United States Department of Agriculture

Natural Resources
Conservation Service

Conservation Effects
Assessment Project
(CEAP)-Cropland

November 2017

Effects of Conservation Practices on Mitigation of Pesticide Loss and Environmental Risk

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

Suggested Citation: U.S. Department of Agriculture, Natural Resources Conservation Service. 2017. Effects of Conservation Practices on Water Erosion and Loss of Sediment at the Edge of the Field: A National Assessment Based on the 2003-06 CEAP Survey and APEX Modeling Databases. 96 pp.

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 29, 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 online 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.

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Summary of Findings

The purpose of this report is to assess how effective conservation practices are in mitigating the loss of pesticides from farm fields and in reducing the environmental risk associated with those losses. 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 of the 12 newly defined CEAP production regions.

How prevalent is pesticide use on cultivated cropland acres?

A total of 305 pesticides were used on cultivated cropland acres within the eight production regions during 2003-06. Nationally, 90 percent of cultivated cropland acres received one or more pesticide application during a 3-year period. This percentage ranged from a low of 73 percent for the Southern Plains (6) region to a high of 96-97 percent for the North Central and Midwest (7) region and the Lower Mississippi and Texas Gulf Coast (9) region.

Most of the 305 pesticides were used infrequently, but a few were in common use in all regions and others in specific regions. Herbicides are by far the most frequently applied pesticides. Nationally, four herbicides stand out as the most frequently applied pesticides in 2003-06:

- Glyphosate was used on 63 percent of cultivated cropland acres nationally and on 70 percent or more in the North Central and Midwest (7) region, the Lower Mississippi and Texas Gulf Coast (9) region, and the Southeast Coastal Plain (12) region.
- Atrazine was used on 39 percent of cultivated cropland acres nationally and on more than 60 percent in the North Central and Midwest (7) region and the Northeast (10) region.
- S-Metolachlor was used on 13 percent of cultivated cropland acres nationally and on 20 percent or more in the North Central and Midwest (7) region and the Northeast (10) region.
- Acetochlor was used on 12 percent of cultivated cropland acres nationally, including 27 percent in the North Central and Midwest (7) region.

What is the extent to which pesticide residues are lost from farm fields?

A baseline scenario was constructed using farmer survey data on pesticide use for 2003-06. Estimates of the loss of pesticides from farm fields were estimated using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX). APEX simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.

Model simulations showed that, overall for the eight regions, total pesticide loss for all pesticides combined averaged 14 grams of active ingredient per hectare per year, or about 1 percent of the 1,653 grams per hectare applied, on average. (Grams per hectare is the standard reporting unit for pesticide active ingredients.) Losses vary substantially, however, among the eight regions. The highest per-hectare losses occur in the Lower Mississippi and Texas Gulf Coast (9) region, with an average loss of 66 grams per hectare. The East Central (11) region and the Southeast Coastal Plain (12) region also had relatively high per-hectare pesticide losses, averaging 32 grams per hectare in the Southeast Coastal Plain (12) region and 29 grams per hectare in the East Central (11) region. Average pesticide losses for cultivated cropland in the three westernmost regions were very low, averaging less than 3 grams per hectare.

The APEX model simulations showed that 15 pesticides accounted for 85 percent of the total quantity of pesticides lost from farm fields. Of these, 7 pesticides were among those in the top 15 with the largest quantities of pesticides applied—atrazine, glyphosate, S-metolachlor, acetochlor, metolachlor, pendimethalin, and 2,4-D dimethylamine salt.

Atrazine stands out as the pesticide with the largest quantities lost from farm fields—27 percent of the total amount of pesticides lost in all eight regions. Moreover, atrazine is among the pesticides with the largest quantities lost in each of the eight regions. Atrazine dominated pesticide losses in four regions:

- the Southern Plains (6) region, where atrazine accounted for 50 percent of total pesticide loss from farm fields in the region,
- the North Central and Midwest (7) region, where atrazine accounted for 42 percent of total pesticide loss,

- the East Central (11) region, where atrazine accounted for 35 percent of total pesticide loss, and
- the Northeast (10) region, where atrazine accounted for 32 percent of total pesticide loss.

Glyphosate (isopropylamine salt) dominated losses in 2 regions—the Northern Plains (5) region, where glyphosate accounted for 20 percent of pesticide losses, and the Northwest Non-Coastal (3) region, where glyphosate accounted for 15 percent of pesticide losses. Glyphosate also had a significant percentage of total losses in the remaining six regions, ranking either second, third, or fourth highest in each region.

In the Southeast Coastal Plain (12) region, the insecticide methoxyfenozide dominated pesticide loss, accounting for 29 percent of total pesticide loss in the region. The herbicide sodium chlorate dominated losses in the Lower Mississippi and Texas Gulf Coast (9) region, accounting for 44 percent of total pesticide loss in the region.

To what extent do conservation practices mitigate pesticide loss from farm fields?

Management practices that reduce the potential for loss of pesticides from farm fields are combinations of:

- Water erosion control practices that reduce surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment, and
- Integrated Pest Management (IPM), which is a management strategy for prevention, avoidance, monitoring, and suppression of pest populations.

The baseline results presented above include the benefits and effects of these and other 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. Annual practices such as tillage are also simulated. Pesticide management practices are reflected in the rate, timing, and method of application as well as the number of applications used to control or prevent pest infestations.

Model simulation results indicate that use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 5 grams of active ingredient per hectare per year. This represents a 27-percent reduction, on average, relative to the amount lost in the no-practice scenario. About 42 percent of the cropped acres had reductions in pesticide loss above 1 gram per hectare per year due to the use of conservation practices. About half of the cultivated cropland acres had zero or negligible reductions.

Reductions in pesticide quantities lost from farm fields were highest in four regions:

- 11.0 grams per hectare per year for the Lower Mississippi and Texas Gulf Coast (9) region, representing a 14-percent reduction relative to the no-practice scenario.
- 10.5 grams per hectare per year for the Southeast Coastal Plain (12) region, representing a 24-percent reduction relative to the no-practice scenario.
- 7.3 grams per hectare per year for the East Central (11) region, representing a 20-percent reduction relative to the no-practice scenario.
- 6.8 grams per hectare per year for the North Central and Midwest (7) region, representing a 32-percent reduction relative to the no-practice scenario.

A few acres in each region have relatively large reductions in total pesticide loss due to use of conservation practice use. Reductions of more than 20 grams per hectare of active ingredient (all pesticides combined) occur on up to 15 percent of the cultivated cropland acres within a region. Reductions of more than 50 grams per hectare occur on up to 5 percent in some regions. These are acres where the pesticides in use are applied at higher rates than other pesticides, and where erosion control and IPM practices are being used effectively.

To what extent do conservation practices mitigate the potential for environmental risk associated with pesticide residues?

The environmental risk posed by the loss of pesticide residues from farm fields depends not only on the amount of pesticide lost, but also on the toxicity of the pesticide to non-target species that may be exposed to the pesticide. Pesticide risk indicators were developed to represent risk at the edge of the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As ratios of two concentrations, these risk indicators do not have units. The ratios are called Aquatic Risk Factors, or ARFs. ARF values of less than 1 are considered “safe” because the concentration is below the toxicity threshold for long-term exposure at the edge of the field.

The pesticide risk indicators are used to extend the assessment of the effects of conservation practices beyond the quantity of pesticides lost from farm fields to include the potential for harmful environmental effects from the loss of the pesticide residues that are the most toxic to non-target species. Three separate edge-of-field risk indicators were developed:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and invertebrates and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not yet been set.

These risk indicators are suitable primarily for evaluation of ***potential*** risk under one set of conditions ***relative to*** another set of conditions, such as comparisons from field to field, comparisons of different farming activities on the same field, or comparisons from one region or area to another. The “safe” threshold value of 1 for the pesticide risk indicator is a useful benchmark, as it would be unlikely that ecosystem dysfunction or species mortality would occur in any nearby environmental setting where the edge-of-field risk indicator was less than 1. In actual environmental settings, where dilution from other sources of water occurs, a “safe” edge-of-field risk indicator would be expected to be greater than 1, perhaps much greater. In the baseline scenario, pesticide risk indicators were greater than 1 for only about one-third of the 305 pesticides used on cultivated cropland in 2003-06. Most of these occurred on only a few cultivated cropland acres.

The herbicide atrazine was the dominant pesticide contributing to all three risk indicators at the national level. Based on the model simulations, the pesticide risk indicator for atrazine exceeded 1 for 23 percent of the cropped acres for risk to aquatic ecosystems, 11 percent of the cropped acres for surface water risk to humans, and 2 percent of the cropped acres for groundwater risk to humans. Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb)**.**

For all eight regions combined, conservation practices have:

- Reduced the average annual surface water pesticide risk indicator for aquatic ecosystems from 4.3 without conservation practices to 2.4 with conservation practices, a 44-percent reduction,
- Reduced the average annual surface water pesticide risk indicator for humans from 0.83 without conservation practices to 0.57 with conservation practices, a 32-percent reduction, and
- Reduced the average annual groundwater pesticide risk indicator for humans from 0.19 without conservation practices to 0.16 with conservation practices, an 18-percent reduction.

Conservation practices have been more effective at reducing potential environmental risk to aquatic ecosystems than to humans because the level of environmental risk to aquatic ecosystems from exposure to pesticide residues is much higher than for humans. Similarly, the potential for risk to humans through exposure to drinking water from groundwater sources is very low compared to exposure of humans and aquatic organisms to surface water.

The pesticide risk indicators reflect reductions in pesticide loss for the more toxic pesticides. Since some of these pesticides are not used as commonly as the other pesticides, most acres have no or little reduction in potential risk due to the use of conservation practices:

- 60 percent of the cropped acres have no or negligible reductions in the surface water pesticide risk indicator for aquatic ecosystems due to use of conservation practices,

- 70 percent of the cropped acres have no or negligible reductions in the surface water pesticide risk indicator for humans due to use of conservation practices, and
- 85 percent of the cropped acres have no or negligible reductions in the groundwater pesticide risk indicator for humans due to use of conservation practices.

