus lost to surface water were greater than 3 pounds per acre per year for 24 percent of the cropped acres.

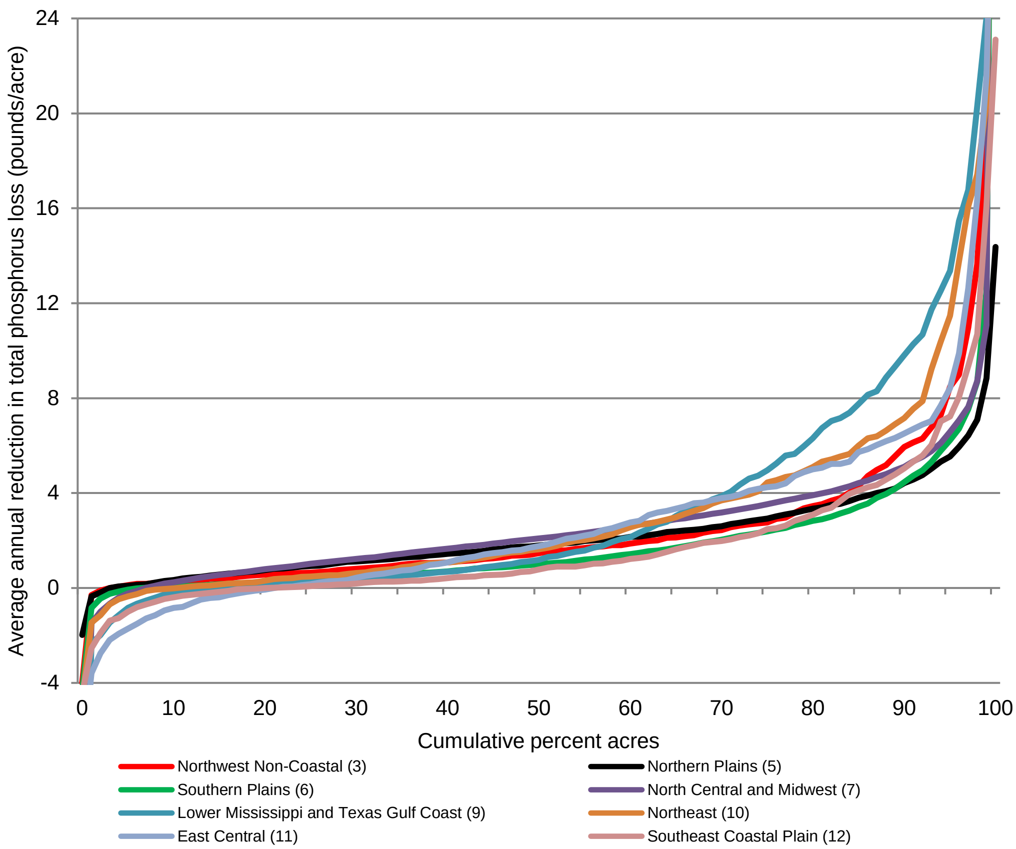
Conservation practices were effective in reducing phosphorus lost with waterborne sediment in all but the Northern Plains (5) region, which had relatively small amounts of phosphorus loss through this pathway. Two regions stand out as being the most effective in controlling phosphorus lost with waterborne sediment:

- the Northeast (10) region, where the average annual reduction due to use of conservation practices was 2.31 pounds per acre per year and 17 percent of cropped acres had average annual reductions greater than 4 pounds per acre per year, and
- the East Central (11) region, where the average annual reduction due to use of conservation practices was 2.25 pounds per acre per year and 12 percent of cropped acres had average annual reductions greater than 4 pounds per acre per year.

The differences and similarities in the effectiveness of conservation practices on total phosphorus loss among regions are best illustrated by comparing the cumulative acre distributions of average annual reductions, shown in the figure below. For all loss pathways combined, the Lower Mississippi and Texas Gulf Coast (9) region had the largest reductions in total phosphorus loss; the average annual reduction in total phosphorus loss was 3.36 pounds per acre per year, representing a 41-percent reduction due to the use of conservation practices, and 20 percent of the cropped acres had reductions greater than 6 pounds per acre per year. The Northeast (10) region had the second largest reductions in total phosphorus loss; the average annual reduction in total phosphorus loss was 3.11 pounds per acre per year, representing a 35-percent reduction due to the use of conservation practices.

The Southeastern Coastal Plains (12) region had the smallest reductions in total phosphorus loss; the average annual reduction in total phosphorus loss was 1.73 pounds per acre per year, representing a 36-percent reduction due to the use of conservation practices. The Southern Plains (6) region had the second smallest reductions in total phosphorus loss; the average annual reduction in total phosphorus loss was 1.83 pounds per acre per year, representing a 48-percent reduction due to the use of conservation practices.

Comparison of cumulative acre distributions of average annual REDUCTIONS in total phosphorus loss (all loss pathways) due to conservation practices for CEAP sample points in eight production regions.



Introduction

Conservation practices have been used in the United States to control water erosion since the 1930s and 1940s. Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and surface water runoff. Land shaping structural practices (such as terraces, contour farming, and stripcropping) and sediment control structures were widely adopted during these early years. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Today, conservation tillage is widely used either alone or in combination with structural practices to control water erosion and sediment loss from farm fields.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

Today, nutrient management—especially phosphorus management—is a critical part of halting and sometimes reversing the long-term trend of excessive nutrients that are transported from farm fields into many of our Nation's bays, estuaries, lakes, rivers, and streams.

NRCS has previously published a series of regional reports that assess the effects of conservation practices on reducing phosphorus from farm fields.[1] That assessment used a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory (NRI) provided the statistical framework and soils data. Information on farming activities and conservation practices during the period 2003–06 was obtained for a subset of NRI sample points, and a field-level physical process simulation model called APEX was used to estimate losses of soil, nutrients, and pesticides at the edge of the field. The assessment was done using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level. Survey data and modeling results were reported for Water Resource Regions that represented the major drainage basins in the United States.

The purpose of this report is to re-assess and summarize, at both the national and regional levels, how effective conservation practices are in reducing phosphorus loss from farm fields. For this assessment, the 2003-06 survey data and APEX modeling results were aggregated according to the new CEAP production regions, shown in figure 2.

Sufficient sample size was available to conduct this reassessment for 8 of the 12 production regions, representing a total of 290 million cultivated cropland acres (table 1 and fig. 3). This coverage represents 95 percent of the 305 million total acres of cultivated cropland in the US in 2003, according to the 2003 NRI. As shown in figure 3, the bulk of the cultivated cropland (79 percent) is found in three regions—

- the North Central and Midwest (7) region, with 41 percent of the cultivated cropland in the eight regions,
- the Southern Plains (6) region, with 22 percent, and
- the Northern Plains (5) region, with 16 percent.

Results are reported for each of the eight regions and for all eight regions combined. Because the bulk of the cultivated cropland is found in the three regions listed above, the results reported for the eight regions combined largely reflects results for the combination of these three regions.

Table 1. Cultivated cropland acreage estimates for the 2003-06 CEAP sample for eight CEAP production regions, derived from the 2003 NRI.

CEAP production region	Number of 2003-06 CEAP sample points	Cultivated cropland acres based on the 2003 NRI	Percent of total acres
Northwest Non-Coastal (3)	817	11,477,012	4
Northern Plains (5)	1,518	47,688,900	16
Southern Plains (6)	2,606	63,563,684	22
North Central and Midwest (7)	8,065	117,423,200	41
Lower Mississippi and Texas Gulf Coast (9)	1,820	21,162,500	7
Northeast (10)	888	6,547,500	2
East Central (11)	915	8,723,200	3
Southeast Coastal Plain (12)	1,289	13,502,000	5
All eight regions	17,918	290,087,996	100

Note: See Appendix A for documentation of how the original CEAP sample weights for the 2003-06 CEAP sample were adjusted to represent cultivated cropland acreage for the new CEAP production regions.

Figure 1. The water cycle is the process by which water circulates between the atmosphere, oceans, and rivers.

[1] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/

Figure 2. CEAP production regions (boundaries defined by 8-digit hydrologic unit codes).

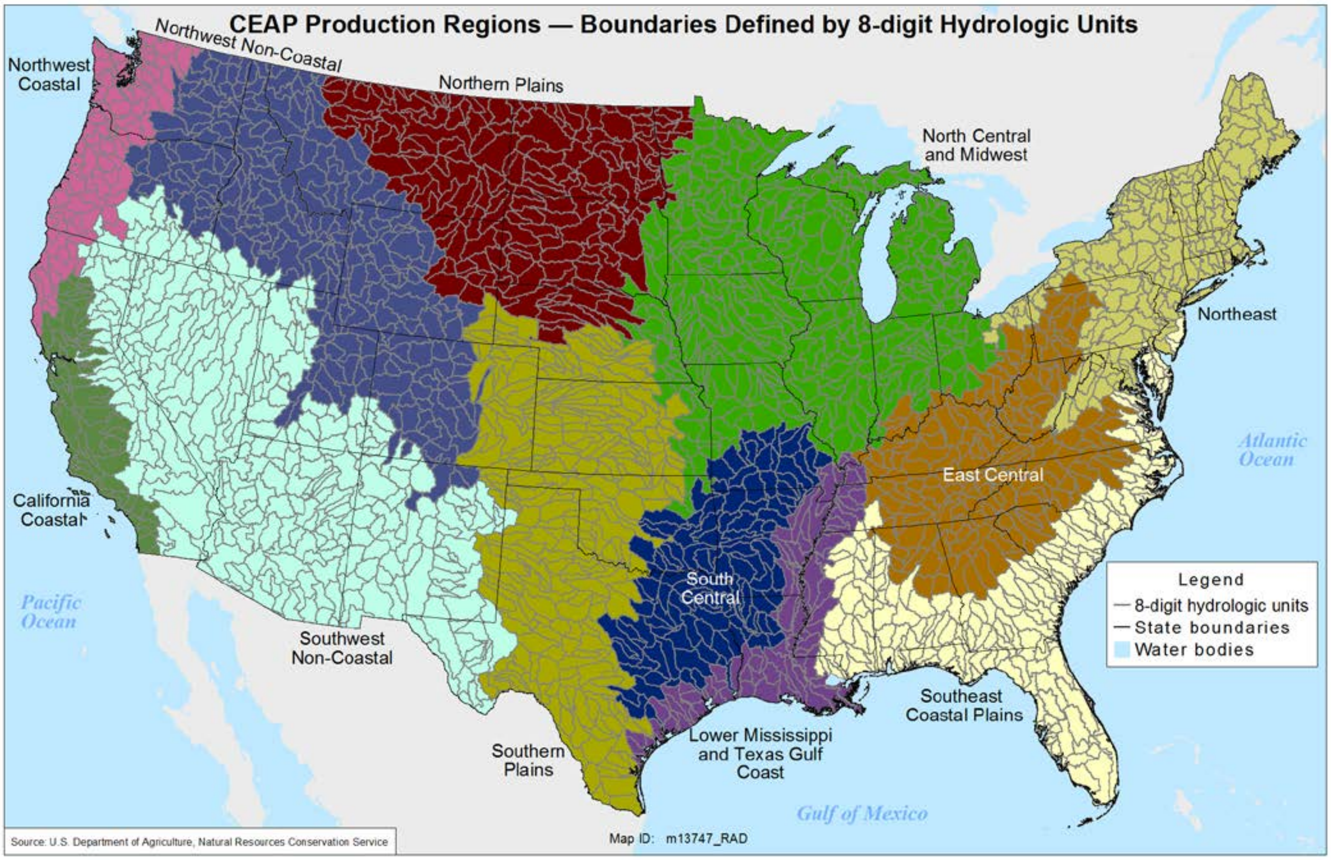
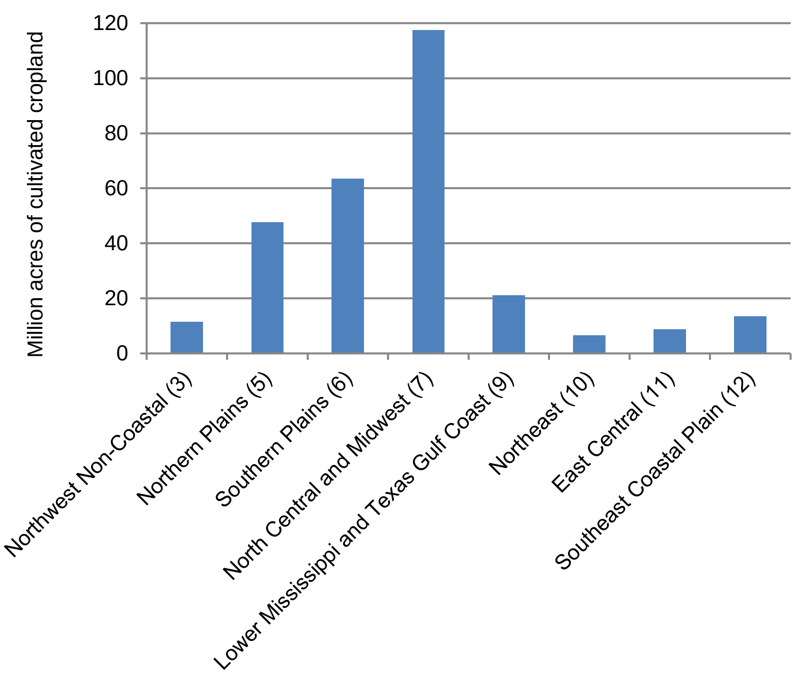


Figure 3. Cultivated cropland acreage derived from the 2003 NRI for the eight CEAP production regions covered in this report.



Use of Conservation Practices to Control Phosphorus Loss from Farm Fields

Effective control of phosphorus loss from farm fields typically consists of a combination of practices that:

- avoid or limit the potential for phosphorus losses by using appropriate phosphorus management practices on *all* crops in the rotation;
- control erosion and the movement of soil within the field; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

Phosphorus management practices address the rate, timing, and method of phosphorus application to promote crop growth. Erosion control practices include residue and tillage management (annual practices) and structural practices which, once implemented, are usually kept in place for several years.

Structural Practices

Data on erosion control structural practices for the farm field associated with each CEAP sample point were obtained from four sources.

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.

2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans.

3. **The USDA-Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).

4. **The 2003 NRI** provided additional information for practices that could be reliably identified from aerial photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Structural practices evaluated in the APEX model include:

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

Structural practices for water erosion control. Structural practices for water erosion control are in widespread use on cultivated cropland acres. Overall, about 38 percent of cultivated cropland acres had one or more structural water erosion control practice in 2003-06 (table 2). Overland flow practices were the most prevalent; 26 percent of cultivated cropland acres had some kind of overland flow practice installed. Concentrated flow control practices were used on 21 percent of cultivated cropland acres. Edge-of-field buffering and filtering practices were in much lower use in 2003-06, reported to be in use on only 5 percent of cultivated cropland acres for all eight regions combined.

Cultivated cropland acres designated as HEL (Highly Erodible Land)[2] had slightly lower proportions of acres treated with structural practices for water erosion control as non-HEL in 2003-06 for all 8 regions combined (table 2). Acres designated as HEL represent about 29 percent of all cultivated cropland acres in the eight regions. For HEL in all eight regions, about 34 percent of acres had one or more water erosion control practice. Overland flow practices were used on 21 percent of HEL cropped acres; concentrated flow control practices were used on 18 percent; and edge-of-field buffering and filtering practices were in use on only 6 percent.

[2] HEL acres have a higher vulnerability to erosion due to the forces of wind or water. Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. EI is derived from the Sheet and Rill Erosion Equation USLE and the Wind Erosion Equation WEQ. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Table 2. Structural water erosion control practices in use in 2003-06, by region and for all regions combined—percent of Highly-Erodible land (HEL), percent of non-HEL, and percent of all cultivated cropland acres.

	Overland flow control practices*			Concentrated flow control practices**			Edge-of-field buffering and filtering practices***			One or more structural erosion control practices		
	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres
Production region												
Northwest Non-Coastal (3)	15	29	22	8	20	14	7	5	6	25	43	34
Northern Plains (5)	11	17	13	10	14	12	2	0	2	19	28	22
Southern Plains (6)	42	39	41	18	16	17	2	1	2	46	42	44
North Central and Midwest (7)	16	48	23	23	50	29	10	8	9	37	70	45
Lower Mississippi and Texas Gulf Coast (9)	9	31	12	9	24	11	3	7	3	17	45	20
Northeast (10)	22	50	36	7	20	14	6	5	5	29	56	43
East Central (11)	26	55	41	22	41	32	9	6	8	43	72	58
Southeast Coastal Plain (12)	22	41	24	11	31	13	6	5	6	29	49	31
All eight regions	21	38	26	18	29	21	6	4	5	34	50	38

* Includes terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, and in-field vegetative barriers.
** Includes Grassed waterways, grade stabilization structures, diversions, and other structures for water control.
*** Includes Riparian forest buffers, riparian herbaceous buffers, and filter strips
Source: Conservation practice use as reported in the 2003-06 NRI-CEAP Cropland Survey and other sources and subsequently used in the APEX simulation modeling.

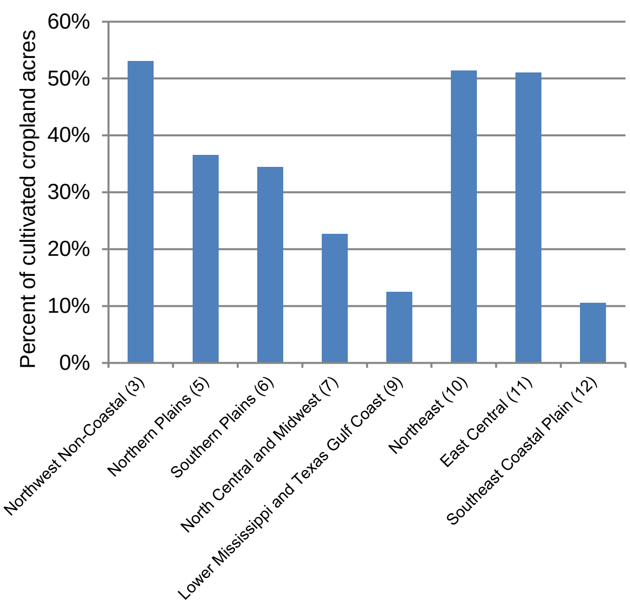
However, HEL is much more concentrated in some regions than others, as shown in figure 4. About half of the cultivated cropland acres in three regions are HEL: the Northwest Non-Coastal (3) region, the Northeast (10) region, and the East Central (11) region.

Not all cultivated cropland acres require structural conservation practices for water erosion control. Acres that are essentially flat with permeable soil types are more prone to infiltration of water and have a low potential for erosion.

About 63 percent of cultivated cropland acres in the eight regions have field slopes of 2 percent or less, some of which may not need to be treated with structural practices. The prevalence of field slopes of 2 percent or less varies from region to region, as shown in figure 5. Regions with the most acres with field slopes of 2 percent or less are:

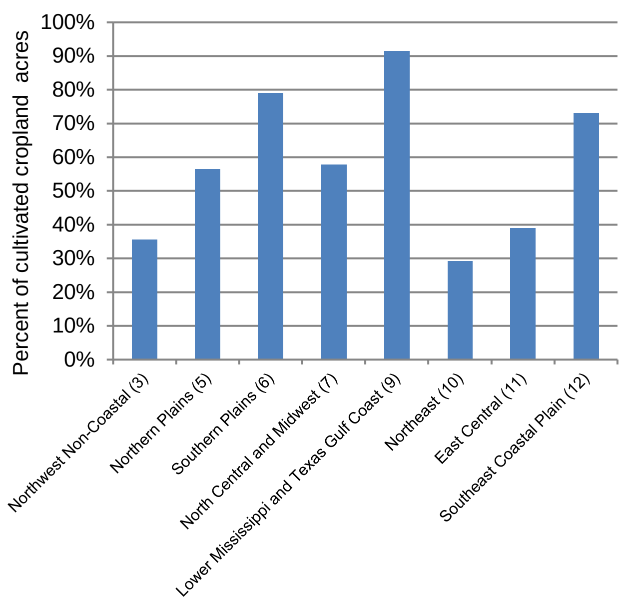
- the Lower Mississippi and Texas Gulf Coast (9) region, with 91 percent;
- the Southern Plains (6) region, with 79 percent; and
- the Southeast Coastal Plain (12) region, with 73 percent.

Figure 4. Percent of cultivated cropland acres classified as HEL (Highly-Erodible Land), by region.



Note: For all eight regions combined, HEL represents 29 percent of cultivated cropland acres.

Figure 5. Percent of cultivated cropland acres with field slopes of 2 percent or less, by region.



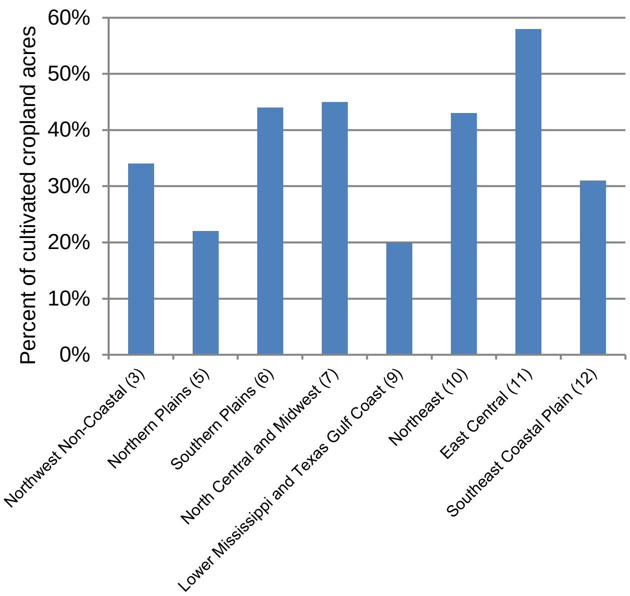
Note: For all eight regions combined, 63 percent of cultivated cropland acres have field slopes of 2 percent or less.

Structural practices for water erosion control were most prevalent in the East Central (11) region (table 2 and fig. 6), where 58 percent of cultivated cropland acres had one or more water erosion control practice in 2003-06. Structural practices were least prevalent in the Lower Mississippi and Texas Gulf Coast (9) region and the Northern Plains (5) region, where only 20-22 percent of cultivated cropland acres had one or more water erosion control practice in 2003-06.

Table 2 shows that, for most regions, non-HEL acres are treated with structural practices for water erosion control at higher proportions than HEL acres. For example, in the North Central and Midwest (7) region, overland flow practices were used on 48 percent of non-HEL acres but only 16 percent of HEL acres. Similarly, concentrated flow control practices were used on 50 percent of non-HEL cropped acres in this region but only 23 percent of HEL acres. HEL acres accounted for 23 percent of the cultivated cropland acres in this region.

The Southern Plains (6) region was the only region where HEL acres were treated with structural practices for water erosion control at a higher proportion than non-HEL acres for one or more structural conservation practice—46 percent of HEL acres versus 42 percent for non-HEL acres (table 2). HEL acres accounted for 34 percent of the cultivated cropland acres in this region.

Figure 6. Percent of cultivated cropland acres with one or more structural practice for water erosion control, by region.



To better represent the overall level of water erosion control that the various combinations of structural practice use represents, four levels of conservation treatment (high, moderately high, moderate, and low) were defined for each sample point, as follows:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

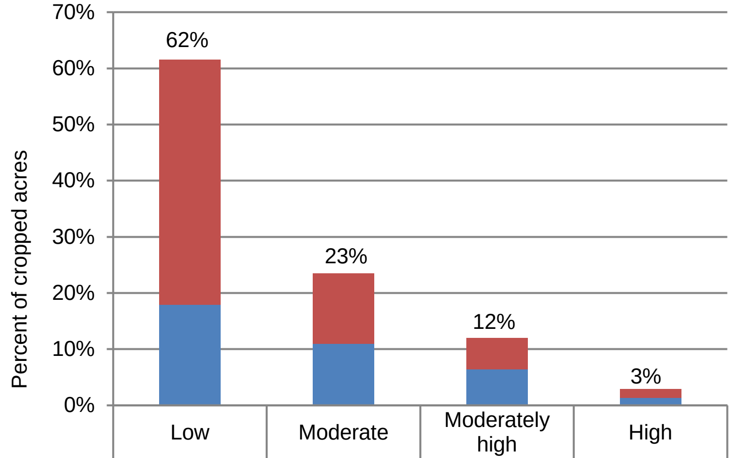
For the eight regions combined, only about 3 percent of cropped acres have a "high" level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice) (fig. 7 and table 3). Another 12 percent of cultivated cropland acres have a "moderately high" level of treatment, which could be achieved for some acres with edge-of-field buffering and filtering practices alone. The 62 percent of acres with a "low" level of treatment did not have any structural practice use, but this group includes 44 percent of cropped acres in the eight regions where field slopes were 2 percent or less.

Two regions stand out as having more structural practice use than the other regions—the East Central (11) region and the North Central and Midwest (7) region (table 3 and fig. 8). The East Central (11) region had 23 percent of cropped acres in the "high" or "moderately high" level of structural practice treatment, including 5 percent with a "high" level of treatment.

This region is one of the three regions with about half of cropped acres designated as HEL (fig. 4), and had 61 percent of cropped acres with field slopes more than 2 percent (fig. 5).The North Central and Midwest (7) region had 21 percent of cropped acres in the "high" or "moderately high" level of structural practice treatment, including 5 percent with a "high" level of treatment.

Two regions have the lowest level of structural practice use—the Northern Plains (5) region and the Lower Mississippi and Texas Gulf Coast (9) region. The Lower Mississippi and Texas Gulf Coast (9) region also has 91 percent of cropped acres with field slopes of 2 percent or less and only 12 percent of acres designated as HEL.

Figure 7. Percent of cropped acres at four conservation treatment levels for structural practices for water erosion control, all eight regions combined.



	Low	Moderate	Moderately high	High
Slope 2 percent or less	44%	13%	6%	2%
Slope greater than 2 percent	18%	11%	6%	1%

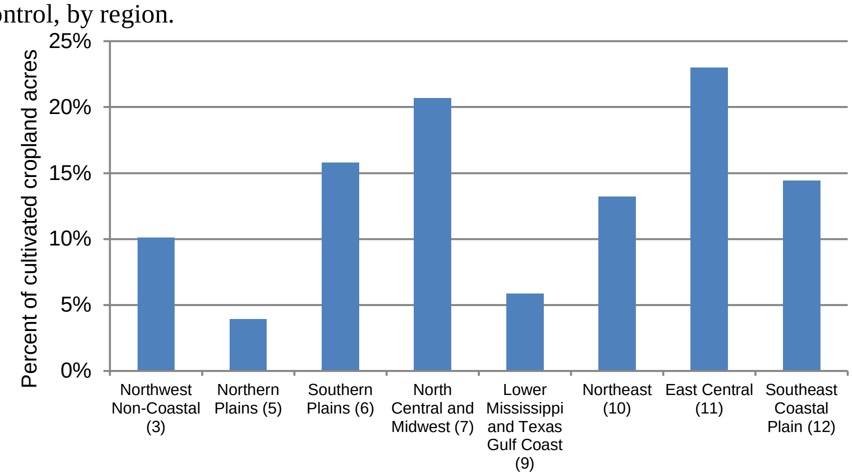
Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

Table 3. Percent of cropped acres at four conservation treatment levels for structural practices for water erosion control, by region.

	Low	Moderate	Moderately high	High
Production region				
Northwest Non-Coastal (3)	66	24	7	3
Northern Plains (5)	78	18	3	1
Southern Plains (6)	56	29	15	1
North Central and Midwest (7)	55	24	16	5
Lower Mississippi and Texas Gulf Coast (9)	80	15	4	2
Northeast (10)	57	30	10	4
East Central (11)	42	35	18	5
Southeast Coastal Plain (12)	69	17	12	3
All eight regions	62	23	12	3

Figure 8. Percent of cultivated cropland acres with “high” or “moderately high” levels of conservation treatment with structural practices for water erosion control, by region.



Structural practices for wind erosion control. In some regions, phosphorus loss from farm fields with windborne sediment is an important loss pathway. Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS practice standards for wind erosion control practices include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak/shelterbelt establishment.

Structural practices for wind erosion control are not in widespread use. Cultivated cropland acreage with wind erosion control practices averages 6 percent for all eight regions combined—8 percent of HEL acres and 6 percent of non-HEL acres (table 4). The Northern Plains (5) region has the highest percentage of use—22 percent of HEL acres and 17 percent of non-HEL acres. The Lower Mississippi and Texas Gulf Coast (9) region has the lowest, with only 1 percent of cultivated cropland acres treated for wind erosion with structural practices.

Table 4. Wind erosion control practices* in use in 2003-06, by region and for all regions combined—percent of Highly-Erodible land (HEL), percent of non-HEL, and percent of all cultivated cropland acres.

	% of HEL	% of Non-HEL	% of all acres
Production region			
Northwest Non-Coastal (3)	2	2	2
Northern Plains (5)	22	17	19
Southern Plains (6)	5	6	6
North Central and Midwest (7)	4	3	3
Lower Mississippi and Texas Gulf Coast (9)	<1	1	1
Northeast (10)	8	4	6
East Central (11)	3	2	3
Southeast Coastal Plain (12)	7	2	3
All eight regions	8	6	6

* Includes windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, and hedgerow planting.
Source: Conservation practice use as reported in the 2003-06 NRI-CEAP Cropland Survey and other sources and subsequently used in the APEX simulation modeling.

Figure 9. In some regions, phosphorus loss from farm fields with windborne sediment is an important loss pathway. Wind erosion control practices such as this tree windbreak are designed to reduce the force of the wind on the field.

Figure 10. Soybeans growing in a field of corn residues from the previous year. The soybeans were planted with a no-till method where no tillage was done prior to planting, to save soil, nutrients, energy, time, and money.

Conservation Tillage and Residue Management Practices

Model simulation of the use of conservation tillage and residue management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined using APEX processes of the daily tillage activities as reported in the survey.

To evaluate the level of conservation tillage and residue management, the Soil Tillage Intensity Rating (STIR)[3] was used for tillage intensity, and gains or losses in soil organic carbon (based on model simulation results) were used as an indicator of residue management.

Tillage intensity. STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[4] The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops).

STIR criteria used to define four levels of tillage intensity were as follows:

- No-till—average annual STIR over all crop years in the rotation is less than 30;
- Mulch till—average annual STIR over all crop years in the rotation is between 30 and 100;
- Some reduced tillage—STIR values indicate there was some reduced tillage on some crops in the rotation but the average annual tillage intensity is greater than criteria for mulch till; and
- Continuous conventional tillage—the STIR value for every crop year in the rotation is more than 100.

Most cropland acres met criteria for either mulch till or no-till. For all eight regions combined, about 32 percent of cultivated cropland acres met the tillage intensity criteria for no-till, including 42 percent of HEL acres and 28 percent of non-HEL acres (table 5). About 50 percent of cultivated cropland acres met the tillage intensity criteria for mulch till, including 42 percent of HEL acres and 54 percent of non-HEL acres. About 7 percent of cropped acres did not meet criteria for mulch till or no-till, but had reduced tillage on some crops in the rotation. Only about 10 percent of the cropped acres in all eight regions were conventionally tilled in 2003-06.

No-till was in most use in two regions (table 5 and fig. 12):

- the East Central (11) region, where 52 percent of cultivated cropland met criteria for no-till, including 51 percent of HEL acres, and
- the Northern Plains (5) region, where 47 percent of cultivated cropland met criteria for no-till, including 63 percent of HEL acres.

No-till was used on less than 20 percent of cropped acres in two regions—the Northwest Non-Coastal (3) region and the Southern Plains (6) region.

Use of mulch till was common in all eight regions (table 5 and fig. 13). Mulch till was most prevalent in the Northwest Non-Coastal (3) region, where 62 percent of cultivated cropland acres met criteria for mulch till, including 64 percent of HEL acres. Mulch till was least prevalent in the East Central (11) region, where only 35 percent of cultivated cropland acres met criteria for mulch till.

Use of continuous conventional tillage was highest in the Southern Plains (6) region, where 26 percent of the cultivated cropland acres are conventionally tilled (table 5).

Figure 11. Conventional tillage leaves the soil unprotected.

[3] A description of the Soil Tillage Intensity Rating (STIR) can be found on the NRCS website.

[4] Percent residue cover was not used to evaluate no-till or mulch till because this criterion is not included in the current NRCS practice standard for Residue and Tillage Management. Residue is, however, factored into erosion and runoff estimates in APEX.

Table 5. Conservation tillage use in 2003-06, by region and for all regions combined—percent of Highly-Erodible land (HEL), percent of non-HEL, and percent of all cultivated cropland acres.

	No-till*			Mulch till**			Some reduced tillage***			Continuous conventional tillage****		
	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres	% of HEL	% of Non-HEL	% of all acres
Production region												
Northwest Non-Coastal (3)	21	16	19	64	60	62	9	14	11	6	10	8
Northern Plains (5)	63	38	47	30	46	40	5	11	9	2	6	4
Southern Plains (6)	18	20	19	47	45	46	9	9	9	26	26	26
North Central and Midwest (7)	52	29	34	43	61	57	3	5	5	2	5	4
Lower Mississippi and Texas Gulf Coast (9)	50	21	24	34	57	54	5	8	7	12	15	14
Northeast (10)	27	19	23	51	59	55	8	13	10	14	9	12
East Central (11)	51	53	52	33	38	35	10	5	8	6	4	5
Southeast Coastal Plain (12)	31	33	32	55	48	49	8	8	8	5	12	11
All eight regions	42	28	32	42	54	50	6	8	7	10	11	10

* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till.
**** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: Percent residue cover was not used to determine no-till or mulch till.
Source: Conservation tillage levels were derived from field operations as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.

Figure 12. Percent of cultivated cropland acres meeting STIR criteria for no-till, by region.

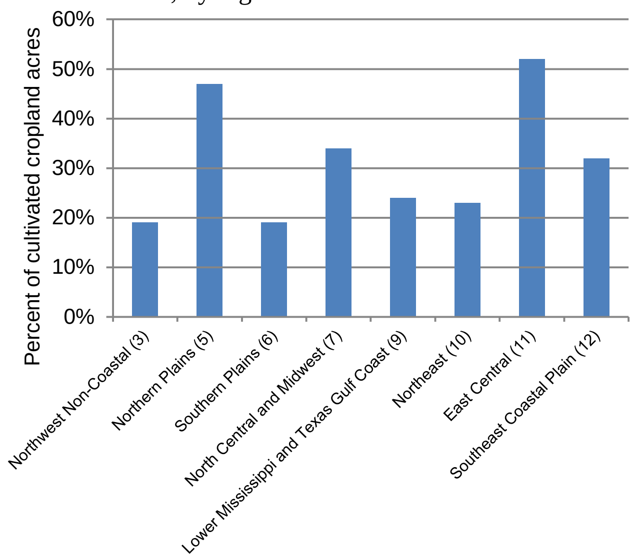
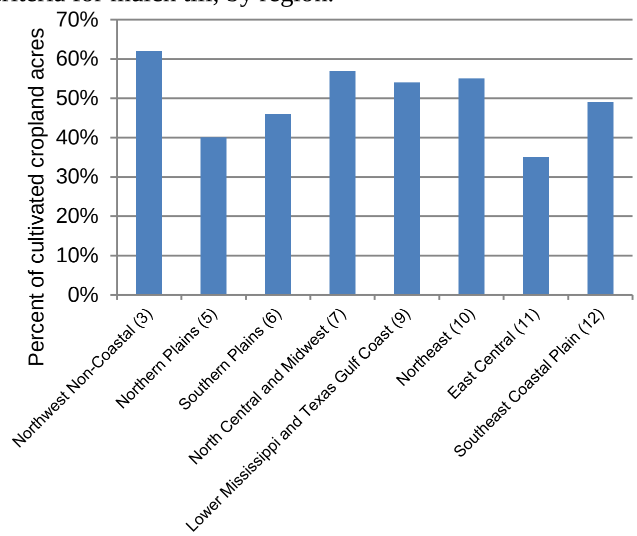


Figure 13. Percent of cultivated cropland acres meeting STIR criteria for mulch till, by region.



Soil organic carbon. The average annual change in soil organic carbon was used as an indicator of residue management. Higher levels of residue are correlated with increasing rates of soil organic carbon accumulation in the soil over time. Soil organic carbon improves water holding capacity and reduces erodibility through enhanced soil aggregate stability. Removal of residue by the farmer decreases this benefit.

In the APEX model simulation, the daily level of soil organic carbon is tracked and included in the model output. The annual change is calculated as the difference between the end-of-year carbon value and the beginning-of-year carbon value for each of the 47 years in the model simulation. (If soil organic carbon was decreasing in a given year, the value for that year would be negative.) The average annual change in soil organic carbon in pounds per acre is determined as the mean over the 47 years of model simulation results for each sample point.

Residue management was considered to be “good” for a sample point if the average annual change in soil organic carbon was positive, indicating soil organic carbon was increasing every year, on average. It was considered to be “poor” if the average annual change in soil organic carbon was negative, indicating soil organic carbon was decreasing every year, on average.

According to the simulation model results, 51 percent of cultivated cropland acres had gains in soil organic carbon for all eight regions combined (table 6 and fig. 14). However, some regions had indications of much better residue management than other regions (fig. 16). The North Central and Midwest (7) region had by far the highest percentage of acres gaining in soil organic carbon—73 percent. The lowest percentages were in two regions—the Southeast Coastal Plain (12) region with 23 percent and the Northeast (10) region with 27 percent. Percentages of cultivated cropland acres gaining in soil organic carbon for the remaining regions ranged from 33 to 44 percent.

Table 6. Percent of cultivated cropland acres gaining in soil organic carbon, by region.

	Percent
Northwest Non-Coastal (3)	33
Northern Plains (5)	44
Southern Plains (6)	34
North Central and Midwest (7)	73
Lower Mississippi and Texas Gulf Coast (9)	35
Northeast (10)	27
East Central (11)	43
Southeast Coastal Plain (12)	23
All eight regions	51

Figure 14. Distribution of average annual change in soil organic carbon for sample points in all eight regions.