However, conservation practices in use on the acres that had potential risks were effective in reducing those risks:

- Reductions in the surface water pesticide risk indicator for aquatic ecosystems due to use of conservation practices were greater than 1 for 20 percent of the cultivated cropland acres,
- Reductions in the surface water pesticide risk indicator for humans due to use of conservation practices were greater than 1 for 6 percent of the cultivated cropland acres, and
- Reductions in the groundwater pesticide risk indicator for humans due to use of conservation practices were greater than 1 for less than 1 percent of the cultivated cropland acres.

These are acres where erosion control and IPM practices were most effective in reducing the potential risk from use of pesticides that were more toxic to non-target species than other kinds of pesticides.

Conservation systems include the structural practices shown in this photograph as well as management practices such as integrated pest management (IPM) to further reduce the risk of pesticide loss from cropland fields.

Introduction

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production (fig. 1). While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

NRCS has previously published a national assessment of the effects of conservation practices on reducing erosion and contaminant loss from farm fields, including pesticides.[1] The 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 how effective conservation practices are in mitigating the loss of pesticides from farm fields and in reducing the environmental risk associated with those losses. 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.

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 reflect results for the combination of these three regions.

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.

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
Northwest Non-Coastal (3)	817	11,477,012
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
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 eight regions	17,918	290,087,996

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.

The effects of conservation practices on pesticide losses from farm fields are largely determined by the effects of conservation practices on water and sediment losses from farm fields. In addition to reporting the average annual mass loss of pesticides from farm fields, results are also presented for:

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

Figure 2. Pesticides are used to protect crops from weeds, insects, and diseases during crop production.

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

Figure 3. CEAP production regions (boundaries defined by 8-digit hydrologic unit codes).

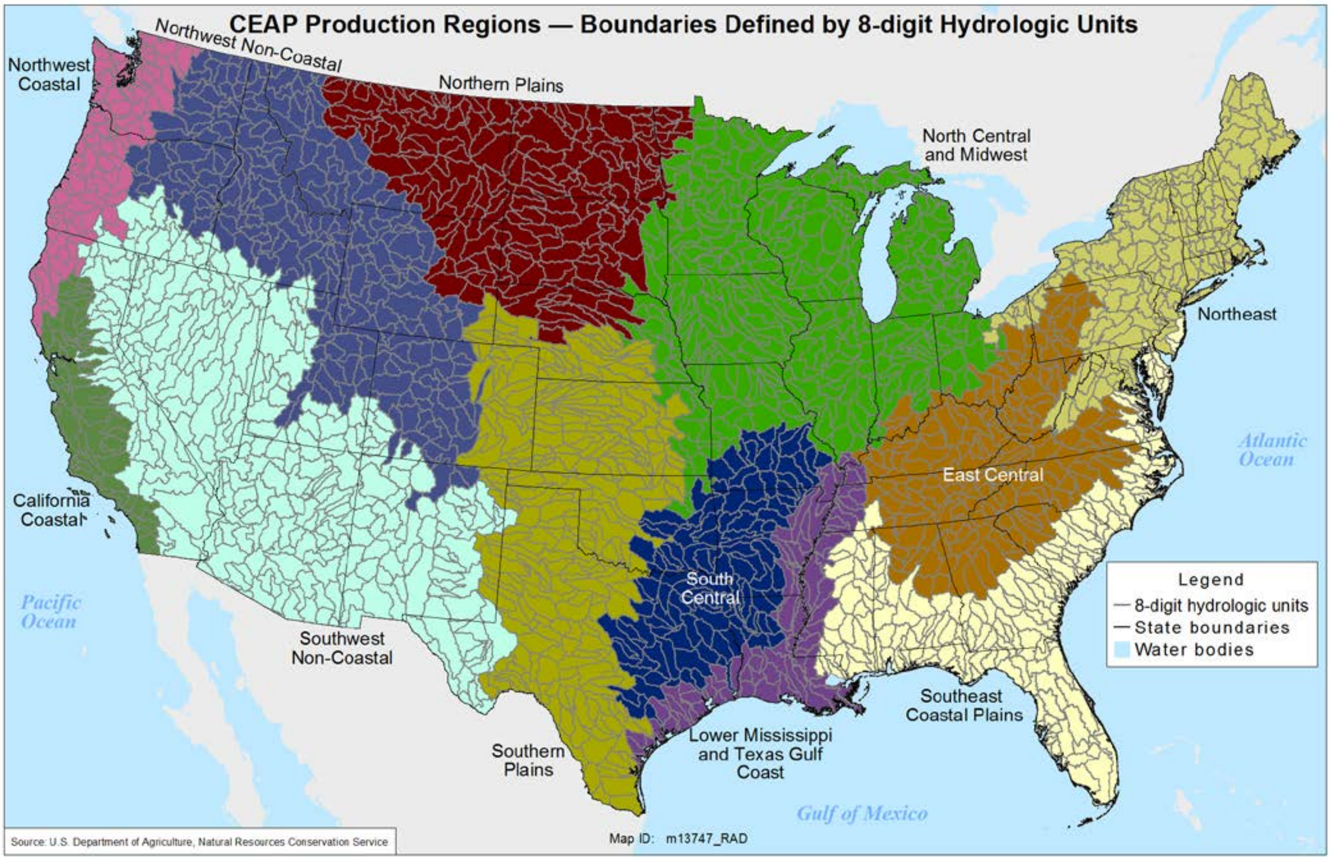
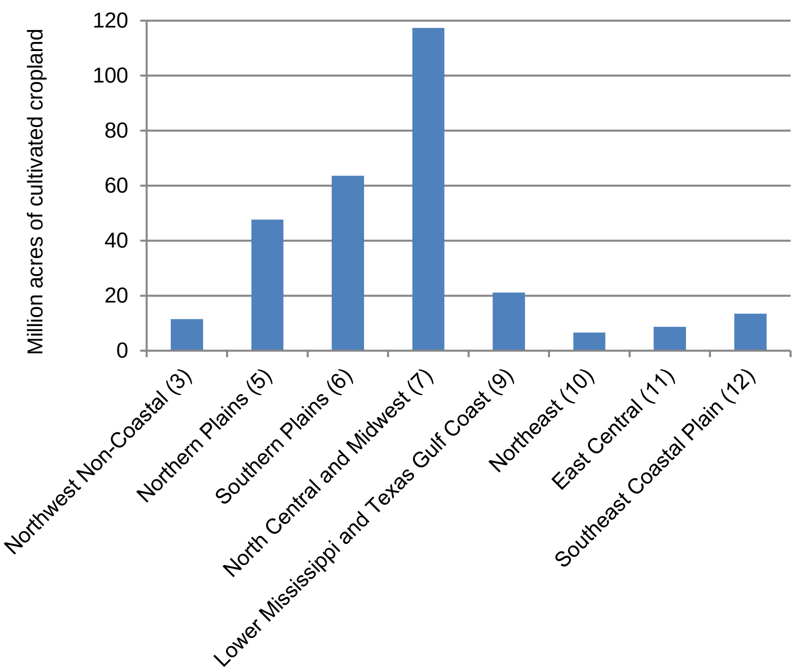


Figure 4. Cultivated cropland derived from the 2003 NRI for the eight CEAP production regions covered in this report.



APEX Modeling and the Baseline Scenario

The loss of pesticides from farm fields was estimated using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.

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; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. 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.

The model tracks the mass loss of pesticides through three loss pathways:

- pesticides dissolved in surface water runoff leaving the edge of the field,
- pesticides adsorbed to sediment lost through water erosion beyond the edge of the field, and
- pesticides dissolved in subsurface flow pathways, some of which eventually return to surface water.[2]

At the time these model results were obtained, the APEX model did not estimate pesticides lost in spray drift, volatilization, or with windblown sediment.

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 pesticides 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 and policy 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, total pesticide losses to all three pesticide loss pathways, summed over all pesticides, is 14 grams per hectare of active ingredient, on average, for all cultivated cropland acres in the eight regions. (Grams per hectare is the standard reporting unit for pesticide active ingredients.) This estimate was calculated as follows:

1. First, the mass loss was summed over all pesticides at each sample point (including multiple applications) for each of the 47 years of model simulation data to create a sum total of mass loss for all pesticides combined.
2. Second, the average annual loss at each of the 17,918 CEAP sample points was calculated as the mean of the 47 years of total mass loss.
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 total pesticide loss from farm fields—14 grams per hectare of active ingredient.

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 often 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.

[2] Subsurface water flows include: 1) deep percolation to groundwater, including groundwater return flow to surface water, 2) lateral subsurface flows intercepted by tile drainage systems or surface drainage ditches, and 3) lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

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 pesticide loss from farm fields in those regions. 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 2 and figures 4 and 5. 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 2).

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 2).

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

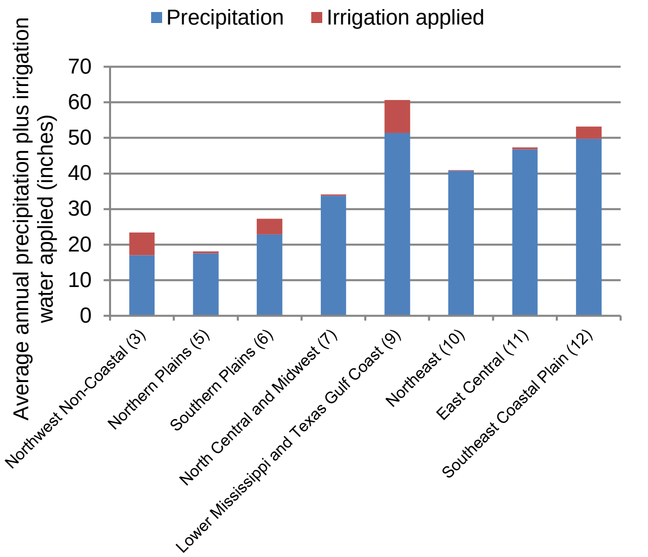


Figure 6. Distributions of average annual water sources (precipitation plus irrigation water applied) for CEAP sample points in eight production regions.