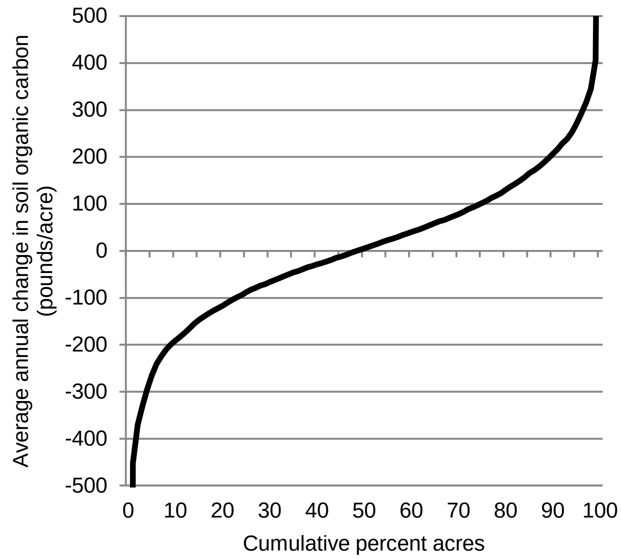
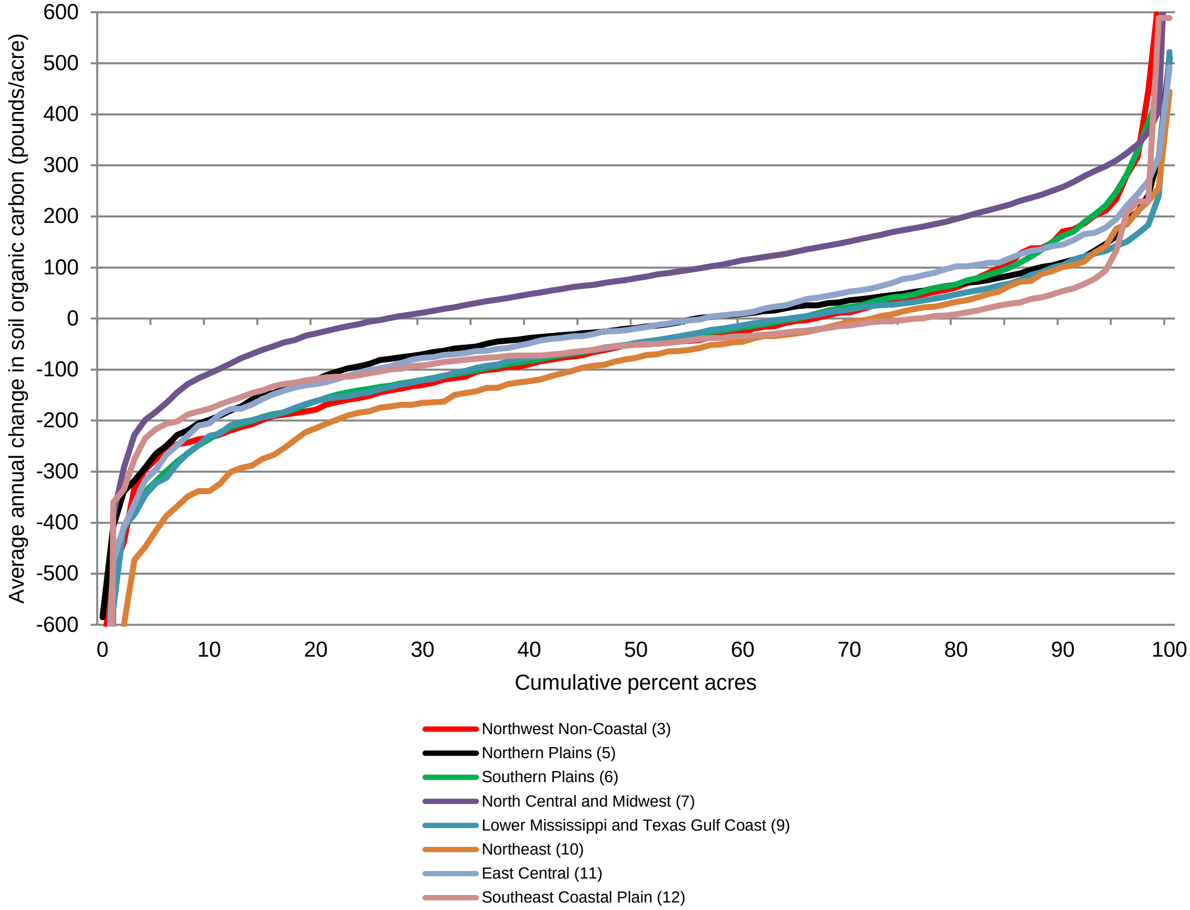


Figure 15. Terraces, buffers, and conservation tillage are among the practices being used by Shelby County, Iowa farmers in a water quality improvement project to benefit a nearby lake.

Figure 16. Distributions of average annual change in soil organic carbon for sample points in each of the eight regions.



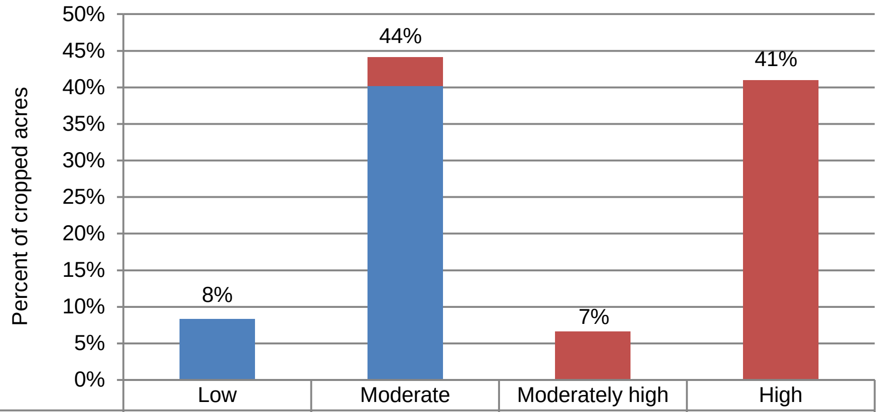
Conservation treatment levels. As was done for structural practices, four levels of conservation treatment (high, moderately high, moderate, or low) were defined for conservation tillage use at each sample point. The criteria combined tillage intensity and residue management, where residue management was represented by the change in the average annual soil organic carbon level derived from the APEX simulation model.[5] Criteria for four levels of treatment with conservation tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but rotation is losing soil organic carbon, or crop rotation is gaining soil organic carbon and the *average annual* tillage intensity exceeds criteria for mulch till.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

For the eight regions combined, 41 percent of acres had a "high" level of tillage and residue management (fig. 17, table 7). Another 7 percent had a "moderately high" level. The "high" and "moderately high" treatment levels represent the 48 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon. Only 8 percent had a "low" treatment level, since few acres had continuous conventional tillage and were also losing soil organic carbon. The remaining 44 percent had a "moderate" treatment level. These were acres that had some kind of reduced tillage but less than mulch till; most acres in this treatment level are losing soil organic carbon.

[5] STIR values in combination with carbon trends are in line with the use of the Soil Conditioning Index (SCI), which approximates the primary criteria for NRCS residue management standards. The NRCS practice standard, as applied at the field, may include other considerations to meet site specific resource concerns that are not considered in this evaluation.

Figure 17. Percent of cropped acres at four conservation treatment levels for tillage and residue management practices, all eight regions combined.



	Low	Moderate	Moderately high	High
Gaining carbon	0%	4%	7%	41%
Losing carbon	8%	40%	0%	0%

Criteria for four levels of treatment with tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but rotation is losing soil organic carbon, or crop rotation is gaining soil organic carbon and tillage intensity exceeds criteria for mulch till.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

Table 7. Percent of cropped acres at four conservation treatment levels for tillage and residue management practices, by region.

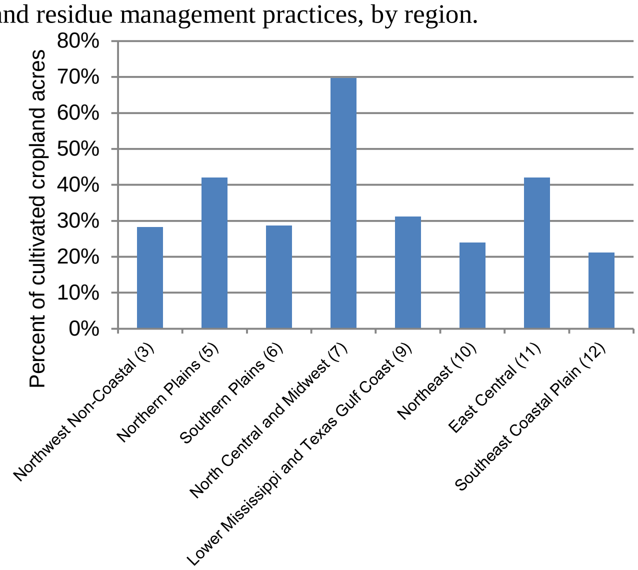
	Low	Moderate	Moderately high	High
Production region				
Northwest Non-Coastal (3)	5	66	9	20
Northern Plains (5)	3	55	4	38
Southern Plains (6)	22	50	5	23
North Central and Midwest (7)	3	28	8	61
Lower Mississippi and Texas Gulf Coast (9)	12	56	5	26
Northeast (10)	10	67	9	15
East Central (11)	5	53	7	35
Southeast Coastal Plain (12)	10	69	7	14
All eight regions	8	44	7	41

The North Central and Midwest (7) region stands apart from other regions with a "high" treatment level for 61 percent of cultivated cropland acres and 69 percent of acres with either a "high" or "moderately high" treatment level (table 7 and fig. 18).

Two regions had the lowest percentages of cropped acres with either a "high" or "moderately high" treatment level—the Southeast Coastal Plain (12) region with 21 percent and the Northeast (10) region with 24 percent. These are also the two regions that had the lowest percentages of acres gaining soil organic carbon (table 6).

Percentages of cropped acres with either a "high" or "moderately high" treatment level for the remaining regions ranged from 28 to 42 percent (fig. 18).

Figure 18.: Percent of cultivated cropland acres with "high" or "moderately high" levels of conservation treatment for tillage and residue management practices, by region.



Phosphorus Management Practices

Phosphorus and other nutrients are essential inputs to profitable crop production. They promote plant growth and increase crop yields. Phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers and manure to supplement low quantities of plant-available phosphorus in the soil. Not all of the phosphorus applied to the land, however, is taken up by crops. Some is lost to the environment through wind and water processes, which can contribute to offsite water quality problems.

Nutrient management systems can minimize phosphorus losses from farm fields while providing adequate soil fertility and nutrient availability to ensure realistic yields. Such systems are tailored to address the specific crop rotation, nutrient sources available in the soil, and other site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure.[6]

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.

2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.

3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.

4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses. Even though nutrient transport and losses from farm fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

The presence or absence of phosphorus management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were used. The following criteria were used to identify the appropriate rate, time, and method of phosphorus application for each crop or crop rotation.

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting.

- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.

- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial phosphorus fertilizer and manure, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

Phosphorus application rate criteria apply to the *full crop rotation* to account for infrequent phosphorus applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications. Thus, phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation would not.

These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans and are consistent with recommended rates. They do not, however, necessarily represent the best possible set of nutrient management practices. For example, lower application rates are possible when timing and method criteria are also met and when soil erosion and runoff are controlled.

For APEX modeling, it was necessary to adjust the rates of phosphorus application reported in the survey to account for missing data and data-entry errors to prevent insufficient crop growth throughout the 47 years in the model simulation. Crop growth, and thus canopy development its influence on erosion, is a function of available nutrients in the APEX model. Insufficient nutrients in the model simulation results in overestimates of soil erosion and thus overestimates of sediment and nutrient losses from farm fields. Missing phosphorus application data occurred not only because of errors in reporting, but also because the 3-year data period for which information was reported was often too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques.

[6] These criteria are also referred to as "4R nutrient stewardship—right rate, right time, right place, and right source."

Additional commercial phosphorus fertilizer was added to crop samples for which model results indicated that more phosphorus was needed for reasonable crop yields as estimated by the simulation model. The amount of phosphorus added brought application rates for these sample points up to levels consistent with application rates for the unadjusted set of crop samples. Phosphorus was added by increasing the existing applications proportionately (thus preserving the reported timing and methods), when present, or were applied at plant.[7]

Overall for all eight regions combined, about 37 percent of cultivated cropland acres had phosphorus application rates adjusted upward relative to survey data to assure sufficient crop growth in the APEX model simulation.

Phosphorus management practices for all eight regions combined. For all eight regions combined, the majority of acres met at least one of the three management practices—timing, rate, or method of application for manure and commercial fertilizer—in 2003-06. However, much fewer acres met criteria for all three.

As shown in table 8, 64 percent of cropped acres met criteria for timing of phosphorus applications for all crops in the rotation, including both manure and commercial fertilizer applications. This excludes the 7 percent of cropped acres that did not have any phosphorus application. Thus, about 29 percent of acres did not meet the criteria for timing for one or more crops in the rotation.

For the method of phosphorus application, 61 percent of cropped acres met the criteria for phosphorus management, and about 32 percent did not meet the criteria for one or more crops in the rotation. For the rate of phosphorus application, 47 percent of cropped acres met the criteria for phosphorus management, and about 46 percent did not meet the rate criteria.

Figure 19. Fertigation involves adding fertilizer directly into the irrigation water. A very effective way to apply plant nutrients without waste and reduce the risk of water pollution.

Only 30 percent of cropped acres met criteria for timing and method and rate. After accounting for the 7 percent of acres that did not receive phosphorus applications, about 63 percent of cropped acres did not fully meet the criteria for phosphorus management.

Acres with manure applied—about 10 percent of cropped acres in all eight regions—met the criteria for phosphorus application much less frequently than for acres receiving only commercial fertilizer (table 8). For cultivated cropland acres receiving manure:

- 14 percent met criteria for timing of phosphorus applications (both commercial fertilizer and manure applications) for all crops in the rotation, compared to 69 percent for application of commercial phosphorus fertilizer only;
- 47 percent met criteria for method of phosphorus applications (both commercial fertilizer and manure applications) for all crops in the rotation, compared to 63 percent for application of commercial phosphorus fertilizer only; and
- 26 percent met criteria for the rate of phosphorus application for the crop rotation (both commercial fertilizer and manure applications), compared to 50 percent for application of commercial phosphorus fertilizer only.

Only 2 percent of cultivated cropland acres that received manure in 2003-06 met phosphorus management criteria for timing and rate and method of application, compared to 33 percent for acres without manure applied but had commercial phosphorus fertilizer applied (table 8). An additional 8 percent of the acres without manure applied also did not have any commercial phosphorus applied.

Figure 20. Injecting manure directly into the soil reduces the risk of water pollution and provides accurate application of plant nutrients.

[7] For additional information on adjustment of nutrient application rates, see the CEAP documentation report "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," available at the CEAP website or from the CEAP team in NRCS.

Table 8. Phosphorus (P) management practices based on survey data for 2003-06 for cultivated cropland acres.

Production region	No crops in rotation have application of P	All crops in rotation have application of P within 3 weeks before planting or within 60 days after planting	All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	Crop rotation has P applied at an annual rate less than 1.1 times the removal of P in the yield at harvest*	Appropriate timing and rate and method of application (excludes acres with no P applied)
			Percent of all acres		
Northwest Non-Coastal (3)	16	62	63	58	43
Northern Plains (5)	6	82	79	50	41
Southern Plains (6)	21	61	61	42	30
North Central and Midwest (7)	<1	56	57	55	29
Lower Mississippi and Texas Gulf Coast (9)	4	75	64	34	19
Northeast (10)	2	51	56	28	16
East Central (11)	1	71	40	32	14
Southeast Coastal Plain (12)	4	61	51	28	13
All eight regions	7	64	61	47	30
			Percent of acres without manure applied		
Northwest Non-Coastal (3)	16	64	63	60	44
Northern Plains (5)	7	85	80	50	42
Southern Plains (6)	22	63	61	43	31
North Central and Midwest (7)	<1	64	58	60	34
Lower Mississippi and Texas Gulf Coast (9)	4	76	64	34	19
Northeast (10)	4	80	59	38	27
East Central (11)	2	79	42	33	16
Southeast Coastal Plain (12)	4	66	50	30	15
All eight regions	8	69	63	50	33
			Percent of acres with manure applied		
Northwest Non-Coastal (3)	0	15	54	11	<1
Northern Plains (5)	0	4	36	35	<1
Southern Plains (6)	0	14	50	20	3
North Central and Midwest (7)	0	13	47	29	2
Lower Mississippi and Texas Gulf Coast (9)	0	30	59	23	5
Northeast (10)	0	17	53	17	3
East Central (11)	0	23	30	24	5
Southeast Coastal Plain (12)	0	21	54	11	1
All eight regions	0	14	47	26	2

* Rate of phosphorus application was evaluated after adjusting the rates of application reported in the survey to account for missing data and data-entry errors so as to prevent insufficient crop growth throughout the 47 years in the model simulation. See text.
Note: The assessment included application of both commercial phosphorus fertilizers and manure.

As was done for structural practices and tillage and residue management practices, four levels of conservation treatment (high, moderately high, moderate, or low) were defined for phosphorus management at each sample point using combinations of appropriate timing, rate, and method criteria. The four levels of phosphorus management are:

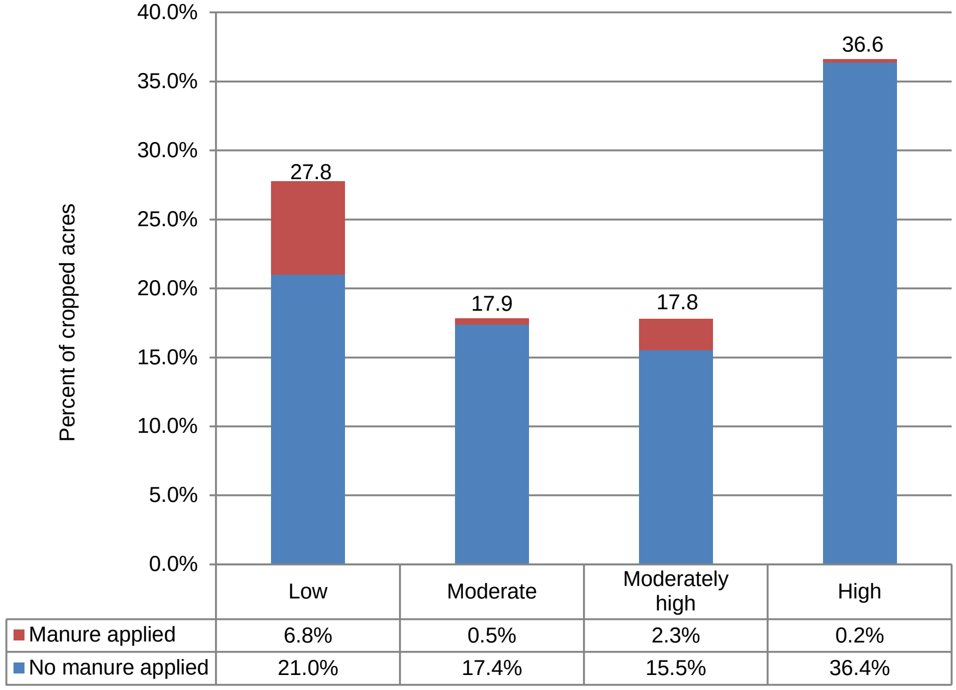
- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. Acres without any phosphorus application are included in this management level.
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points do not meet the application rate criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: Sample points do not meet the application rate criteria and have inadequate method or timing of application for at least one crop in the rotation.

For all eight regions combined, 37 percent of cropped acres have a "high" phosphorus management level, including acres that did not have any phosphorus applied (fig. 21 and table 9). Only a small number of these acres had received manure.

Another 18 percent have a "moderately high" level of phosphorus management, including about one-fourth of the acres that received manure. These acres met criteria for application rate, but did not meet criteria for either timing or method or both.

About 28 percent of cultivated cropland acres have a "low" level of phosphorus management. Most of the acres receiving manure have a "low" level of phosphorus management (fig. 21).

Figure 21. Percent of cropped acres at four conservation treatment levels for phosphorus management, all eight regions combined.



Criteria for four levels of phosphorus management are:

- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. Acres without any phosphorus application are included in this management level.
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All sample points have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

Table 9. Percent of cropped acres for four conservation treatment levels of phosphorus management, by region.

	Low	Moderate	Moderately high	High
Production region				
Northwest Non-Coastal (3)	17	9	15	58
Northern Plains (5)	12	31	9	47
Southern Plains (6)	18	18	12	51
North Central and Midwest (7)	35	9	26	30
Lower Mississippi and Texas Gulf Coast (9)	27	35	15	23
Northeast (10)	51	19	12	18
East Central (11)	49	18	17	16
Southeast Coastal Plain (12)	49	20	14	17
All eight regions	28	18	18	37

Phosphorus management practices by production region. Two regions stand out as having better overall phosphorus management than the others (table 8):

- the Northern Plains (5) region, where 82 percent of cropped acres met criteria for time of application and 79 percent of cropped acres met criteria for method of application, and
- the Northwest Non-Coastal (3) region, where 58 percent of cropped acres met the phosphorus application rate criteria.

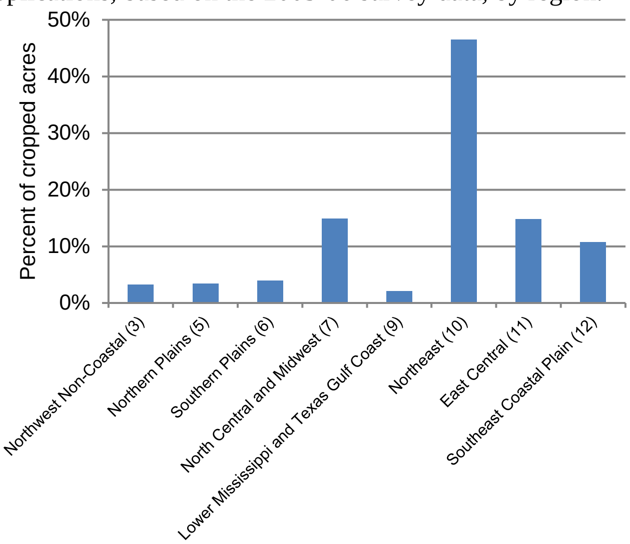
These two regions also had the highest percentages of acres that met all three phosphorus management criteria—41 percent for the Northern Plains (5) region and 43 percent for the Northwest Non-Coastal (3) region (table 8). When acres that did not have phosphorus applications are taken into account, the Southern Plains (6) region joins these two regions in having the highest percentages of acres with a "high" level of phosphorus management (table 9). None of these three regions had significant acreage that received manure (fig. 22).

Three regions had the poorest phosphorus management, each with about half of the cropped acres with a "low" level of phosphorus management and only 16-18 percent of cropped acres with a "high" level of phosphorus management:

- the East Central (11) region,
- the Southeast Coastal Plain (12) region, and
- the Northeast (10) region.

Ten percent or more of the cropped acres in each of these three regions received manure applications (fig. 22). In the Northeast (10) region, 47 percent of the cropped acres received manure applications.

Figure 22. Percent of cultivated cropland acres with manure applications, based on the 2003-06 survey data, by region.



Note: About 10 percent of cropped acres (28 million acres) had manure applied in 2003-06 on cultivated cropland acres in the eight regions.

Combinations of Water Erosion Control Practices and Phosphorus Management Practices

Nearly all cultivated cropland acres had conservation practices or phosphorus management practices in use that would be expected to reduce phosphorous losses from farm fields to some extent.

For all eight regions combined, 94 percent of cultivated cropland acres had some kind of practice use to control water erosion (table 10):

- 34 percent had one or more structural practice and some form of reduced tillage,
- 55 percent had some form of reduced tillage but no structural practices,
- 4 percent had one or more structural practice but no reduced tillage, and
- only 6 percent had no reduced tillage and no structural practices.

There are important regional differences in the use of these practices, as shown in previous sections, but at least one water erosion control practice is used on nearly all cultivated cropland acres in each region (table 10). The East Central (11) region had at least one water erosion control practice on 99 percent of the cultivated cropland acres in that region. The North Central and Midwest (7) region had at least one water erosion control practice on 97 percent of cropped acres. Even the region with the least percentage of treated acres—87 percent for the Southern Plains (6) region—still had most acres treated, including 31 percent of the acres with one or more structural practice and some form of reduced tillage.

When phosphorus management practices are factored in, only about 2 percent of cultivated cropland acres in the eight regions had neither erosion control practices nor phosphorus management levels of 'moderate" or better.

To evaluate the overall level of conservation treatment for water erosion control together with phosphorus management, four conservation treatment levels for phosphorus runoff control were defined for each sample point (high, moderately high, moderate, or low), as was done previously for each of the three practice groups (figure 7 for structural practices, figure 17 for tillage and residue management, and figure 21 for phosphorus management).

First, scores were assigned to the four treatment levels for each of the three practice groups as follows:

- sample points with a "high" treatment level were assigned a score of 4;
- sample points with a "moderately high" treatment level were assigned a score of 3;
- sample points with a "moderate" treatment level were assigned a score of 2; and
- sample points with a "low" treatment level were assigned a score of 1.

Table 10. Percent of cropped acres with combinations of structural practices and residue and tillage management practices, by region.

	Percent of acres with one or more structural practice and some form of reduced tillage	Percent of acres with some form of reduced tillage but no structural practices	Percent of acres with one or more structural practice only	Percent of acres with no structural practices and no reduced tillage
Production region				
Northwest Non-Coastal (3)	33	60	2	6
Northern Plains (5)	22	74	<1	4
Southern Plains (6)	31	42	13	13
North Central and Midwest (7)	43	52	1	3
Lower Mississippi and Texas Gulf Coast (9)	17	68	3	11
Northeast (10)	37	51	6	6
East Central (11)	53	41	4	1
Southeast Coastal Plain (12)	28	61	3	8
All eight regions	34	55	4	6

If the field slope was 2 percent or less, the phosphorus runoff control treatment level was based on combinations of the residue and tillage management level and the phosphorus management level, determined as follows:

- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (i.e., "high" treatment level for both residue and tillage management and phosphorus management).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level was based on combinations of all three treatment groups, determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (i.e., "high" treatment level for all three practice groups.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

The percentages of cropped acres at each of these four conservation treatment levels for phosphorus runoff control are presented in figure 23 and table 11 for all eight regions combined. About 9 percent of cultivated cropland acres had a "high" level of phosphorus runoff control treatment. Another 32 percent of cultivated cropland acres had a "moderately high" level of phosphorus runoff control treatment.

About 43 percent of cultivated cropland acres had a "moderate" level of phosphorus runoff control treatment, and 17 percent had a "low" level of phosphorus runoff control treatment.

Three regions had the best coverage in providing phosphorus runoff control treatment for cultivated cropland acres (table 11 and fig. 24):

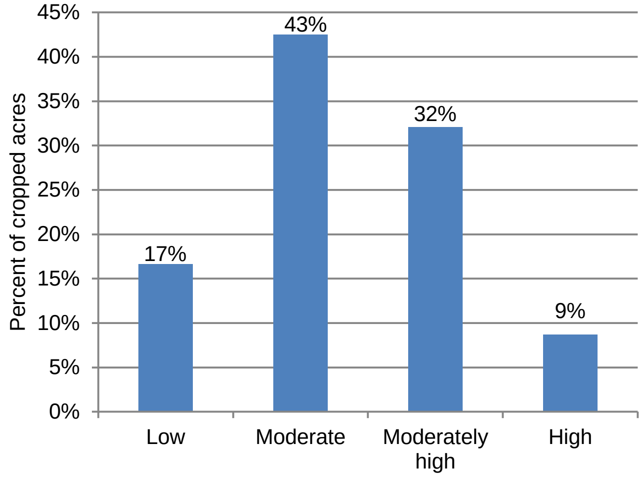
- the North Central and Midwest (7) region, where 11 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 35 percent had a "moderately high" level;
- the Northern Plains (5) region, where 10 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 33 percent had a "moderately high" level; and
- the Southern Plains (6) region, where 9 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 35 percent had a "moderately high" level.

The Northern Plains (5) region and the Southern Plains (6) region were two of the three regions with the best phosphorus management treatment among the eight regions (table 9).

Three regions stand out as having the least treatment for phosphorus runoff control (table 11 and fig. 24), primarily because of insufficient phosphorus management, especially for acres receiving manure:

- the Northeast (10) region, where only 1 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 14 percent had a "moderately high" level,
- the Southeast Coastal Plain (12) region, where only 2 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 17 percent had a "moderately high" level, and
- the East Central (11) region, where only 2 percent of cropped acres had a "high" level of treatment for phosphorus runoff control and 20 percent had a "moderately high" level.

Figure 23. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control, all eight regions combined.

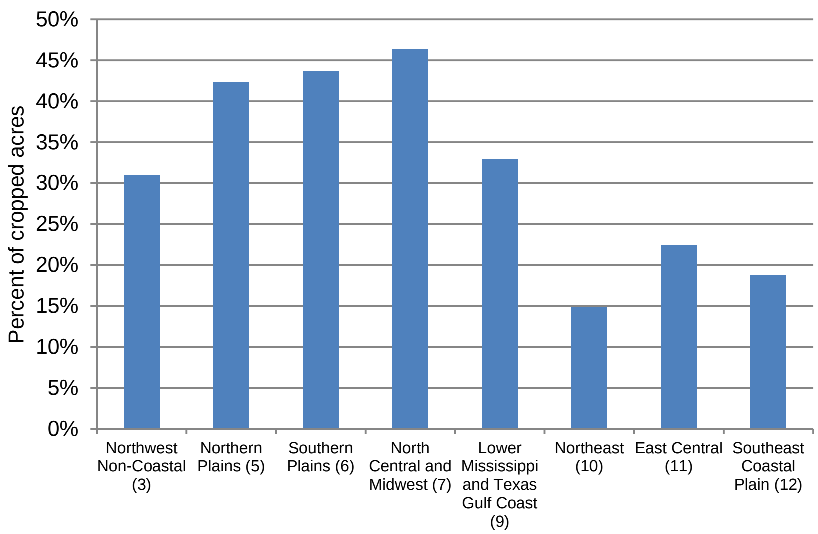


See text for criteria used to define the four phosphorus runoff control treatment levels.

Table 11. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control, by region.

	Low	Moderate	Moderately high	High
Production region				
Northwest Non-Coastal (3)	14	55	28	3
Northern Plains (5)	13	45	33	10
Southern Plains (6)	18	38	35	9
North Central and Midwest (7)	11	42	35	11
Lower Mississippi and Texas Gulf Coast (9)	23	44	28	5
Northeast (10)	45	41	14	1
East Central (11)	26	51	20	2
Southeast Coastal Plain (12)	42	39	17	2
All eight regions	17	43	32	9

Figure 24. Percent of cultivated cropland acres with “high” or “moderately high” levels of conservation treatment for phosphorus runoff control, by region.



APEX Modeling and the Baseline Scenario

Phosphorus loss from farm fields was estimated using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX). APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade, depending on climatic conditions, cropping systems, and management.

A baseline scenario consists of APEX model simulation results that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey for 2003-06. Model simulation results for the baseline scenario therefore reflect the mix of treated and untreated acres for the time period 2003-06.

Weather is the predominant factor determining the loss of soil and nutrients from farm fields. To capture the effects of weather, the baseline scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. In the model simulations, weather is the only input variable that changes year to year. Since only the cropping patterns and practices for the 2003–06 time period were simulated, model estimates of losses from farm fields are *not actual* loses for each of these 47 years. Rather, the yearly model estimates, when aggregated over the 47 years, provide estimates of what would be expected at a sample point over the long-term in the future if weather continues to vary as it has in the past. Thus, we report model simulation estimates of *what would be expected after accounting for weather variability* so as to best inform program decision makers on what has been accomplished and what remains to be done.

All model results reported herein are in terms of the 47-year averages at each sample point. For every model output, the 47-year average is first calculated for each sample point, and then more aggregated statistics are determined for the full set or a subset of sample points. Estimates determined by aggregating over sample points are always weighted by the acreage weight associated with each sample point (see Appendix A).

For example, APEX model results showed that phosphorus loss for the baseline scenario was 2.79 pounds per acre per year, on average, for all cultivated cropland acres in the eight regions. This estimate was calculated as follows:

1. First, the annual phosphorus loss was obtained from APEX model output at each sample point for each of the 47 years of model simulation data.
2. Second, the average annual loss at each of the 17,918 CEAP sample points was calculated.
3. Then the acreage-weighted mean of these average annual estimates over all sample points was calculated, representing the mean of the average annual amount of phosphorus loss from farm fields—2.79 pounds per acre per year.

In addition to reporting the mean of the average annual estimates, various percentiles of the distribution of average annual estimates are also presented. For example, the median of the average annual values is sometimes reported, representing the average annual estimate for the sample point where half of the acres have higher values and half have lower values—the 50th percentile value. Cumulative distributions are also shown so as to represent the variability among the average annual estimates within the sample; these distributions are obtained using the percentile values for each percentile from 1 to 100.

The APEX model tracks phosphorus loss from farm fields through four pathways[8]:

- phosphorus lost with windborne sediment;
- phosphorus lost with waterborne sediment;
- soluble phosphorus lost with surface water runoff, including soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems; and
- soluble phosphorus that percolates through the soil profile into the groundwater.

Phosphorus losses from farm fields are thus the result of surface water runoff, infiltration of water into the soil, sediment loss beyond the edge of the field from water erosion, and wind erosion. Consequently, in addition to reporting the average annual estimates of phosphorus loss from farm fields, results are also presented for:

- water sources (precipitation and irrigation) and water loss from farm fields,
- sediment loss from farm fields, and
- wind erosion rates.

Water sources and loss, sediment loss, and wind erosion results for the baseline scenario are presented in the following three sections of this chapter to provide perspective for the phosphorus loss results presented in the next chapter.

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[8] Unlike nitrogen, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component for phosphorus.

Water Sources and Water Loss Pathways

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. Hydrologic conditions prevalent in each production region are critical to understanding the estimates of phosphorus loss from farm fields. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, and percolation beyond the bottom of the soil profile.

Precipitation and irrigation—the sources of water for a field—vary substantially among the eight production regions, as shown in table 12 and figures 25 and 26. Cultivated cropland in the Northern Plains (5) region and the Northwest Non-Coastal (3) region have the lowest precipitation, averaging about 17 inches per year for the 47 years simulated with APEX. Irrigation is widely used on cultivated cropland in the Northwest Non-Coastal (3) region (37 percent of cultivated cropland acres), averaging an additional 17 inches of water per acre on irrigated acres (table 12).

Precipitation is highest for cultivated cropland acres in the Lower Mississippi and Texas Gulf Coast (9) region and the Southeast Coastal Plain (12) region, averaging about 50 inches per year in each region. Nearly half of the cultivated cropland acres in the Lower Mississippi and Texas Gulf Coast (9) region are also irrigated, averaging an additional 19 inches of water per year on irrigated acres (table 12).

About 20 percent of cultivated cropland acres in the Southeast Coastal Plain (12) region are also irrigated, averaging an additional 17 inches of water per year on irrigated acres.

Figure 25. Water sources—precipitation and irrigation water applied—for farm fields, as represented in the APEX model simulations.

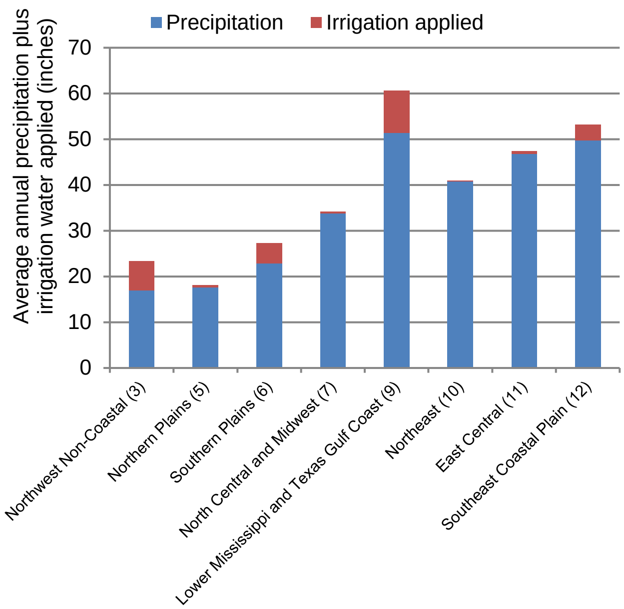


Figure 26. Distributions of average annual water sources (precipitation plus irrigation water applied) for sample points in each of the eight regions.

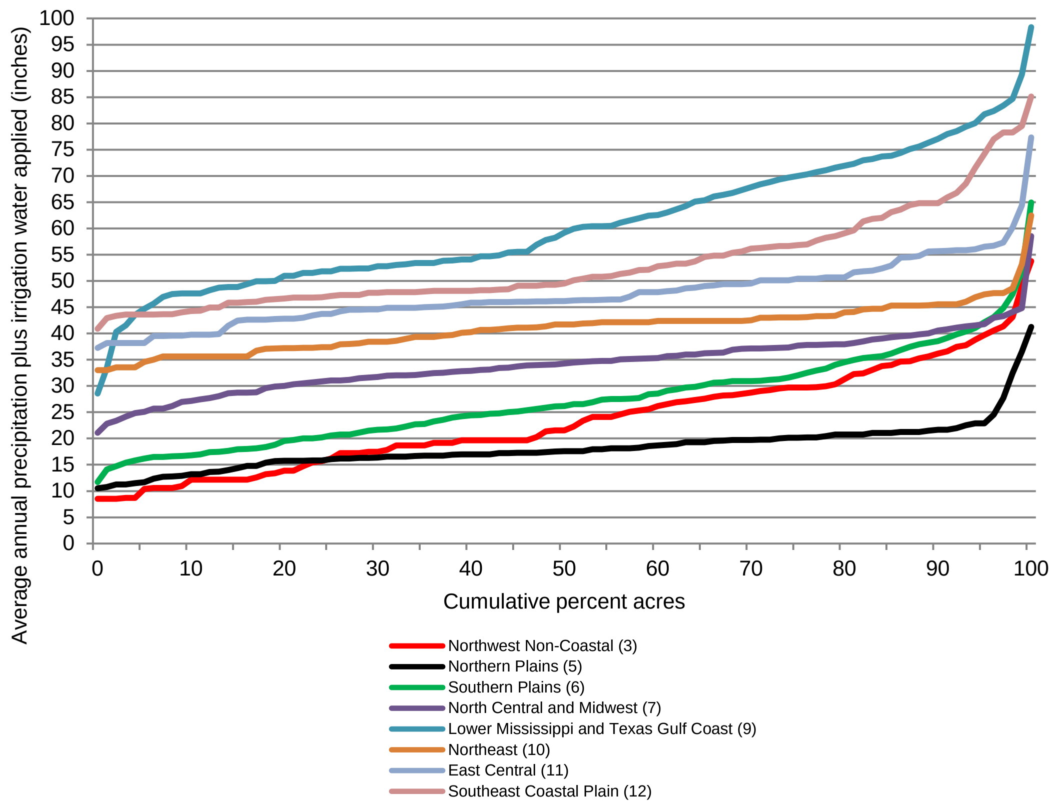


Table 12. Water sources and water loss for cultivated cropland, as represented in the APEX model simulations.

	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)
Water sources				
Non-irrigated cultivated cropland acres				
Percent of acres non-irrigated	63%	96%	74%	96%
Average annual precipitation (inches)				
Mean	18	18	24	34
20-to-80 percentile range	12-23	16-20	18-29	30-38
Irrigated cultivated cropland acres				
Percent of acres irrigated	37%	4%	26%	4%
Average annual precipitation (inches)				
Mean	15	18	21	31
20-to-80 percentile range	11-19	15-24	17-25	26-36
Average annual irrigation water applied (inches)				
Mean	17	13	17	10
20-to-80 percentile range	11-23	10-18	11-21	7-13
Water loss pathways				
Average annual evapotranspiration (inches)				
Mean	17.3	16.3	23.2	23.5
Percent of all 3 loss pathways	79%	90%	87%	69%
20-to-80 percentile range	12.1-22.6	14.0-18.5	17.9-27.2	21.5-25.5
Average annual surface water runoff (inches)				
Mean	1.7	0.7	1.4	4.3
Percent of all 3 loss pathways	8%	4%	5%	13%
20-to-80 percentile range	0.4-2.9	0.3-0.9	0.2-2.3	2.3-6.1
Average annual subsurface water flows (inches)				
Mean	2.9	1.2	2.2	6.4
Percent of all 3 loss pathways	13%	7%	8%	19%
20-to-80 percentile range	0.3-5.3	0.1-1.9	<0.1-3.8	3.9-8.6

Table 12.—continued.