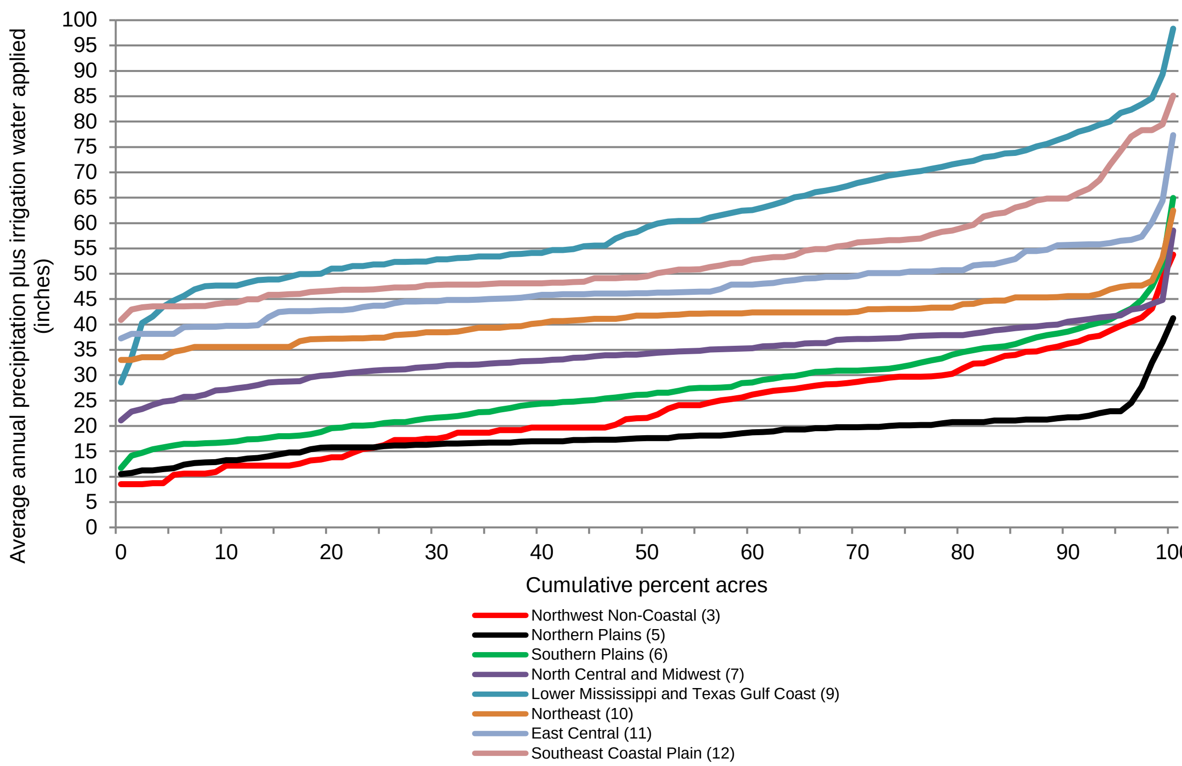


Table 2. Water sources and water loss for cultivated cropland, as represented in the APEX model simulations.

	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 2.—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 2). On average, about 80-90 percent of the water loss for cultivated cropland acres is through evapotranspiration in the three most western 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 from 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[3]. 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 2 and figs. 6 and 7). 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 (fig. 8).

Surface water runoff directly affects the loss of pesticides 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 2 and fig. 6). 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 7. Mean of the average annual surface water runoff from farm fields, by production region.

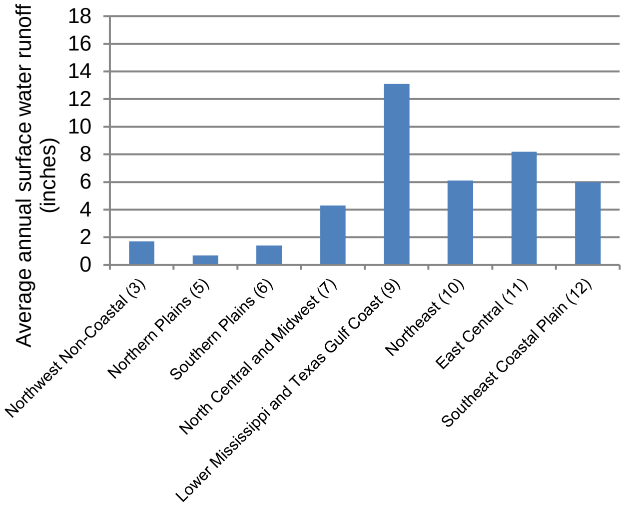
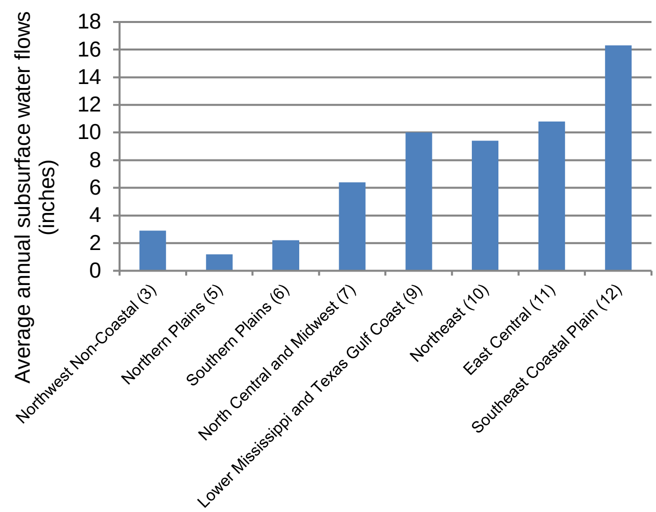


Figure 8. Mean of the average annual loss of water from farm fields through subsurface water flows, by production region.



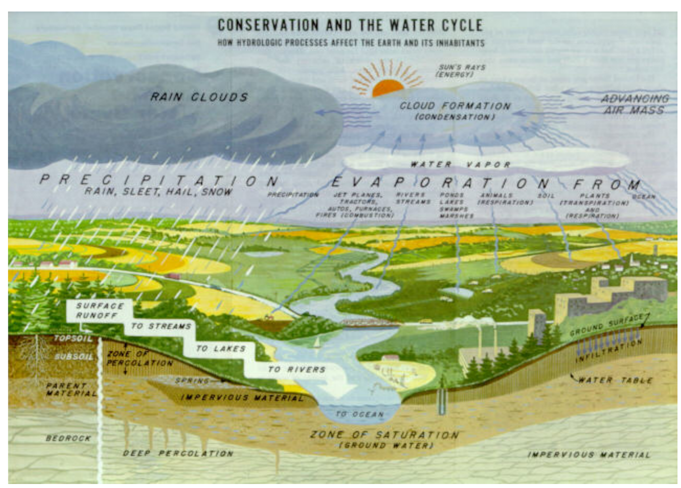


Figure 9. The water cycle is the constant movement of water through the atmosphere, soil, rivers, streams, and oceans.

[3] 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.

Sediment Loss

Pesticide loss is also highly correlated with sediment loss from farm fields, as pesticides often adhere to soil particles, some more so than others depending on their chemical properties. Sediment loss is correlated with surface water runoff, but also reflects the higher propensity for soil movement from fields with higher slopes, especially slopes above 2 percent.

According to the APEX model simulations, 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 3 and fig. 9). This region also had the largest amount of precipitation and irrigation water applied (fig. 4) and the largest amount of surface water runoff per year (fig. 6). Average annual sediment loss 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. Figure 11 shows that 30-40 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 few cultivated cropland acres (figure 11).

The remaining three regions averaged less than 1 ton per acre per year of sediment loss (table 3 and fig. 9), but figure 11 shows that the annual average exceeds 2 tons per acre per year for about 10 percent of cultivated cropland acres in these regions (fig. 18).

Figure 11 also shows that most of the cultivated cropland acres have very low average annual sediment loss from farm fields, 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. The largest of these losses 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. The skewed nature of the distributions shown in figure 11 is also revealed in table 3. For each region, the mean values are consistently higher than the median values. In some cases, the mean value approaches or exceeds the 80th percentile, indicating that there are a few very large values in the distribution.

Figure 10. Mean of the average annual sediment loss from farm fields, by production region.