	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)
Water sources				
Non-irrigated cultivated cropland acres				
Percent of acres non-irrigated	52%	98%	96%	80%
Average annual precipitation (inches)				
Mean	52	41	47	50
20-to-80 percentile range	48-56	37-43	43-50	46-55
Irrigated cultivated cropland acres				
Percent of acres irrigated	48%	2%	4%	20%
Average annual precipitation (inches)				
Mean	51	44	46	50
20-to-80 percentile range	48-54	42-46	45-48	47-52
Average annual irrigation water applied (inches)				
Mean	19	8	13	17
20-to-80 percentile range	12-26	3-11	9-16	13-25
Water loss pathways				
Average annual evapotranspiration				
Mean (inches)	36.4	25.5	28.7	32.6
Percent of all 3 loss pathways	61%	62%	60%	59%
20-to-80 percentile range (inches)	31.4-41.8	22.6-28.2	25.2-32.0	29.0-36.0
Average annual surface water runoff				
Mean (inches)	13.1	6.1	8.2	6.0
Percent of all 3 loss pathways	22%	15%	17%	11%
20-to-80 percentile range (inches)	10.5-15.6	4.2-7.9	4.8-11.3	3.2-8.1
Average annual subsurface water flows				
Mean (inches)	10.0	9.4	10.8	16.3
Percent of all 3 loss pathways	17%	23%	23%	30%
20-to-80 percentile range (inches)	6.8-13.4	7.7-11.1	8.5-12.5	10.2-20.9

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) (table 12). On average, about 80-90 percent of the water loss for cultivated cropland acres is through evapotranspiration in the three westernmost regions—the Northwest Non-Coastal (3) region, the Northern Plains (5) region, and the Southern Plains (6) region. About 69 percent of the water loss for cultivated cropland acres is through evapotranspiration in the North Central and Midwest (7) region. For the remaining four regions, evapotranspiration accounts for about 60 percent of the water loss from cultivated cropland acres.

The remaining water loss from farm fields is either surface water runoff or water that infiltrates into the soil and then is transported from the field through various subsurface flow pathways.[9] The APEX model simulations show that, overall, more water is lost through subsurface flow pathways than as surface water runoff for all but one region—the Lower Mississippi and Texas Gulf Coast (9) region (table 12 and figs. 27 and 28). Subsurface flow pathways include—

- deep percolation to groundwater, including groundwater return flow to surface water,
- subsurface flow that is intercepted by tile drains or drainage ditches, when present, and
- lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

The Southeast Coastal Plain (12) region has the largest amount of water lost through subsurface flow pathways—16 inches per year, on average, which is nearly three times higher than the amount lost as surface water runoff in that region.

Surface water runoff directly effects sheet and rill erosion and edge-of-field sediment loss from farm fields. For all eight regions combined, average annual surface water runoff was 3.8 inches per year. Surface water runoff is highest in the Lower Mississippi and Texas Gulf Coast (9) region, where it averages 13.1 inches per year (table 12 and fig. 27). It is lowest in the three westernmost and driest regions—the Northern Plains (5) region, the Southern Plains (6) region, and the Northwest Non-Coastal (3) region—where it averaged less than 2 inches per year. In the remaining four regions, the average annual surface water runoff ranges from a low of 4.3 inches per year in the North Central and Midwest (7) region to a high of 8.2 inches per year in the East Central (11) region.

Figure 27. Mean of the average annual surface water runoff from farm fields, by production region.

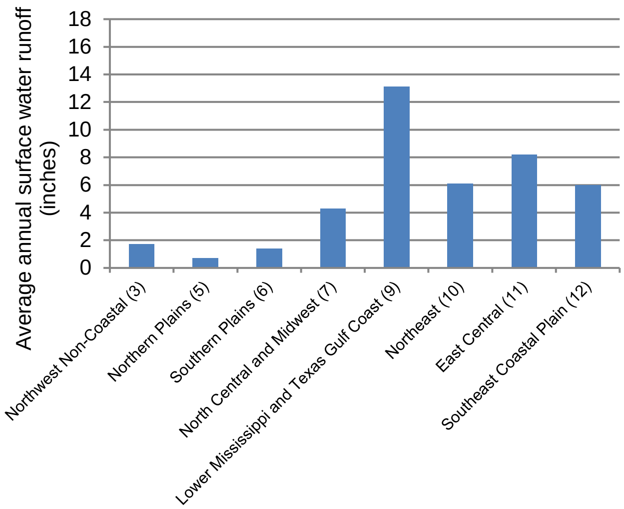


Figure 28. Mean of the average annual loss of water from farm fields through subsurface water flows, by production region.

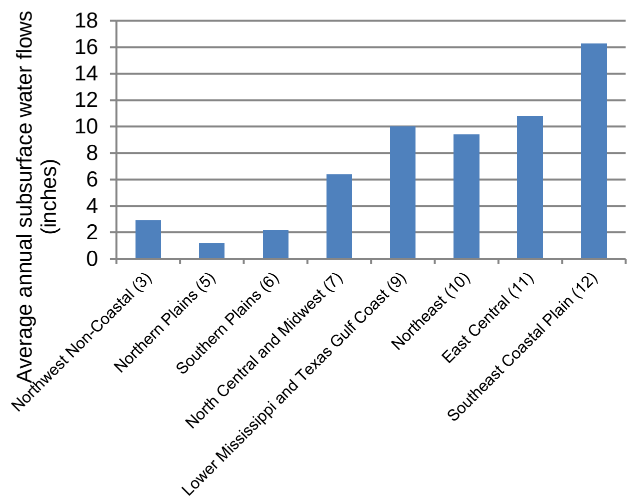


Figure 29. Sediments leaving a field contain plant nutrients in solution and attached to soil particles. Conservation practices can solve this problem.

[9] Model simulations did not include increased infiltration for some structural practices—model parameter settings conservatively prevented infiltration of run-on water and its dissolved contaminants in conservation buffers including field borders, filter strips and riparian forest buffers.

Edge-of-Field Sediment Loss from Water Erosion

The APEX component for water-induced erosion simulates erosion caused by rainfall, runoff, and irrigation. APEX contains eight equations capable of simulating rainfall and runoff erosion: universal soil loss equation (USLE); Onstad-Foster modification of the USLE; revised universal soil loss equation (RUSLE); RUSLE2; the modified universal soil loss equation (MUSLE); two variations of MUSLE; and a MUSLE function that accepts input coefficients. In any given simulation, only one of the equations interacts with other APEX components. For this study, a modified version of MUSLE, called MUST, was used for this purpose.[10]

The model variant MUST has an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates in some cases.

Sediment loss is thus the portion of the sheet and rill eroded material that is transported beyond the edge of the field and settles offsite as well as some sediment that originates from gully erosion processes.[11] Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable than other acres to sediment losses beyond the edge of the field.

According to the APEX model simulations, the mean of the average annual sediment loss estimates for cultivated cropland acres in all eight regions was 0.79 ton per acre per year (table 13). Sediment loss for HEL acres averaged 1.40 tons per acre per year, compared to only 0.55 tons per acre for non-HEL acres.

The median value for sediment loss for all acres—0.185—is much lower than the mean, indicating that the distribution of average annual estimates consists mostly of acres with low average annual sediment loss, in part due to the ameliorating effects of erosion control practices in use in 2003-06. In contrast, a few acres have very large losses; these are acres that are more vulnerable to erosion than other acres, such as HEL acres, and are inadequately treated with conservation practices. As shown in figure 30, about 77 percent of the cropped acres have average annual sediment loss estimates less than the mean of 0.79 tons per acre per year. Ten percent of cropped acres have average annual sediment loss above 2 tons per acre per year. Three percent have average annual sediment loss above 5 tons per acre per year.

Sediment loss is highest in the Lower Mississippi and Texas Gulf Coast (9) region, averaging 2.66 tons per acre per year for cultivated cropland (table 13 and figure 31). This region also had the largest amount of precipitation and irrigation water applied (fig. 26) and the largest amount of surface water runoff per year (fig. 27). Sediment loss averaged higher in this region for both HEL and non-HEL than in any of the other regions (table 13 and figs. 32 and 33).

Figure 30. Distribution of average annual sediment loss from water erosion (tons/acre) for sample points in all eight regions.

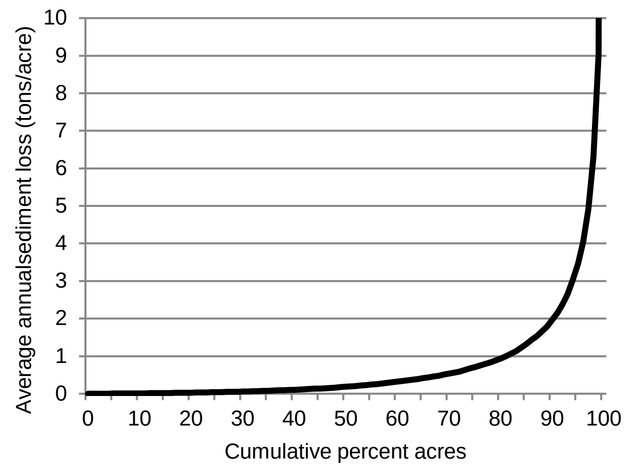
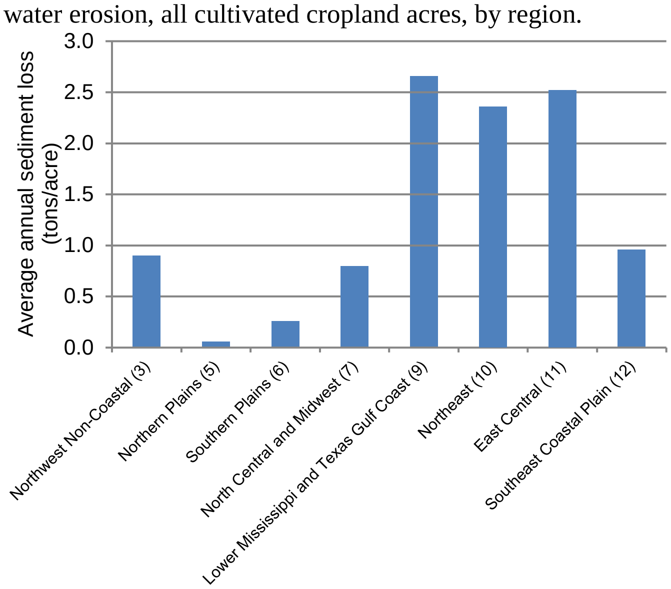


Figure 31. Mean of the average annual sediment loss from water erosion, all cultivated cropland acres, by region.



[10] For the study on the Texas Gulf Basin, the APEX model was set up to estimate sediment loss using MUSLE as the specified driver in APEX. This change was necessary to achieve better calibration of instream sediment loads in streams and rivers in this region when running the SWAT model as part of the modeling to estimate offsite effects of conservation practices.

[11] Estimates of sediment loss from water erosion do not include wind-eroded material that is subsequently deposited along field borders or in ditches and transported as sediment with rainfall and runoff events. However, wind eroded material incorporated into the soil with tillage or biological activity prior to a runoff event would be included.

Figure 32. Mean of the average annual sediment loss from water erosion, HEL acres, by region.

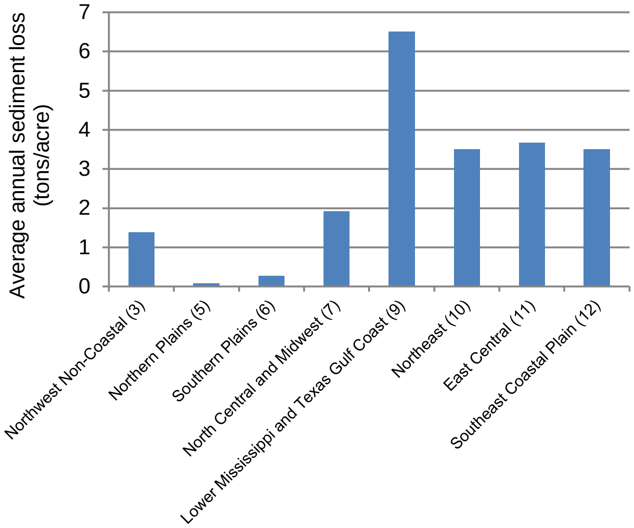


Figure 33. Mean of the average annual sediment loss from water erosion, non-HEL acres, by region.

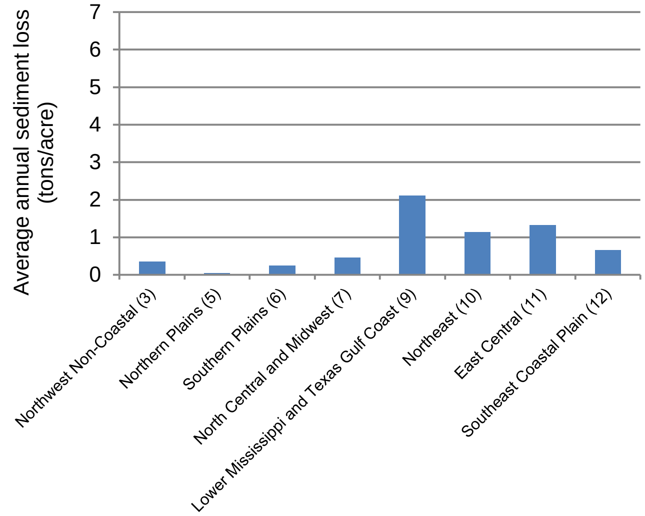


Table 13. Average annual estimates of sediment loss at edge of field from water erosion (tons/acre),* by region.

	Mean	Median	20th percentile	80th percentile
	All cultivated cropland acres			
Production region				
Northwest Non-Coastal (3)	0.901	0.144	0.026	0.840
Northern Plains (5)	0.063	0.032	0.010	0.081
Southern Plains (6)	0.260	0.057	0.008	0.307
North Central and Midwest (7)	0.797	0.340	0.091	1.050
Lower Mississippi and Texas Gulf Coast (9)	2.663	1.519	0.588	3.512
Northeast (10)	2.360	1.035	0.290	3.686
East Central (11)	2.523	1.073	0.286	3.213
Southeast Coastal Plain (12)	0.960	0.321	0.079	1.028
All eight regions	0.793	0.185	0.029	0.934
	HEL acres			
Production region				
Northwest Non-Coastal (3)	1.385	0.248	0.045	1.715
Northern Plains (5)	0.089	0.043	0.009	0.117
Southern Plains (6)	0.274	0.045	0.005	0.313
North Central and Midwest (7)	1.921	1.078	0.287	2.940
Lower Mississippi and Texas Gulf Coast (9)	6.500	3.666	1.646	9.278
Northeast (10)	3.505	2.079	0.593	5.268
East Central (11)	3.675	1.998	0.450	6.831
Southeast Coastal Plain (12)	3.503	1.335	0.359	4.189
All eight regions	1.399	0.250	0.024	1.913
	Non-HEL acres			
Production region				
Northwest Non-Coastal (3)	0.354	0.077	0.017	0.307
Northern Plains (5)	0.048	0.028	0.010	0.065
Southern Plains (6)	0.253	0.067	0.010	0.301
North Central and Midwest (7)	0.467	0.258	0.076	0.713
Lower Mississippi and Texas Gulf Coast (9)	2.115	1.373	0.550	2.990
Northeast (10)	1.147	0.562	0.207	1.511
East Central (11)	1.320	0.644	0.187	1.508
Southeast Coastal Plain (12)	0.659	0.274	0.073	0.836
All eight regions	0.547	0.170	0.030	0.739

*Estimated using MUSS, which includes some sediment from gully erosion. See text.
Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Average annual sediment loss for cropped acres was only slightly lower for two other regions—the East Central (11) region, with an average of 2.52 tons per acre per year, and the Northeast (10) region, with an average of 2.36 tons per acre per year (table 13 and fig. 31).

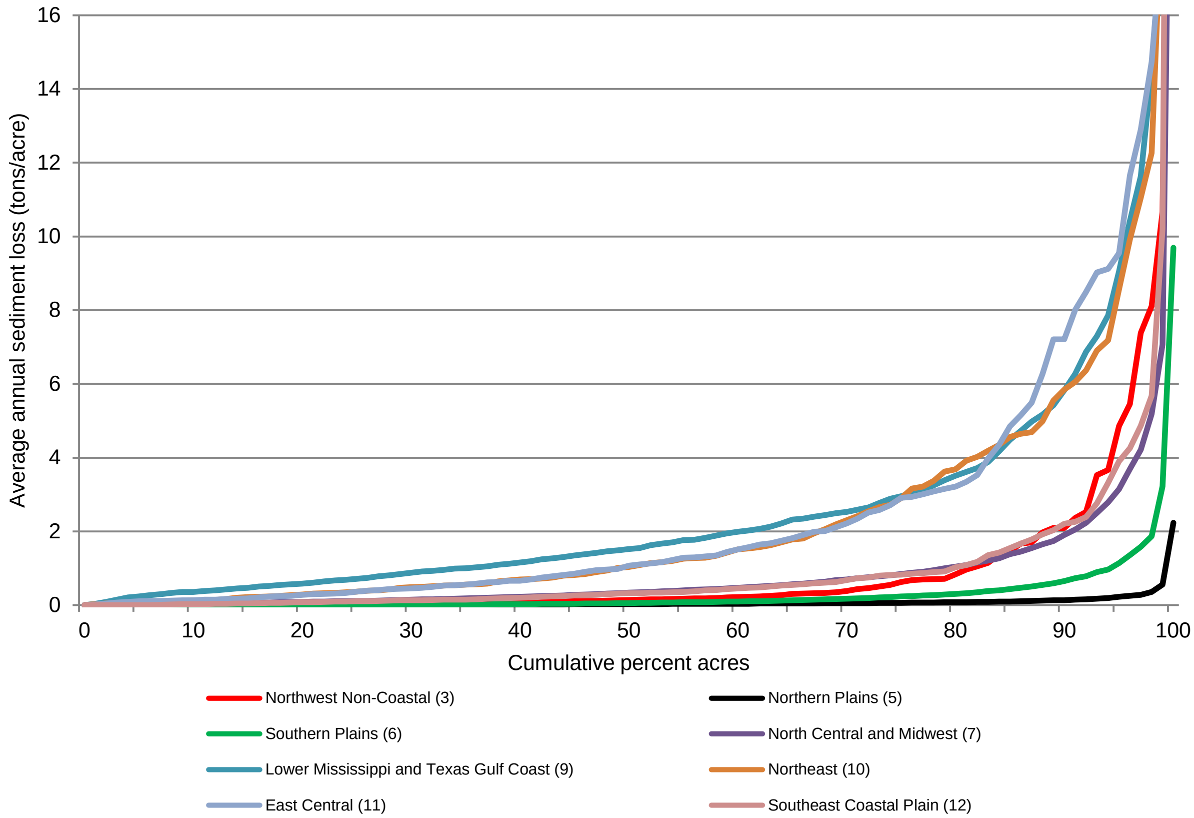
The distributions of the average annual sediment loss (tons/acre) for sample points in each of the eight production regions are contrasted in figure 34, which demonstrates the extent to which these three regions stand out as having the highest sediment losses at the edge of the field. Figure 26 shows that 32-40 percent of cultivated acres in these three regions exceeded 2 tons per acre per year.

Average annual sediment loss estimates in the Northern Plains (5) and Southern Plains (6) regions were low for all but a very few cultivated cropland acres (figs. 31-34). The average annual sediment loss was only 0.06 ton per acre per year in the Northern Plains (5) region and only 0.26 ton per acre per year in the Southern Plains (6) region.

The remaining three regions averaged less than 1 ton per acre per year of sediment loss for all cropped acres (table 13 and figure 23), but figure 34 shows that annual average sediment loss exceeds 2 tons per acre per year for between 9 and 12 percent of cultivated cropland acres in these three regions.

The largest of the losses shown in figure 34 are a combination of inadequate conservation treatment and a high intrinsic propensity for erosion determined by high slopes, soil types that erode more easily, and higher levels of precipitation and/or irrigation water applied. The smallest of the losses are acres that are essentially flat with permeable soil types that are more prone to infiltration than surface water runoff, or they are adequately treated with conservation practices. Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field.

Figure 34. Distributions of average annual sediment loss from water erosion for sample points in each of the eight regions.



Wind Erosion

Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

A concern of crop producers with wind erosion is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre have been known to cause physical damage to young seedlings.

Wind erosion can also deposit sediment rich in nutrients into adjacent ditches and surface drainage systems, where it is then transported to water bodies with runoff. Wind erosion rates greater than 2 tons per acre per year can result in significant losses of soil and associated contaminants over time. Wind erosion rates greater than 4 tons per acre can result in excessive soil loss annually and can also have adverse effects on human health.

According to the APEX model simulations, the mean of the average annual wind erosion rate for cultivated cropland acres in all eight regions was 1.35 tons per acre per year (table 14). The median, however, was much lower—0.17 ton per acre per year—indicating that wind erosion problems are important for a minority of cultivated cropland acres throughout the eight regions.

Table 14 and figure 35 shows that wind erosion concerns are mostly concentrated in the three westernmost regions:

- the Southern Plains (6) region, where the mean of the average annual wind erosion rate was 3.71 tons per acre per year and 23 percent of cropped acres had average annual wind erosion rates greater than 4 tons per acre per year,
- the Northwest Non-Coastal (3) region, where the mean of the average annual wind erosion rate was 2.07 tons per acre per year and 15 percent of cropped acres had average annual wind erosion rates greater than 4 tons per acre per year, and
- the Northern Plains (5) region, where the mean of the average annual wind erosion rate was 1.51 tons per acre per year and 10 percent of cropped acres had average annual wind erosion rates greater than 4 tons per acre per year.

Average annual wind erosion rates were below 1 ton per acre per year for all cropped acres in the Northeast (10) region, the East Central (11) region, and the Southeast Coastal Plain (12) region (fig. 35).

The North Central and Midwest (7) region and the Lower Mississippi and Texas Gulf Coast (9) region have a few acres with high average annual wind erosion rates, as shown in figure 35, but the bulk of the cultivated cropland acres in these two regions are low.

Table 14. Average annual estimates of wind erosion (tons/acre) for cultivated cropland acres,* by region.

	Mean	Median	20th percentile	80th percentile
Production region				
Northwest Non-Coastal (3)	2.067	0.731	0.040	3.543
Northern Plains (5)	1.514	0.630	0.147	2.149
Southern Plains (6)	3.709	1.201	0.181	5.045
North Central and Midwest (7)	0.386	0.065	0.007	0.413
Lower Mississippi and Texas Gulf Coast (9)	0.638	0.048	0.004	0.282
Northeast (10)	0.036	0.013	0.001	0.052
East Central (11)	0.017	0.003	0.000	0.023
Southeast Coastal Plain (12)	0.086	0.019	0.002	0.083
All eight regions	1.351	0.168	0.010	1.345

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Figure 35. Distributions of average annual wind erosion rates for sample points in each of the eight regions.

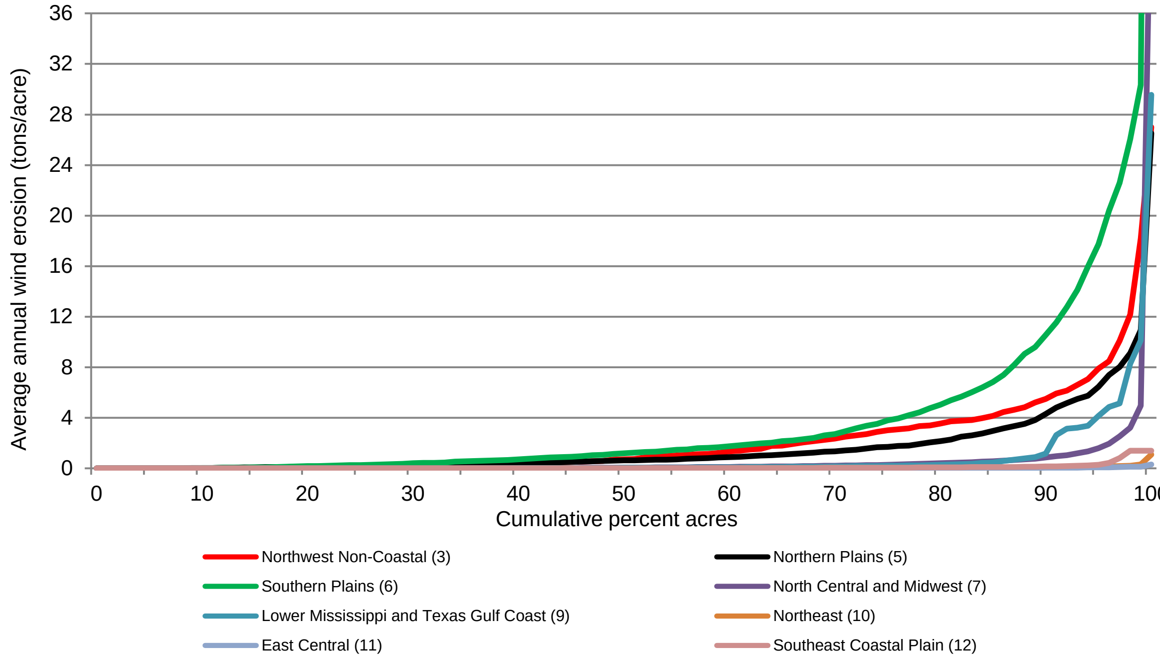


Figure 36. Feld windbreaks help protect the soil from erosion, provide wildlife habitat, improve air and water quality, and add aesthetic qualities to the landscape.

Phosphorus Loss from Farm Fields

Phosphorus Loss for All Regions Combined

The amount of phosphorus applied as commercial phosphorus and as manure, as represented in the APEX model simulations based on the 2003-06 survey data, averaged 17.4 pounds per acre for all eight regions combined (table 15). About 75 percent of this was taken up by crops and removed with the crop yield at harvest. About 9 percent—1.6 pounds per acre on average—was retained in the soil as soil phosphorus. The remaining 16 percent was lost from the farm fields through various loss pathways. According to the APEX model simulations, the mean of the average annual estimates of total phosphorus loss was 2.79 pounds per acre per year (table 15).

(Results throughout this report are in terms of elemental phosphorus—not the phosphate fertilizer equivalent.)

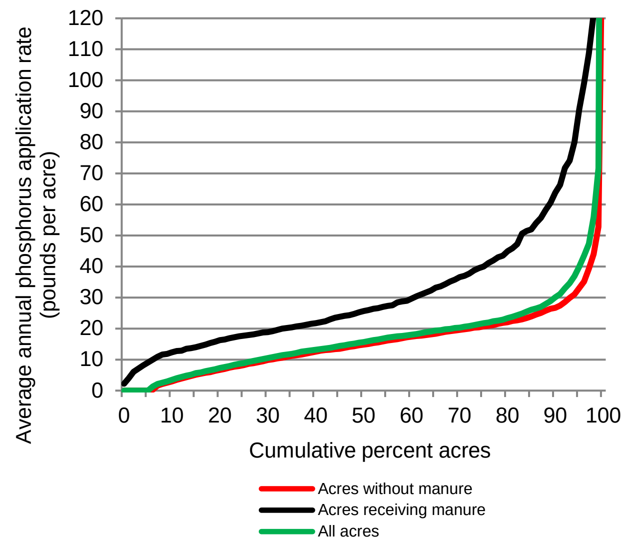
The amount of phosphorus applied ranged from zero for about 5 percent of the cropped acres to less than 10 pounds per acre for about one-fourth of the acres to 10-25 pounds per acre for over half of the acres and to amounts exceeding 100 pounds per acre for a few acres (fig. 37).

Acres with manure applied generally had higher application rates. For example, figure 37 shows that about 40 percent of the acres receiving manure had application rates of 30 pounds per acre or more, compared to only 7 percent of the acres not receiving manure. The average annual phosphorus application rate for acres receiving manure was 34 pounds per acre per year, nearly twice the average annual amount applied for acres not receiving manure (table 15).

The amount of phosphorus taken up by crops and removed with the crop yield at harvest is directly related to the amount of phosphorus applied, and also varies by crop. On average, the amount taken up by the crop and removed at harvest was 12.9 pounds per acre per year (table 15). However, the amount ranged from less than 5 pounds per acre per year for 15 percent of the acres to rates greater than 20 pounds per acre per year for 10 percent of the acres (fig. 38). The average was somewhat higher for acres receiving manure because of the higher application rates (table 15).

Some acres utilize more phosphorus than is applied, drawing it from reserves in the soil, while for other acres phosphorus levels build up over time. In the model simulations, about half of the cultivated cropland acres were building up phosphorus stocks in the soil and about half were mining phosphorus from the soil (fig. 39). About 70 percent of the acres had an average annual change in soil phosphorus between -5 and 5 pounds per acre per year. For about 5 percent of cropped acres, however, soil phosphorus was building up at a rate of 20 pounds per acre per year or more. The largest gains in soil phosphorus were for acres receiving manure. The average change in soil phosphorus for acres receiving manure was 12.7 pounds per acre per year, compared to an average of only 0.4 for acres not receiving manure (table 15). The 80th percentile change in soil phosphorus for acres receiving manure was 21.4 pounds per acre per year.

Figure 37. Distributions of the average annual amount of phosphorus applied for sample points in all eight regions.



Note: About 10 percent of cropped acres had manure applied in the eight regions

Figure 38. Distribution of the average annual amount of phosphorus in the crop yield removed at harvest for sample points in all eight regions.

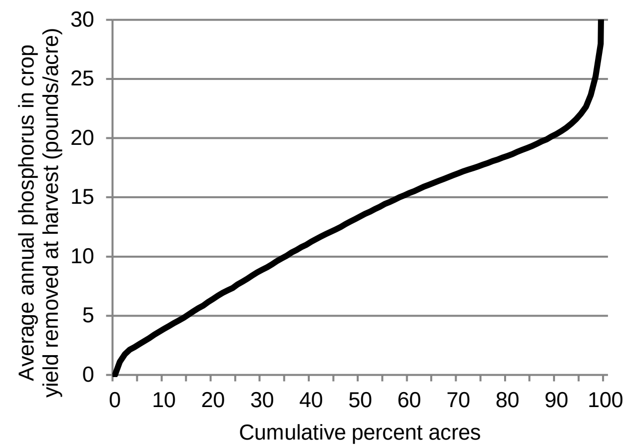


Figure 39. Distribution of the average annual amount of change in soil phosphorus for sample points in all eight regions.

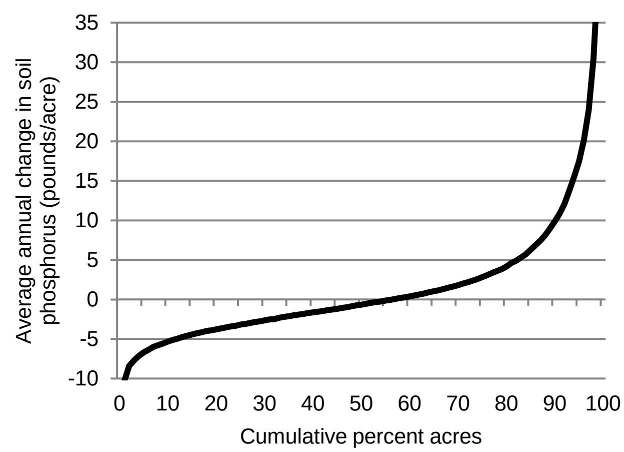


Table 15. Average annual estimates of phosphorus sources and losses from farm fields for cultivated cropland acres in all eight regions combined.

	Mean	Median	20th percentile	80th percentile
	All cultivated cropland acres, pounds per acre			
Phosphorus applied as commercial fertilizer and manure	17.37	15.69	7.30	23.35
Phosphorus in crop yield removed at harvest	12.88	13.38	6.42	18.51
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.83	0.24	0.02	1.18
Soluble phosphorus lost to surface water*	0.89	0.24	0.03	1.19
Phosphorus loss with waterborne sediment	1.04	0.33	0.05	1.36
Soluble phosphorus loss to groundwater	0.03	0.01	0.00	0.04
Total phosphorus loss for all loss pathways	2.79	1.69	0.72	3.87
Change in soil phosphorus	1.58	-0.67	-3.78	4.16
	Acres without manure applied, pounds per acre			
Phosphorus applied as commercial fertilizer and manure	15.58	14.86	6.70	22.03
Phosphorus in crop yield removed at harvest	12.57	12.95	6.03	18.35
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.79	0.24	0.02	1.16
Soluble phosphorus lost to surface water*	0.78	0.20	0.03	1.04
Phosphorus loss with waterborne sediment	0.91	0.29	0.04	1.24
Soluble phosphorus loss to groundwater	0.03	0.01	0.00	0.04
Total phosphorus loss for all loss pathways	2.50	1.59	0.67	3.57
Change in soil phosphorus	0.38	-0.91	-3.88	3.12
	Acres with manure applied, pounds per acre			
Phosphorus applied as commercial fertilizer and manure	34.05	25.61	16.22	44.97
Phosphorus in crop yield removed at harvest	15.73	16.09	11.40	19.71
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.24	0.19	0.02	1.37
Soluble phosphorus lost to surface water*	1.89	0.79	0.19	3.07
Phosphorus loss with waterborne sediment	2.29	0.82	0.21	3.07
Soluble phosphorus loss to groundwater	0.03	0.02	0.00	0.06
Total phosphorus loss for all loss pathways	5.45	3.19	1.30	7.34
Change in soil phosphorus	12.72	5.83	-1.90	21.45

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.
* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
Note: Phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Figure 40. The water cycle is the process by which water circulates between the atmosphere, oceans, and rivers.

The median of the estimate of total phosphorus loss for all loss pathways combined was 1.69 pounds per acre per year (table 9), substantially lower than the mean of 2.79 pounds per acre per year, indicating that the distribution includes some acres with much higher losses than most of the other acres. Based on the distribution of total phosphorus loss for all cultivated cropland acres in the eight regions, shown in figure 41:

- 29 percent had annual average phosphorus loss (all loss pathways) less than 1 pound per acre per year;
- 28 percent had total phosphorus loss between 1 and 2 pounds per acre per year;
- 23 percent had total phosphorus loss between 2 and 4 pounds per acre per year;
- 11 percent had total phosphorus loss between 4 and 7 pounds per acre per year; and
- 8 percent had total phosphorus loss greater than 7 pounds per acre per year.

Total phosphorus losses were highest for acres receiving manure. For example, 41 percent of cropped acres receiving manure had total phosphorus loss amounts greater than 4 pounds per acre per year, compared to 16 percent of cropped acres without manure (fig. 41). The average annual estimate of total phosphorus loss for acres receiving manure was 5.45 pounds per acre per year, over twice the average annual amount lost for acres not receiving manure (table 15).

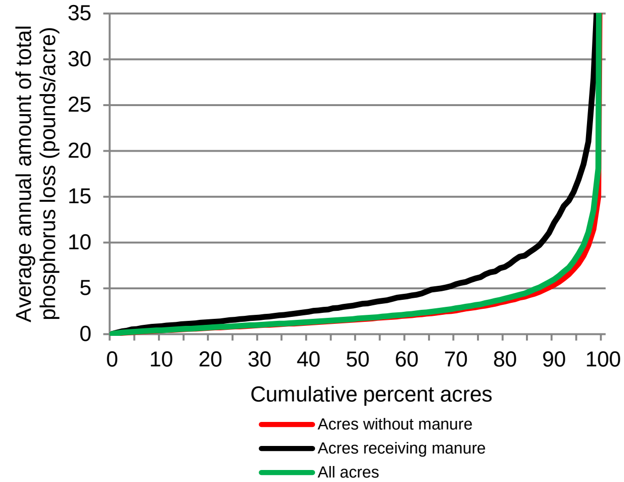
The APEX model simulation tracks phosphorus loss from farm fields through four loss pathways. On average for all sample points in the eight regions (table 15):

- phosphorus lost with windborne sediment averages 0.83 pound per acre per year, accounting for 30 percent of the total phosphorus loss;
- phosphorus lost with waterborne sediment averages 1.04 pounds per acre per year, accounting for 37 percent of the total phosphorus loss;
- soluble phosphorus lost to surface water, including phosphorus dissolved in surface water runoff and water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, averages 0.89 pound per acre per year, accounting for 32 percent of the total phosphorus loss; and
- soluble phosphorus that percolates through the soil profile into the groundwater averages 0.03 pound per acre per year, accounting for only 1 percent of the total phosphorus loss.

Phosphorus losses in all loss pathways were higher, on average, for acres receiving manure than for acres without manure applications (table 15).

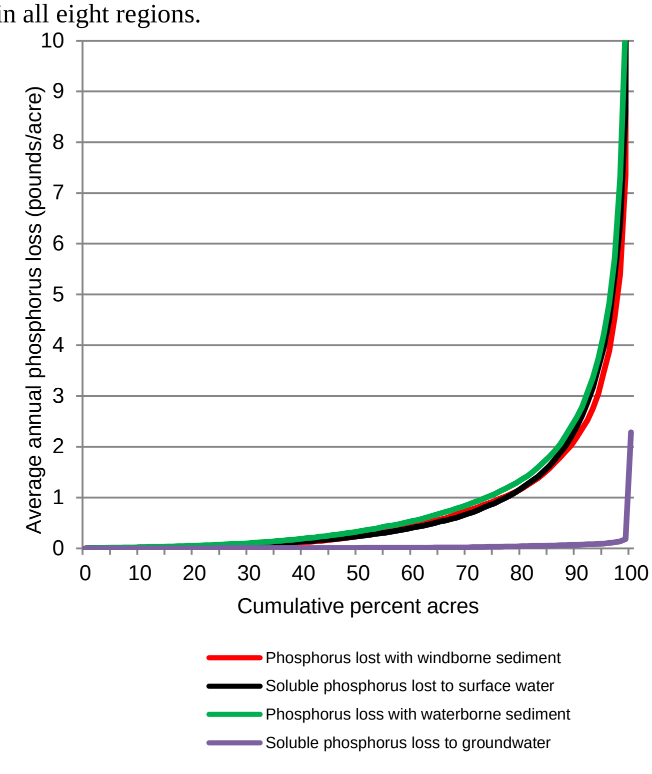
The amount of phosphorus lost in each of the three principal loss pathways varies considerably from acre to acre, as shown by the distributions presented in figure 42.

Figure 41. Distributions of average annual amount of total phosphorus lost from farm fields (all loss pathways) for sample points in all eight regions.



Note: About 10 percent of cropped acres had manure applied in the eight regions

Figure 42. Distributions of average annual amount of phosphorus lost through four loss pathways for sample points in all eight regions.



Phosphorus Loss by Production Region

A large part of the variability shown in the distributions presented in figures 37-39 and 41-42 is because of differences in climate, soils, crops grown, nutrient management, and use of conservation practices from region to region.

Most cultivated cropland acres in the three westernmost regions—the Northwest Non-Coastal (3) region, the Northern Plains (5) region, and the Southern Plains (6) region—have, relative to the other five regions (table 16 and figs. 43-48):

- the lowest phosphorus application rates,
- the smallest amount of phosphorus removed in the crop yields at harvest, and
- the smallest amounts of total phosphorus lost (all loss pathways) from farm fields.

The sharp distinction between these three regions and the others is clearly shown in the regional comparisons of the distributions of phosphorus application rates, uptake and removal rates, and total losses from farm fields in figures 46, 47, and 48.

As shown previously, these three regions also have:

- the smallest average amounts of precipitation and irrigation water applied (fig. 25),
- the smallest average amounts of surface water runoff (fig. 27),
- the smallest average amounts of loss of water through subsurface flow pathways (fig. 28), and
- the smallest average amounts of sediment loss from farm fields (together with the North Central and Midwest (7) region) (fig. 31).

The two regions with the largest average amount of total phosphorus loss (all loss pathways) (table 16, figs. 45 and 48) are the same two regions that had the largest amount of phosphorus applied (table 16, figs. 43 and 46):

- the East Central (11) region, where the mean of the average annual total phosphorus loss is 5.91 pounds per acre per year, and
- the Northeast (10) region, where the mean of the average annual total phosphorus loss is 5.86 pounds per acre per year.

The North Central and Midwest (7) region, which has the most cultivated cropland acres (fig. 2), had the largest average amount of phosphorus taken up by the crop and removed at harvest—16.94 pounds per acre per year (fig. 44 and fig. 47). This region ranked fourth in average annual total phosphorus loss (table 16 and fig. 45), following the three westernmost regions. About 14 percent of the average annual amount applied per acre was lost from farm fields in this region, the second lowest proportion only to the Northern Plains (6) region with 13 percent. The relatively high yields in the North Central and Midwest (7) resulted in a smaller proportion of the amount of phosphorus applied being susceptible to the forces of wind and water.

Figure 43. Mean of the average annual phosphorus applied as commercial fertilizer and manure, by region.

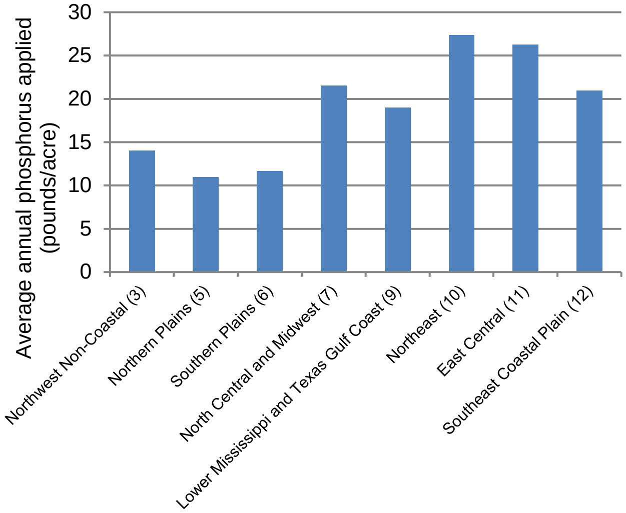


Figure 44. Mean of the average annual phosphorus in crop yield removed at harvest, by region.

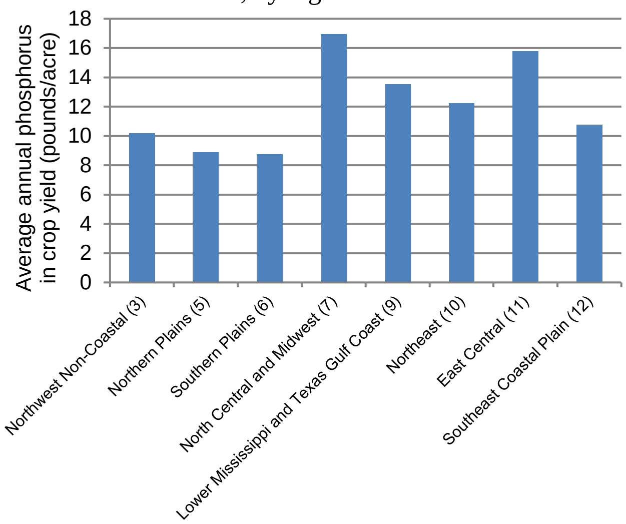


Figure 45. Mean of the average annual total phosphorus loss for all loss pathways, by region.

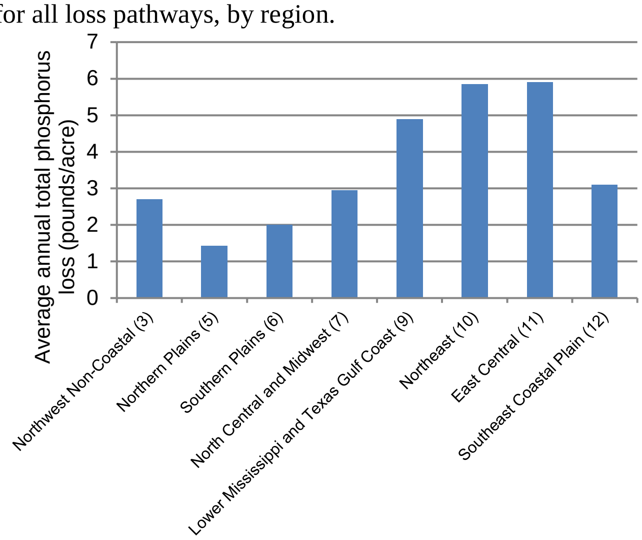


Table 16. Average annual estimates of phosphorus sources and losses from farm fields for cultivated cropland acres, by region combined.

	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)
	All cultivated cropland acres, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	14.02	10.94	11.62	21.51
Phosphorus in crop yield removed at harvest	10.19	8.91	8.74	16.94
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.56	1.22	1.48	0.55
Soluble phosphorus lost to surface water*	0.29	0.13	0.18	1.10
Phosphorus loss with waterborne sediment	0.84	0.09	0.31	1.28
Soluble phosphorus loss to groundwater	0.02	0.00	0.03	0.02
Total phosphorus loss for all loss pathways	2.70	1.43	2.00	2.95
Change in soil phosphorus	1.06	0.59	0.71	1.46
	Acres without manure applied, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	11.90	10.52	10.64	19.49
Phosphorus in crop yield removed at harvest	9.90	8.81	8.53	16.96
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.30	1.18	1.37	0.48
Soluble phosphorus lost to surface water*	0.24	0.12	0.17	0.99
Phosphorus loss with waterborne sediment	0.80	0.08	0.31	1.11
Soluble phosphorus loss to groundwater	0.02	0.00	0.03	0.02
Total phosphorus loss for all loss pathways	2.36	1.38	1.87	2.60
Change in soil phosphorus	-0.44	0.33	0.11	-0.25
	Acres with manure applied, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	76.73	22.56	35.52	33.07
Phosphorus in crop yield removed at harvest	18.93	11.71	13.74	16.85
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	9.15	2.36	4.18	0.97
Soluble phosphorus lost to surface water*	1.88	0.38	0.46	1.73
Phosphorus loss with waterborne sediment	1.84	0.12	0.52	2.25
Soluble phosphorus loss to groundwater	0.03	0.01	0.03	0.03
Total phosphorus loss for all loss pathways	12.89	2.87	5.19	4.97
Change in soil phosphorus	45.26	8.01	15.39	11.22

Table 16.– continued.

	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)
	All cultivated cropland acres, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	18.98	27.37	26.26	20.94
Phosphorus in crop yield removed at harvest	13.53	12.23	15.81	10.76
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.19	0.05	0.02	0.13
Soluble phosphorus lost to surface water*	2.06	2.31	2.75	1.81
Phosphorus loss with waterborne sediment	2.58	3.44	3.08	1.08
Soluble phosphorus loss to groundwater	0.06	0.06	0.05	0.08
Total phosphorus loss for all loss pathways	4.89	5.86	5.91	3.10
Change in soil phosphorus	0.43	9.19	4.24	7.06
	Acres without manure applied, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	18.67	16.93	24.43	19.65
Phosphorus in crop yield removed at harvest	13.49	11.28	15.48	10.51
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.19	0.05	0.02	0.13
Soluble phosphorus lost to surface water*	2.00	1.40	2.61	1.73
Phosphorus loss with waterborne sediment	2.58	2.31	2.80	1.09
Soluble phosphorus loss to groundwater	0.06	0.06	0.05	0.08
Total phosphorus loss for all loss pathways	4.83	3.82	5.48	3.03
Change in soil phosphorus	0.22	1.68	3.20	6.07
	Acres with manure applied, mean value (pounds per acre)			
Phosphorus applied as commercial fertilizer and manure	33.81	39.38	36.80	31.72
Phosphorus in crop yield removed at harvest	15.15	13.33	17.72	12.86
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.08	0.05	0.03	0.08
Soluble phosphorus lost to surface water*	5.11	3.35	3.57	2.44
Phosphorus loss with waterborne sediment	2.26	4.75	4.74	1.02
Soluble phosphorus loss to groundwater	0.05	0.06	0.06	0.08
Total phosphorus loss for all loss pathways	7.51	8.20	8.40	3.62
Change in soil phosphorus	10.43	17.83	10.22	15.30

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Note: Phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Figure 46. Distributions of average annual amount of phosphorus applied for sample points in each of the eight regions.

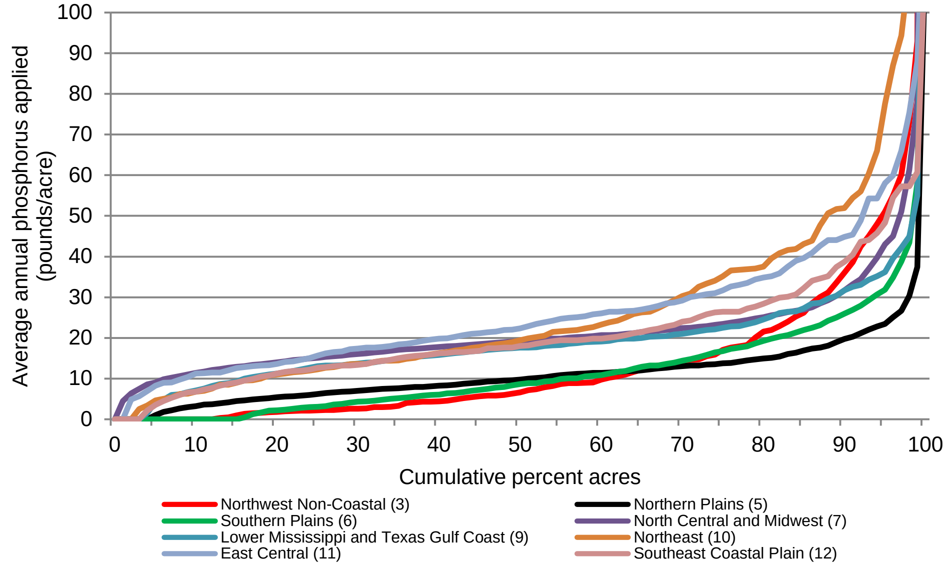


Figure 47. Distributions of average annual amount of phosphorus in the crop yield removed at harvest for sample points in each of the eight regions.

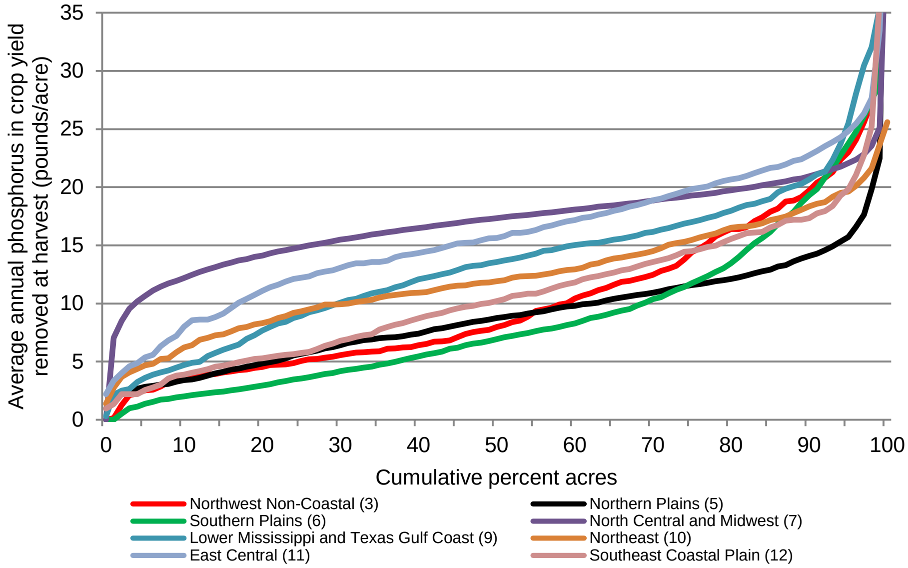
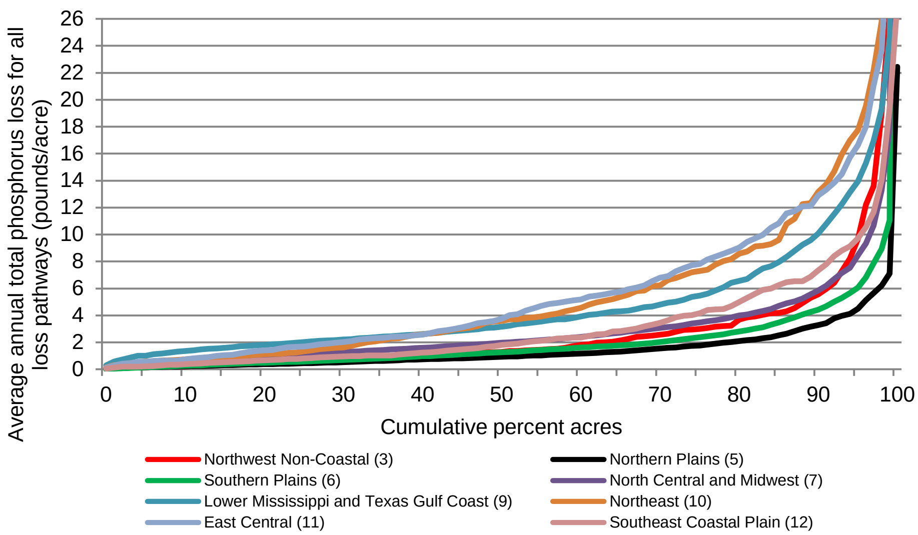


Figure 48. Distributions of average annual amount of total phosphorus lost from farm fields (all loss pathways) for sample points in each of the eight regions.



The principal phosphorus loss pathways also differed by region, reflecting differences in precipitation and surface water runoff, as shown in figures 49 through 54. Soluble phosphorus loss to groundwater was insignificant for all cropped acres, representing less than 2 percent of the total phosphorus loss in each region.

The principal loss pathway in the three westernmost regions, where wind erosion rates are high (fig. 35), was phosphorus lost with windborne sediment (figs. 49 and 52, table 16):

- 85 percent of total phosphorus loss from farm fields in the Northern Plains (5) region was lost with windborne sediment;
- 74 percent of total phosphorus loss from farm fields in the Southern Plains (6) region was lost with windborne sediment; and
- 58 percent of total phosphorus loss from farm fields in the Northwest Non-Coastal (3) region was lost with windborne sediment.

Soluble phosphorus lost to surface water, which includes phosphorus dissolved in surface water runoff and water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, is an important loss pathway in all but the three westernmost regions (figs. 50 and 53). It was the principal loss pathway for cropped acres only in the Southeast Coastal Plain (12) region, where it represented 58 percent of total phosphorus loss, on average (fig. 50). However, it is an important secondary loss pathway in the other four regions, accounting for 37-47 percent of total phosphorus losses.

In three regions, over half of the total phosphorus lost from farm fields was phosphorus lost with waterborne sediment. In these regions, phosphorus lost with waterborne sediment represented (fig. 51):

- 59 percent of total phosphorus loss in the Northeast (10) region,
- 53 percent of total phosphorus loss in the Lower Mississippi and Texas Gulf Coast (9) region, and
- 52 percent of total phosphorus loss in the East Central (11) region.

Phosphorus lost with waterborne sediment was an important secondary loss pathway in all other regions except the Northern Plains (5) and the Southern Plains (6) regions (figs. 51 and 54).

The North Central and Midwest (7) region is the only region where all phosphorus loss pathways, other than the loss of soluble phosphorus to groundwater, had average annual losses above 1 pound per acre per year for a significant percentage of cropped acres (figs. 52-54). Average annual losses were above 1 pound per acre per year for:

- 14 percent of cropped acres for phosphorus loss with windborne sediment,
- 30 percent of cropped acres for soluble phosphorus lost to surface water, and
- 37 percent of cropped acres for phosphorus loss with waterborne sediment.

Figure 49. Phosphorus lost with windborne sediment as a percent of total phosphorus loss, by region.

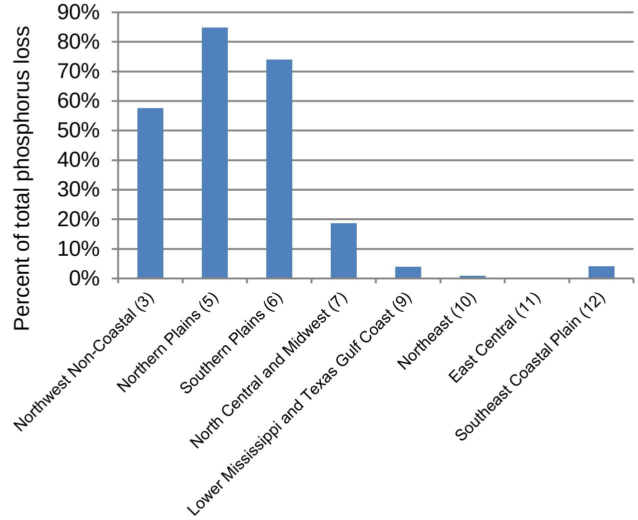


Figure 50. Soluble phosphorus lost to surface water as a percent of total phosphorus loss, by region.

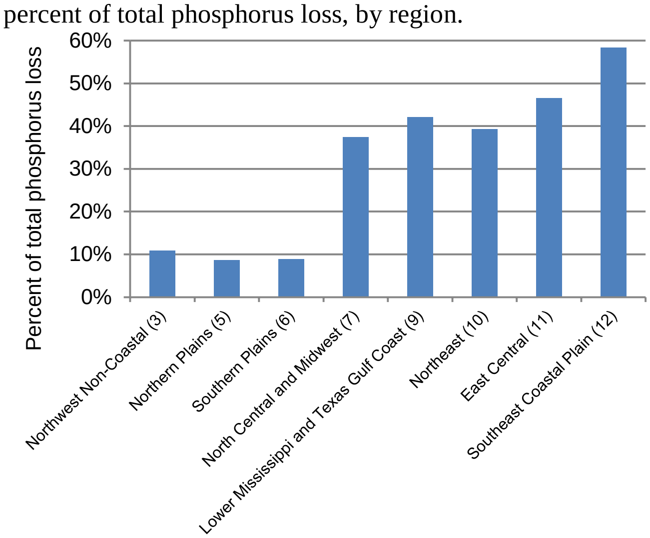


Figure 51. Phosphorus lost with waterborne sediment as a percent of total phosphorus loss, by region.

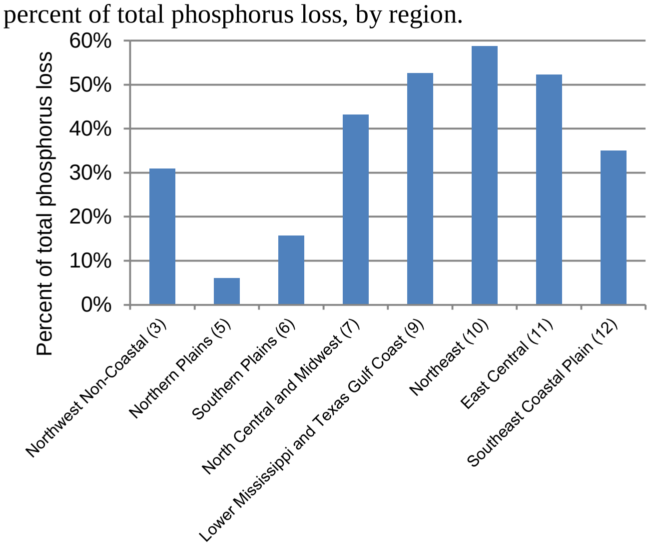


Figure 52. Distributions of average annual amount of phosphorus lost with windborne sediment for sample points in each of the eight regions.

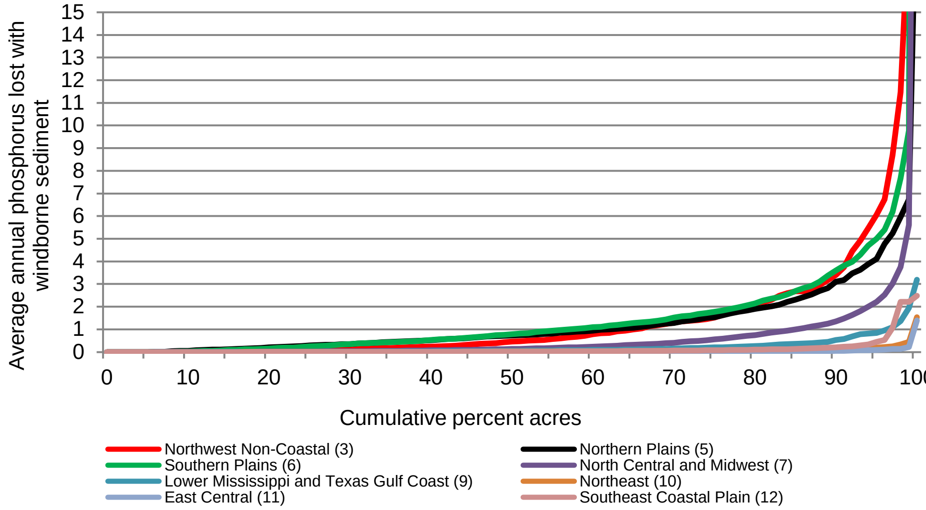


Figure 53. Distributions of average annual amount of soluble phosphorus lost to surface water for sample points in each of the eight regions.

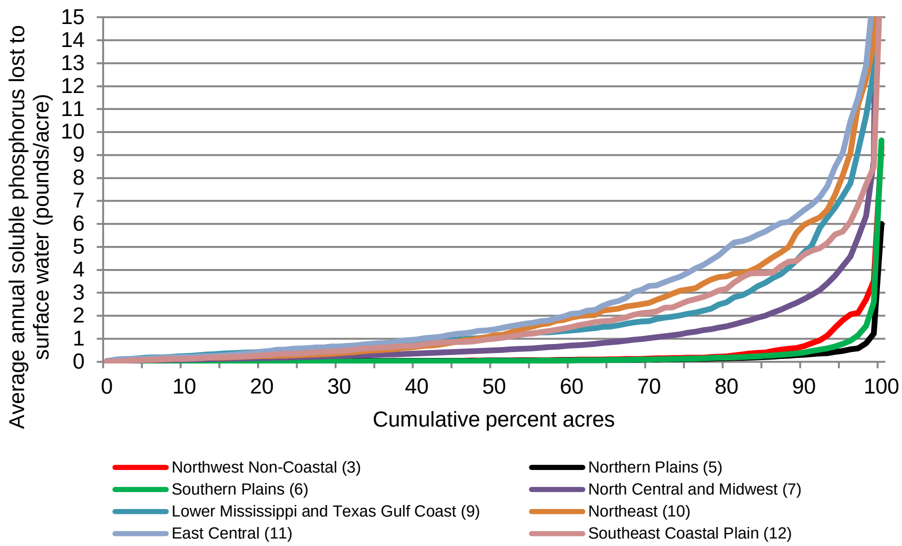
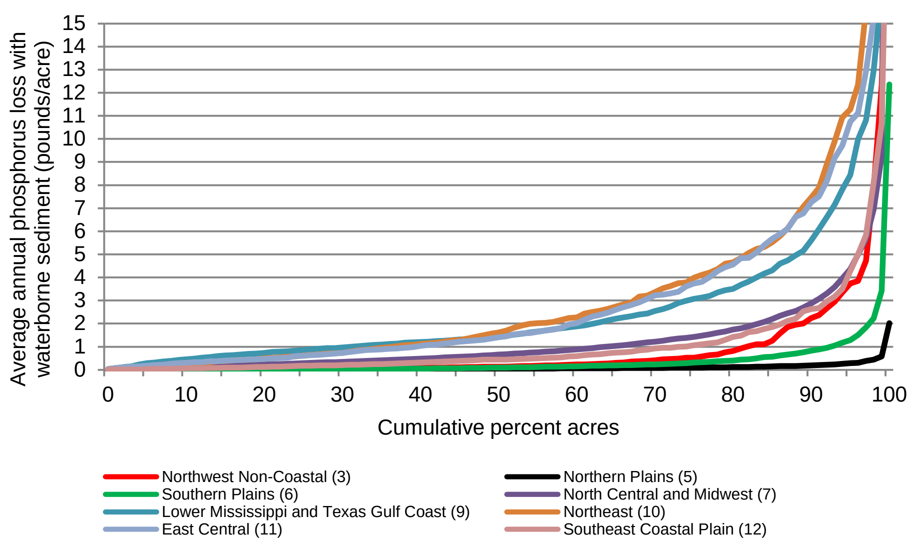


Figure 54. Distributions of average annual amount of phosphorus lost with waterborne sediment for sample points in each of the eight regions.



Breakdown of Phosphorus Loss Estimates by Levels of Conservation Treatment

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to soluble nutrient losses through subsurface flow pathways.

The adequacy of conservation practice use in 2003-06 for control of total phosphorus lost to surface water was evaluated. Estimates of "total phosphorus lost to surface water" were obtained by adding the amount of waterborne phosphorus (phosphorus attached to sediment) to estimates of soluble phosphorus lost to surface water (soluble phosphorus in surface water runoff and phosphorus in water moving laterally within the soil into drainage systems and natural seeps). The evaluation accounts for four levels of soil vulnerability to runoff and four levels of conservation treatment.

Criteria were defined for four "soil runoff potentials" to characterize the inherent vulnerability for water runoff to occur. These criteria are presented in Appendix B. The criteria were then used to define the soil runoff potential at each sample point.[12] For all eight regions combined, about 10 percent of the cultivated cropland acres have a "high" soil runoff potential, most of which are HEL acres (fig. 55). Another 19 percent have a moderately high soil runoff potential, more than half of which are HEL acres. The majority of acres—53 percent—have a "low" soil runoff potential. (A significant proportion of acres with a "low" soil runoff potential are also HEL acres, shown in figure 55. These are primarily HEL acres in the drier regions and are designated as HEL because of a high vulnerability to wind erosion.)

Average annual phosphorus loss estimates were determined for the each of four "phosphorus runoff control treatment levels" (presented previously; see figure 23) at each of the four "soil runoff potentials" to provide further insight on what factors were most responsible for the amounts of total phosphorus lost to surface water as estimated in the model simulations.

This resulted in a 4-by-4 matrix with 16 cells where each cell consisted of a mean value of the average annual estimates of total phosphorus lost to surface water for a specific subset of sample points. Table 17 provides estimates of acres and the average annual total phosphorus lost to surface water for each of the 16 cells for all eight regions combined, as well as estimates of the percentage of acres with unacceptably high losses.

The mean of the average annual total phosphorus lost to surface water was 1.93 pounds per acre per year for all cropped acres in all eight regions. As the soil runoff potential increased from "low" to "high," the mean steadily increased. The mean of the average annual total phosphorus lost to surface water was (table 17):

- 2.31 pounds per acre per year for cropped acres with a "low" soil runoff potential;
- 3.49 pounds per acre per year for cropped acres with a "moderate" soil runoff potential;
- 5.54 pounds per acre per year for cropped acres with a "moderately high" soil runoff potential; and
- 8.95 pounds per acre per year for cropped acres with a "high" soil runoff potential.

Similarly, the mean steadily decreased with increasing levels of conservation treatment for phosphorus runoff control. The mean of the average annual total phosphorus lost to surface water was (table 17):

- 3.91 pounds per acre per year for cropped acres with a "low" level of treatment;
- 2.14 pounds per acre per year for cropped acres with a "moderate" level of treatment;
- 0.97 pound per acre per year for cropped acres with a "moderately high" level of treatment; and
- 0.66 pound per acre per year for cropped acres with a "high" level of treatment.

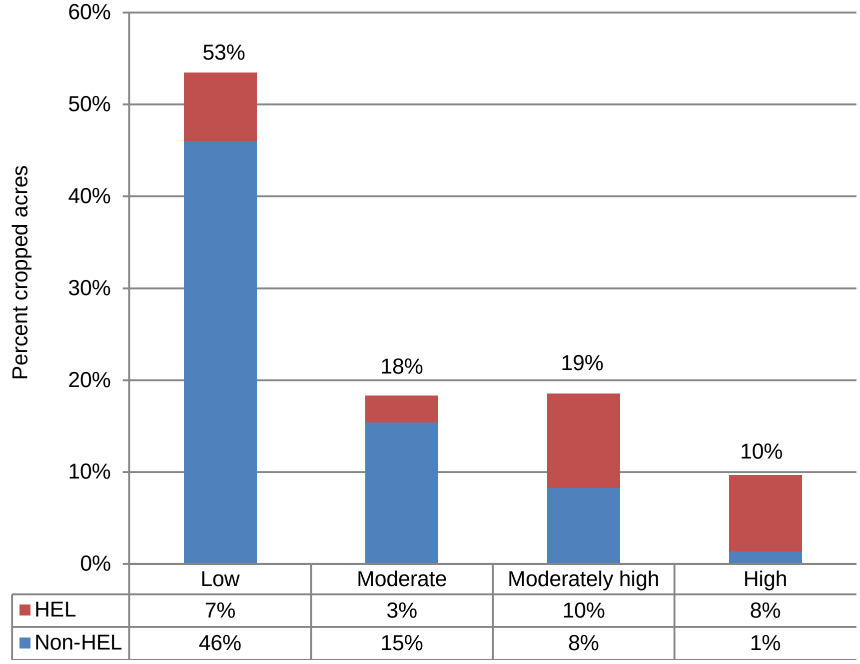
Table 17 also shows that the mean steadily decreased with increasing levels of conservation treatment for groups of acres within each soil runoff potential. The highest estimate of the average annual total phosphorus lost to surface water shown in the table 17 matrix—8.95 pounds per acre per year—was for acres with a "low" level of conservation treatment for phosphorus runoff control and a 'high" soil runoff potential.

At the "high" level of conservation treatment, estimates of the average annual total phosphorus lost to surface water were low at all soil runoff potentials, ranging from 0.49 to 1.16 pounds per acre per year. The increasing trend in phosphorus loss with increasing levels of soil runoff potentials breaks down for the "high" level of conservation treatment because at that level all the acres would be expected to be adequately treated.

At the "moderately high" level of conservation treatment, estimates of the average annual total phosphorus lost to surface water were also relatively low at all soil runoff potentials, ranging from 0.66 to 1.64 pounds per acre per year. Estimates of the average annual total phosphorus lost to surface water were more substantial at all soil runoff potentials for the "moderate" and the "low" conservation treatment levels, steadily increasing as the soil runoff potential increased.

[12] Soil runoff potentials were used with conservation treatment levels to estimate conservation treatment needs in the previously published CEAP reports for each water resource region.

Figure 55. Soil runoff potential for cultivated cropland acres, all eight regions combined.



Note: Criteria for defining the soil runoff potentials are presented in Appendix B.

Table 17. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, all eight regions combined.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	24,416,126	59,089,674	52,984,293	18,689,071	155,179,165
Moderate	8,683,356	22,739,116	17,494,947	4,077,118	52,994,537
Moderately high	9,889,206	26,533,647	15,061,970	2,304,120	53,788,943
High	5,274,371	15,035,647	7,626,200	189,133	28,125,352
All	48,263,060	123,398,084	93,167,411	25,259,442	290,087,997
Percent of cropped acres					
Low	8%	20%	18%	6%	53%
Moderate	3%	8%	6%	1%	18%
Moderately high	3%	9%	5%	1%	19%
High	2%	5%	3%	<1%	10%
All	17%	43%	32%	9%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	2.31	1.51	0.66	0.51	1.22
Moderate	3.49	2.43	1.33	1.16	2.14
Moderately high	5.54	2.60	1.29	1.08	2.71
High	8.95	3.37	1.64	0.49	3.93
All	3.91	2.14	0.97	0.66	1.93
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	19%	9%	1%	<1%	7%
Moderate	31%	19%	4%	<1%	15%
Moderately high	48%	21%	5%	<1%	21%
High	66%	29%	7%	0%	30%
All	32%	16%	3%	<1%	13%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 17 also presents the percentage of acres in each of the 16 cells of the 4-by-4 matrix that exceed 4 pounds per acre per year of total phosphorus lost to surface water as a guide to determining the extent of cropped acres with excessive phosphorus loss. Estimates of total phosphorus lost to surface water at the edge of the field greater than 4 pounds per acre per year are generally considered to be unacceptable and require additional conservation treatment. [13]

About 13 percent of the cropped acres in the eight regions—totaling 38 million acres—have average annual estimates of total phosphorus lost to surface water greater than 4 pounds per acre per year (table 17). Most of these acres (18.3 million acres) are concentrated in the four groups of acres with "low" or "moderate" levels of conservation treatment and "high" or "moderately high" soil runoff potentials. For example, 66 percent of the acres with a "low" conservation treatment level and a "high" soil runoff potential have estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year (table 17).

Overall, 32 percent of cropped acres with a "low" level of conservation treatment for runoff control had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year (table 17). About 16 percent of cropped acres with a "moderate" level of conservation treatment for runoff control had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year. Only 3 percent of the cropped acres with a "moderately high" level of conservation treatment and less than 1 percent of cropped acres with a "high" level of conservation treatment had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year.

The four matrixes in table 17 are repeated in tables 18-25 for each of the regions. The decreasing trend in phosphorus loss with increasing levels of conservation treatment and the increasing trend in phosphorus loss with increasing levels of soil runoff potentials shown in table 17 for all eight regions combined remained strong in two regions (except for a couple of combinations where the number of samples was very small)—the North Central and Midwest (7) region and the Northeast (10) region.

In most other regions, the trends are evident but generally weaker because, in part, one or more of the soil runoff potentials or conservation treatment levels are represented by too few acres to make reliable comparisons. The decreasing trend in phosphorus loss with increasing levels of conservation treatment held up in most cases. The increasing trend in phosphorus loss with increasing levels of soil runoff potentials was generally weaker and would break down for some comparisons, even where the sample sizes were adequate for comparisons. In the three westernmost regions, where phosphorus lost with windborne sediment was the principal loss pathway for phosphorus, the very low levels of total phosphorus lost to surface water obfuscated the trends in some cases, as differences in the average annual estimates were often small.

Nevertheless, these matrixes clearly show that for each region the lowest rates of total phosphorus lost to surface water are for acres with the higher levels of conservation treatment for phosphorus runoff control when the inherent soil runoff vulnerability is taken into account.

About two-thirds of the 38 million acres with estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year are concentrated in two regions:

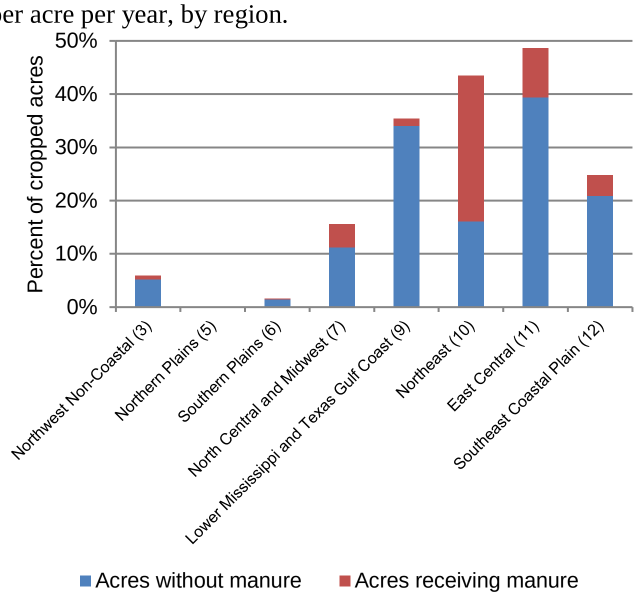
- the North Central and Midwest (7) region, where 16 percent of cropped acres (18.4 million acres) had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year, and
- the Lower Mississippi and Texas Gulf Coast (9) region, where 35 percent of cropped acres (7.5 million acres) had estimates of average annual total phosphorus lost to surface water greater than 4 pounds per acre per year.

Three other regions had a high percentage of cropped acres with excessive phosphorus loss rates (fig. 56):

- the Northeast (10) region, with 43 percent of cropped acres,
- the East Central (11) region, with 49 percent, and
- the Southeast Coastal Plain (12) (fig. 56), with 25 percent.

Together, these three regions account for 27 percent of the cropped acres with excessive levels of total phosphorus lost to surface water. The remaining three regions each accounted for less than 3 percent.

Figure 56. Percent of cultivated cropland acres with estimates of total phosphorus lost to surface water greater than 4 pounds per acre per year, by region.



[13] In previous CEAP reports, acceptable levels for edge-of-field sediment loss, nitrogen loss, and phosphorus loss were used to estimate conservation treatment needs. Losses above these levels were treated as unacceptable levels of loss based on what could be realistically achieved with today's crop production and conservation technologies.