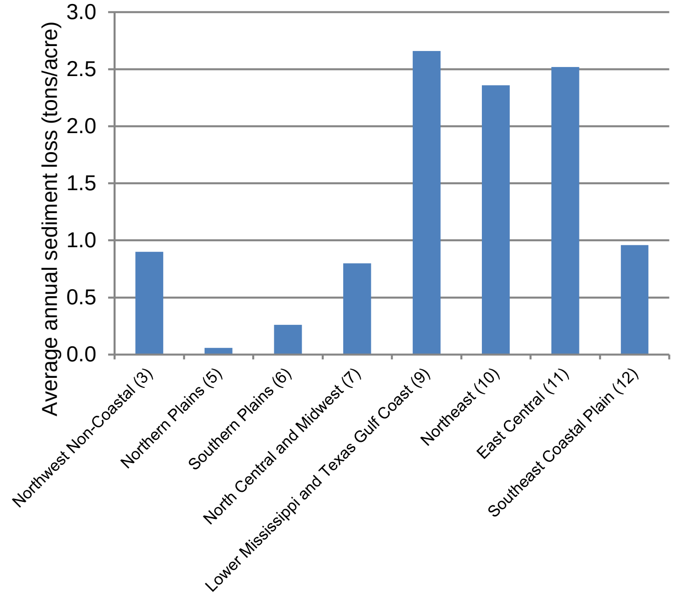


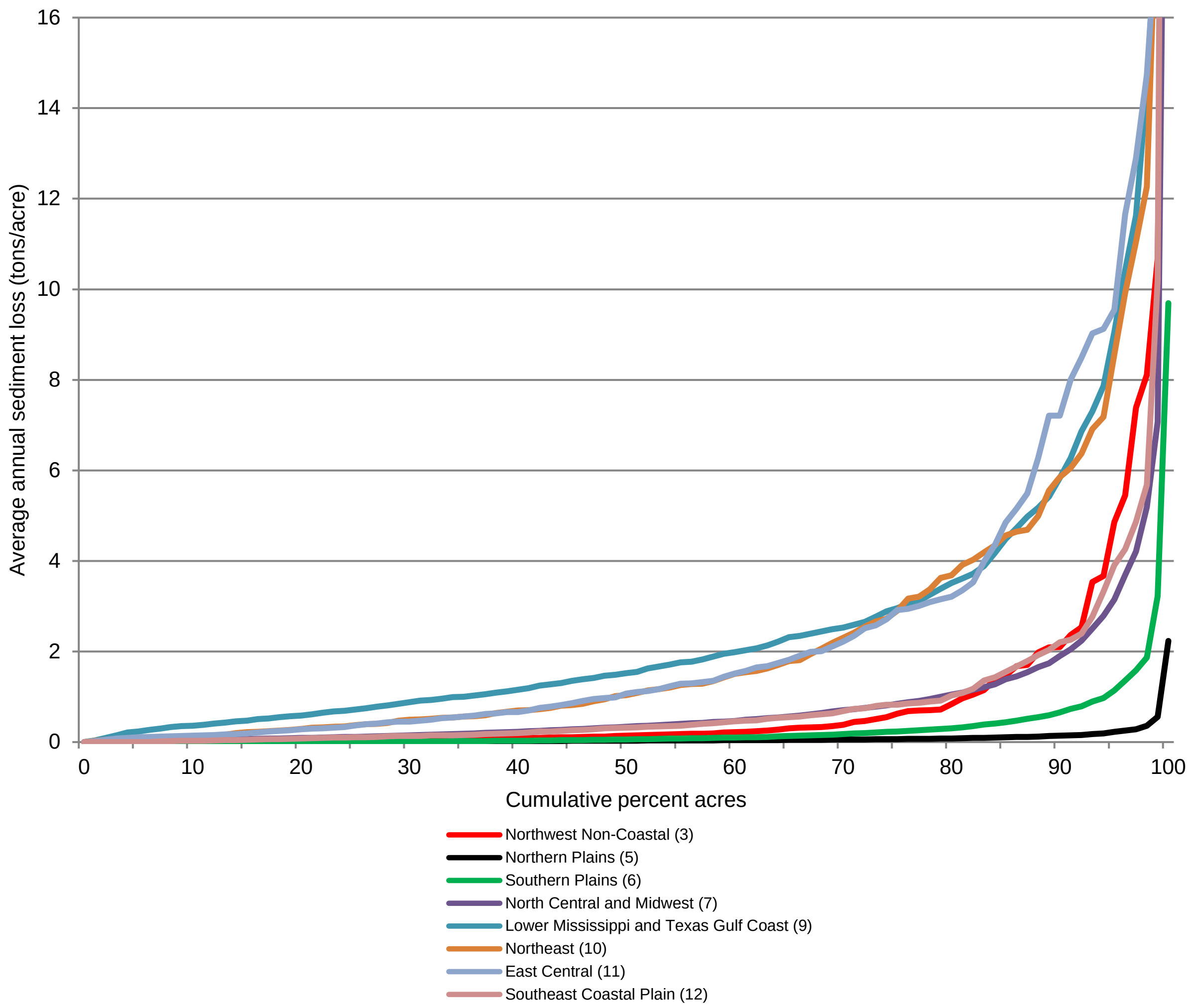
Figure 11. Pesticide loss is also highly correlated with sediment loss from farm fields, as pesticides often adhere to soil particles.

Table 3. Average annual sediment loss at edge of field due to water erosion (tons/acre), cultivated cropland.

	Mean	Median	20th percentile	80th percentile
Northwest Non-Coastal (3)	0.90	0.14	0.03	0.84
Northern Plains (5)	0.06	0.03	0.01	0.08
Southern Plains (6)	0.26	0.06	0.01	0.31
North Central and Midwest (7)	0.80	0.34	0.09	1.05
Lower Mississippi and Texas Gulf Coast (9)	2.66	1.52	0.59	3.51
Northeast (10)	2.36	1.04	0.29	3.69
East Central (11)	2.52	1.07	0.29	3.21
Southeast Coastal Plain (12)	0.96	0.32	0.08	1.03
All eight regions	0.79	0.19	0.03	0.93

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

Figure 12. Distributions of average annual sediment loss from farm fields for CEAP sample points in eight production regions.



Pesticide Use on Cultivated Cropland

Pesticide use data for each of the CEAP sample points was obtained from a farmer survey—the NRI-CEAP Cropland Survey—conducted over four years from 2003 to 2006.[4] The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices. The survey obtained information on farming practices and conservation practices in use on a farm field coinciding with a selected NRI sample point. The survey included questions on pesticide applications (chemical, rate, timing, and method of application) for 3 consecutive years as well as questions on pest management practices.

A total of 305 pesticides were used on cultivated cropland acres within the eight production regions during 2003-06 (table 4). Most acres received pesticide applications. The percentage of cultivated cropland acres receiving one or more pesticide application ranged from a low of 73 percent for the Southern Plains (6) region to a high of 96-97 percent for the North Central and Midwest (7) region and the Lower Mississippi and Texas Gulf Coast (9) region.

Table 4. Summary of cultivated cropland acres treated with pesticides in 2003-06.

	Number of different pesticides used	Percent of acres receiving one or more pesticide application
Northwest Non-Coastal (3)	176	91
Northern Plains (5)	145	93
Southern Plains (6)	184	73
North Central and Midwest (7)	209	96
Lower Mississippi and Texas Gulf Coast (9)	190	97
Northeast (10)	131	85
East Central (11)	156	91
Southeast Coastal Plain (12)	187	91
All eight regions	305	90

Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.

Most of the 305 pesticides were used infrequently, but a few were in common use in all regions and others in specific regions. Table 5 lists the 15 most commonly used pesticides in 2003-06 throughout all eight production regions. The most frequently applied pesticides for each production region—in terms of percentage of acres receiving one or more pesticide applications in each region—are presented in table 6.

Herbicides are by far the most frequently applied pesticides. Nationally, four herbicides stand out as the most frequently applied pesticides in 2003-06 (table 5 and figs. 18 through 20):

- Glyphosate was used on 63 percent of cultivated cropland acres nationally and on 70 percent or more in the North Central and Midwest (7) region, the Lower Mississippi and Texas Gulf Coast (9) region, and the Southeast Coastal Plain (12) region.
- Atrazine was used on 39 percent of cultivated cropland acres nationally and on more than 60 percent in the North Central and Midwest (7) region and the Northeast (10) region.
- S-Metolachlor was used on 13 percent of cultivated cropland acres nationally and on 20 percent or more in the North Central and Midwest (7) region and the Northeast (10) region.
- Acetochlor was used on 12 percent of cultivated cropland acres nationally, including 27 percent in the North Central and Midwest (7) region.

Table 5. The 15 most frequently applied pesticides on cultivated cropland acres in 2003-06 (percent of acres in the eight regions receiving one or more pesticide applications).

Active ingredient	Pesticide type	Percent acres treated
Glyphosate, isopropylamine salt	Herbicide	62.9%
Atrazine	Herbicide	39.2%
S-Metolachlor	Herbicide	12.8%
Acetochlor	Herbicide	12.4%
2,4-D, 2-ethylhexyl ester	Herbicide	7.2%
Mesotrione	Herbicide	7.0%
Pendimethalin	Herbicide	6.6%
2,4-Dichlorophenoxyacetic acid	Herbicide	6.5%
Nicosulfuron	Herbicide	6.2%
Thifensulfuron methyl	Herbicide	6.1%
Dicamba	Herbicide	6.1%
Trifluralin	Herbicide	6.0%
Clopyralid	Herbicide	5.7%
Tribenuron-methyl	Herbicide	5.4%
Rimsulfuron	Herbicide	5.2%

Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling. See Appendix B for a complete listing of pesticides applied in each region in 2003-06.

Figure 13. A crop consultant scouts a field for pests as part of an integrated pest management system.

[4] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap.

Figure 14. A farmer washes his sprayer after application of herbicide. He is careful to wear complete protection and to clean equipment at the designated location to catch polluted water for proper disposal.

Figure 15. A farmer mixes herbicide prior to application. He is careful to wear complete protection while using the chemicals and to mix them at the proper location to prevent spillage and possible soil and/or water pollution.

Figure 16. It is recommended that all farm spraying tanks be filled with water a distance away from the water supply, so that any spills would not be near the supply.

Figure 17. This farmer uses a stop watch to calibrate his sprayer prior to applying herbicide. Careful management helps prevent over application of pesticides.

Figure 18. Percent of cultivated cropland acres receiving one or more applications of glyphosate (isopropylamine salt) in 2003-06.

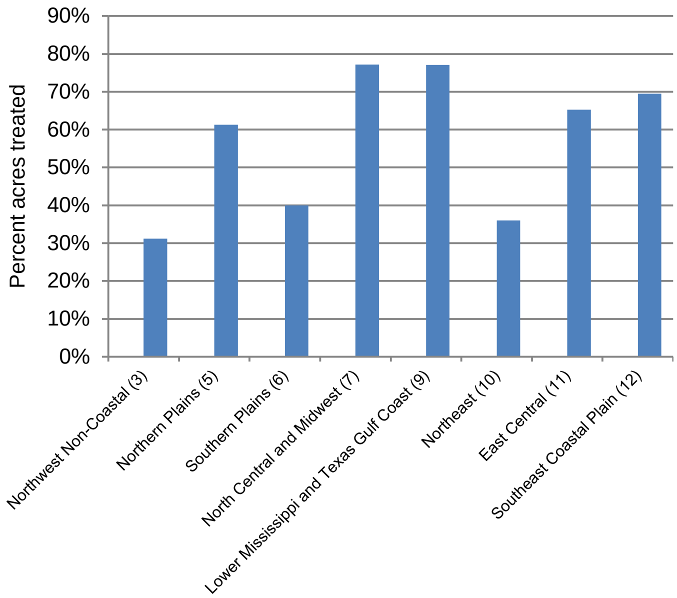


Figure 20. Percent of cultivated cropland acres receiving one or more applications of S-metolachlor in 2003-06.

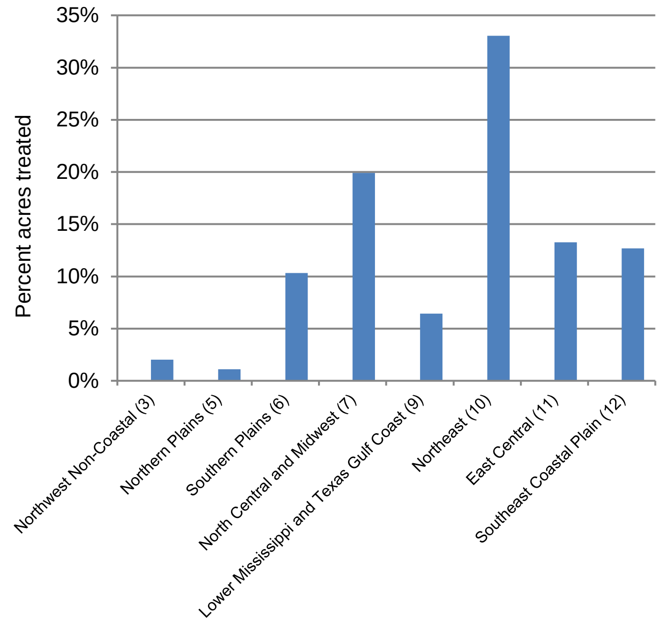


Figure 19. Percent of cultivated cropland acres receiving one or more applications of atrazine in 2003-06.

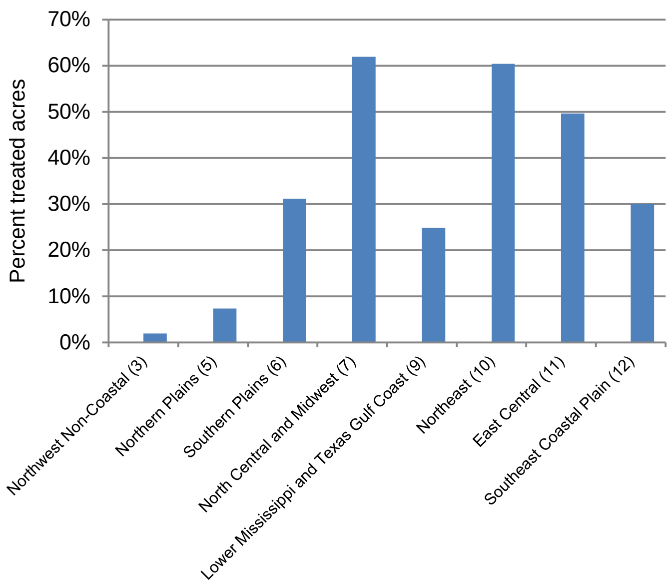


Figure 21. Percent of cultivated cropland acres receiving one or more applications of acetochlor in 2003-06.

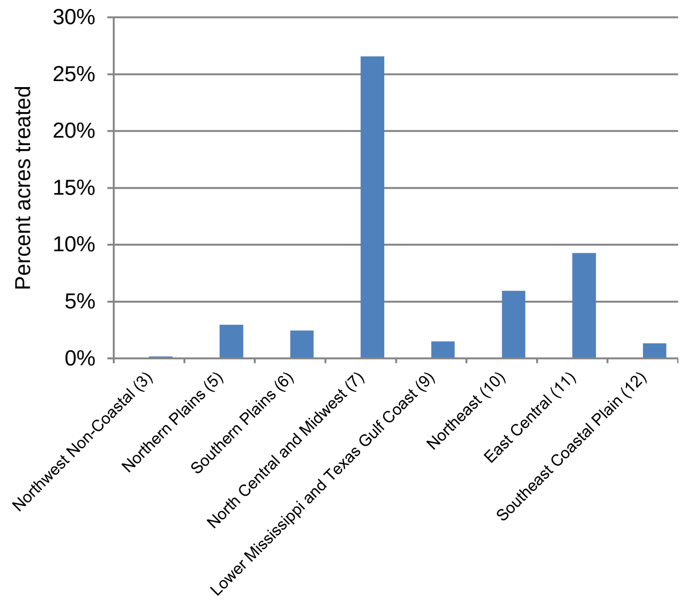


Table 6. Most frequently applied pesticides used in 2003-06 on cultivated cropland acres, percent acres treated by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of acres treated in region
Northwest Non-Coastal (3)			
	Tribenuron-methyl	Herbicide	33.7%
	Thifensulfuron methyl	Herbicide	31.4%
	Glyphosate, isopropylamine salt	Herbicide	31.2%
	Metsulfuron-methyl	Herbicide	19.4%
	2,4-D, 2-ethylhexyl ester	Herbicide	18.3%
	MCPA, 2-ethylhexyl ester	Herbicide	17.1%
	2,4-Dichlorophenoxyacetic acid	Herbicide	14.0%
	Metribuzin	Herbicide	12.4%
	MCPA	Herbicide	12.2%
	Bromoxynil octanoate	Herbicide	12.0%
	2,4-D, dimethylamine salt	Herbicide	11.2%
	Fluroxypyr	Herbicide	8.1%
	Bromoxynil	Herbicide	7.6%
Northern Plains (5)			
	Glyphosate, isopropylamine salt	Herbicide	61.3%
	MCPA	Herbicide	23.1%
	Fenoxaprop-ethyl	Herbicide	18.8%
	Bromoxynil octanoate	Herbicide	17.3%
	2,4-Dichlorophenoxyacetic acid	Herbicide	13.5%
	Dicamba	Herbicide	12.8%
	Thifensulfuron methyl	Herbicide	12.4%
	MCPA, 2-ethylhexyl ester	Herbicide	12.2%
	2,4-D, 2-ethylhexyl ester	Herbicide	12.0%
	Tribenuron-methyl	Herbicide	11.2%
	Clopyralid	Herbicide	9.3%
	Clodinafop-propargyl	Herbicide	8.5%
	Fenoxaprop-p-ethyl	Herbicide	8.4%
	Clethodim	Herbicide	7.8%
	Trifluralin	Herbicide	7.5%
	Bromoxynil	Herbicide	7.5%
	Atrazine	Herbicide	7.4%
	Fluroxypyr	Herbicide	7.3%
Southern Plains (6)			
	Glyphosate, isopropylamine salt	Herbicide	39.9%
	Atrazine	Herbicide	31.2%
	Metsulfuron-methyl	Herbicide	10.8%
	Trifluralin	Herbicide	10.6%
	S-Metolachlor	Herbicide	10.3%
	2,4-Dichlorophenoxyacetic acid	Herbicide	8.1%
	2,4-D, 2-ethylhexyl ester	Herbicide	7.1%
North Central and Midwest (7)			
	Glyphosate, isopropylamine salt	Herbicide	77.2%
	Atrazine	Herbicide	61.9%
	Acetochlor	Herbicide	26.6%
	S-Metolachlor	Herbicide	19.9%
	Mesotrione	Herbicide	13.9%
	Nicosulfuron	Herbicide	10.7%
	Clopyralid	Herbicide	9.2%
	Rimsulfuron	Herbicide	8.7%
	Flumetsulam	Herbicide	8.6%

Table 6.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of acres treated in region
Lower Mississippi and Texas Gulf Coast (9)			
	Glyphosate, isopropylamine salt	Herbicide	77.1%
	Atrazine	Herbicide	24.9%
	Ethephon	Herbicide	19.9%
	Acephate	Insecticide	17.1%
	Clomazone	Herbicide	15.3%
	Thidiazuron	Herbicide	14.6%
	lambda-Cyhalothrin	Insecticide	13.3%
	Tribuphos	Herbicide	12.6%
	Propanil	Herbicide	12.0%
	Diuron	Herbicide	11.9%
	Mepiquat chloride	Herbicide	11.7%
	Dicrotophos	Insecticide	10.7%
	Azoxystrobin	Fungicide	9.9%
	Pendimethalin	Herbicide	8.5%
	Quinclorac	Herbicide	8.0%
	2,4-D, dimethylamine salt	Herbicide	7.8%
	Paraquat dichloride	Herbicide	7.4%
Northeast (10)			
	Atrazine	Herbicide	60.4%
	Glyphosate, isopropylamine sal	Herbicide	36.0%
	S-Metolachlor	Herbicide	33.0%
	Pendimethalin	Herbicide	19.9%
	Mesotrione	Herbicide	16.9%
	Rimsulfuron	Herbicide	11.8%
	Nicosulfuron	Herbicide	9.9%
	Thifensulfuron methyl	Herbicide	8.9%
	Metolachlor	Herbicide	8.2%
	Paraquat dichloride	Herbicide	7.2%
	lambda-Cyhalothrin	Insecticide	7.0%
East Central (11)			
	Glyphosate, isopropylamine salt	Herbicide	65.2%
	Atrazine	Herbicide	49.6%
	S-Metolachlor	Herbicide	13.3%
	Pendimethalin	Herbicide	9.4%
	Acetochlor	Herbicide	9.3%
	Metolachlor	Herbicide	9.0%
	Paraquat dichloride	Herbicide	8.5%
	Thifensulfuron methyl	Herbicide	7.7%
	lambda-Cyhalothrin	Insecticide	7.7%
	Acephate	Insecticide	7.7%
Southeast Coastal Plain (12)			
	Glyphosate, isopropylamine salt	Herbicide	69.5%
	Atrazine	Herbicide	30.0%
	Ethephon	Herbicide	22.8%
	Pendimethalin	Herbicide	21.4%
	Chlorothalonil	Fungicide	20.4%
	Tribuphos	Herbicide	16.2%
	Aldicarb	Insecticide	16.2%
	Mepiquat chloride	Herbicide	15.8%
	Paraquat dichloride	Herbicide	13.5%
	S-Metolachlor	Herbicide	12.7%
	lambda-Cyhalothrin	Insecticide	12.1%
	Thidiazuron	Herbicide	9.9%
	Acephate	Insecticide	9.8%
	Diuron	Herbicide	9.3%
	Tebuconazole	Fungicide	9.2%
	Cyfluthrin	Insecticide	8.1%

Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.
See Appendix B for a complete listing of pesticides applied in each region in 2003-06.