Table 18. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Northwest Non-Coastal (3) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,050,714	1,912,676	1,402,101	209,244	4,574,735
Moderate	89,860	99,523	94,540	0	283,923
Moderately high	301,815	1,869,218	681,517	83,858	2,936,408
High	148,629	2,438,583	1,060,190	34,545	3,681,946
All	1,591,018	6,320,000	3,238,348	327,646	11,477,012
Percent of cropped acres					
Low	9%	17%	12%	2%	40%
Moderate	1%	1%	1%	0%	2%
Moderately high	3%	16%	6%	1%	26%
High	1%	21%	9%	<1%	32%
All	14%	55%	28%	3%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	1.14	0.52	0.25	0.33	0.57
Moderate	1.14	0.26	0.23	na	0.53
Moderately high	4.24	0.83	0.22	0.38	1.03
High	1.64	2.56	0.65	0.21	1.95
All	1.78	1.40	0.37	0.33	1.13
Percent of acres in baseline scenario with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	6%	3%	0%	0%	3%
Moderate	5%	0%	0%	0%	2%
Moderately high	28%	7%	0%	0%	7%
High	8%	13%	0%	0%	9%
All	10%	8%	0%	0%	6%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 19. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Northern Plains (5) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	2,445,471	8,622,174	8,867,860	3,832,794	23,768,299
Moderate	1,105,021	4,762,849	3,197,043	363,980	9,428,893
Moderately high	1,999,260	5,720,220	3,104,050	420,146	11,243,675
High	577,644	2,268,284	402,104	0	3,248,032
All	6,127,396	21,373,526	15,571,057	4,616,921	47,688,900
Percent of cropped acres					
Low	5%	18%	19%	8%	50%
Moderate	2%	10%	7%	1%	20%
Moderately high	4%	12%	7%	1%	24%
High	1%	5%	1%	0%	7%
All	13%	45%	33%	10%	100%
Estimates of phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	0.23	0.19	0.11	0.15	0.16
Moderate	0.42	0.27	0.17	0.25	0.25
Moderately high	0.26	0.23	0.24	0.24	0.24
High	0.39	0.40	0.22	NA	0.38
All	0.29	0.24	0.15	0.17	0.21
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	<1%	0%	0%	1%	<1%
Moderate	0%	0%	0%	0%	0%
Moderately high	0%	0%	0%	0%	0%
High	0%	0%	0%	0%	0%
All	<1%	0%	0%	1%	<1%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 20. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Southern Plains (6) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	8,585,364	17,050,406	16,853,402	5,005,293	47,494,465
Moderate	1,663,111	2,663,461	2,587,653	347,611	7,261,836
Moderately high	1,188,741	3,632,653	2,271,488	337,992	7,430,874
High	118,195	850,509	407,806	0	1,376,509
All	11,555,411	24,197,029	22,120,348	5,690,896	63,563,684
Percent of cropped acres					
Low	14%	27%	27%	8%	75%
Moderate	3%	4%	4%	1%	11%
Moderately high	2%	6%	4%	1%	12%
High	<1%	1%	1%	0%	2%
All	18%	38%	35%	9%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	0.47	0.30	0.17	0.32	0.29
Moderate	1.43	1.07	0.43	0.69	0.91
Moderately high	1.97	1.45	0.87	0.65	1.32
High	0.75	1.34	0.47	NA	1.04
All	0.76	0.59	0.28	0.36	0.49
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	<1%	0%	0%	0%	<1%
Moderate	8%	8%	0%	0%	5%
Moderately high	20%	7%	2%	0%	8%
High	0%	12%	0%	0%	8%
All	3%	2%	<1%	0%	2%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 21. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, North Central and Midwest (7) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	5,019,325	21,983,494	20,427,371	8,819,872	56,250,063
Moderate	2,167,206	8,470,329	7,374,923	2,733,304	20,745,761
Moderately high	3,672,756	11,527,279	8,263,025	1,390,841	24,853,901
High	2,508,952	7,659,580	5,250,354	154,588	15,573,475
All	13,368,239	49,640,682	41,315,673	13,098,605	117,423,200
Percent of cropped acres					
Low	4%	19%	17%	8%	48%
Moderate	2%	7%	6%	2%	18%
Moderately high	3%	10%	7%	1%	21%
High	2%	7%	4%	<1%	13%
All	11%	42%	35%	11%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	2.45	2.21	1.09	0.70	1.59
Moderate	3.37	2.88	1.55	1.19	2.24
Moderately high	6.18	3.44	1.77	1.44	3.18
High	8.84	4.19	2.00	0.56	4.17
All	4.82	2.92	1.42	0.88	2.38
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	19%	14%	2%	<1%	8%
Moderate	27%	22%	3%	0%	13%
Moderately high	61%	29%	7%	1%	25%
High	73%	40%	8%	0%	34%
All	42%	23%	4%	<1%	16%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 22. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Lower Mississippi and Texas Gulf (9) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,447,313	3,270,160	2,191,034	394,173	7,302,679
Moderate	2,168,750	4,850,424	3,632,191	586,059	11,237,424
Moderately high	974,286	1,118,551	118,232	32,046	2,243,116
High	200,729	164,694	13,858	0	379,281
All	4,791,079	9,403,829	5,955,315	1,012,278	21,162,500
Percent of cropped acres					
Low	7%	15%	10%	2%	35%
Moderate	10%	23%	17%	3%	53%
Moderately high	5%	5%	1%	<1%	11%
High	1%	1%	<1%	0%	2%
All	23%	44%	28%	5%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	8.31	5.01	2.56	1.60	4.74
Moderate	4.87	3.86	2.57	1.82	3.53
Moderately high	12.43	6.16	4.42	2.39	8.74
High	14.87	7.42	1.10	NA	11.13
All	7.86	4.60	2.60	1.75	4.64
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	72%	38%	15%	1%	36%
Moderate	46%	32%	11%	2%	26%
Moderately high	90%	61%	33%	0%	71%
High	100%	64%	0%	0%	81%
All	65%	38%	13%	2%	35%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 23. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus control, Northeast (10) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	950,871	733,015	483,246	31,714	2,198,846
Moderate	309,950	331,989	149,673	15,582	807,195
Moderately high	734,106	812,904	158,830	9,333	1,715,173
High	929,119	773,898	123,269	0	1,826,286
All	2,924,046	2,651,806	915,019	56,630	6,547,500
Percent of cropped acres					
Low	15%	11%	7%	<1%	34%
Moderate	5%	5%	2%	<1%	12%
Moderately high	11%	12%	2%	<1%	26%
High	14%	12%	2%	0%	28%
All	45%	41%	14%	1%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	6.48	2.58	0.97	0.64	3.89
Moderate	8.28	3.91	1.93	1.10	5.17
Moderately high	8.48	4.30	1.79	0.84	5.84
High	11.86	4.77	1.73	NAa	8.17
All	8.88	3.91	1.37	0.80	5.75
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	52%	13%	3%	0%	27%
Moderate	72%	38%	10%	0%	45%
Moderately high	69%	28%	10%	0%	44%
High	81%	48%	6%	0%	62%
All	67%	31%	6%	0%	44%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 24. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, East Central (11) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	615,260	1,533,634	779,330	154,635	3,082,859
Moderate	331,646	730,583	251,596	18,437	1,332,261
Moderately high	594,581	1,460,726	373,524	23,234	2,452,065
High	738,860	753,612	363,544	0	1,856,015
All	2,280,346	4,478,554	1,767,994	196,306	8,723,200
Percent of cropped acres					
Low	7%	18%	9%	2%	35%
Moderate	4%	8%	3%	<1%	15%
Moderately high	7%	17%	4%	<1%	28%
High	8%	9%	4%	0%	21%
All	26%	51%	20%	2%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	7.37	4.39	1.55	2.16	4.16
Moderate	5.94	4.83	1.38	1.47	4.41
Moderately high	10.41	6.14	2.54	1.74	6.58
High	13.86	6.68	2.15	NA	8.65
All	10.06	5.42	1.86	2.05	5.83
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	67%	35%	4%	10%	32%
Moderate	68%	52%	5%	0%	46%
Moderately high	90%	56%	12%	0%	57%
High	94%	62%	21%	0%	67%
All	82%	49%	9%	8%	49%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 25. Breakdown of cultivated cropland acres and estimates of total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Southeast Coastal Plain (12) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	4,301,808	3,984,115	1,979,950	241,345	10,507,218
Moderate	847,812	829,958	207,329	12,145	1,897,243
Moderately high	423,660	392,097	91,303	6,670	913,731
High	52,243	126,488	5,076	0	183,808
All	5,625,524	5,332,658	2,283,658	260,160	13,502,000
Percent of cropped acres					
Low	32%	30%	15%	2%	78%
Moderate	6%	6%	2%	<1%	14%
Moderately high	3%	3%	1%	<1%	7%
High	<1%	1%	<1%	0%	1%
All	42%	39%	17%	2%	100%
Estimates of total phosphorus lost to surface water for the baseline scenario (average annual pounds/acre)					
Low	3.62	1.95	0.69	0.39	2.36
Moderate	5.88	3.73	1.13	1.03	4.39
Moderately high	8.07	4.68	1.20	0.99	5.88
High	4.68	2.30	0.55	NA	2.93
All	4.31	2.44	0.75	0.43	2.89
Percent of acres in baseline scenario with average annual total phosphorus lost to surface water more than 4 pounds/acre					
Low	37%	14%	<1%	0%	20%
Moderate	62%	26%	0%	0%	39%
Moderately high	61%	42%	0%	0%	46%
High	21%	25%	0%	0%	23%
All	42%	18%	<1%	0%	25%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Effects of Conservation Practices—Preliminaries

The No-Practice Scenario

The baseline results presented in previous sections include the benefits and effects of conservation practices in use in 2003-06. Program routines and parameter settings within the APEX model allow for simulation of the presence of structural erosion control practices, and tillage practices are represented by daily field operations simulated in the model. The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey.

To estimate the effects of these practices already represented in the baseline scenario, an alternative simulation was created by removing the practices or reversing their effects, called the "no-practice" scenario. The "no-practice" scenario simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline scenario. For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used instead. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios at each sample point, and then aggregating over the points for national and regional estimates. The reduction in phosphorus loss, for example, is the phosphorus loss estimate for the no-practice scenario minus the phosphorus loss estimate for the baseline scenario. This calculation is made using the average annual values at each sample point. National level results are then obtained by calculating the acres-weighted mean of the average annual reduction over all the sample points in the eight production regions. The percent reduction is calculated by dividing the difference by the no-practice scenario estimate.

The no-practice scenario also included specific features to remove or reverse the effects of other practices not targeted specifically at reducing nutrient loss, but which could have some effect on nutrient loss:[14]

- Cover crops, which could also affect soil erosion and nutrient loss, but were not in common use in 2003-06.
- Irrigation management, which could increase nutrient losses in the no-practice scenario where less efficient irrigation systems are simulated.

No-practice representation of structural practices. The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "good" to "poor" for the determination of the runoff curve number for erosion prediction.

For overland flow practices such as terraces and contouring, which slow the flow of water across the field, the P factor of the USLE-based equation was increased to 1. Slope length was also changed to reflect the absence of these slope-interrupting practices.

For concentrated flow practices such as grassed waterways and grade stabilization structures, which are designed to prevent areas of concentrated flow from developing gullies, or to stabilize gullies that have developed, the no-practice protocol removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully. Sediment contributions from the gully will come from downcutting. (Headcutting and sloughing of the sides are not simulated in APEX.)

For edge-of-field practices such as buffers and filters, which occur outside the primary production area, the no-practice protocol removes these areas from the model representation as well as their management. The slope length is also restored to the undisturbed length that it would have been had the practices not been in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

Windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. In the baseline scenario, the unsheltered distance was reduced to represent the presence of these wind control practices. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Wind control practices represented in the baseline scenario were removed in the no-practice scenario and the unsheltered distance returned to 400 meters.

No-practice representation of conservation tillage. The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, the no-practice scenario simulates conventional tillage based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. Those crops grown with a STIR value of less than 100 in the baseline scenario had tillage operations added in the no-practice scenario. Two consecutive tandem disk operations were added prior to planting.[15] The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the

[14] For more information on the representation of the no-practice scenario in the APEX model simulation, see the collection of previously published regional CEAP reports based on the 2003-06 survey database.

[15] The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all regions, and for both dryland and irrigated agriculture.

crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from "good" to "poor" on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a "poor" hydrologic condition curve number.

No-practice representation of nutrient management practices. The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques. Three of the four basic aspects of nutrient application—rate, timing, and method—were altered to represent nutrient applications that would be expected if there was no regard to the levels of nutrient losses from farm fields. The form of application was not addressed because of the inability based on survey responses to determine if proper form was being applied.

<u>**Commercial nitrogen fertilizer rate and manure applications**</u>**.** For the no-practice scenario, the amount of nitrogen applied was increased for crops that met the following criteria, indicating that appropriate application rates were in use as represented in the modeling of the baseline scenario.

- The total of all applications of nitrogen (commercial fertilizer and manure applications) was less than or equal to 1.4 times the amount of nitrogen removed at harvest in the baseline scenario for non-legume crops except cotton and small grain crops.
- The total of all applications of nitrogen (commercial fertilizer and manure applications) was less than or equal to 1.6 times the amount of nitrogen removed at harvest in the baseline scenario for small grain crops.
- The total of all applications of nitrogen (commercial fertilizer and manure applications) for cotton was less than or equal to 60 pounds per bale.

The assessment was made on an average annual basis for <u>each crop</u> in the rotation using average annual model output on nitrogen removed with the yield at harvest in the model results for the baseline scenario. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer.

For cotton, the amount of nitrogen applied in the no-practice scenario was increased to 90 pounds per acre for cotton crops that met the above criterion.

For other crops that met the above criteria, the amount of nitrogen applied in the no-practice scenario was increased sufficiently to raise the ratio of the application rate to harvest removal to a higher value. For small grain crops, the application rate was increased to bring the application rate up to 2.0 times the amount of nitrogen removed at harvest. For other non-legume crops, the application rate was increased to bring the application rate up to a level that depended on the Water Resource Region where the sample point was located in order to account for yield potential differences from region to region. These application rate levels ranged from a low of 1.64 times the amount of nitrogen removed at harvest in the Upper Mississippi River Basin to a high of 2.0 times the amount of nitrogen removed at harvest in the Pacific Northwest Water Resource Region (table 26). (These rate-to-yield-removal ratios were determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4 in each Water Resource Region.)

All nitrogen applications, including manure applications, were increased proportionately so that the total application rate equaled the no-practice rate of application described above.

Nitrogen application rates were not adjusted for legume crops in the no-practice scenario, remaining the same as in the baseline scenario.

<u>**Commercial phosphorus fertilizer rate**</u>**.** Phosphorus application rates in the no-practice scenario were adjusted to higher levels based on the total amount of phosphorus applied to <u>all of the crops in the crop rotation</u>, rather on a crop-by-crop basis as was done for nitrogen.

The threshold for identifying proper commercial phosphorus application rates as represented in the modeling of the baseline scenario was 1.1 times the amount of phosphorus taken up by <u>all</u> the crops in rotation and removed at harvest. Phosphorus application rates for sample points with phosphorus applications at or below this threshold were increased for the no-practice scenario.[16] Any increase in phosphorus from manure added to meet the nitrogen criteria for the no-practice scenario was taken into account in setting the no-practice commercial phosphorus fertilizer application rate.

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased sufficiently to raise the ratio of the application rate to harvest removal for the full crop rotation to a higher value. As was done for nitrogen, the higher level depended on the Water Resource Region where the sample point was located in order to account for yield potential differences from region to region. These commercial phosphorus application rates ranged from a low of 1.57 times the amount of phosphorus removed at harvest in the Missouri River Basin to a high of 2.7 times the amount of phosphorus removed at harvest in the South Atlantic Gulf Water Resource Region (table 26). (These rate-to-yield-

[16] The threshold is lower for phosphorus than for nitrogen because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles.

removal ratios were determined by the average rate-to-yield-removal ratio for sample points where the amount of phosphorus applied to all crops in the rotation exceeded 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest in each Water Resource Region.)

Commercial phosphorus application rates were increased proportionately for all crops in the rotation. No adjustment was made to manure applied at rates below the P threshold of 1.1 in the no-practice scenario because the manure application rate was based on the nitrogen level in the manure.

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment.

All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting for the no-practice scenario.

Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Commercial fertilizer applications and manure applications that were incorporated or banded in the baseline scenario were changed to a surface broadcast application method for the no-practice scenario.

Table 26. Levels to which nutrient application rates were increased to represent the no-practice scenario in model simulations.

Water Resource Regions	Increase in nitrogen application rates for each non-legume crop other than small grain crops and cotton.	Increase in commercial phosphorus application rates for all crops in the rotation
Upper Mississippi River Basin	to 1.64 times amount removed at harvest by cop	to 1.60 times amount removed at harvest from all crops in rotation
Ohio and Tennessee River Basins and Great Lakes Basin	to 1.70 times amount removed at harvest by crop	to 1.80 times amount removed at harvest from all crops in rotation
Souris-Red-Rainy River Basins	to 1.83 times amount removed at harvest by crop	to 1.71 times amount removed at harvest from all crops in rotation
Chesapeake Bay and Delaware River Basins	to 1.98 times amount removed at harvest by crop	to 2.20 times amount removed at harvest from all crops in rotation
South Atlantic Gulf Region	to 1.85 times amount removed at harvest by crop	to 2.70 times amount removed at harvest from all crops in rotation
Lower Mississippi River Basin	to 1.90 times amount removed at harvest by crop	to 2.30 times amount removed at harvest from all crops in rotation
Pacific Northwest Region	to 2.00 times amount removed at harvest by crop	to 2.05 times amount removed at harvest from all crops in rotation
Missouri River Basin	to 1.68 times amount removed at harvest by crop	to 1.57 times amount removed at harvest from all crops in rotation
Texas Gulf Region and Arkansas-White-Red River Basins	to 1.90 times amount removed at harvest by crop	to 2.00 times amount removed at harvest from all crops in rotation

Effects of Conservation Practices on Water Loss

Water loss from farm fields is a principle determinant of sediment and nutrient losses. The effect of conservation practices on water loss is summarized in this section to provide a perspective on the results presented for phosphorus loss in the next chapter.

Model simulations indicate that conservation practices have reduced surface water runoff by an average of about 0.64 inch per year averaged over all acres, representing a 14-percent reduction nationally (table 27). The distributions of the average annual estimates of surface water runoff in the baseline scenario and the no-practice scenario are contrasted in figure 57. The distribution for the no-practice scenario shows what surface water runoff would be if there were no conservation practices in use—more surface water runoff and thus less subsurface flow and thus less soil moisture available for crop growth.

The average annual reductions in surface water runoff due to conservation practices range among the sample points from less than zero to above 5 or more inches per year (fig. 58). The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off or infiltrate. Figure 58 shows that, for about 45 percent of the cultivated cropland acres in the eight regions, the effects of conservation practices on surface water runoff were very small—average annual reductions less than 0.2 inch per year. In contrast, the effects of practices were high for the top 15 percent, where surface water runoff was reduced by 1 inch or more per year due to the use of conservation practices.

About 10 percent of the acres had less surface water runoff in the no-practice scenario than in the baseline scenario resulting in the negative reductions shown in figure 58. In general, these gains in surface water runoff due to practices are small, and occur on soils with low to moderate potential for surface water runoff together with: (1) higher nutrient application rates in the no-practice scenario that result in more biomass production, which can reduce surface water runoff (typically rotations with hay or continuous corn); or (2) the additional tillage simulated in the no-practice scenario provided increased random roughness of the surface reducing runoff on nearly level landscapes with low crop residue rotations.

Most of the reductions in surface water runoff are re-routed to subsurface flow loss pathways, resulting in gains in subsurface flows for many acres due to the use of conservation practices. Model simulations indicate that conservation practices have increased the volume of water lost through subsurface flow pathways by an average annual amount of 0.5 inch per year, representing a 9-percent increase nationally (table 27). The re-routing of surface water to subsurface flows is shown graphically in figures 59 and 60. The baseline scenario curve in figure 48 shows higher subsurface flows than the no-practice curve. Figure 60 shows that the gain in subsurface flows due to conservation practices ranges among the sample points from an average of less than zero to 5 or more inches per year.

Figure 57. Distributions of average annual surface water runoff for the baseline and no-practice scenarios, all eight regions combined.

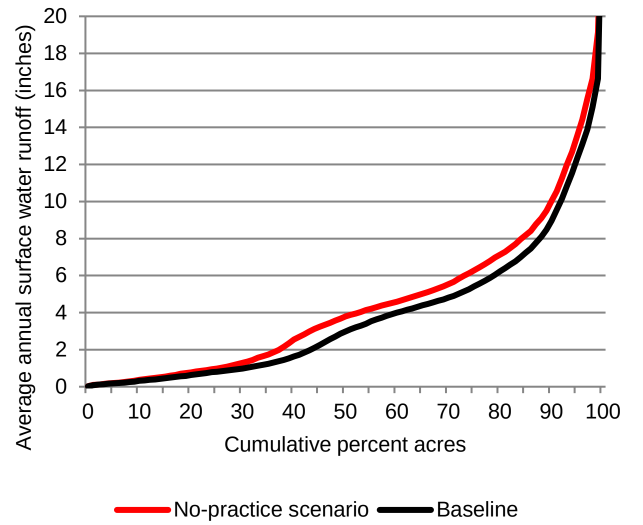
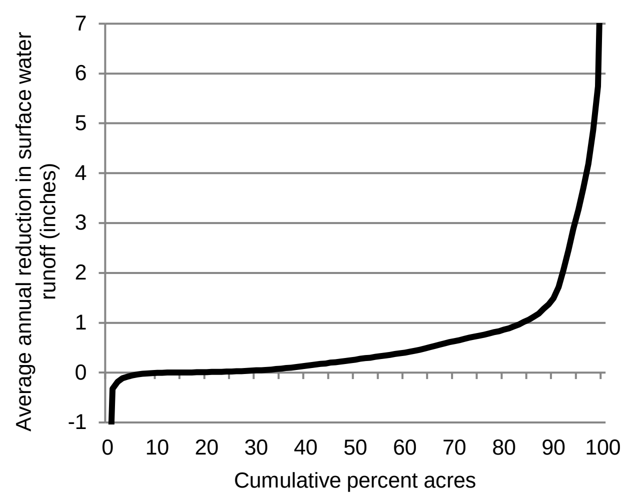


Figure 58. Distribution of average annual reductions in surface water runoff due to the use of conservation practices, all eight regions combined.



For about 30 percent of the cultivated cropland acres the effects of conservation practices on subsurface water flows were near zero. Conservation practice use resulted in gains ranging from 0.1 to 1.0 inch per year for about 45 percent of cultivated cropland acres. Gains were greater than 1 inch per year for only about 15 percent (fig. 60).

Model simulations showed that reductions in subsurface water flows (shown as negative gains in figure 60) occur on up to about 10 percent of cultivated cropland acres. These were mostly irrigated acres in areas where weather during the growing season was often hot and dry. In some of these situations, a significant portion of the surface water runoff that is re-routed through infiltration into the soil is taken up by the crop and thus does not contribute to any of the subsurface flow loss pathways. In addition, any ponding of irrigation water applied on nearly level landscapes would also be susceptible to greater rates of evaporation, further reducing the volume of water available for loss through subsurface flow pathways.

Table 27. Effects of conservation practices on water loss from farm fields.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
Northwest Non-Coastal (3) region				
Average annual surface water runoff (inches)	1.71	2.56	0.86	33%
Average annual subsurface water flow (inches)	2.94	2.89	-0.06*	-2%
Northern Plains (5) region				
Average annual surface water runoff (inches)	0.66	0.77	0.11	14%
Average annual subsurface water flow (inches)	1.19	1.03	-0.15*	-15%
Southern Plains (6) region				
Average annual surface water runoff (inches)	1.38	2.33	0.94	41%
Average annual subsurface water flow (inches)	2.19	2.12	-0.08*	-4%
North Central and Midwest (7) region				
Average annual surface water runoff (inches)	4.32	4.78	0.46	10%
Average annual subsurface water flow (inches)	6.42	5.74	-0.68*	-12%
Lower Mississippi and Texas Gulf Coast (9) region				
Average annual surface water runoff (inches)	13.07	14.63	1.56	11%
Average annual subsurface water flow (inches)	9.95	8.84	-1.11*	-13%
Northeast (10) region				
Average annual surface water runoff (inches)	6.11	6.59	0.48	7%
Average annual subsurface water flow (inches)	9.42	8.83	-0.60*	-7%
East Central (11) region				
Average annual surface water runoff (inches)	8.22	8.99	0.77	9%
Average annual subsurface water flow (inches)	10.82	10.00	-0.82*	-8%
Southeast Coastal Plain (12) region				
Average annual surface water runoff (inches)	6.02	6.98	0.95	14%
Average annual subsurface water flow (inches)	16.28	15.85	-0.44*	-3%
All eight regions combined				
Average annual surface water runoff (inches)	3.85	4.49	0.64	14%
Average annual subsurface water flow (inches)	5.41	4.96	-0.46*	-9%

* Represents gains in water lost in subsurface flow pathways because of re-routing of surface water runoff due to conservation practice use.

Figure 59. Distributions of average annual subsurface water flow for the baseline and no-practice scenarios, all eight regions combined.

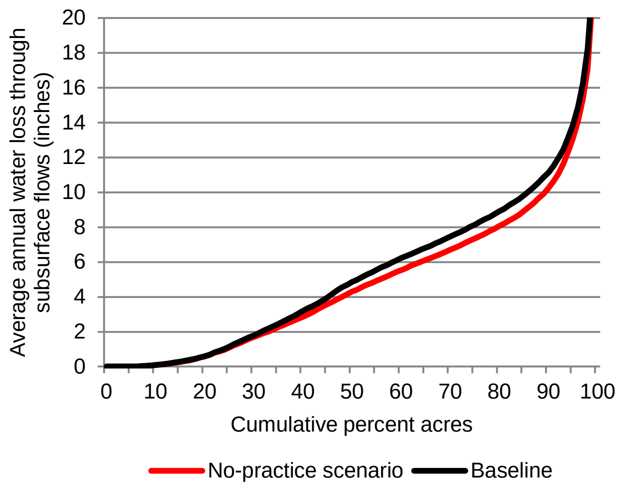
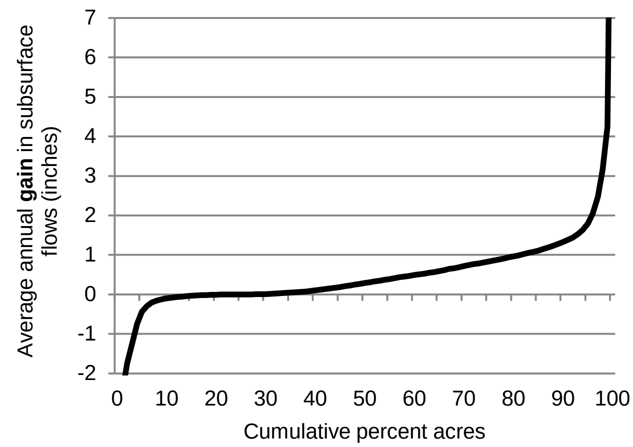


Figure 60. Distribution of average annual gain in subsurface water flows due to the use of conservation practices, all eight regions combined.



The effects of conservation practices on water loss from farm fields vary substantially across the eight production regions (table 27, figs. 61-64).

Conservation practices have been the most effective in reducing surface water runoff in the Lower Mississippi and Texas Gulf Coast (9) region. The mean of the average annual reductions in surface water runoff due to conservation practices was 1.56 inches per year, representing an 11 percent reduction relative to the no-practice scenario (table 27 and fig. 61). This region also had the largest amount of surface water runoff in the baseline scenario. Figure 63 shows that about 60 percent of cropped acres in the Lower Mississippi and Texas Gulf Coast (9) region had average annual reductions in surface water runoff of 1 inch or more due to the use of conservation practices.

Reductions in surface water runoff were also significant in three other regions (table 27, fig. 61, and fig. 63):

- the Southeast Coastal Plain (12) region, where conservation practice use reduced surface water runoff by an average of 0.95 inches per year, representing a 14-percent reduction,
- the Southern Plains (6) region, where conservation practice use reduced surface water runoff by an average of 0.94 inches per year, representing a 41-percent reduction, and
- the Northwest Non-Coastal (3) region, where conservation practice use reduced surface water runoff by an average of 0.86 inches per year, representing a 33-percent reduction.

A significant portion of the reductions in surface water runoff for the Southern Plains (5) region, the Northwest Non-Coastal (3) region, and the Lower Mississippi and Texas Gulf Coast (9) region results from improvements in irrigation efficiency in those regions—the three regions with the highest proportions of irrigated acres (i.e., lower efficiency irrigation systems simulated in the no-practice scenario).

Conservation practices have been the least effective in reducing surface water runoff in the Northern Plains (5) region, where conservation practice use reduced surface water runoff only by an average of 0.11 inch per year. This region also had the smallest amount of surface water runoff in the baseline scenario. Figure 63 shows that, for this region, 95 percent of the cultivated cropland acres had reductions in surface water runoff less than 0.25 inch per year due to conservation practice use.

Conservation practices generally have been less effective on water lost through subsurface loss pathways (table 27, fig. 62, and fig. 64). On average, all eight regions had gains in subsurface flows from the re-routing of surface water runoff by conservation practice use, although some gains were very small.

The region with the largest gains in subsurface flows was the Lower Mississippi and Texas Gulf Coast (9) region, which also had the largest average reductions in surface water runoff and the most volume of water in subsurface flows in the baseline scenario. The mean of the average annual gains in subsurface water flows due to conservation practice use was 1.11 inches per year, representing a 13-percent reduction relative to the no-practice scenario (table 27 and fig. 62).

Three regions were the least effective in attaining gains in subsurface water flows due to conservation practice use (table 27, fig. 62, and fig. 64):

- the Northwest Non-Coastal (3) region, where conservation practice use increased subsurface water flows by an average of only 0.06 inch per year, representing a 2-percent increase relative to the no-practice scenario,
- the Southern Plains (6) region, where conservation practice use increased subsurface water flows by an average of only 0.08 inch per year, representing a 4-percent increase, and
- the Northern Plains (5) region, where conservation practice use increased subsurface water flows by an average of only 0.15 inch per year, representing a 15-percent increase— the highest percent increase among all the regions only because both the baseline and no-practice scenario values were so small.

Figure 61. Mean of the average annual reduction in surface water runoff due to the use of conservation practices, by region.

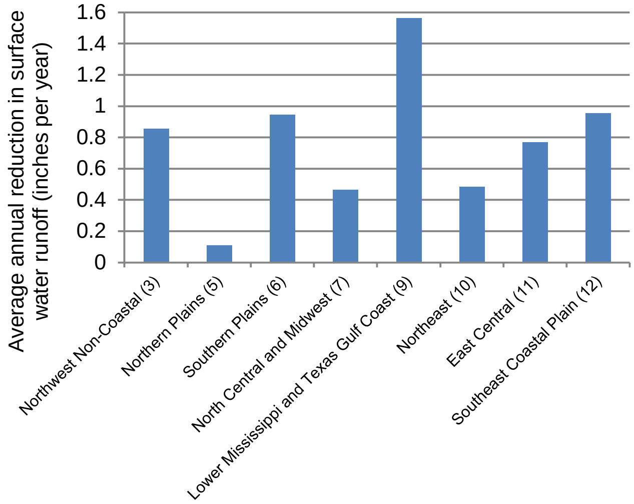


Figure 62. Mean of the average annual gains in subsurface water flows due to the use of conservation practices, by region.

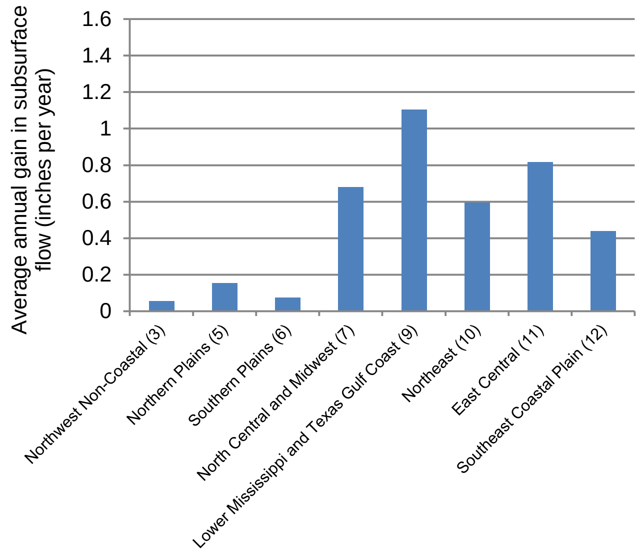


Figure 63. Distributions of average annual reductions in surface water runoff due to the use of conservation practices, representing CEAP sample points in eight production regions.

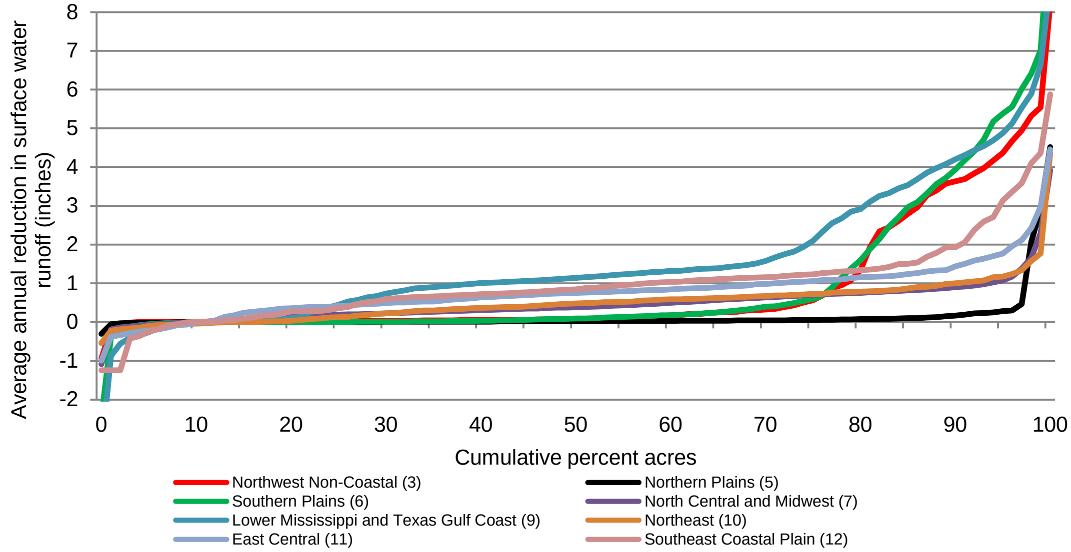
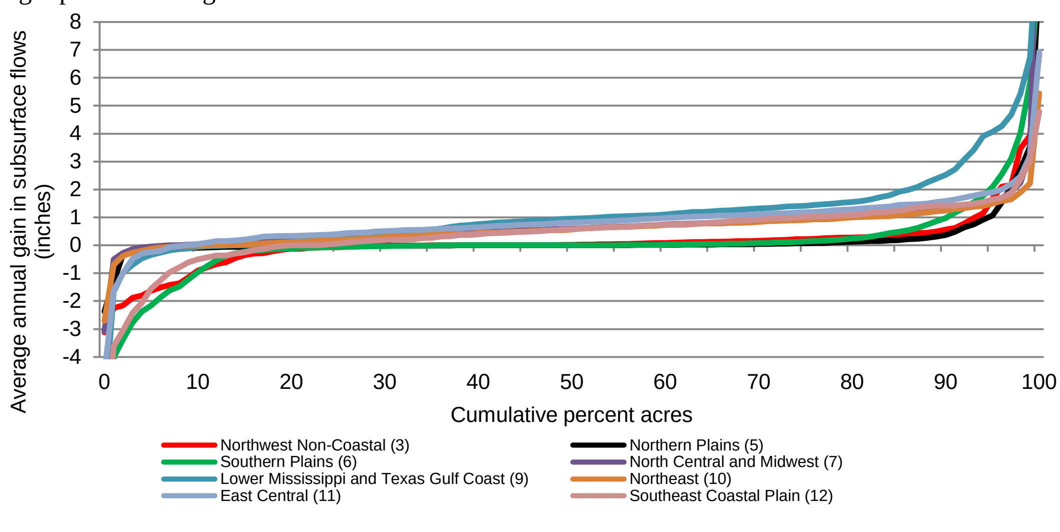


Figure 64. Distributions of average annual gains in subsurface flows due to the use of conservation practices, representing CEAP sample points in eight production regions.



Effects of Conservation Practices on Sediment Loss from Water Erosion

Sediment loss from farm fields is a principle determinant of nutrient losses. The effect of conservation practices on sediment loss is summarized in this section to provide a perspective on the results presented for phosphorus loss in the next chapter.

Model simulations indicate that the use of conservation practices has reduced average annual sediment loss from water erosion by 54 percent for cultivated cropland acres in all eight regions, including both treated and untreated acres (table 28). Without conservation practices, the average annual sediment loss for these acres would have been 1.74 tons per acre per year compared to 0.79 ton per acre average for the baseline scenario. The reduction in sediment loss due to the use of conservation practices averaged about 0.95 ton per acre per year.

Reductions in edge-of-field sediment loss due to conservation practices are much higher for HEL acres than for non-HEL acres, although the percent reduction is about the same (table 28). For HEL acres, the average annual reduction was 1.79 tons per acre per year, representing a 56-percent reduction. For non-HEL acres, the average annual reduction was 0.61 ton per acre per year, representing a 53-percent reduction.

The distributions of the average annual estimates of sediment loss in the baseline scenario and the no-practice scenario are contrasted in figure 65. Figure 65 shows that about 25 percent of the acres would have more than 2 tons per acre per year sediment loss without practices, on average, compared to 10 percent with conservation practices.

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. For about half of the cultivated cropland acres in the eight regions, the average annual sediment loss reduction due to practices was less than 0.2 ton per acre per year (fig. 66). In contrast, about 25 percent had average annual reductions in sediment loss greater than 1 ton per acre per year and the top 10 percent had reductions greater than 2.7 tons per acre per year.

For 2 percent of the cultivated cropland acres, sediment loss estimates were higher in the baseline scenario than in the no-practice scenario, resulting in negative reductions due to use of conservation practices (fig. 66). These negative reductions in sediment loss are the result of tradeoffs in benefits of conservation practices previously discussed with respect to figure 58, where a small number of acres had negative reductions in surface water runoff due to use of conservation practices.

Figure 65. Distributions of average annual edge-of-field sediment loss from water erosion for the baseline and no-practice scenarios, all eight regions combined.

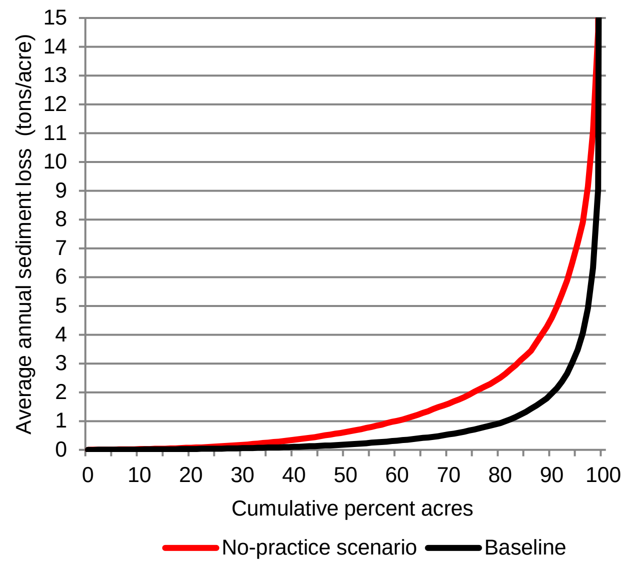


Figure 66. Distribution of average annual reduction in edge-of-field sediment loss from water erosion due to the use of conservation practices, all eight regions combined.

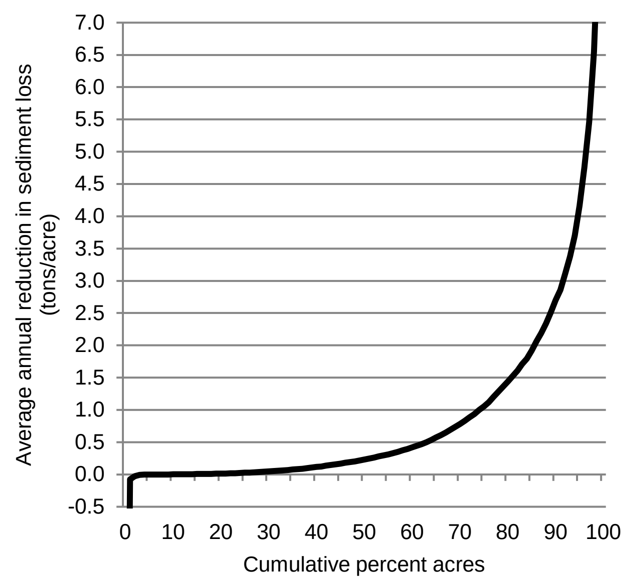


Table 28. Effects of conservation practices on sediment loss from water erosion.

	Baseline scenario (tons/acre)	No-practice scenario (tons/acre)	Reduction due to practices (tons/acre)	Percent reduction
		All cultivated cropland acres		
Production region				
Northwest Non-Coastal (3)	0.901	1.740	0.839	48%
Northern Plains (5)	0.063	0.135	0.072	53%
Southern Plains (6)	0.260	0.917	0.657	72%
North Central and Midwest (7)	0.797	2.044	1.248	61%
Lower Mississippi and Texas Gulf Coast (9)	2.663	3.797	1.135	30%
Northeast (10)	2.360	4.095	1.735	42%
East Central (11)	2.523	5.355	2.832	53%
Southeast Coastal Plain (12)	0.960	1.983	1.024	52%
All eight regions	0.793	1.742	0.949	54%
		HEL acres		
Production region				
Northwest Non-Coastal (3)	1.385	2.496	1.111	45%
Northern Plains (5)	0.089	0.191	0.103	54%
Southern Plains (6)	0.274	1.098	0.824	75%
North Central and Midwest (7)	1.921	4.923	3.002	61%
Lower Mississippi and Texas Gulf Coast (9)	6.500	10.933	4.433	41%
Northeast (10)	3.505	6.280	2.775	44%
East Central (11)	3.675	7.828	4.153	53%
Southeast Coastal Plain (12)	3.503	6.516	3.013	46%
All eight regions	1.399	3.191	1.792	56%
		Non-HEL acres		
Production region				
Northwest Non-Coastal (3)	0.354	0.886	0.532	60%
Northern Plains (5)	0.048	0.103	0.055	53%
Southern Plains (6)	0.253	0.823	0.570	69%
North Central and Midwest (7)	0.467	1.200	0.733	61%
Lower Mississippi and Texas Gulf Coast (9)	2.115	2.779	0.664	24%
Northeast (10)	1.147	1.782	0.635	36%
East Central (11)	1.320	2.771	1.451	52%
Southeast Coastal Plain (12)	0.659	1.448	0.789	54%
All eight regions	0.547	1.152	0.606	53%

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Conservation practices were most effective in reducing sediment loss from water erosion in the East Central (11) region (table 28 and fig. 67). In this region, the mean of the average annual reductions in sediment loss was 2.83 tons per acre per year. Conservation practices reduced average sediment loss from 5.36 tons per acre per year in the no-practice scenario to an average of 2.52 tons per acre per year in the baseline scenario—a 53-percent reduction. The average annual reduction in sediment loss averaged 4.15 tons per acre per year for HEL acres in this region and 1.45 tons per acre for non-HEL acres, representing a 53-percent and a 52-percent reduction, respectively (table 28, figs. 68 and 69).