The number of acres treated provides an important perspective on pesticide use, but it is incomplete. The quantity of pesticides applied also needs to be considered in evaluating pesticide use and losses from farm fields. Some pesticides are applied in large quantities per acre, while others are applied in very small amounts.

On average, 1,653 grams of active ingredient per hectare was applied annually on cultivated cropland acres throughout the eight regions in 2003-06, as represented in the APEX simulation model (table 7). Whereas the bulk of cultivated cropland acres were treated with pesticides in all regions, the amount applied varied substantially among regions (table 7 and fig. 22). The amount of pesticides applied per hectare was highest in the Southeast Coastal Plain (12) region, averaging about 5,794 grams of active ingredient per hectare of cultivated cropland when summed over all pesticides applied. The lowest amount was in the Northern Plains (5) region, averaging only 752 grams per hectare.

The 15 pesticides applied in the largest quantities on cultivated cropland acres in 2003-06 are listed in table 8. These 15 pesticides accounted for 76 percent of the total quantity of pesticides applied in 2003-06. Glyphosate and atrazine were applied in the highest amounts, largely because of the large number of acres treated with these two pesticides. Glyphosate accounted for 24 percent of the total amount of all pesticides applied and atrazine accounted for 14 percent (table 8). Three other pesticides listed in table 6 were also among the 15 most frequently applied pesticides listed in table 5—S metolachlor, acetochlor, and pendimethalin. The remaining pesticides listed in table 8 were significant in terms of the total amount applied but were not among the pesticides most frequently applied in terms of acres treated.

The effects of conservation practices, such as erosion control practices, are measured in terms of reductions in the amount of pesticide lost from the farm field, which is determined in part by the quantity applied. Pesticides applied in the largest quantities by production region are listed in table 9. The pesticides listed in table 9 for each region account for 84 percent or more of the total amount of pesticides applied in each region.

Figure 22. Modern farmers can use digital soil maps for precision farming applications of chemicals.

Table 7. Summary of the application rate of pesticides (grams of active ingredient per hectare, all pesticides combined) applied on cultivated cropland acres in 2003-06.

	Average annual amount of pesticides applied (grams/hectare)*
Northwest Non-Coastal (3)	3,091
Northern Plains (5)	752
Southern Plains (6)	870
North Central and Midwest (7)	1,571
Lower Mississippi and Texas Gulf Coast (9)	2,542
Northeast (10)	1,484
East Central (11)	3,062
Southeast Coastal Plain (12)	5,794
All eight regions	1,653

* Quantity summed over all pesticides.
Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.

Figure 23. Mean of the average annual grams of active ingredient per hectare applied on cultivated cropland acres in 2003-06.

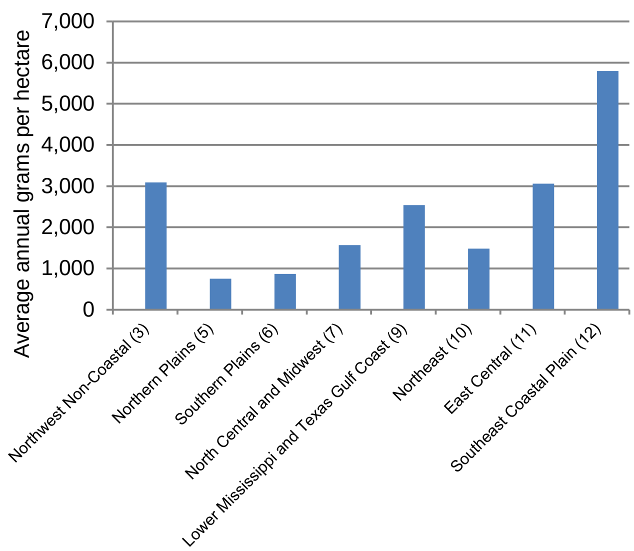


Table 8. Top 15 pesticides applied in the largest quantities on cultivated cropland acres in 2003-06, percent of total amount of all pesticides applied.

Pesticide (active ingredient)	Pesticide type	Percent
Glyphosate, isopropylamine salt	Herbicide	24.3%
Atrazine	Herbicide	14.3%
Acetochlor	Herbicide	6.6%
1,3-Dichloropropene	Fungicide	5.3%
S-Metolachlor	Herbicide	5.0%
Metam-sodium	Multi-Target	3.8%
Chlorothalonil	Fungicide	3.5%
Pendimethalin	Herbicide	2.1%
Chloropicrin	Fumigant	1.9%
Trifluralin	Herbicide	1.9%
Metolachlor	Herbicide	1.8%
Ethephon	Herbicide	1.7%
Fatty alcohol	Growth regulator	1.2%
Mancozeb	Fungicide	1.2%
2,4-D, dimethylamine salt	Herbicide	1.1%
Total		75.6%

Table 9. Pesticides applied in the largest quantities on cultivated cropland acres in 2003-06, percent of total amount of all pesticides applied by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides applied in region
Northwest Non-Coastal (3)			
	Metam-sodium	Multi-Target	39.4%
	1,3-Dichloropropene	Fungicide	31.4%
	Glyphosate, isopropylamine salt	Herbicide	3.5%
	EPTC	Herbicide	1.7%
	2,4-D, 2-ethylhexyl ester	Herbicide	1.4%
	Mancozeb	Fungicide	1.3%
	2,4-Dichlorophenoxyacetic acid	Herbicide	1.2%
	MCPA, 2-ethylhexyl ester	Herbicide	1.2%
	MCPA	Herbicide	1.1%
	Chlorothalonil	Fungicide	1.0%
	2,4-D, dimethylamine salt	Herbicide	1.0%
	Sulfur	Fungicide	0.9%
	Aldicarb	Insecticide	0.8%
Total			85.9%
Northern Plains (5)			
	Glyphosate, isopropylamine salt	Herbicide	40.1%
	Trifluralin	Herbicide	5.5%
	MCPA	Herbicide	5.1%
	Atrazine	Herbicide	3.5%
	2,4-D, 2-ethylhexyl ester	Herbicide	3.4%
	2,4-Dichlorophenoxyacetic acid	Herbicide	3.1%
	Bromoxynil octanoate	Herbicide	3.0%
	Ethalfluralin	Herbicide	2.9%
	MCPA, 2-ethylhexyl ester	Herbicide	2.5%
	Acetochlor	Herbicide	2.3%
	Sodium bentazon	Herbicide	2.1%
	Pendimethalin	Herbicide	1.8%
	EPTC	Herbicide	1.8%
	Triallate	Herbicide	1.6%
	2,4-D, dimethylamine salt	Herbicide	1.3%
	Terbufos	Insecticide	1.2%
	Bromoxynil	Herbicide	1.2%
	Dicamba	Herbicide	1.1%
	Glyphosate-trimesium	Insecticide	0.9%
Total			84.3%
Southern Plains (6)			
	Glyphosate, isopropylamine salt	Herbicide	26.9%
	Atrazine	Herbicide	20.1%
	Trifluralin	Herbicide	7.7%
	S-Metolachlor	Herbicide	6.3%
	Ethephon	Herbicide	3.1%
	Malathion	Insecticide	2.9%
	Pendimethalin	Herbicide	2.7%
	Metolachlor	Herbicide	2.5%
	Acetochlor	Herbicide	2.5%
	Alachlor	Herbicide	2.0%
	2,4-Dichlorophenoxyacetic acid	Herbicide	1.9%
	2,4-D, dimethylamine salt	Herbicide	1.9%
	2,4-D, 2-ethylhexyl ester	Herbicide	1.7%
	Propargite	Insecticide	1.6%
	Glyphosate	Herbicide	1.1%
	Chlorpyrifos	Insecticide	1.0%
	Paraquat dichloride	Herbicide	0.9%
	Diuron	Herbicide	0.8%
	Tribuphos	Herbicide	0.8%
Total			88.6%

Table 9.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides applied in region
North Central and Midwest (7)			
	Glyphosate, isopropylamine salt	Herbicide	29.2%
	Atrazine	Herbicide	22.6%
	Acetochlor	Herbicide	15.1%
	S-Metolachlor	Herbicide	8.6%
	Metolachlor	Herbicide	2.7%
	Pendimethalin	Herbicide	1.8%
	Metam-sodium	Multi-Target	1.3%
	Chlorpyrifos	Insecticide	1.3%
	Trifluralin	Herbicide	1.1%
	Dimethenamide-P	Herbicide	1.1%
	Alachlor	Herbicide	1.0%
Total			85.9%
Lower Mississippi and Texas Gulf Coast (9)			
	Glyphosate, isopropylamine salt	Herbicide	32.5%
	Propanil	Herbicide	8.7%
	Atrazine	Herbicide	7.6%
	Ethephon	Herbicide	6.8%
	Acephate	Insecticide	4.7%
	Malathion	Insecticide	3.2%
	Sodium chlorate	Herbicide	2.5%
	Tribuphos	Herbicide	2.3%
	Diuron	Herbicide	2.3%
	Pendimethalin	Herbicide	2.2%
	Bacillus cereus strain BP01	Bacillus lic	1.8%
	Glyphosate-trimesium	Insecticide	1.6%
	2,4-D, dimethylamine salt	Herbicide	1.6%
	S-Metolachlor	Herbicide	1.4%
	Dicrotophos	Insecticide	1.2%
	Clomazone	Herbicide	1.2%
	Methyl parathion	Insecticide	1.1%
	Metolachlor	Herbicide	1.0%
Total			83.6%
Northeast (10)			
	Atrazine	Herbicide	26.0%
	S-Metolachlor	Herbicide	16.6%
	Glyphosate, isopropylamine salt	Herbicide	13.7%
	Pendimethalin	Herbicide	7.9%
	Metolachlor	Herbicide	4.1%
	Acetochlor	Herbicide	3.6%
	Mancozeb	Fungicide	3.6%
	Simazine	Herbicide	2.4%
	Chlorothalonil	Fungicide	2.1%
	Alachlor	Herbicide	1.9%
	Chlorpyrifos	Insecticide	1.5%
	Paraquat dichloride	Herbicide	1.4%
	Dimethenamid	Herbicide	1.1%
	EPTC	Herbicide	1.1%
Total			86.9%

Table 9.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides applied in region
East Central (11)			
	Chloropicrin	Fumigant	28.8%
	Glyphosate, isopropylamine salt	Herbicide	18.4%
	Atrazine	Herbicide	11.9%
	1,3-Dichloropropene	Fungicide	6.2%
	Fatty alcolhol	Plant growth regulator	5.6%
	S-Metolachlor	Herbicide	2.6%
	Maleic hydrazide, potassium salt	Herbicide	2.5%
	Acetochlor	Herbicide	2.4%
	Metolachlor	Herbicide	2.2%
	Pendimethalin	Herbicide	1.8%
	Ethephon	Herbicide	1.7%
	Simazine	Herbicide	1.3%
	Acephate	Insecticide	1.3%
	Metam-sodium	Multi-Target	1.1%
	Chlorothalonil	Fungicide	1.0%
Total			88.8%
Southeast Coastal Plain (12)			
	Chlorothalonil	Fungicide	19.0%
	1,3-Dichloropropene	Fungicide	15.5%
	Glyphosate, isopropylamine salt	Herbicide	10.7%
	Atrazine	Herbicide	5.7%
	Fatty alcolhol	Plant growth regulator	5.6%
	Mancozeb	Fungicide	5.3%
	Copper hydroxide	Fungicide	3.9%
	Ethephon	Herbicide	3.1%
	2,4-D, dimethylamine salt	Herbicide	2.8%
	Pendimethalin	Herbicide	2.2%
	Metam-sodium	Multi-Target	1.8%
	Monocarbamide	NA	1.6%
	Chloropicrin	Fumigant	1.6%
	Aldicarb	Insecticide	1.6%
	Tribuphos	Herbicide	1.4%
	S-Metolachlor	Herbicide	1.3%
	Endosulfan	Insecticide	1.2%
Total			84.2%

Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.

Figure 24. Farmer spraying pesticide as part of his pest management plan.

Figure 25. A water quality project team monitors nutrient and pesticide levels in water, as well as other possible non-point source pollutants.

Pesticide Loss from Farm Fields

In the APEX model, pesticide residues are lost from farm fields through the processes of surface water runoff, infiltration, and soil erosion. Runoff and infiltration are the primary modes of transport for the more water soluble pesticides, and erosion is the primary mode for pesticides that adsorb to soil particles. Not all acres treated with pesticides are equally vulnerable to pesticide loss. Acres that are susceptible to soil erosion and sediment loss are also more vulnerable to pesticide loss. Similarly, porous soils in regions with relatively high precipitation or irrigation water use are more vulnerable than other acres to pesticide leaching.

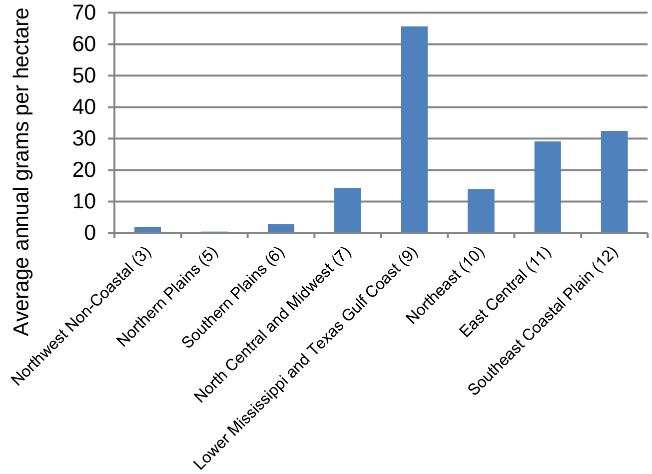
Methods and timing of pesticide applications also influence the extent to which pesticides move offsite (figs. 21, 23, 24). For example, pesticide loss is directly related to weather and soil conditions at the time of application, and to whether or not the pesticide was broadcast-applied to bare soil, incorporated into the soil, or foliar applied into an established crop canopy.

The chemical properties of the pesticides have a pronounced effect on how pesticide residues move offsite (figs.13-16). The organic carbon partitioning coefficient, or Koc, is a measure of a pesticide's soil adsorptive/absorptive or "sorption" potential. Pesticides with low Koc values will have a low affinity for soil organic matter and a relatively high solubility in water. These pesticides will readily become dissolved in surface water runoff or leach through permeable soils. The amount of organic carbon in the soil also influences pesticide loss. Higher soil organic carbon levels generally decrease pesticide leaching, but may also increase the loss of pesticides adsorbed to eroding sediment.

Overall for the eight regions, total pesticide loss for all pesticides combined averaged 14 grams per hectare per year (table 10), or about 1 percent of the 1,653 grams per hectare applied (table 7).

Losses vary substantially, however, among the eight regions (figs. 25 and 26, and table 10). The highest per-hectare losses occur in the Lower Mississippi and Texas Gulf Coast (9) region, with an average loss of 66 grams per hectare. The East Central (11) region and the Southeast Coastal Plain (12) region also had relatively high per-hectare pesticide losses, averaging 32 grams per hectare in the Southeast Coastal Plain (12) region and 29 grams per hectare in the East Central (11) region. These three regions also had the largest amounts of surface water runoff and loss of water through subsurface flows (figs. 6 and 7).

Figure 26. Mean of the average annual grams of active ingredient per hectare lost from cultivated cropland acres (per-hectare mass loss of all pesticides and all three loss pathways combined).



Note: Per-hectare rates represent all cultivated cropland acres in each region, including acres that did not receive pesticide applications.

Average pesticide losses for cultivated cropland in the three westernmost regions were very low, averaging less than 3 grams per hectare (figs. 25 and 26 and table 10). These three regions also had the lowest amounts of water loss (figs. 6 and 7). Two regions—the Northern Plains (5) region and the Southern Plains (6) region—had very low sediment loss rates as well (figs. 9 and 11).

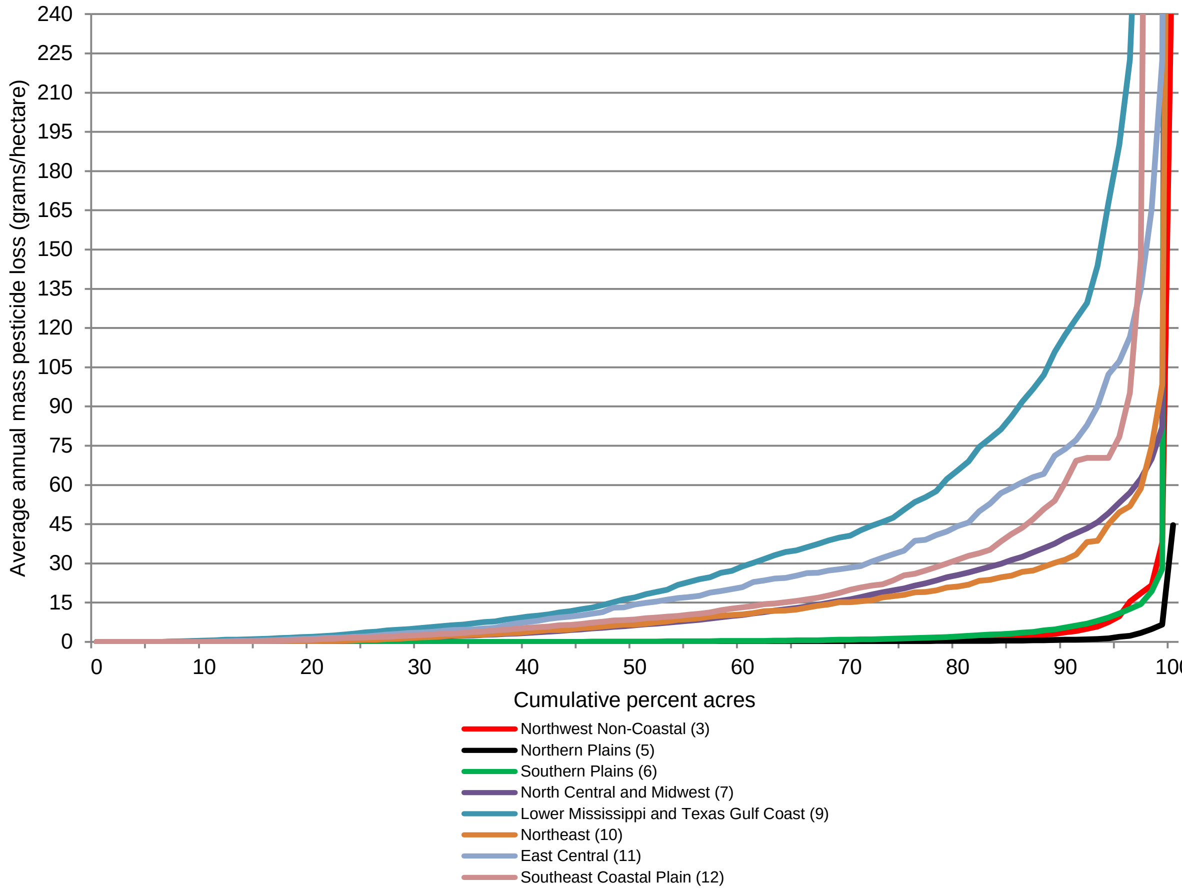
Similar to sediment loss from farm fields, pesticide loss is also low for most cultivated cropland acres, as shown in figure 15. The median loss ranges from less than 1 gram per hectare for the three westernmost regions to a high of 17 grams per hectare for the Lower Mississippi and Texas Gulf Coast (9) region (table 10). A minority of acres, however, has higher losses in the central and eastern regions, where rainfall is highest, and some acres have very high per-hectare losses. Losses exceeding 200 grams per hectare occur in up to 5 percent of the acres in these five production regions (fig. 26).