The region with the smallest reductions in sediment loss due to conservation practice use was the Northern Plains (5) region, where the mean of the average annual reductions in sediment loss was only 0.07 ton per acre per year, which nevertheless represented a 53-percent reduction because of the very low sediment loss in both the baseline and the no-practice scenarios.

The remaining regions had mean average annual reductions in sediment loss ranging from 0.66 ton per acre per year for the Southern Plains (6) region to 1.74 tons per acre per year in the Northeast (10) region (table 28 and fig. 67).

In terms of the percent reduction, the Southern Plains (6) region and North Central and Midwest (7) region had the largest—72 percent and 61 percent reduction, respectively, in sediment loss rates for all cultivated cropland acres due to conservation practices. Percent reduction for the Southern Plains (6) region was slightly higher for HEL acres and slightly lower for non-HEL acres. Percent reductions for HEL acres and non-HEL acres in the North Central and Midwest (7) region were the same as for all cropped acres.

The Lower Mississippi and Texas Gulf Coast (9) region had the smallest percent reduction in sediment loss rates due to conservation practices—24 percent for non-HEL acres and 41 percent for HEL acres (table 28).

Figure 70 contrasts the distributions of the average annual reductions for all eight regions. Again, the East Central (11) region stands out as having the most benefit from use of conservation practices. About 62 percent of the cropped acres in this region had reductions in edge-of-field sediment loss of 1 or more ton per acre per year due to conservation practice use. About 45 percent of the cropped acres had reductions of 2 or more tons per acre per year and 22 percent of the cropped acres had reductions of 4 or more tons per acre per year.

In contrast, the Northern Plains (5) region stands out as having the least benefit from the use of conservation practices for control of sediment loss from water erosion, primarily because of the generally low potential for surface water runoff in the region (fig. 27). In this region, 95 percent of the cropped acres had reductions of less than 0.2 tons per acre per year due to the use of conservation practices (fig. 70).

Figure 67. Mean of the average annual reduction in edge-of-field sediment loss from water erosion due to conservation practices for all cultivated cropland acres, by region.

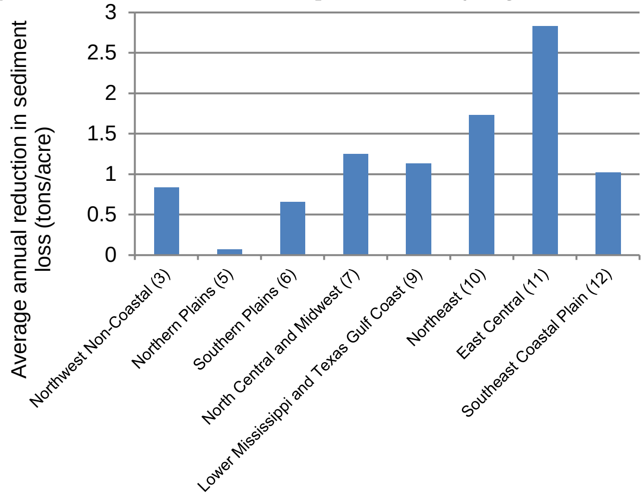


Figure 68. Mean of the average annual reduction in edge-of-field sediment loss from water erosion due to conservation practices for HEL acres, by region.

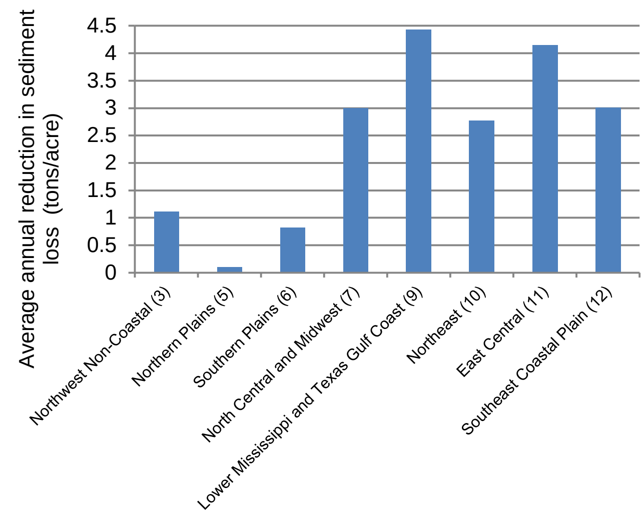
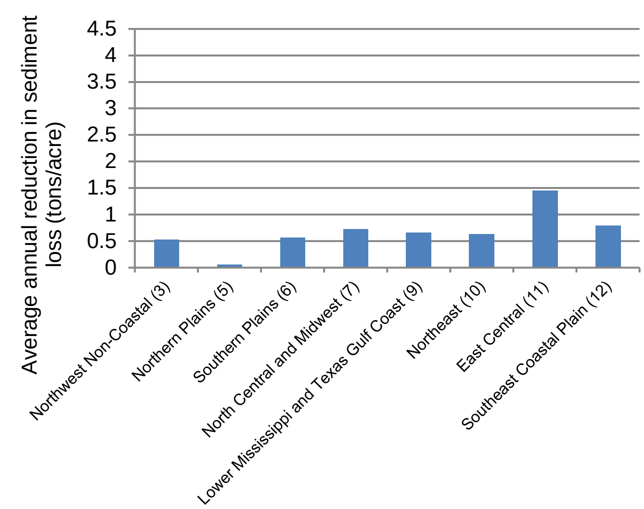
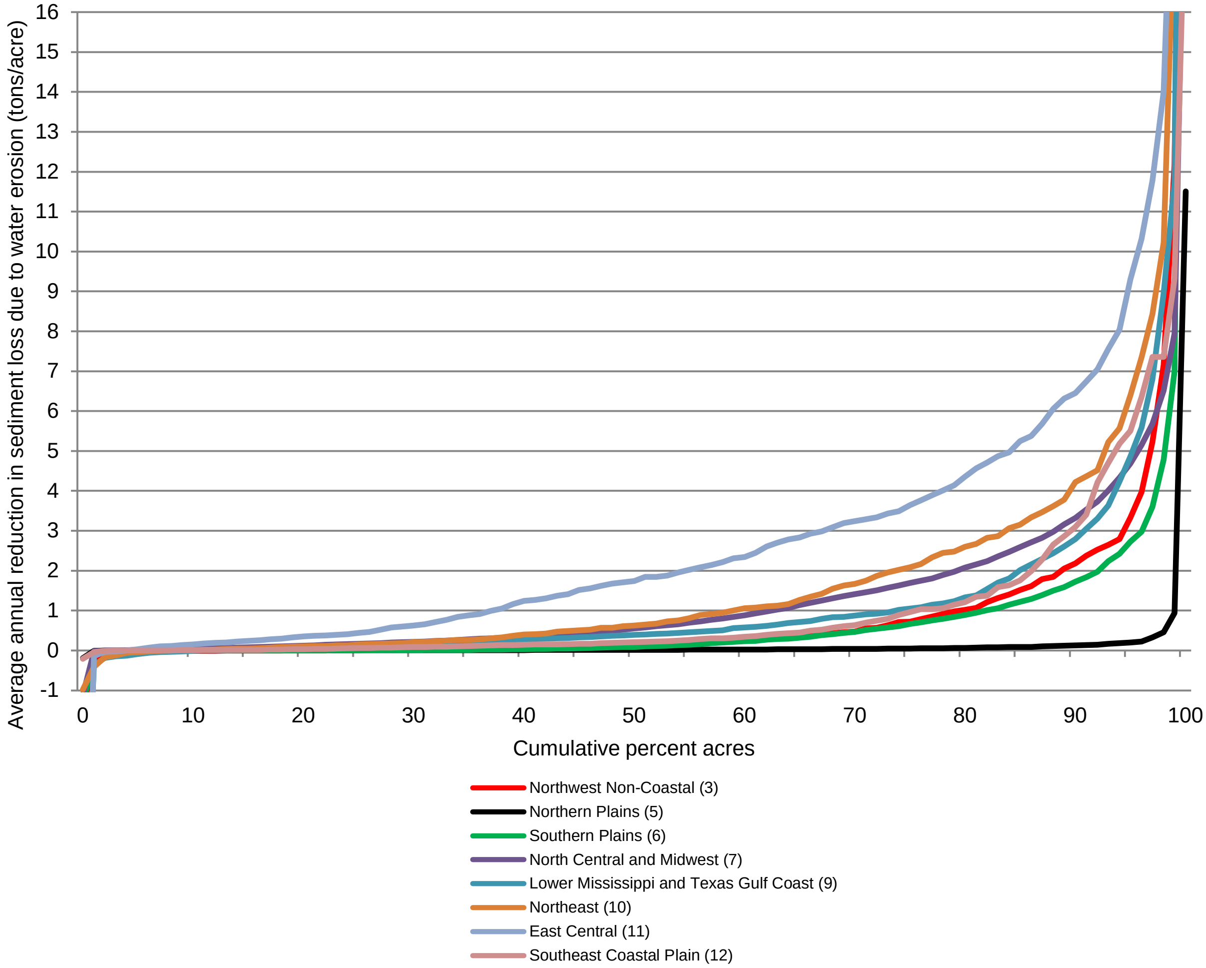


Figure 69. Mean of the average annual reduction in edge-of-field sediment loss from water erosion due to conservation practices for non-HEL acres, by region.



The remaining six regions had little or no benefit from the use of conservation practices for over half of the acres but had significant benefits for some acres (fig. 70). Reductions in sediment loss for acres with the highest reductions—those acres that were treated the most for erosion control—ranged to above 5 tons per acre per year for at least some acres in all 6 regions.

Figure 70. Distributions of average annual reductions in sediment loss from water erosion due to the use of conservation practices, representing CEAP sample points in eight production regions.



Effects of Conservation Practices on Wind Erosion

Windborne phosphorus loss from farm fields is a principal loss pathway for phosphorus in some regions, as shown previously. The effect of conservation practices on reducing wind erosion is summarized in this section to provide a perspective on the results presented for phosphorus loss in the next chapter.

Farmers address wind erosion using conservation practices designed to enhance the soil's ability to resist and reduce the wind velocity near the soil surface. Physical barriers such as windbreaks or shelterbelts, herbaceous wind barriers or windbreaks, cross wind trap strips, or ridges constructed perpendicular to the prevailing wind direction reduce the intensity of wind energy at the surface. As shown in table 4, these structural practices for wind erosion control are in use on only 6 percent of the cropped acres in the eight regions. However, other practices in common use in all regions, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion. Properly planned and applied residue management reduces wind erosion by leaving more organic material on the soil surface, which in turn helps preserve soil aggregate stability and promotes further aggregation. Row direction or arrangement, surface roughening, and stripcropping also lessen the wind's energy.

Model simulations indicate that conservation practices have reduced the average wind erosion rate by 37 percent for cultivated cropland acres in all eight regions combined, on average (table 29). The distributions of the average annual estimates of wind erosion in the baseline scenario and the no-practice scenario are contrasted in figure 71. Figure 71 shows that about 28 percent of the acres would have wind erosion rates greater than 2 tons per acre per year without conservation practices, compared to 15 percent with conservation practices.

On average, conservation practices have reduced wind erosion by 0.8 ton per acre. Reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (fig. 72).

For about 5 percent of cropped acres, average annual wind erosion rates were higher in the baseline scenario than in the no-practice scenario, resulting in the negative reductions shown in figure 72. This condition occurs in areas with relatively low precipitation because the higher fertilization rates used to simulate the no-practice scenario produce significantly more vegetative cover, which in turn provides better protection for the soil from the forces of the wind than in the baseline scenario, where biomass production is less and crop residue losses are higher.

Figure 71. Distributions of average annual wind erosion for the baseline and no-practice scenarios, all eight regions combined.

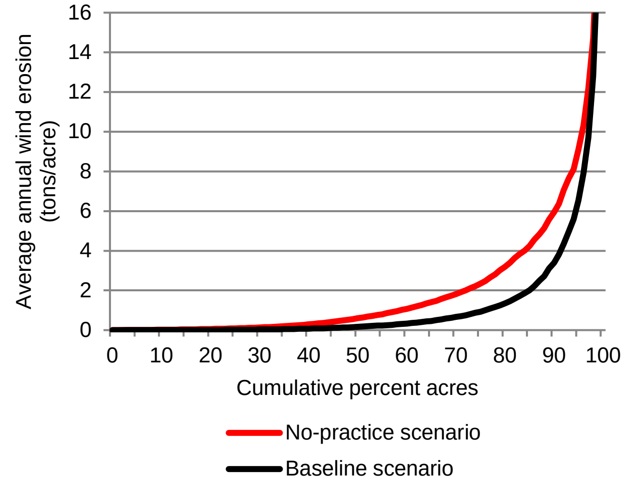
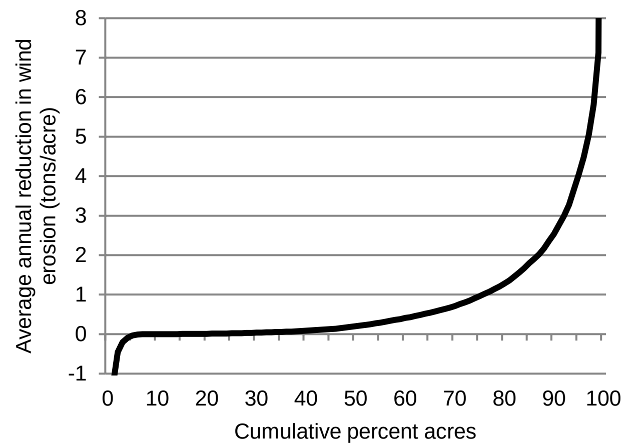


Figure 72. Distribution of average annual reduction in wind erosion due to the use of conservation practices, all eight regions combined.



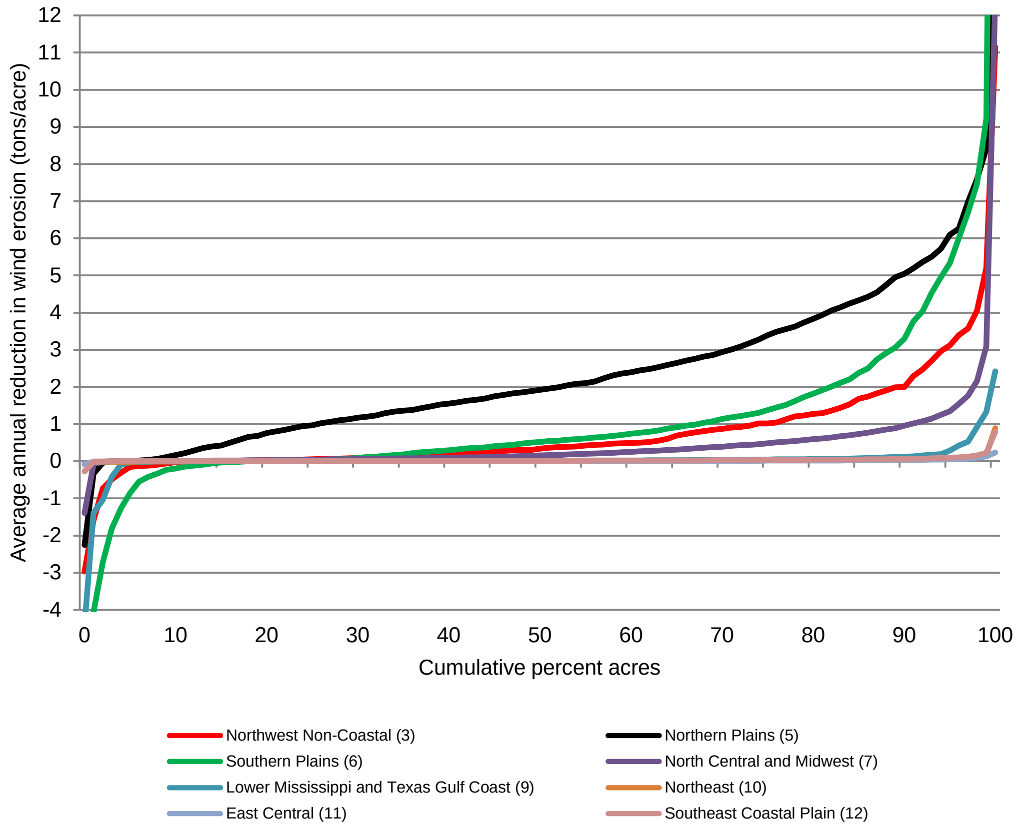
The largest reductions in wind erosion due to conservation practices are in the three westernmost regions, where wind erosion rates are sometimes extremely high (table 29 and fig. 73).

- In the Northern Plains (5) region, conservation practices have reduced wind erosion by 2.36 tons per acre per year, on average, representing a 61-percent reduction; reductions exceed 2 tons per acre per year for 47 percent of the cropped acres.
- In the Southern Plains (6) region, conservation practices have reduced wind erosion by 1.03 tons per acre per year, on average, representing a 22-percent reduction; reductions exceed 2 tons per acre per year for 18 percent of the cropped acres.
- In the Northwest Non-Coastal (3) region, conservation practices have reduced wind erosion by 0.73 ton per acre per year, on average, representing a 26-percent reduction; reductions exceed 2 tons per acre per year for 9 percent of the cropped acres.

Table 29. Effects of conservation practices on wind erosion, all cultivated cropland acres.

	Baseline scenario (tons/acre)	No-practice scenario (tons/acre)	Reduction due to practices (tons/acre)	Percent reduction
Production region				
Northwest Non-Coastal (3)	2.067	2.800	0.733	26%
Northern Plains (5)	1.514	3.878	2.364	61%
Southern Plains (6)	3.709	4.742	1.033	22%
North Central and Midwest (7)	0.386	0.763	0.377	49%
Lower Mississippi and Texas Gulf Coast (9)	0.638	0.666	0.028	4%
Northeast (10)	0.036	0.056	0.020	35%
East Central (11)	0.017	0.030	0.013	44%
Southeast Coastal Plain (12)	0.086	0.112	0.026	23%
All eight regions	1.351	2.152	0.801	37%

Figure 73. Distributions of average annual reductions in wind erosion due to the use of conservation practices, representing CEAP sample points in eight production regions.



Effects of Conservation Practices on Phosphorus Loss

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrients to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or use of other runoff control practices to reduce the wind and water erosion mechanisms of loss. The reduction in phosphorus loss due to the effects of conservation practices is estimated here as the difference between the model simulation results for the no-practice and the baseline scenario, which represents the use of a combination of structural practices, tillage and residue management practices, and phosphorus management practices.

Effects of Practice Use for All Regions Combined

Overall for all eight regions combined, model simulation results show that conservation practices have reduced total phosphorus loss (all loss pathways) by an average annual amount of 2.35 pounds per acre per year, representing a 46-percent reduction relative to the no-practice scenario (table 30). Without conservation practices, the average annual amount of total phosphorus loss would have been 5.13 pounds per acre per year as represented by the no-practice scenario, compared to an average of 2.79 pounds per acre per year for the baseline scenario, which includes a mix of fully treated, partially treated and untreated acres. Reductions in total phosphorus loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil.

Distributions of the average annual estimates of total phosphorus loss in the baseline scenario and the no-practice scenario are contrasted in figure 74, which shows that about 48 percent of the acres would have more than 4 pounds per acre per year of total phosphorus loss without practices, on average, compared to 20 percent with conservation practices. The average annual reductions in total phosphorus loss are shown in figure 75. About 15 percent of the cropped acres had reductions in losses of more than 4 pounds per acre per year; these are the acres that were treated the most.

In contrast, about 28 percent of the cropped acres had reductions in losses between 0 and 1 pound per acre per year, representing the least treated acres. Another 7 percent of cropped acres had negative reductions, indicating that phosphorus losses increased slightly for those acres resulting from tradeoffs in the benefits of conservation practice use for wind and water erosion presented in the previous chapter.

Figure 74. Distributions of average annual total phosphorus loss (all loss pathways) for the baseline and no-practice scenarios, all eight regions combined.

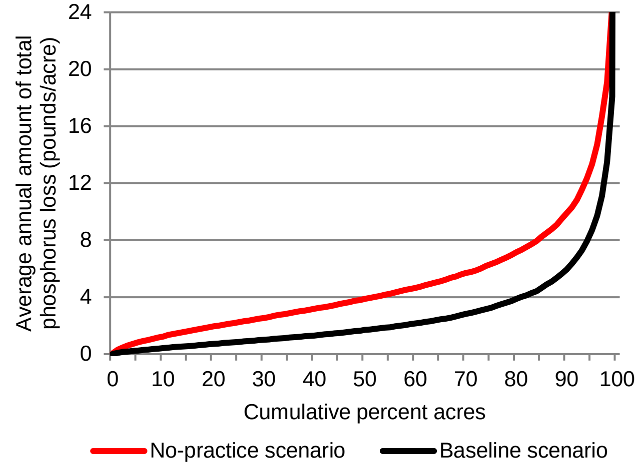


Figure 75. Distribution of average annual reduction in total phosphorus loss (all loss pathways) due to the use of conservation practices, all eight regions combined.

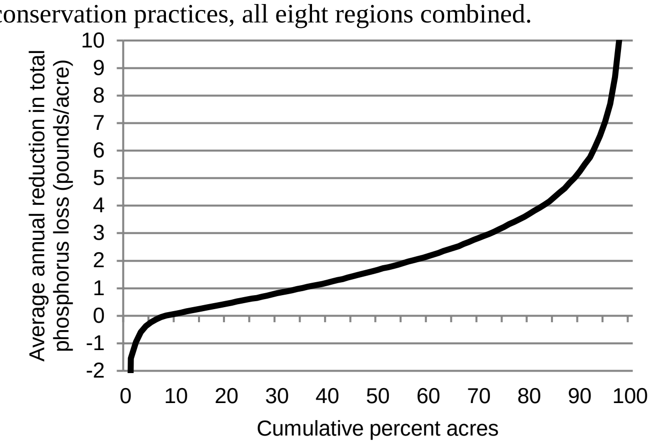


Table 30. Effects of conservation practices on phosphorus loss from farm fields, all eight regions combined.

	Baseline scenario (pounds/acre)	No-practice scenario (pounds/acre)	Reduction due to practices (pounds/acre)	Percent reduction
Phosphorus applied as commercial fertilizer and manure	17.37	24.11	6.74	28%
Phosphorus in crop yield removed at harvest	12.88	14.11	1.23	9%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.83	1.68	0.85	51%
Soluble phosphorus lost to surface water*	0.89	1.39	0.50	36%
Phosphorus loss with waterborne sediment	1.04	2.03	0.99	49%
Soluble phosphorus loss to groundwater	0.026	0.028	0.002	6%
Total phosphorus loss for all loss pathways	2.79	5.13	2.35	46%
Change in soil phosphorus	1.58	4.75	3.17	--

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices. Note: Phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

As presented in the previous chapter, phosphorus application rates were increased above the rates reported in the farmer survey as part of the representation of the no-practice scenario. On average, the amount of phosphorus added for the no-practice simulation was 6.74 pounds per acre per year, which is represented in table 30 as a reduction of 28 percent due to the use of phosphorus management practices. As a consequence of the increased application rates, the no-practice scenario also had an increase, on average, of 1.23 pounds per acre per year of phosphorus in the crop yield removed at harvest, which is also represented in table 30 as a reduction in yield of 9 percent due to the use of conservation practices.

The extent to which conservation practices reduced losses in each of the three principal loss pathways tracked by the APEX model varies (table 30 and figs.76-81). The average annual reduction for all cropped acres in all eight regions combined was (table 30):

- 0.85 pounds per acre per year for phosphorus lost with windborne sediment, a 51-percent reduction relative to the results for the no-practice scenario;
- 0.50 pounds per acre per year for soluble phosphorus lost to surface water, a 36-percent reduction; and
- 0.99 pounds per acre per year for phosphorus lost with waterborne sediment, a 49-percent reduction.

The effect of practices on soluble phosphorus lost to groundwater was negligible.

Reductions were relatively low for the least treated acres and/or acres with low vulnerability to the forces of wind or water. Average annual reductions ranged from 0.0 to 0.5 pounds per acre per year for:

- 54 percent of cropped acres for phosphorus lost with windborne sediment (fig. 77);
- 48 percent of cropped acres for annual soluble phosphorus lost to surface water (fig. 79); and
- 53 percent of cropped acres for in phosphorus lost with waterborne sediment (fig. 81).

At the high end of the distributions, representing the cropped acres with the most conservation treatment, average annual reductions were greater than 2 pounds per acre per year for:

- 13 percent of cropped acres for phosphorus lost with windborne sediment (fig. 77);
- 8 percent of cropped acres for annual soluble phosphorus lost to surface water (fig. 79); and
- 14 percent of cropped acres for in phosphorus lost with waterborne sediment (fig. 81).

Each loss pathway had a few acres where model simulation results showed larger phosphorus losses for the baseline scenario than for the no-practice scenario, resulting in negative reductions in losses due to conservation practices. For wind and waterborne phosphorus losses, these negative reductions in phosphorus loss are the result of tradeoffs in benefits of conservation practices previously discussed with respect to figures 58, 66, and 72.

For soluble phosphorus loss, simulation results show that 22 percent of cropped acres had an increase in phosphorus loss with use of conservation practices (fig. 79). In some cases these increases in phosphorus loss are also the result of small increases in surface water runoff due to conservation practices. In other cases, however, increases in soluble phosphorus loss due to conservation practices resulted from a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. On these types of landscapes, improved phosphorus management along with light incorporation and maintenance of crop residue on the soil surface may be necessary to reduce soluble phosphorus loss.

Figure 76. Distributions of average annual phosphorus lost with windborne sediment for the baseline and no-practice scenarios, all eight regions combined.

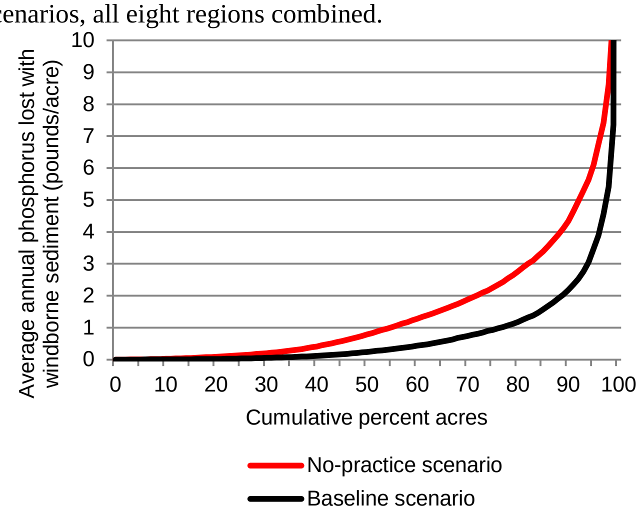


Figure 77. Distribution of average annual reductions in phosphorus lost with windborne sediment due to the use of conservation practices, all eight regions combined.

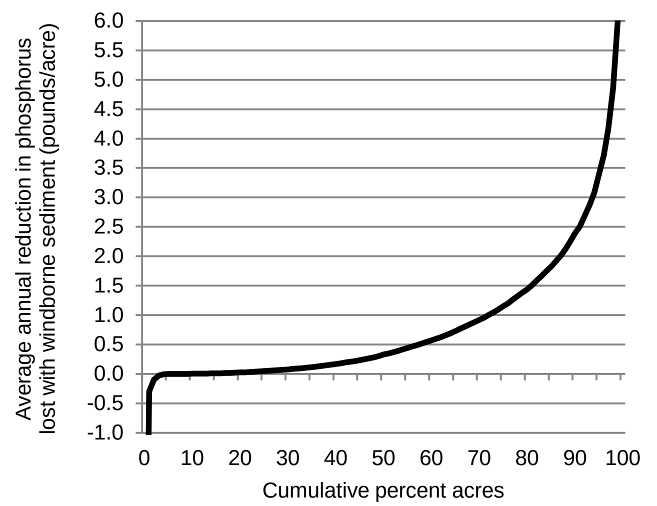


Figure 78. Distributions of average annual soluble phosphorus lost to surface water for the baseline and no-practice scenarios, all eight regions combined.

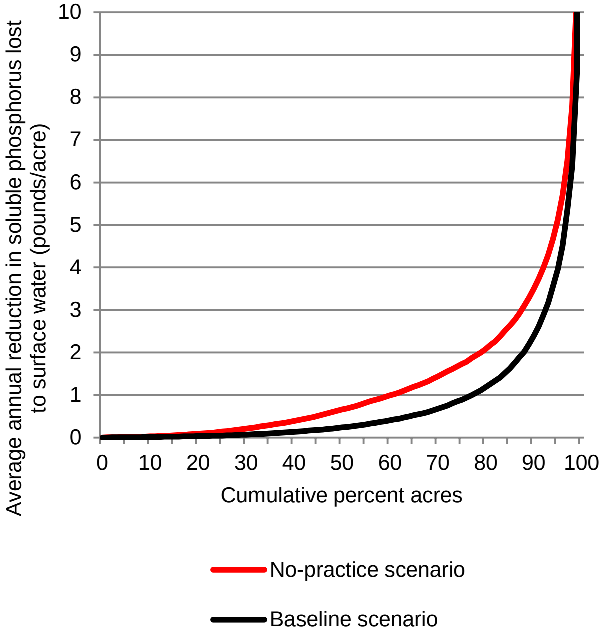


Figure 79. Distribution of average annual reduction in soluble phosphorus lost to surface water due to the use of conservation practices, all eight regions combined.

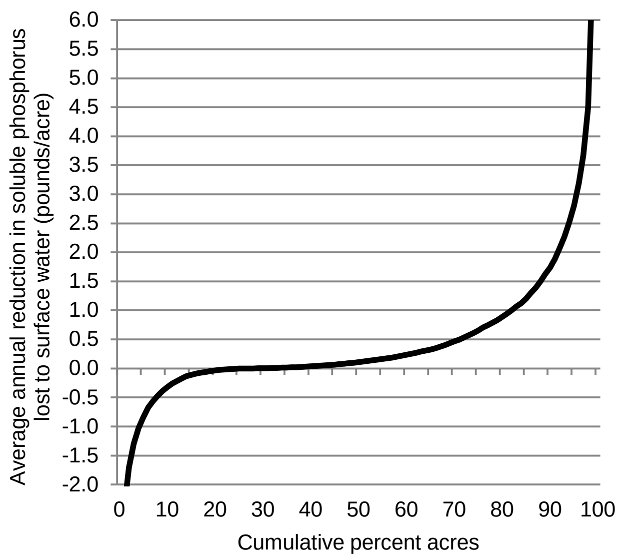


Figure 80. Distributions of average annual phosphorus lost with waterborne sediment for the baseline and no-practice scenarios, all eight regions combined.

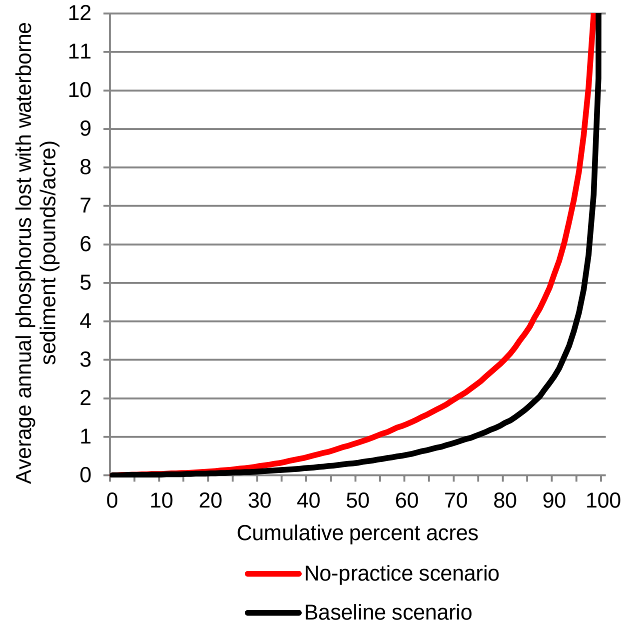
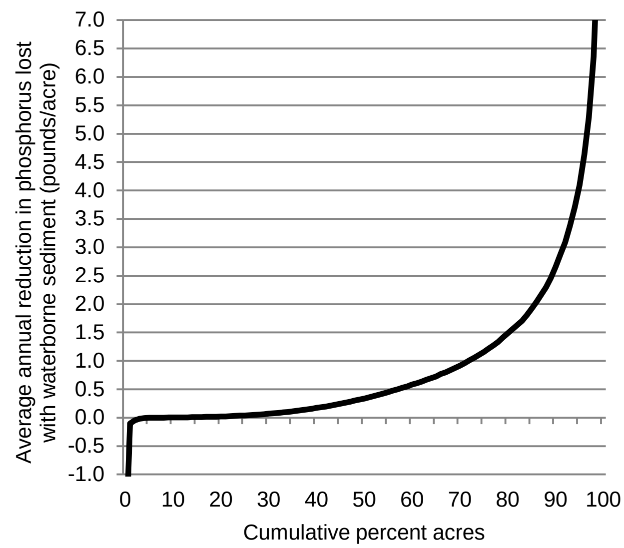


Figure 81. Distribution of average annual reductions in phosphorus lost with waterborne sediment due to the use of conservation practices, all eight regions combined.



Effects of Practice Use by Production Region

Conservation practices were most effective in reducing phosphorus losses in different regions depending on the loss pathway (figs. 82 through 89 and table 31).

For phosphorus lost with windborne sediment, conservation practices were most effective in the three westernmost regions, where wind erosion is the principal loss pathway for phosphorus loss (figs. 82 and 86).The largest reductions were in the Northern Plains (5) region, where the mean of the average annual reduction in phosphorus lost with windborne sediment was 2.05 pounds per acre per year, representing a 63-percent reduction (table 31, fig. 82). Figure 86 shows that, in this region, average annual reductions in phosphorus lost with windborne sediment were greater than 1 pound per acre per year for 70 percent of the cropped acres, and greater than 3 pounds per acre per year for 21 percent of the cropped acres, far more than any other region. Reductions were also significant for cropped acres in three other regions—the Northwest Non-Coastal (3) region, the Southern Plains (6 region), and the North Central and Midwest (7) region. The effect of conservation practices for most cropped acres in the remaining four regions was slight because wind erosion is generally not a major concern.

Conservation practices were the most effective in controlling soluble phosphorus lost to surface water in the Lower Mississippi and Texas Gulf Coast (9) region, where the mean of the average annual reduction in soluble phosphorus lost to surface water was 1.94 pounds per acre per year, representing a 48-percent reduction (table 31, fig. 83). Figure 86 shows that, in this region, average annual reductions in soluble phosphorus lost to surface water were greater than 3 pounds per acre per year for 24 percent of the cropped acres, more than any other region. The mean of the average annual reductions was 0.5 pounds per acre per year or greater in three other regions—the Southeast Coastal Plain (12) region, the Northeast (10) region, and the Northwest Non-Coastal (3) region.

Conservation practices were effective in reducing phosphorus lost with waterborne sediment in all but the region in which this loss pathway had the least amount of phosphorus loss. The mean of the average annual reductions in phosphorus lost with waterborne sediment was greater than 0.5 pounds per acre per year in all but the Northern Plains (5) region (table 31, fig. 84). Two regions stand out as being the most effective in controlling phosphorus lost with waterborne sediment:

- the Northeast (10) region, where the mean of the average annual reduction due to use of conservation practices was 2.31 pounds per acre per year (fig. 84) and 17 percent of cropped acres had average annual reductions greater than 4 pounds per acre per year (fig. 88), and
- the East Central (11) region, where the mean of the average annual reduction due to use of conservation practices was 2.25 pounds per acre per year (fig. 84) and 12 percent of cropped acres had average annual reductions greater than 4 pounds per acre per year (fig. 88).

Figure 82. Mean of the average annual reduction in phosphorus lost with windborne sediment due to the use of conservation practices, by region.

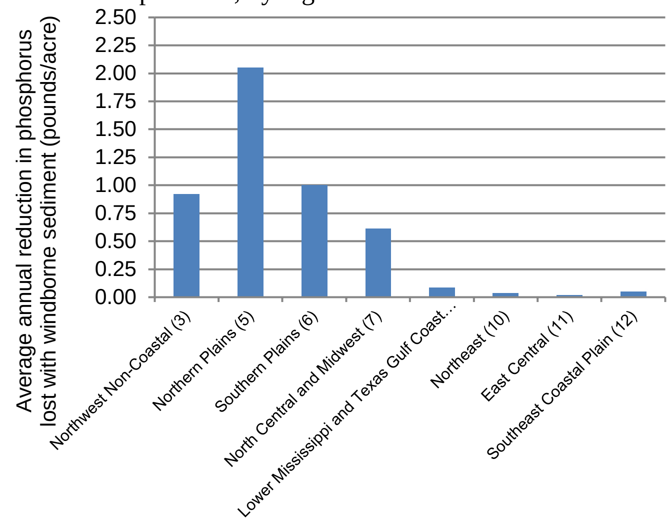


Figure 83. Mean of the average annual reduction in soluble phosphorus lost to surface water due to the use of conservation practices, by region.

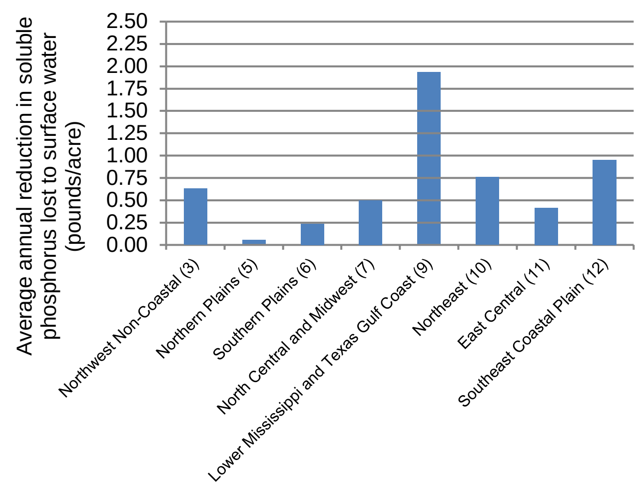
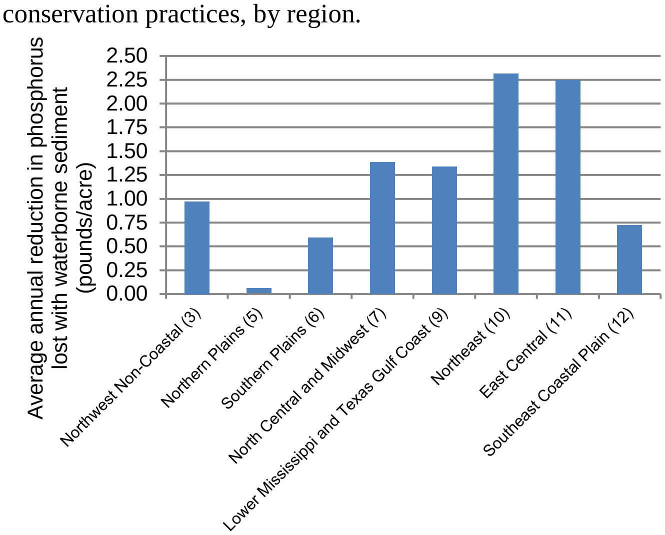


Figure 84. Mean of the average annual reduction in phosphorus lost with waterborne sediment due to the use of conservation practices, by region.



For all loss pathways combined, the Lower Mississippi and Texas Gulf Coast (9) region had the largest reductions in total phosphorus loss (figs. 85 and 89). For this region, the mean of the average annual reduction in total phosphorus loss was 3.36 pounds per acre per year, representing a 41-percent reduction due to the use of conservation practices (table 31), and 20 percent of the cropped acres had reductions greater than 6 pounds per acre per year (fig. 89). The Northeast (10) region had the second largest reductions in total phosphorus loss; the mean of the average annual reduction in total phosphorus loss was 3.11 pounds per acre per year, representing a 35-percent reduction due to the use of conservation practices (table 31).

The Southeastern Coastal Plains (12) region had the smallest reductions in total phosphorus loss; the mean of the average annual reduction in total phosphorus loss was 1.73 pounds per acre per year, representing a 36-percent reduction due to the use of conservation practices (table 31). The Southern Plains (6) region had the second smallest reductions in total phosphorus loss; the mean of the average annual reduction in total phosphorus loss was 1.83 pounds per acre per year, representing a 48-percent reduction due to the use of conservation practices (table 31).

The Northern Plains (5) region had the largest percent reduction in total phosphorus loss, averaging 60 percent relative to the no-practice scenario. This region also had the smallest amount of total phosphorus loss in both the baseline and the no-practice scenarios (table 31).

Figure 85. Mean of the average annual reduction in total phosphorus loss (all loss pathways) due to the use of conservation practices, by region.

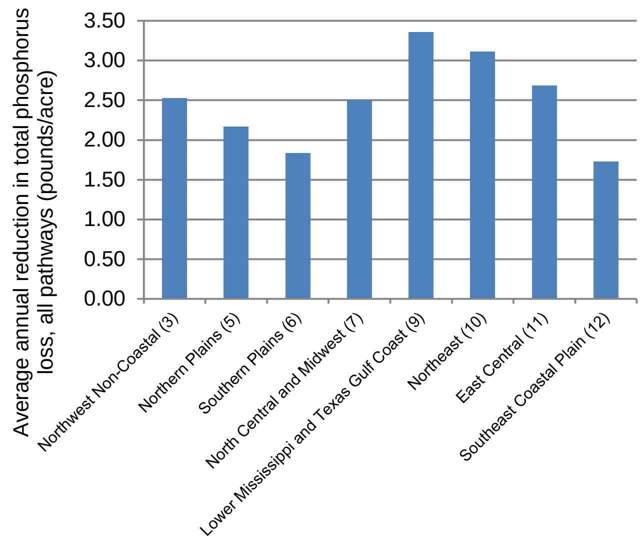


Table 31. Effects of conservation practices on phosphorus loss from farm fields, by region.

	Baseline scenario (pounds/acre)	No-practice scenario (pounds/acre)	Reduction due to practices (pounds/acre)	Percent reduction
		Northwest Non-Coastal (3) region		
Phosphorus applied as commercial fertilizer and manure	14.02	22.74	8.72	38%
Phosphorus in crop yield removed at harvest	10.19	12.41	2.22	18%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.56	2.48	0.92	37%
Soluble phosphorus lost to surface water*	0.29	0.92	0.63	68%
Phosphorus loss with waterborne sediment	0.84	1.81	0.97	54%
Soluble phosphorus loss to groundwater	0.016	0.020	0.004	19%
Total phosphorus loss for all loss pathways	2.70	5.23	2.53	48%
Change in soil phosphorus	1.06	5.08	4.02	--
		Northern Plains (5) region		
Phosphorus applied as commercial fertilizer and manure	10.94	15.44	4.50	29%
Phosphorus in crop yield removed at harvest	8.91	9.94	1.04	10%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.22	3.27	2.05	63%
Soluble phosphorus lost to surface water*	0.13	0.18	0.06	31%
Phosphorus loss with waterborne sediment	0.09	0.15	0.06	42%
Soluble phosphorus loss to groundwater	0.005	0.005	0.000	1%
Total phosphorus loss for all loss pathways	1.43	3.60	2.17	60%
Change in soil phosphorus	0.59	1.89	1.30	--
		Southern Plains (6 region)		
Phosphorus applied as commercial fertilizer and manure	11.62	17.82	6.20	35%
Phosphorus in crop yield removed at harvest	8.74	10.23	1.49	15%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.48	2.49	1.00	40%
Soluble phosphorus lost to surface water*	0.18	0.42	0.24	57%
Phosphorus loss with waterborne sediment	0.31	0.90	0.59	65%
Soluble phosphorus loss to groundwater	0.027	0.028	0.001	4%
Total phosphorus loss for all loss pathways	2.00	3.84	1.83	48%
Change in soil phosphorus	0.71	3.52	2.80	--
		North Central and Midwest (7) region		
Phosphorus applied as commercial fertilizer and manure	21.51	28.67	7.16	25%
Phosphorus in crop yield removed at harvest	16.94	18.11	1.16	6%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.55	1.17	0.61	53%
Soluble phosphorus lost to surface water*	1.10	1.60	0.50	31%
Phosphorus loss with waterborne sediment	1.28	2.66	1.39	52%
Soluble phosphorus loss to groundwater	0.019	0.022	0.003	15%
Total phosphorus loss for all loss pathways	2.95	5.46	2.50	46%
Change in soil phosphorus	1.46	4.97	3.52	--
		Lower Mississippi and Texas Gulf Coast (9) region		
Phosphorus applied as commercial fertilizer and manure	18.98	27.77	8.79	32%
Phosphorus in crop yield removed at harvest	13.53	14.45	0.92	6%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.19	0.28	0.09	32%
Soluble phosphorus lost to surface water*	2.06	4.00	1.94	48%
Phosphorus loss with waterborne sediment	2.58	3.91	1.33	34%
Soluble phosphorus loss to groundwater	0.063	0.063	0.000	0%
Total phosphorus loss for all loss pathways	4.89	8.25	3.36	41%
Change in soil phosphorus	0.43	5.02	4.59	--

Table 31.—continued.

	Baseline scenario (pounds/acre)	No-practice scenario (pounds/acre)	Reduction due to practices (pounds/acre)	Percent reduction
		Northeast (10) region		
Phosphorus applied as commercial fertilizer and manure	27.37	35.68	8.31	23%
Phosphorus in crop yield removed at harvest	12.23	13.25	1.02	8%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.05	0.09	0.04	43%
Soluble phosphorus lost to surface water*	2.31	3.07	0.76	25%
Phosphorus loss with waterborne sediment	3.44	5.76	2.31	40%
Soluble phosphorus loss to groundwater	0.061	0.061	0.000	0%
Total phosphorus loss for all loss pathways	5.86	8.97	3.11	35%
Change in soil phosphorus	9.19	13.52	4.33	--
		East Central (11) region		
Phosphorus applied as commercial fertilizer and manure	26.26	32.78	6.52	20%
Phosphorus in crop yield removed at harvest	15.81	17.00	1.19	7%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.02	0.04	0.02	44%
Soluble phosphorus lost to surface water*	2.75	3.17	0.42	13%
Phosphorus loss with waterborne sediment	3.08	5.33	2.25	42%
Soluble phosphorus loss to groundwater	0.054	0.055	0.002	3%
Total phosphorus loss for all loss pathways	5.91	8.59	2.68	31%
Change in soil phosphorus	4.24	7.02	2.78	--
		Southeast Coastal Plain (12) region		
Phosphorus applied as commercial fertilizer and manure	20.94	28.89	7.95	28%
Phosphorus in crop yield removed at harvest	10.76	11.84	1.08	9%
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.13	0.18	0.05	27%
Soluble phosphorus lost to surface water*	1.81	2.76	0.96	35%
Phosphorus loss with waterborne sediment	1.08	1.81	0.72	40%
Soluble phosphorus loss to groundwater	0.076	0.079	0.003	4%
Total phosphorus loss for all loss pathways	3.10	4.83	1.73	36%
Change in soil phosphorus	7.06	12.23	5.17	--

Source: APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.
* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
Note: Phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Figure 86. Distributions of average annual reductions in phosphorus lost with windborne sediment due to the use of conservation practices, CEAP sample points in eight production regions.

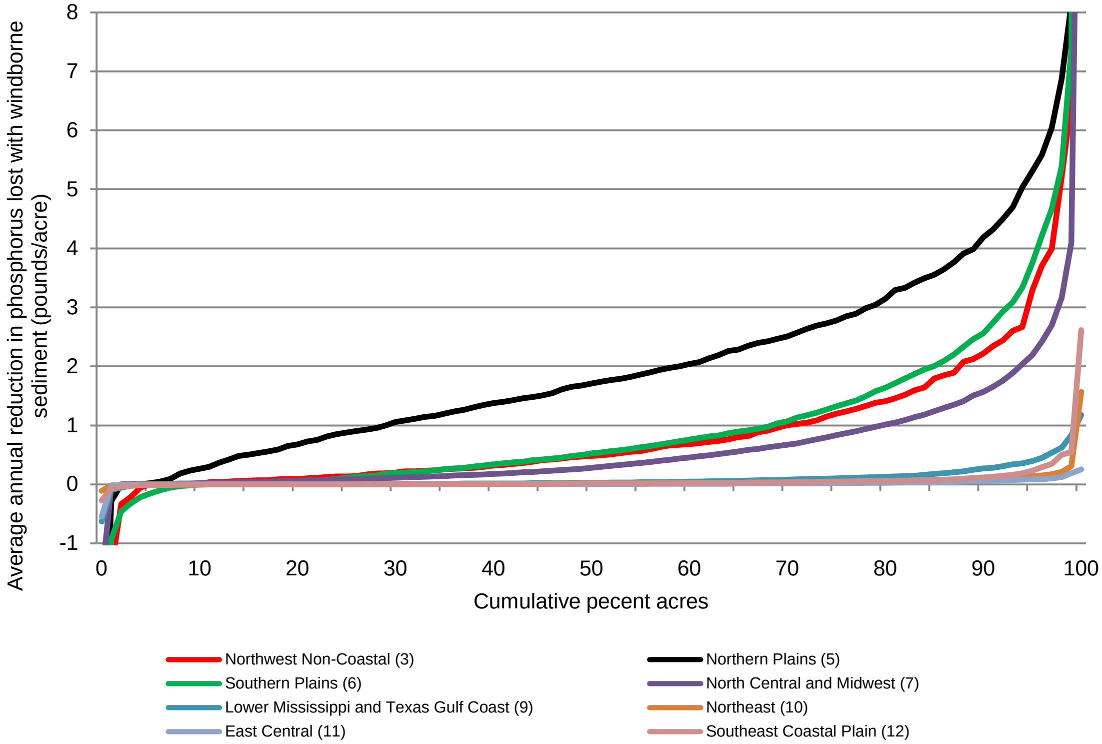


Figure 87. Distributions of average annual reductions in soluble phosphorus lost to surface water due to the use of conservation practices, CEAP sample points in eight production regions.

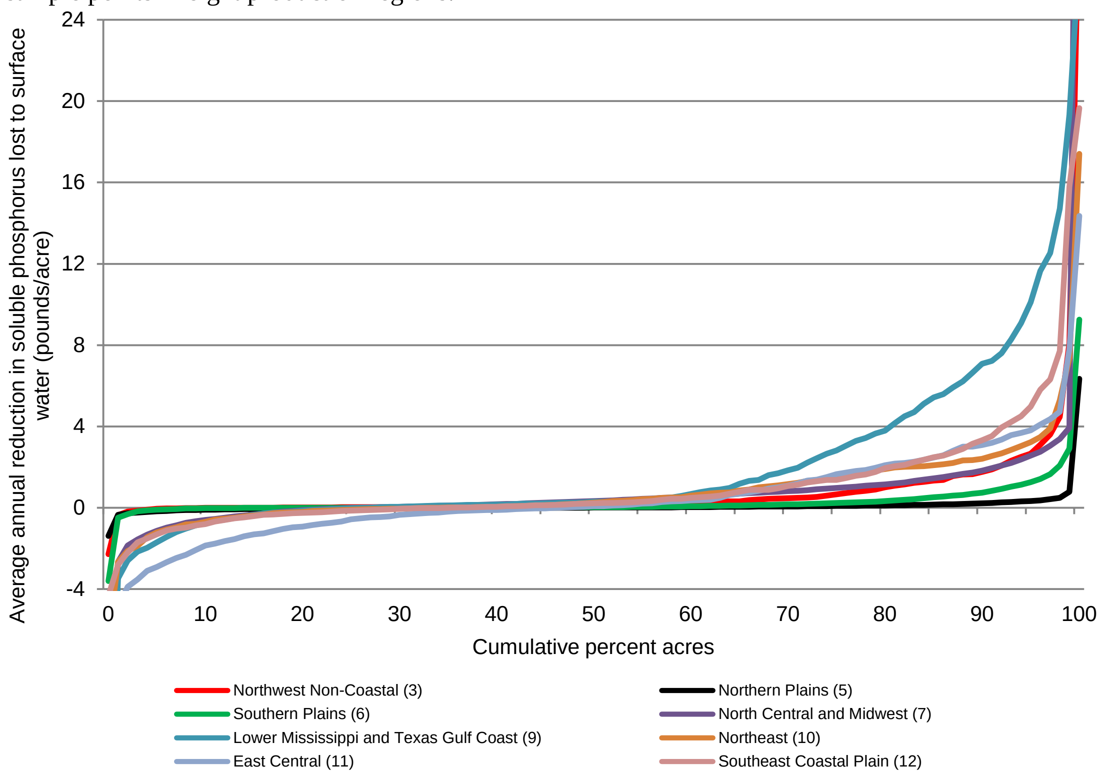


Figure 88. Distributions of average annual reductions in phosphorus lost with waterborne sediment due to the use of conservation practices, CEAP sample points in eight production regions.

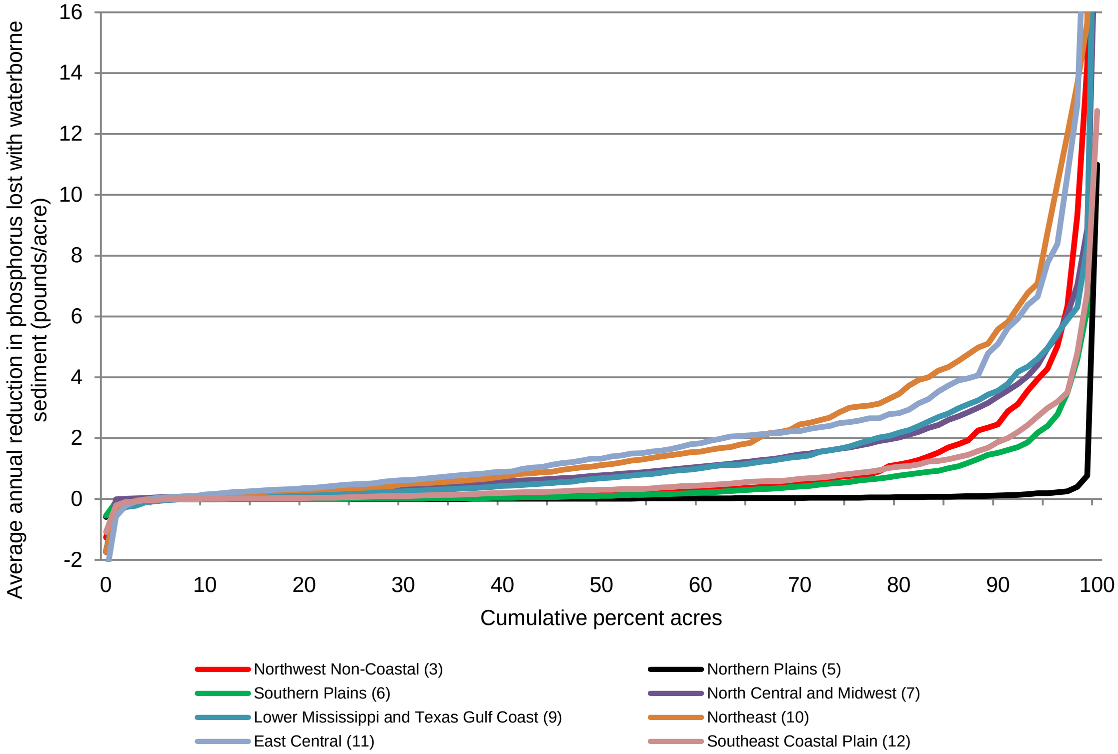
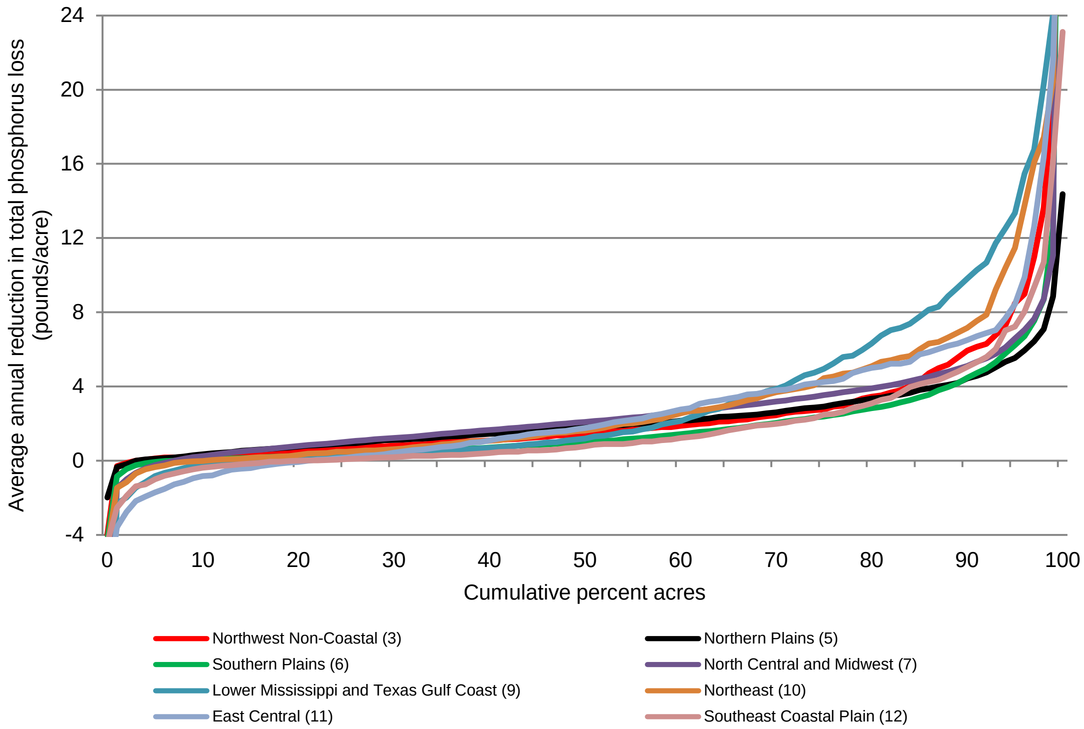


Figure 89. Distributions of average annual reductions in total phosphorus loss (all loss pathways) due to the use of conservation practices, CEAP sample points in eight production regions.



Breakdown of the Effects of Practice Use by Levels of Conservation Treatment

To extend the assessment of the effects of conservation practices further, average annual reductions in total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus) were estimated for the four soil runoff potentials and the four treatment levels of phosphorus runoff control. Results for these 16 combinations of vulnerability and treatment levels were previously presented table 17 for in the baseline scenario. Table 32 presents estimates for the no-practice scenario and estimates of reductions in total phosphorus lost to surface water due to conservation practices for all eight regions combined.

As shown previously in table 17, the amounts of total phosphorus lost to surface water are highest for soils with the highest soil runoff potential. Table 32 shows that phosphorus losses for the no-practice scenario also increase as the soil runoff potential increases.

With respect to increases in the phosphorus runoff control treatment levels, the matrix for phosphorus losses in the no-practice scenario exhibit decreasing trends in phosphorus loss estimates as conservation treatment levels increase, although not consistently, in spite of modeling efforts to remove or reverse the effects of conservation practices. These trends may be due to the benefits of practices other than phosphorus runoff control that may be correlated with the phosphorus runoff control treatment levels.

Table 32 shows that **reductions** in phosphorus losses follow the trend of increasing amounts with increasing soil runoff potentials. Overall losses are highest for soils with the higher soil runoff potentials, and so reductions due to conservation practices also tend to be higher for these sample points as well. The mean average annual reduction due to conservation practice use in all eight regions, averaged over the four treatment levels, was:

- 1.04 pounds per acre per year for acres with a “low” soil runoff potential,
- 1.61 pounds per acre per year for acres with a “moderate” soil runoff potential,
- 1.89 pounds per acre per year for acres with a “moderately high” soil runoff potential, and
- 3.01 pounds per acre per year for acres with a “high” soil runoff potential.

As expected, average annual reductions in total phosphorus lost to surface water increased as treatment levels increased (table 32). The mean average annual reduction due to conservation practice use in all eight regions, averaged over the four soil runoff potentials, was:

- 0.91 pound per acre per year for acres with a “low” phosphorus runoff control treatment level,
- 1.36 pounds per acre per year for acres with a “moderate” phosphorus runoff control treatment level,
- 1.87 pounds per acre per year for acres with a “moderately high” phosphorus runoff control treatment level, and
- 1.85 pounds per acre per year for acres with a “high” phosphorus runoff control treatment level (essentially the same amount as for acres with a “moderately high” level).

Percent reductions strongly increased with increasing conservation treatment levels. Percent reductions due to conservation practice use in all eight regions were:

- 19 percent for acres with a “low” conservation treatment level,
- 39 percent for acres with a “moderate” conservation treatment level,
- 66 percent for acres with a “moderately high” conservation treatment level, and
- 74 percent for acres with a “high” conservation treatment level.

Percent reductions among the four soil runoff potentials within each treatment level did not vary much and trends were inconsistent.

The same trends are manifested for model simulation results for most of the eight regions, as shown in tables 33 through 40, but are sometimes inconsistent in places, mostly due to the small sample sizes in some cells of the matrix. For example:

- the increasing trend in the average amount of the **reduction** in phosphorus loss as conservation treatment levels increase, averaged over the four soil runoff potentials, was evident in the matrix for all regions when results for the “moderately high” and “high” treatment levels were combined.
- the increasing trend in the **percent reduction** in phosphorus loss as conservation treatment levels increase, averaged over the four soil runoff potentials, was also evident in the matrix for all but two regions—the Northwest Non-Coastal (3) region and the Southern Plains (6) region.
- the increasing trend in the average amount of the **reduction** in phosphorus loss as soil runoff potentials increased, averaged over the four conservation treatment levels, was evident in the matrix for all but two regions—the Northern Plains (5) region and the Lower Mississippi and Texas Gulf Coast (9) region.

Table 32. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, all eight regions combined.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	8%	20%	18%	6%	53%
Moderate	3%	8%	6%	1%	18%
Moderately high	3%	9%	5%	1%	19%
High	2%	5%	3%	<1%	10%
All	17%	43%	32%	9%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	2.93	2.34	2.01	1.89	2.26
Moderate	4.08	3.65	3.55	4.51	3.75
Moderately high	6.68	4.45	3.61	3.80	4.60
High	11.32	6.15	5.47	5.82	6.93
All	4.82	3.50	2.84	2.52	3.42
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.62	0.83	1.35	1.38	1.04
Moderate	0.59	1.22	2.22	3.35	1.61
Moderately high	1.14	1.85	2.32	2.73	1.89
High	2.37	2.78	3.83	5.33	3.01
All	0.91	1.36	1.87	1.85	1.49
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	21%	35%	67%	73%	46%
Moderate	15%	33%	62%	74%	43%
Moderately high	17%	42%	64%	72%	41%
High	21%	45%	70%	92%	43%
All	19%	39%	66%	74%	44%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 33. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Northwest Non-Coastal (3) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	9%	17%	12%	2%	40%
Moderate	1%	1%	1%	0%	2%
Moderately high	3%	16%	6%	1%	26%
High	1%	21%	9%	0%	32%
All	14%	55%	28%	3%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	3.29	1.68	1.83	1.23	2.07
Moderate	3.77	2.12	1.19	NA	2.33
Moderately high	9.77	2.61	0.71	1.37	2.87
High	3.38	4.27	1.71	1.72	3.47
All	4.55	2.96	1.54	1.32	2.73
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	2.14	1.16	1.58	0.90	1.50
Moderate	2.63	1.86	0.96	NA	1.80
Moderately high	5.53	1.77	0.49	0.98	1.84
High	1.74	1.70	1.07	1.52	1.52
All	2.78	1.56	1.17	0.99	1.60
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	65%	69%	86%	73%	72%
Moderate	70%	88%	81%	NA	77%
Moderately high	57%	68%	70%	72%	64%
High	51%	40%	62%	88%	44%
All	61%	53%	76%	75%	59%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 34. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Northern Plains (5) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	5%	18%	19%	8%	50%
Moderate	2%	10%	7%	1%	20%
Moderately high	4%	12%	7%	1%	24%
High	1%	5%	1%	0%	7%
All	13%	45%	33%	10%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	0.24	0.24	0.24	0.39	0.26
Moderate	0.50	0.46	0.38	0.53	0.44
Moderately high	0.27	0.24	0.36	0.48	0.29
High	0.39	0.67	0.56	NA	0.60
All	0.31	0.33	0.30	0.41	0.33
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.01	0.05	0.13	0.24	0.11
Moderate	0.08	0.19	0.21	0.29	0.19
Moderately high	0.02	0.01	0.12	0.25	0.05
High	0.00	0.26	0.33	NA	0.22
All	0.02	0.09	0.15	0.24	0.12
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	4%	21%	54%	61%	40%
Moderate	16%	41%	54%	54%	42%
Moderately high	6%	3%	33%	51%	17%
High	0%	39%	60%	NA	37%
All	7%	28%	50%	59%	36%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 35. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Southern Plains (6) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	14%	27%	27%	8%	75%
Moderate	3%	4%	4%	1%	11%
Moderately high	2%	6%	4%	1%	12%
High	0%	1%	1%	0%	2%
All	18%	38%	35%	9%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	1.09	0.82	0.73	1.36	0.89
Moderate	1.79	2.35	1.15	2.09	1.78
Moderately high	2.58	3.56	2.84	2.82	3.15
High	8.96	3.65	2.65	NA	3.81
All	1.43	1.50	1.03	1.49	1.32
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.63	0.52	0.56	1.04	0.61
Moderate	0.36	1.28	0.72	1.40	0.88
Moderately high	0.61	2.11	1.97	2.17	1.83
High	8.21	2.30	2.17	NA	2.77
All	0.67	0.91	0.75	1.13	0.83
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	57%	64%	76%	77%	68%
Moderate	20%	54%	63%	67%	49%
Moderately high	24%	59%	69%	77%	58%
High	92%	63%	82%	NA	73%
All	47%	60%	73%	76%	63%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 36. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, North Central and Midwest (7) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	4%	19%	17%	8%	48%
Moderate	2%	7%	6%	2%	18%
Moderately high	3%	10%	7%	1%	21%
High	2%	7%	4%	<1%	13%
All	11%	42%	35%	11%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	3.04	2.88	2.76	2.45	2.79
Moderate	4.18	3.85	4.14	4.19	4.03
Moderately high	7.29	5.55	4.98	4.96	5.58
High	10.82	7.71	6.53	6.73	7.81
All	5.85	4.41	3.93	3.13	4.26
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.59	0.67	1.68	1.75	1.20
Moderate	0.81	0.98	2.59	3.00	1.80
Moderately high	1.11	2.11	3.21	3.52	2.40
High	1.99	3.52	4.53	6.18	3.64
All	1.03	1.50	2.51	2.25	1.88
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	19%	23%	61%	71%	43%
Moderate	19%	25%	62%	71%	45%
Moderately high	15%	38%	64%	71%	43%
High	18%	46%	69%	92%	47%
All	18%	34%	64%	72%	44%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 37. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Lower Mississippi and Texas Gulf Coast (9) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	7%	15%	10%	2%	35%
Moderate	10%	23%	17%	3%	53%
Moderately high	5%	5%	1%	<1%	11%
High	1%	1%	0%	0%	2%
All	23%	44%	28%	5%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	8.65	8.96	8.48	8.51	8.73
Moderate	5.34	6.19	6.61	9.73	6.35
Moderately high	14.05	9.90	11.34	10.83	11.79
High	17.17	13.84	5.46	NA	15.30
All	8.61	7.73	7.39	9.29	7.91
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.34	3.95	5.92	6.91	3.99
Moderate	0.48	2.33	4.05	7.91	2.82
Moderately high	1.62	3.73	6.92	8.44	3.05
High	2.30	6.43	4.36	NA	4.17
All	0.75	3.13	4.79	7.53	3.27
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	4%	44%	70%	81%	46%
Moderate	9%	38%	61%	81%	44%
Moderately high	12%	38%	61%	78%	26%
High	13%	46%	80%	NA	27%
All	9%	41%	65%	81%	41%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 38. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Northeast (10) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	15%	11%	7%	<1%	34%
Moderate	5%	5%	2%	<1%	12%
Moderately high	11%	12%	2%	<1%	26%
High	14%	12%	2%	0%	28%
All	45%	41%	14%	1%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	8.59	3.94	2.89	2.45	5.70
Moderate	10.00	6.12	4.30	3.58	7.23
Moderately high	11.47	8.44	7.52	5.37	9.64
High	15.90	9.42	6.62	NA	12.53
All	11.79	7.19	4.43	3.24	8.82
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	2.11	1.36	1.92	1.81	1.81
Moderate	1.73	2.21	2.37	2.48	2.06
Moderately high	2.99	4.14	5.73	4.53	3.80
High	4.04	4.65	4.88	NA	4.36
All	2.90	3.28	3.05	2.44	3.07
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	25%	35%	66%	74%	32%
Moderate	17%	36%	55%	69%	29%
Moderately high	26%	49%	76%	84%	39%
High	25%	49%	74%	NA	35%
All	25%	46%	69%	75%	35%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 39. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, East Central (11) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	7%	18%	9%	2%	35%
Moderate	4%	8%	3%	<1%	15%
Moderately high	7%	17%	4%	<1%	28%
High	8%	9%	4%	0%	21%
All	26%	51%	20%	2%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	8.37	6.04	4.47	6.10	6.11
Moderate	6.78	6.94	5.93	5.62	6.69
Moderately high	11.43	9.35	5.67	7.69	9.28
High	16.54	10.70	9.18	NA	12.73
All	11.59	8.05	5.90	6.24	8.50
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	1.00	1.64	2.93	3.94	1.95
Moderate	0.83	2.10	4.55	4.15	2.28
Moderately high	1.02	3.22	3.13	5.95	2.70
High	2.68	4.01	7.03	NA	4.07
All	1.53	2.63	4.04	4.20	2.66
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	12%	27%	65%	65%	32%
Moderate	12%	30%	77%	74%	34%
Moderately high	9%	34%	55%	77%	29%
High	16%	38%	77%	NA	32%
All	13%	33%	69%	67%	31%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Table 40. Breakdown of the effects of conservation practices on total phosphorus lost to surface water (phosphorus attached to sediment plus soluble phosphorus*) into 16 combinations of four soil runoff potentials and four conservation treatment levels for phosphorus runoff control, Southeast Coastal Plain (12) region.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Percent of cropped acres					
Low	32%	30%	15%	2%	78%
Moderate	6%	6%	2%	<1%	14%
Moderately high	3%	3%	1%	<1%	7%
High	<1%	1%	<1%	0%	1%
All	42%	39%	17%	2%	100%
Estimates of total phosphorus lost to surface water for the no-practice scenario (average annual pounds/acre)					
Low	3.94	3.51	4.79	3.53	3.93
Moderate	6.62	5.48	5.63	10.98	6.04
Moderately high	9.11	8.71	5.91	3.44	8.58
High	6.81	5.56	12.97	NA	6.12
All	4.76	4.25	4.93	3.88	4.57
Reduction in total phosphorus lost to surface water due to conservation practices (average annual pounds/acre)					
Low	0.32	1.56	4.10	3.15	1.57
Moderate	0.74	1.75	4.50	9.95	1.65
Moderately high	1.04	4.03	4.71	2.45	2.70
High	2.13	3.25	12.42	NA	3.19
All	0.46	1.81	4.18	3.45	1.68
Percent reduction in total phosphorus lost to surface water due to conservation practices					
Low	8%	44%	86%	89%	40%
Moderate	11%	32%	80%	91%	27%
Moderately high	11%	46%	80%	71%	31%
High	31%	59%	96%	NA	52%
All	10%	43%	85%	89%	37%

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps. It does not include soluble phosphorus lost to groundwater.

Appendix A: Adjustment of CEAP Sample Weights for the 2003-06 CEAP Sample for Use with the 12 New CEAP Production Regions

The first CEAP national assessment was based on a subset of NRI sample points from the 2003 NRI.[17] The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[18] The sample is statistically representative of cultivated cropland acres for the year 2003. Statistical sample weights were originally derived for each CEAP sample point so as to approximate acres reported in the 2003 NRI for similar cropping systems when aggregated to the 4-digit HUC level.

These original CEAP sample acreage weights, however, distort the cultivated cropland acreage estimates when the sample points are aggregated to geographic areas other than the 4-digit HUC. It was thus necessary to adjust the sample weights for reporting cultivated cropland acres by the new CEAP production regions.

Original Derivation of Cropping Systems

Cropping systems were originally derived based on the 2003 NRI database for cultivated cropland, as described in the CEAP documentation report "CEAP and NRI Cropping Systems 2008 Documentation."(A cropping system represents a suite of crops that is typically grown in the same field over a period of a few years.) This set of data (BROAD03=1) included 96,661 points representing 309,866,800 cultivated cropland acres. The five year crop sequence from 1999 through 2003 was used to derive the NRI cropping systems. Second crops (NRI variable name "scdcrpxx") were included when reported. NRI crop groups were simplified somewhat prior to developing cropping systems to help reduce the number of possible crop combinations. Oats was combined with "other close grown crops;" tobacco was combined with vegetables; summer fallow and idle cropland were combined; the three types of NRI hay were combined into one group; and the three types of NRI pasture were combined into one group.

A total of 62 cropping systems were derived as shown in Table A1. Except for single-crop systems, cropping systems were derived based on the dominant sets of crop sequences. The entire collection of NRI cultivated cropland points was used without consideration for regional dominance. Each of the single-crop systems (systems 2 through 23) was included regardless of how many samples were in the set to provide perspective on the frequency at which "continuous cropping" was present in the NRI. The simplest cropping systems that were mutually exclusive were identified first—through cropping system number 35. Subsequent cropping systems are not mutually exclusive as they depend on the order of operation. For example, cropping systems 40 and 41—rice with other crops—include a small number of points with hay. And, consequently, the following 6 hay systems (43-48) do not include any rice, nor do any of the remaining cropping systems. Similarly, cropping systems numbered above 50 do not include any hay. And so on. The order of operations was determined so as to preserve cropping systems that are important either for data analysis or for other uses. Some cropping systems consist of only a few points and represent less than 1 percent of the cultivated cropland acreage. These were retained to facilitate the derivation of the more aggregated primary cropping systems for use in reporting.

The last cropping system—number 100, at the bottom of the table—consists of 16 2003 NRI sample points that were either aquaculture or non-cultivated crops for all 5 years. This tiny set represents only 36,800 acres. These acres were excluded from the CEAP sample domain. Also shown in Table A1 are four other NRI cropping systems without representation in the CEAP samples—systems 20-23. These are combinations of either fallow and idle with no other crops, with hay only, with pasture only, or with hay and pasture only. The presence of either fallow or idle qualifies the sample as cultivated cropland according to the NRI land use classification rules. Since all the final CEAP samples include at least one close grown or row crop (with the exception of 43 samples with continuous annual hay which is typically a small grain hay), these systems are not represented by CEAP samples. This set (system 100) represents about 5 million acres. These acres were also excluded from the CEAP sample domain prior to derivation of the original CEAP sample weights.

Cropping systems were also derived originally for each CEAP sample point. The rules used for the 2003 NRI sample points were applied to the crops reported for each sample point in the CEAP survey. The number of CEAP sample points corresponding to the original NRI cropping systems is also shown in table A1.

The NRI-CEAP Cropland Survey reported 144 different specific crops grown at 18,691 final sample points. Specific crops were often a combination of crop species and crop use. For example, corn for grain and corn for silage and corn for seed were reported as separate crops in the survey database. These 144 specific crops were aggregated into 20 CEAP crop groups, shown in table A2, to correspond to the NRI crop groups. The crop groups used for NRI crop reporting are also shown in table A2.

While the majority of samples consist of a single crop for each of the three years, it is common to have 2 crops per year. In a few cases, more than 2 crops per year occur. The maximum number of crops reported per year ranged from 3 in 2005 to 5 in 2003 and 2004. Multiple harvests within a year were often reported as separate crops as well. In most cases, samples with 3 or more crops reported per year were instances of split fields, which were simplified by dropping the crops in the part of the field that did not correspond to the NRI cropping history.

[17] See "United States Department of Agriculture, Natural Resources Conservation Service. 2007.
2003 National Resources Inventory. http://www.nrcs.usda.gov/technical/nri."

[18] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.

The crop sequence for each CEAP sample point was converted to the simpler representation in terms of the 20 CEAP crop groups shown in table A2. Typical crop sequences look like the following:

	Year 1	Year 2	Year 3
Sample point A	CN_ _ _	SB_ _ _	CN_ _ _
Sample point B	CN_WH_ _	SB_WH _ _	CN_WH_ _
Sample point C	VT_VT_VT _	VT_VT_VT _	VT_VT_VT _
Sample point D	WH_HY_ _	HY_HY_ _	VT_SB_CG _
Sample point E	_SG_ _	FW_ _ _	_ _CT _

Sample E represents the case where crops were reported for a split field and subsequently edited by dropping some of the crops. Re-plantings were generally edited in the same manner.

Adjustment of acreage weights to represent the 12 new CEAP production regions

The original sample weights used for reporting 2003-06 CEAP findings in the first national assessment reports were adjusted so that, when aggregating over CEAP sample points to obtain estimates for CEAP production regions, the acreage estimates would correspond to the acreage estimates derived from the full 2003 NRI set of points for a set of major cropping systems within each production region.

The first step in this process was to define the "major" cropping systems—cropping systems suitable for reporting—within each of the 12 CEAP production regions (table A3). The original 62 cropping systems for the 2003 NRI and for the 2003-06 CEAP sample, as described above and listed in table A1, were retained without modification or adjustment. These were combined within each production region so that each major cropping system would have sufficient sample size to allow estimates to be reported. These major cropping systems by production region were derived both for the 2003 NRI points and the 2003-06 CEAP sample points using the same rules, and are presented in table A3.

For each production region and major cropping system, the sum of the original CEAP sample weights is compared to the 2003 NRI estimate of cultivated cropland acres in table A3. The ratio of the 2003 NRI acres to the sum of the original CEAP weights provides a multiplier which, when multiplied times the original CEAP sample weights at each sample point produces a set of adjusted weights that can be used to accurately aggregate CEAP sample results to the production region level for reporting.

Thus, aggregating over the CEAP sample point weights within each production region reproduces the estimates of cultivated cropland acreage that correspond to estimates from the full 2003 NRI, as shown in the following table:

PR ID	Number of 2003 NRI points	2003 cultivated cropland acres	Number of 2003-06 CEAP sample points*	Sum of adjusted CEAP sample weights
1	563	1,214,000	158	1,214,000
2	1,125	3,440,500	111	3,440,500
3	4,560	12,315,000	890	12,315,000
4	1,208	2,432,200	190	2,432,200
5	11,255	47,688,900	1,518	47,688,900
6	13,806	63,829,400	2,615	63,829,400
7	42,114	117,423,200	8,065	117,423,200
8	1,631	6,431,200	232	6,431,200
9	6,940	21,162,500	1,820	21,162,500
10	3,430	6,547,500	888	6,547,500
11	3,323	8,723,200	915	8,723,200
12	5,080	13,502,000	1,289	13,502,000
All 12 regions	95,035	304,709,600	18,691	304,709,600

* Includes 368 CEAP sample points in the "West" region.

As indicated earlier in this report, the CEAP sample points from the original "West" region—368 sample points—could not be used to summarize findings by the CEAP production regions because the full set of APEX modeling results were not available. Thus, the sum of the adjusted CEAP sample weights understates the cultivated cropland acres in four production regions (highlighted in yellow in the table below), as shown by comparing the table below to the table above.

Production region	Number of 2003-06 CEAP sample points*	Sum of adjusted CEAP sample weights
Northwest Coastal (1)	158	1,214,000
California Coastal (2)	0	0
Northwest Non-Coastal (3)	817	11,477,012
Southwest Non-Coastal (4)	15	155,242
Northern Plains (5)	1,518	47,688,900
Southern Plains (6)	2,606	63,563,684
North Central and Midwest (7)	8,065	117,423,200
South Central (8)	232	6,431,200
Lower Mississippi and Texas Gulf Coast (9)	1,820	21,162,500
Northeast (10)	888	6,547,500
East Central (11)	915	8,723,200
Southeast Coastal Plain (12)	1,289	13,502,000
All 12 regions	18,323	297,888,439

* Excludes 368 CEAP sample points in the "West" region that could not be used in the national assessments because the full set of APEX modeling results were not available.

Results for two of these production regions—the California Coastal region (2) and the Southwest Non-Coastal region (4)—were not included in this report because neither region had enough 2003-06 sample points to support a regional assessment. When the remaining 2 regions that did not have sufficient sample size are dropped from the table—the Northwest Coastal region (1) and the South Central region (8)—the regional and total estimates of cultivated cropland acres match those presented in table 1.

Table A1. Original cropping systems based on rules derived using the 2003 NRI and then applied to the 2003-06 CEAP sample points.

System number	Cropping system name (nricropsys5)	No. of 2003 NRI cultivated cropland points	2003 NRI acres	No. of CEAP sample points*
1	CN-SB only, w/wout FWID	33,797	94,516,400	7,122
2	corn only, w/wout FWID	3,446	9,668,600	1,196
3	soybean only, w/wout FWID	2,590	6,656,400	949
4	cotton only, w/wout FWID	2,432	8,747,200	715
5	sorghum only, w/wout FWID	538	2,239,400	68
6	wheat only, w/wout FWID	7,894	38,194,500	1,774
7	rice only, w/wout FWID	739	2,228,800	179
8	veg/tobacco only, w/wout FWID	666	1,363,600	90
9	peanuts only, w/wout FWID	96	346,100	16
10	sunflower only, w/wout FWID	10	23,800	3
11	sugar beet only, w/wout FWID	7	15,200	4
12	potato only, w/wout FWID	31	54,700	5
13	NRI other row only, w/wout FWID	364	1,216,300	70
14	barley only, w/wout FWID	316	996,400	87
15	NRI other close grown only, w/wout FWID	825	2,925,200	164
20	pasture only, with FWID	60	200,300	0
21	hay only, with FWID	176	662,500	0
22	pasture and hay only, with FWID	4	8,800	0
23	fallow and/or idle only	1,370	4,248,800	0
27	annual hay only, w/wout FWID (CEAP only)	0	0	43
30	CN-SB-WT only	5,856	15,613,100	1,005
31	SG-WT only	1,611	9,059,800	221
32	SB-WT only	2,158	6,889,600	617
33	CT-PN only	387	1,451,500	110
34	SB-CT only	558	1,742,200	116
35	CN-CT only	412	1,490,000	149
40	RI-SB w/wout other crops	1,428	4,853,600	293
41	RI w/wout other crops, no SB	108	379,200	31
43	HAY/PAST-CN-SB, w/wout other crops	2,794	7,081,000	78
44	HAY/PAST-CN-CLOSE, w/wout other crops (no SB)	1,255	3,364,300	109
45	HAY/PAST-CN, w/wout other crops (no SB, close)	2,536	7,180,600	362
46	HAY/PAST-SB, w/wout other crops (no CN)	960	2,525,700	90
47	HAY/PAST-CLOSE, w/wout other crops (no CN, SB)	2,200	7,306,600	308
48	HAY/PAST w/wout other crops (no CN-SB-close)	529	1,678,500	38
52	veg/tobacco and close grown only	570	2,038,700	212
53	veg/tobacco w/wout other row crops (some close)	2,345	6,727,400	318
60	mix of remaining close grown crops, no row	2,939	12,159,600	302
61	CN and close grown crops	1,862	7,239,600	496
62	SB and close grown crops	333	1,063,100	78
63	CN-SB and close grown crops	612	1,632,600	134
64	CT and close grown crops	602	2,393,700	105
65	SG and close grown crops	109	566,800	11
66	SF and close grown crops	1,267	4,951,500	120
67	PO and close grown crops	559	982,000	89
68	SU and close grown crops	229	616,800	61
69	PN and close grown crops	55	197,700	11
70	OTHROW and close grown crops	90	385,900	23
71	CT-PN and close grown crops	100	380,000	22
72	CT-SB and close grown crops	155	433,300	41
73	CT-CN and close grown crops	98	336,900	10
80	PO and other row crops (some close)	518	1,292,600	47
81	SU and other row crops (no PO)(some close)	671	2,702,500	64
82	SF and other row crops (no PO,SU)(some close)	1,075	4,039,700	65

Table A1.—**continued.**

System number	Cropping system name (nricropsys5)	No. of 2003 NRI cultivated cropland points	2003 NRI acres	No. of CEAP sample points*
83	remaining CT-SG crop mixes (row and close)	868	3,618,600	85
84	remaining CT-PN-row and other crops	263	767,200	34
85	remaining CT-CN-row and other crops	416	1,202,400	41
86	remaining CN-SB-row and other crops	875	2,663,000	45
87	remaining CN-SG crop mixes (row and close)	556	2,364,200	75
88	remaining SB-SG crop mixes (row and close)	914	2,871,000	183
89	remaining NRI OTHROW-row and other crops	190	574,400	8
90	remaining PN-row and other crops	221	700,100	30
100	NRI crops are: 171, 5, 6, 2, 400, 900, or missing	16	36,800	0
	totals	96,661	309,866,800	18,722

Source: Table reprinted from "CEAP and NRI Cropping Systems 2008 Documentation."
* Included are 31 points that were later dropped from the 2003-06 final sample because of inadequate survey data to run the APEX model.

The following abbreviations are used in this table:

CN—corn
SB—soybean
FWID—fallow or idle
SG—sorghum
CT—cotton
PN—peanuts
RI—rice
PAST—pasture
CLOSE—any close grown crops, such as wheat, barley, oats, or grass seed
SU—sugar beets
SF—sunflower
OTHERROW—NRI "other row crop" category
PO—potato

Table A2. Crop groups used to define cropping systems (CEAP crops listed are those reported in the CEAP surveys).

Crop groups	Crop Group Abbrevia-tion	CEAP crop code	CEAP crop	NRI crop code	NRI crop
Row Crops					
Corn	CN	191	Corn, All	11	Corn
	CN	218	Corn, dry fodder, hogged	11	Corn
	CN	6	Corn, grain	11	Corn
	CN	38	Corn, seed	11	Corn
	CN	5	Corn, silage	11	Corn
	CN	7	Corn, white	11	Corn
	CN	19	Popcorn	11	Corn
	CN	2110	Sweet corn, fresh	11	Corn
	CN	4110	Sweet corn, processing	11	Corn
	CN	246	Sweet corn for seed	11	Corn
Sorghum	SG	192	Sorghum, All	12	Sorghum
	SG	25	Sorghum, grain	12	Sorghum
	SG	24	Sorghum, silage	12	Sorghum
Soybean	SB	26	Soybeans	13	Soybeans
Cotton	CT	282	Cotton, Pima	14	Cotton
	CT	281	Cotton, Upland	14	Cotton
Peanuts	PN	16	Peanuts	15	Peanuts
Sugar beets	SU	28	Sugar beets for sugar	17	Sugar beets
Potatoes	PO	20	Potatoes	18	Potatoes
Sugarcane	SC	29	Sugarcane for sugar	20	Other Row Crops
Sunflower	OS	148	Sunflower seed, non-oil	21	Sunflower
	OS	30	Sunflower seed, oil	21	Sunflower
Other row crops	OR	160	Guar	20	Other Row Crops
	OR	181	Kenaf	20	Other Row Crops
	OR	98	Safflower	20	Other Row Crops
Beans and Peas	BP	3	Beans, dry edible	19	Vegetables
	BP	2122	Green peas, Fresh	19	Vegetables
	BP	4122	Green peas, Processing	19	Vegetables
	BP	169	Lentils	19	Vegetables
	BP	268	Lima beans, dry	19	Vegetables
	BP	2115	Lima beans, fresh	19	Vegetables
	BP	4115	Lima beans, processing	19	Vegetables
	BP	197	Mung beans	19	Vegetables
	BP	123	Peas, all other	19	Vegetables
	BP	200	Peas, Austrian winter	19	Vegetables
	BP	124	Peas, black eye	19	Vegetables
	BP	125	Peas, cowpeas	19	Vegetables
	BP	17	Peas, dry edible	19	Vegetables
	BP	4131	Snap bean, processing	19	Vegetables
	BP	2131	Snap beans, fresh	19	Vegetables
	BP	243	Southern peas, cowpeas, etc	19	Vegetables

Table A2.—continued.

Crop groups	Crop Group Abbrevia-tion	CEAP crop code	CEAP crop	NRI crop code	NRI crop
Vegetables and Tobacco	VT	32	Tobacco, (other)	16	Tobacco
	VT	193	Tobacco, burley	16	Tobacco
	VT	196	Tobacco, flue-cured	16	Tobacco
	VT	103	Beets	19	Vegetables
	VT	104	Broccoli	19	Vegetables
	VT	105	Brussel sprouts	19	Vegetables
	VT	2106	Cabbage, Fresh	19	Vegetables
	VT	4106	Cabbage, Processing	19	Vegetables
	VT	4	Cantaloupe	19	Vegetables
	VT	107	Carrots	19	Vegetables
	VT	108	Cauliflower	19	Vegetables
	VT	109	Celery	19	Vegetables
	VT	249	Chinese cabbage	19	Vegetables
	VT	185	Collards	19	Vegetables
	VT	2111	Cucumbers, Fresh	19	Vegetables
	VT	4111	Cucumbers, Processing	19	Vegetables
	VT	112	Eggplant	19	Vegetables
	VT	114	Garlic	19	Vegetables
	VT	117	Lettuce, head	19	Vegetables
	VT	149	Lettuce, other	19	Vegetables
	VT	146	Lettuce, romaine	19	Vegetables
	VT	13	Melons, honeydew	19	Vegetables
	VT	187	Mustard greens	19	Vegetables
	VT	135	Onions, dehydrated	19	Vegetables
	VT	120	Onions, dry	19	Vegetables
	VT	126	Peppers, bell	19	Vegetables
	VT	127	Peppers, chili	19	Vegetables
	VT	244	Peppers, hot	19	Vegetables
	VT	128	Pumpkins	19	Vegetables
	VT	129	Radishes	19	Vegetables
	VT	4132	Spinach, processing	19	Vegetables
	VT	133	Squash, summer	19	Vegetables
	VT	150	Squash, winter	19	Vegetables
	VT	31	Sweet potatoes	19	Vegetables
	VT	2134	Tomatoes, fresh	19	Vegetables
	VT	4134	Tomatoes, processing	19	Vegetables
	VT	145	Turnips	19	Vegetables
	VT	236	Vegetables, other	19	Vegetables
	VT	37	Vegetables, seeds	19	Vegetables
	VT	33	Watermelons	19	Vegetables
Hay, Pasture, Fallow, and Idle					
Pasture	PS	316	Pasture as crop rotation	200	Pasture
Hay	HY	219	Sorghum, hay	12	Sorghum
	HY	310	Clover	144	Hay, all types
	HY	311	Grasses, other than clover	144	Hay, all types
	HY	226	Grass silage	144	Hay, all types
	HY	1	Hay, Alfalfa and alfalfa Mix	144	Hay, all types
	HY	232	Hay, Bahia	144	Hay, all types
	HY	231	Hay, Bermuda grass	144	Hay, all types
	HY	11	Hay, other	144	Hay, all types
	HY	217	Hay, small grain	144	Hay, all types
	HY	225	Hay, wild	144	Hay, all types
	HY	23	Silage & haylage	144	Hay, all types
	HY	180	Sorghum-sudan cross	144	Hay, all types
	HY	167	Sudan	144	Hay, all types
	HY	199	Teff	144	Hay, all types
	HY	39	Vetchseed, hairy	144	Hay, all types

Table A2.—continued.

Crop groups	Crop Group Abbrevia-tion	CEAP crop code	CEAP crop	NRI crop code	NRI crop
Fallow and Idle	FI	333	Idle or fallow (2003 only)		summer fallow or idle
	FW	333	Summer fallow	170	summer fallow
	ID	318	Idle cropland	180	Idle cropland
Close Grown Crops					
Wheat	WH	34	Wheat, All	111	wheat
	WH	172	Wheat, All, for seed	111	wheat
	WH	163	Wheat, durum	111	wheat
	WH	164	Wheat, other spring	111	wheat
	WH	165	Wheat, winter	111	wheat
Rice	RI	21	Rice	113	Rice
	RI	319	Rice, sweet	113	Rice
	RI	178	Rice, wild	113	Rice
Barley	BY	190	Barley, All	114	Barley
	BY	290	Barley, Feed	114	Barley
	BY	2	Barley, feed or malt	114	Barley
	BY	291	Barley, Malt	114	Barley
	BY	173	Barley, seed	114	Barley
Small grain crops	SM	15	Oats	112	Oats
	SM	84	Buckwheat	116	Other Close Grown
	SM	161	Emmer and spelt	116	Other Close Grown
	SM	22	Rye	116	Other Close Grown
	SM	162	Triticale	116	Other Close Grown
Other close grown crops	CG	35	Alfalfa seed	116	Other Close Grown
	CG	228	Bentgrass seed	116	Other Close Grown
	CG	229	Bermuda grass seed	116	Other Close Grown
	CG	40	Bluegrass seed	116	Other Close Grown
	CG	215	Bromegrass seed	116	Other Close Grown
	CG	85	Canola	116	Other Close Grown
	CG	153	Cilantro	116	Other Close Grown
	CG	194	Clover seed	116	Other Close Grown
	CG	214	Clover seed, crimson	116	Other Close Grown
	CG	43	Clover seed, red	116	Other Close Grown
	CG	203	Clover seed, white	116	Other Close Grown
	CG	317	Field and forage crops, Other	116	Other Close Grown
	CG	9	Flaxseed	116	Other Close Grown
	CG	10	Forage and green chop	116	Other Close Grown
	CG	138	Grass seed, other	116	Other Close Grown
	CG	41	Lespedeza seed	116	Other Close Grown
	CG	141	Millet	116	Other Close Grown
	CG	94	Mustard seed	116	Other Close Grown
	CG	42	Orchard grass seed	116	Other Close Grown
	CG	18	Peppermint	116	Other Close Grown
	CG	170	Rapeseed	116	Other Close Grown
	CG	136	Rye grass seed	116	Other Close Grown
	CG	168	Sage	116	Other Close Grown
	CG	44	Tall fescue seed	116	Other Close Grown
	CG	45	Timothy seed	116	Other Close Grown

Source: CEAP and NRI Cropping Systems 2008 Documentation

Table A3. Major cropping systems defined for the 12 new CEAP production regions (PRs), providing basis for sample weight adjustment.

Production region number	Major cropping system	No. of 2003-06 CEAP sample points	Sum of original CEAP sample weights	No. of 2003 NRI points	No. of 2003 cultivated cropland acres	PR and cropping system multiplier
1	Wheat only, w/wout FWID	21	233,823	63	183,400	0.784353
1	All Hay-crop mixes	15	70,038	100	192,900	2.7542188
1	Mix of remaining row crops only	19	81,362	37	50,600	0.6219115
1	Other close grown crops only	91	841,866	283	636,300	0.7558206
1	Remaining mix of row AND close crops	12	74,563	80	150,800	2.0224489
2	rice only, w/wout FWID	36	581,454	204	600,000	1.0318953
2	veg and/or tobacco only, w/wout FWID	14	263,136	184	353,300	1.3426508
2	Mix of remaining row crops only	20	855,671	196	928,400	1.0849962
2	Remaining mix of row AND close crops	24	741,178	242	730,400	0.9854581
2	Hay-crop mix or other close-grown crops	17	688,902	299	828,400	1.2024938
3	wheat only, w/wout FWID	336	5,237,699	1126	4,323,500	0.8254579
3	barley only, w/wout FWID	58	584,879	152	292,100	0.4994192
3	PO and close grown crops	75	634,265	504	756,400	1.1925613
3	Sugar beets with other crops	61	473,755	352	562,700	1.187745
3	All Hay-crop mixes	80	1,542,838	991	2,134,600	1.3835546
3	Mix of remaining row crops only	63	686,260	175	390,400	0.5688808
3	Other close grown crops only	97	1,339,580	796	2,855,800	2.1318618
3	Remaining mix of row AND close crops	120	1,814,434	464	999,500	0.5508606
4	cotton only, w/wout FWID	33	315,512	150	246,500	0.7812697
4	wheat only, w/wout FWID	27	318,336	177	328,700	1.0325573
4	CT and close grown crops	18	213,061	91	160,400	0.7528369
4	Sorghum and other row crops	21	366,192	156	255,900	0.6988145
4	Mix of remaining row crops only	19	265,831	104	169,500	0.6376231
4	Remaining mix of row AND close crops	28	337,811	65	142,500	0.4218336
4	Hay-crop mix or other close-grown crops	44	797,906	465	1,128,700	1.4145769
5	CN-SB only, w/wout FWID	205	5,077,059	1095	3,556,000	0.7004055
5	Corn only, w/wout FWID	41	1,042,354	129	404,800	0.3883518
5	Wheat only, w/wout FWID	395	12,739,650	1834	11,022,600	0.86522
5	SB-WT only	135	4,487,960	713	2,923,700	0.6514541
5	Vegetables/tobacco with close grown only	78	2,697,293	289	1,245,000	0.4615739
5	SF and close grown crops	96	3,117,644	1097	4,254,200	1.3645561
5	CN and/or SB with Close Grown	144	3,684,780	1191	4,222,000	1.1457945
5	CN and hay-other crop mix	22	501,285	307	934,200	1.8636116
5	Hay-crop mix no CN	51	1,667,861	536	2,601,700	1.5599022
5	Mix of remaining row crops only	52	1,420,458	375	1,040,900	0.7327918
5	Other close grown crops only	193	7,240,725	1863	8,232,900	1.1370271
5	Remaining mix of row AND close crops	106	3,770,622	1826	7,250,900	1.9229982
6	CN-SB only, w/wout FWID	201	4,052,440	1018	3,445,600	0.8502532
6	corn only, w/wout FWID	194	3,855,815	895	3,594,700	0.9322803
6	cotton only, w/wout FWID	235	4,429,286	847	3,681,900	0.8312627
6	sorghum only, w/wout FWID	50	1,644,806	351	1,471,200	0.8944522
6	wheat only, w/wout FWID	950	24,642,935	4194	20,594,400	0.8357121
6	SG-WT only	200	5,680,268	1513	8,670,200	1.5263717
6	CT-SG only	49	1,269,672	466	1,905,900	1.5010958
6	CT and close grown crops	69	1,483,395	385	1,739,500	1.1726479
6	CN and/or SB with Close Grown	222	5,849,459	1141	5,736,200	0.9806377
6	All Hay-crop mixes	123	3,255,042	575	2,329,300	0.7155976
6	Mix of remaining row crops only	126	2,638,555	822	3,195,900	1.2112313
6	Other close grown crops only	75	2,143,314	426	2,109,300	0.98413
6	Remaining mix of row AND close crops	121	3,123,913	1173	5,355,300	1.7142923

Table A3.—continued.

Production region number	Major cropping system	No. of 2003-06 CEAP sample points	Sum of original CEAP sample weights	No. of 2003 NRI points	No. of 2003 cultivated cropland acres	PR and cropping system multiplier
7	CN-SB only, w/wout FWID	5554	81,757,632	28865	81,191,400	0.9930743
7	corn only, w/wout FWID	536	8,103,601	1340	3,191,800	0.3938743
7	soybean only, w/wout FWID	334	4,287,452	736	1,652,700	0.3854737
7	CN-SB-WT only	492	5,858,610	3406	9,141,200	1.5603018
7	SB-WT only	289	3,867,223	688	1,784,300	0.4613905
7	vt with other row crops only	49	744,564	381	1,035,700	1.3910146
7	CN and/or SB with Close Grown	185	2,710,443	635	1,721,800	0.6352466
7	SB and SG with or w/out Close Grown	79	1,065,377	355	981,800	0.9215515
7	CN and hay-other crop mix	285	4,445,452	3630	10,539,000	2.3707378
7	Hay-crop mix no CN	133	2,039,617	719	2,117,100	1.0379889
7	Mix of remaining row crops only	57	780,461	743	2,112,000	2.7060945
7	Other close grown crops only	20	361,550	143	391,800	1.0836673
7	Remaining mix of row AND close crops	52	1,079,487	473	1,562,600	1.4475392
8	CN-SB only, w/wout FWID	19	335,271	70	253,600	0.7564032
8	wheat only, w/wout FWID	22	773,816	303	1,203,000	1.554633
8	RI and SB only, w/wout FWID	20	413,676	128	417,000	1.0080346
8	CN and/or SB with Close Grown	52	1,197,750	173	555,900	0.4641203
8	SG and other row drops	13	579,854	91	407,900	0.7034535
8	SG with close grown crops	12	343,465	58	258,900	0.7537885
8	Mix of remaining row crops only	35	1,015,273	384	1,622,500	1.5980927
8	Remaining mix of row AND close crops	28	658,856	147	525,500	0.7975946
8	Hay-crop mix or other close-grown crops	31	1,218,409	277	1,186,900	0.974139
9	CN-SB only, w/wout FWID	256	1,711,982	533	1,277,200	0.746036
9	soybean only, w/wout FWID	352	4,068,845	1094	3,014,800	0.7409474
9	cotton only, w/wout FWID	274	3,333,219	818	2,813,900	0.8441989
9	rice only, w/wout FWID	138	1,840,607	519	1,561,400	0.8483072
9	CN-CT only	66	864,269	194	708,100	0.8193051
9	RI and SB only, w/wout FWID	250	3,301,151	1003	3,332,100	1.0093753
9	CN and/or SB with Close Grown	156	1,400,057	741	1,913,100	1.3664443
9	CT and SB with or w/out other crops	85	891,576	548	1,665,500	1.8680407
9	Mix of remaining row crops only	168	2,608,114	777	2,665,500	1.0220029
9	Remaining mix of row AND close crops	47	534,980	494	1,686,100	3.1517095
9	Hay-crop mix or other close-grown crops	28	358,991	219	524,800	1.4618766
10	CN-SB only, w/wout FWID	211	1,284,297	519	824,600	0.6420634
10	corn only, w/wout FWID	216	1,558,268	541	988,300	0.6342296
10	soybean only, w/wout FWID	33	197,443	67	102,700	0.5201502
10	CN and/or SB with Close Grown	205	1,376,206	458	774,200	0.5625613
10	CN and hay-other crop mix	132	1,096,739	1414	3,025,600	2.7587228
10	Mix of remaining row crops only	37	329,959	169	280,600	0.85041
10	Remaining mix of row AND close crops	26	336,604	93	212,600	0.6316028
10	Hay-crop mix (no CN) or other close-grown crops	28	270,846	169	338,900	1.2512647
11	CN-SB only, w/wout FWID	391	3,405,230	981	2,393,900	0.7030068
11	corn only, w/wout FWID	73	697,777	187	499,200	0.715415
11	soybean only, w/wout FWID	74	791,430	210	514,400	0.6499631
11	CN and/or SB with Close Grown	156	1,687,548	586	1,640,800	0.9722983
11	CT w/ or w/out other row crops, no CGC	65	699,113	199	499,800	0.7149058
11	Mix of remaining row crops only	40	411,426	189	436,200	1.0602145
11	Remaining mix of row AND close crops	49	615,417	151	503,700	0.8184699
11	Hay-crop mix or other close-grown crops	67	856,114	820	2,235,200	2.6108665

Table A3.—continued.

Production region number	Major cropping system	No. of 2003-06 CEAP sample points	Sum of original CEAP sample weights	No. of 2003 NRI points	No. of 2003 cultivated cropland acres	PR and cropping system multiplier
12	CN-SB only, w/wout FWID	288	2,051,602	714	1,573,500	0.7669614
12	corn only, w/wout FWID	53	529,642	114	283,500	0.5352675
12	soybean only, w/wout FWID	113	961,076	254	678,300	0.7057718
12	cotton only, w/wout FWID	132	1,638,755	410	1,297,200	0.7915764
12	CT-PN only	90	1,666,829	231	820,600	0.4923121
12	vt with other row crops only	58	739,082	303	877,600	1.1874197
12	CN and/or SB with Close Grown	244	1,594,228	889	1,671,900	1.0487207
12	CT with other row crops, no close grown	96	1,016,299	429	1,198,600	1.1793775
12	CT and close grown, w/ or w/out other crops	51	547,265	186	627,400	1.1464291
12	Mix of remaining row crops only	79	1,617,572	747	2,122,600	1.3122139
12	Remaining mix of row AND close crops	64	688,055	383	1,056,800	1.5359234
12	Hay-crop mix or other close-grown crops	21	248,708	420	1,294,000	5.2028794
		18,691	304,342,099	95,035	304,709,600	

Appendix B: Intrinsic Vulnerability Factor for Soil Runoff

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and soil erodibility (the water erosion equation K-factor). Soil runoff potentials were estimated for each sample point on the basis of a single set of criteria for all regions and soils in the United States to allow for regional comparisons.

Four soil vulnerability levels are defined: high, moderately high, moderate, and low. A "high" soil potential indicates that the intrinsic vulnerability of the soil is high for surface water runoff, and that sediment loss at the edge of the field would be expected to be relatively high compared to other acres if there were no conservation practices in use. A "low" soil potential indicates that the intrinsic vulnerability of the soil is low for surface water runoff, and sediment loss at the edge of the field would be expected to be relatively low compared to other acres.

Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in table B1.

Three regions have the highest percentages of acres with inherent vulnerability factors for surface runoff (fig. B1):

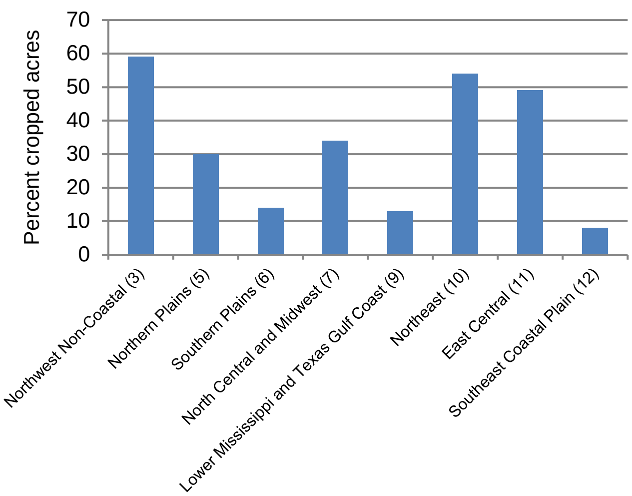
- the Northwest Non-Coastal (3) region, where 58 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential;
- the Northeast (10) region, where 54 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential; and
- the East Central (11) region, where 49 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential.

Three regions have few acres with inherent vulnerability factors for surface runoff (fig. B1):

- the Southeast Coastal Plain (12) region, where only 8 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential;
- the Lower Mississippi and Texas Gulf Coast (9) region, where only 13 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential; and
- the Southern Plains (6) region, where only 14 percent of the cultivated cropland acres have a "high" or "moderately high" soil runoff potential.

In the remaining two regions—the North Central and Midwest (7) region and the Northern Plains (5) region—about half of the cultivated cropland acres have a low soil runoff potential and the rest of the acres have varying levels of soil runoff vulnerabilities.

Figure B1. Percent cultivated cropland acres in each region with a "high" or "moderately high" soil runoff potential.



Figures B2 through B9 show the percentages of cultivated cropland acres in each region for each of the four levels of the soil runoff potential. Because a consistent set of criteria were used for all regions of the country, some soil vulnerability potentials are not well represented in every region.

Table B1. Criteria for the soil runoff potential.

Soil runoff potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28
Moderate	None	Slope >=4 and <=6 and K-factor<0.32	Slope >=2 and <=6 and K-factor<0.28	Slope<2 and K-factor>=0.28
Moderately high	None	Slope >=4 and <=6 and K-factor>=0.32	Slope >=2 and <=6 and K-factor>=0.28	Slope >=2 and <=4
High	None	Slope>6	Slope>6	Slope>4

Hydrologic soil groups are classified as:

- **Group A**—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

The K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

Figure B2. Soil runoff potential for cropped acres in the Northwest Non-Coastal (3) region.

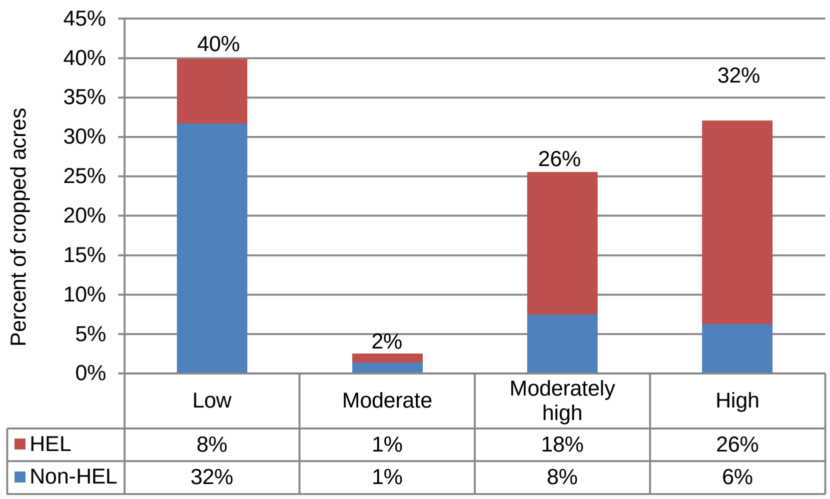


Figure B3. Soil runoff potential for cropped acres in the Northern Plains (5) region.

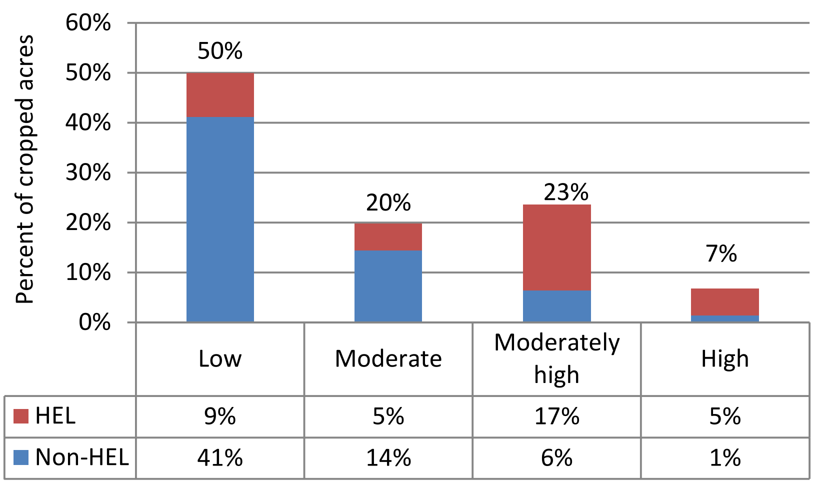
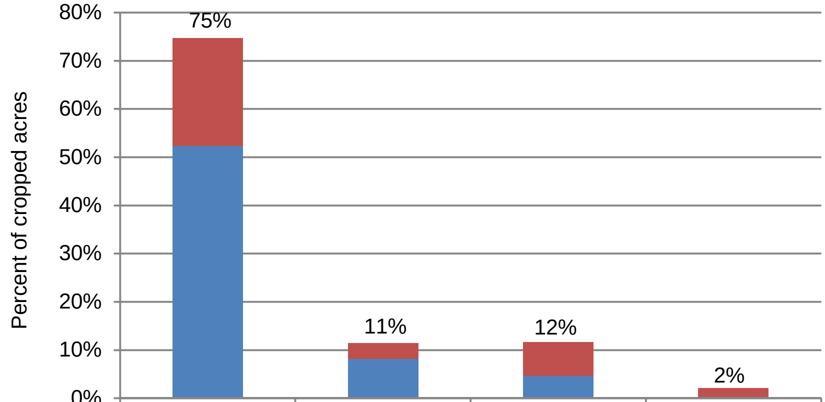
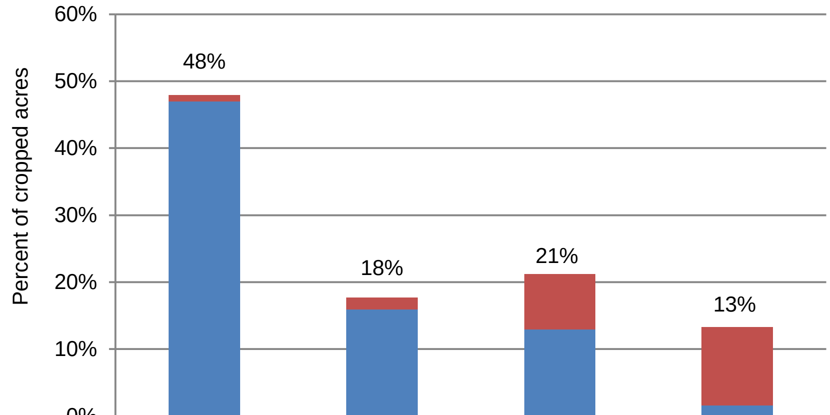


Figure B4. Soil runoff potential for cropped acres in the Southern Plains (6) region.



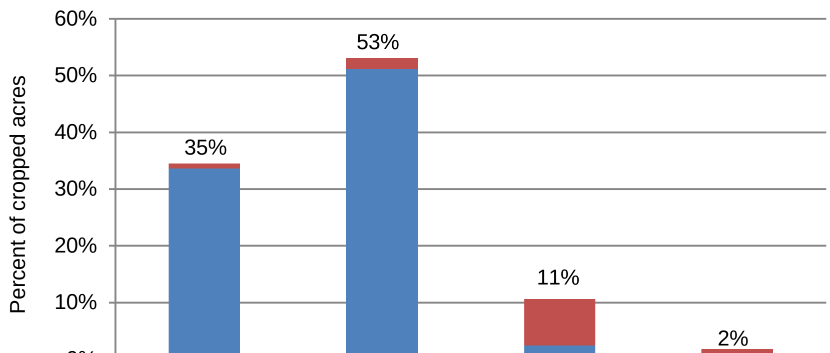
	Low	Moderate	Moderately high	High
HEL	22%	3%	7%	2%
Non-HEL	52%	8%	5%	0.3%

Figure B5. Soil runoff potential for cropped acres in the North Central and Midwest (7) region.



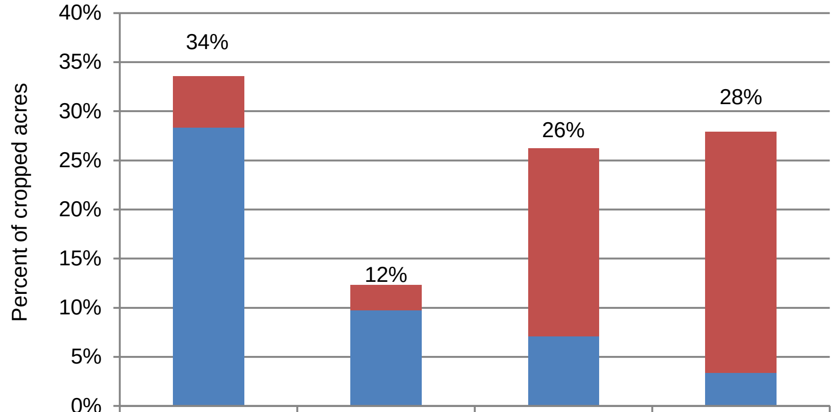
	Low	Moderate	Moderately high	High
HEL	1%	2%	8%	12%
Non-HEL	47%	16%	13%	2%

Figure B6. Soil runoff potential for cropped acres in the Lower Mississippi and Texas Gulf Coast (9) region.



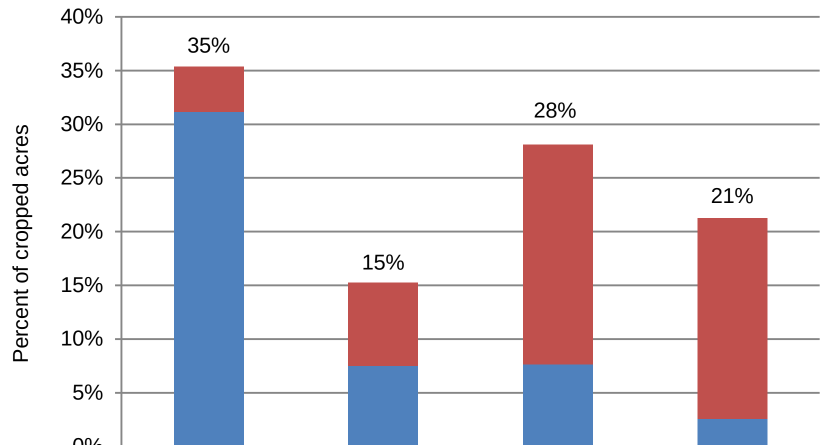
	Low	Moderate	Moderately high	High
HEL	1%	2%	8%	2%
Non-HEL	34%	51%	2%	0.1%

Figure B7. Soil runoff potential for cropped acres in the Northeast (10) region.



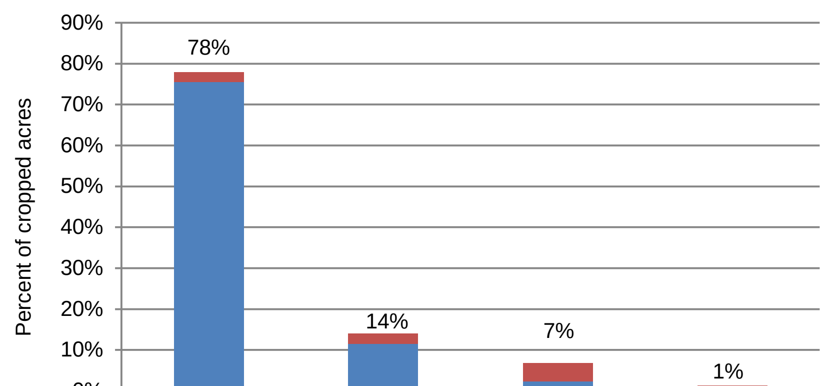
	Low	Moderate	Moderately high	High
HEL	5%	3%	19%	25%
Non-HEL	28%	10%	7%	3%

Figure B8. Soil runoff potential for cropped acres in the East Central (11) region.



	Low	Moderate	Moderately high	High
HEL	4%	8%	20%	19%
Non-HEL	31%	8%	8%	3%

Figure B9. Soil runoff potential for cropped acres in the Southeast Coastal Plain (12) region.



	Low	Moderate	Moderately high	High
HEL	2%	3%	4%	1%
Non-HEL	76%	11%	2%	0.2%