Table 10. Edge-of-field loss of pesticides for three loss pathways, cultivated cropland.

	Mean	Percent of loss in all three pathways for the region	Median	20th percentile	80th percentile
Average annual loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion (grams per hectare)					
Northwest Non-Coastal (3)	0.71	36%	<0.01	<0.01	0.10
Northern Plains (5)	0.13	30%	0.01	<0.01	0.11
Southern Plains (6)	0.52	19%	0.01	0	0.42
North Central and Midwest (7)	2.92	20%	1.09	0.18	4.00
Lower Mississippi and Texas Gulf Coast (9)	10.31	16%	2.49	0.31	13.14
Northeast (10)	5.68	41%	1.53	0.03	7.38
East Central (11)	9.47	33%	2.32	0.34	12.65
Southeast Coastal Plain (12)	5.32	16%	1.07	0.11	5.50
All eight regions	2.76	20%	0.30	<0.01	2.80
Average annual loss of pesticides dissolved in surface water runoff at the edge of field (grams per hectare)					
Northwest Non-Coastal (3)	0.90	46%	0.01	<0.01	0.38
Northern Plains (5)	0.17	40%	0.01	<0.01	0.12
Southern Plains (6)	1.93	69%	0.04	0	0.83
North Central and Midwest (7)	10.16	71%	3.20	0.17	18.32
Lower Mississippi and Texas Gulf Coast (9)	15.09	23%	3.35	0.38	25.50
Northeast (10)	6.00	43%	2.23	0.05	8.39
East Central (11)	13.81	48%	3.47	0.14	19.73
Southeast Coastal Plain (12)	8.26	25%	2.23	0.12	10.27
All eight regions	6.63	47%	0.41	<0.01	8.67
Average annual loss of pesticides dissolved in subsurface flow pathways (grams per hectare)					
Northwest Non-Coastal (3)	0.34	18%	<0.01	<0.01	0.04
Northern Plains (5)	0.13	31%	<0.01	<0.01	0.02
Southern Plains (6)	0.35	13%	<0.01	0	0.06
North Central and Midwest (7)	1.24	9%	0.15	<0.01	1.03
Lower Mississippi and Texas Gulf Coast (9)	40.26	61%	0.20	<0.01	10.52
Northeast (10)	2.32	17%	0.30	<0.01	2.90
East Central (11)	5.78	20%	0.52	<0.01	4.05
Southeast Coastal Plain (12)	18.84	58%	1.16	<0.01	10.87
All eight regions	4.66	33%	0.02	<0.01	0.72
Average annual loss of pesticides for all three loss pathways (grams per hectare)					
Northwest Non-Coastal (3)	1.95	100%	0.06	<0.01	0.89
Northern Plains (5)	0.43	100%	0.05	<0.01	0.35
Southern Plains (6)	2.79	100%	0.14	0	2.14
North Central and Midwest (7)	14.32	100%	6.41	0.88	25.63
Lower Mississippi and Texas Gulf Coast (9)	65.66	100%	17.04	2.01	65.57
Northeast (10)	14.00	100%	6.68	0.24	21.21
East Central (11)	29.06	100%	14.31	1.20	44.33
Southeast Coastal Plain (12)	32.41	100%	8.56	0.90	31.44
All eight regions	14.04	100%	1.47	0.02	16.60

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

Figure 27. Distributions of average annual pesticide loss from farm fields, all pesticides and three loss pathways combined, for CEAP sample points in eight production regions.



All three pathways are important in the transport of pesticide residues from fields, but the dominant loss pathway for pesticide loss in most regions is with surface water runoff (table 10 and figs. 27-30). Over all eight regions, 47 percent of pesticide loss is with surface water runoff. In two regions, the *majority* of the pesticide loss is with surface water runoff:

- the North Central and Midwest (7) region, where 71 percent of pesticide loss is with surface water runoff (table 10 and fig. 31) and
- the Southern Plains (6) region, where 69 percent of pesticide loss is with surface water runoff (table 10 and fig. 29).

Loss of pesticides dissolved in subsurface flows averages 33 percent of pesticide loss for all eight regions combined, and is the dominant loss pathway in 2 regions:

- the Lower Mississippi and Texas Gulf Coast (9) region, where 61 percent of pesticide loss is through subsurface flow pathways (table 10 and fig. 34), and
- the Southeast Coastal Plain (10) region, where 58 percent of pesticide loss is through subsurface flow pathways (table 10 and fig. 33).

Loss of pesticides with waterborne sediment represents only about 20 percent of pesticide loss over all eight regions, but is not the dominant loss pathway in any region. However, loss of pesticides with waterborne sediment is significant in four regions:

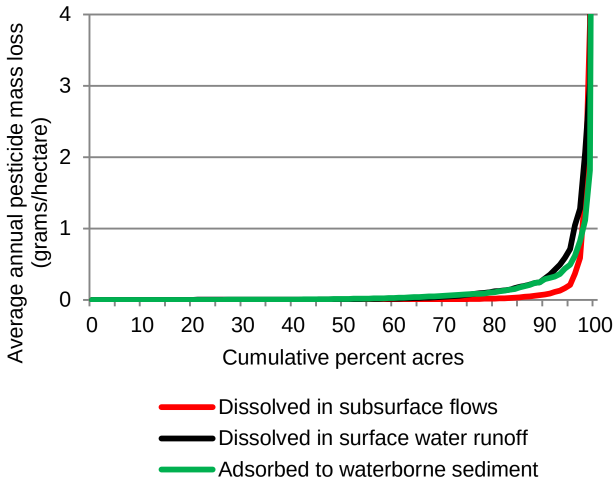
- the Northeast (10) region, where pesticide loss with waterborne sediment (41 percent of total pesticide loss in the region) is only slightly lower than pesticide loss with surface water runoff (43 percent) (table 10 and fig. 30);
- the Northwest Non-Coastal (3) region, where pesticide loss with waterborne sediment (36 percent of total pesticide loss in the region) is second to pesticide loss with surface water runoff (46 percent) (table 10 and fig. 28);
- the East Central (11) region, where pesticide loss with waterborne sediment (33 percent of total pesticide loss in the region) is second to pesticide loss with surface water runoff (48 percent) (table 10 and fig. 32); and
- the Northern Plains (5) region, where all three loss pathways are significant (40 percent lost with surface water runoff, 31 percent lost through subsurface flows, and 30 percent lost with waterborne sediment) (table 10 and fig. 27).

Figures 27-34 have been scaled so that the relationship among the distributions for the three loss pathways can be seen. It is therefore important to adjust for the different scales when comparing across the regions. The figures have been presented in order from the region with the smallest losses (fig. 27) to the region with the largest losses (fig. 34) to facilitate these comparisons.

The skewed nature of the pesticide loss distributions shown in figures 27-34 is similar to what was described for sediment loss in figure11 and total pesticide loss in figure 26, but is even more extreme for some loss pathways in some regions.

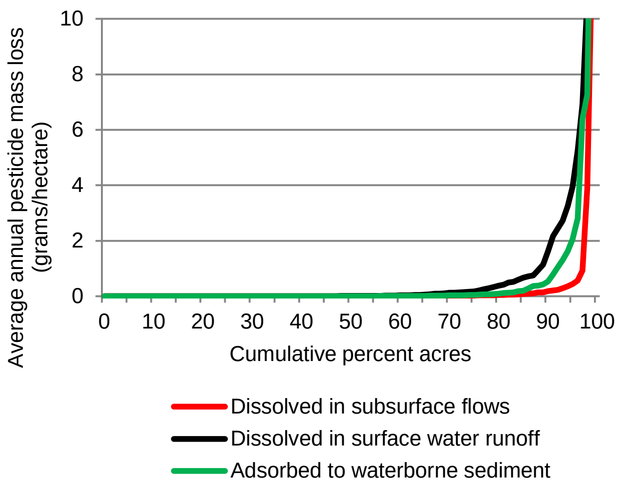
For example, the mean values for the average annual loss of pesticides dissolved in subsurface flow pathways exceed the 80th percentile value for every region other than the Northeast (10) region. As was the case for figure 11, it was necessary to slightly truncate the distributions in figures 27-34 because of a very few extreme values at the high end of the distribution. These extreme values represent only a small number of acres within each region. The largest of these relatively high losses are a combination of inadequate conservation treatment, high soil vulnerability for runoff or infiltration, high pesticide application rates, and/or are pesticides that are more soluble in water than most other pesticides.

Figure 28. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Northern Plains (5) production region.



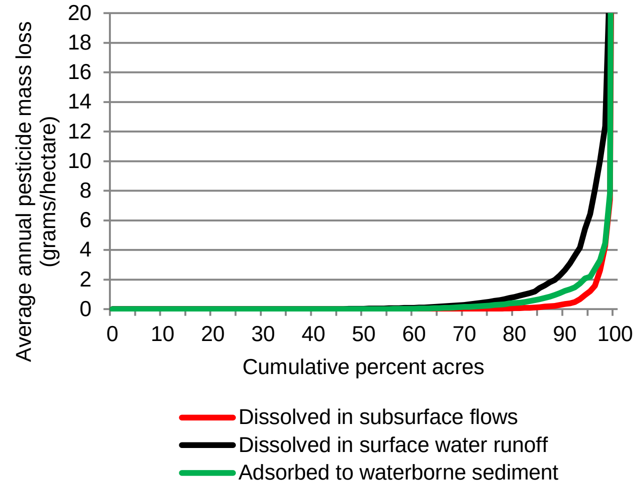
Note: 7 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 29. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Northwest Non-Coastal (3) production region.



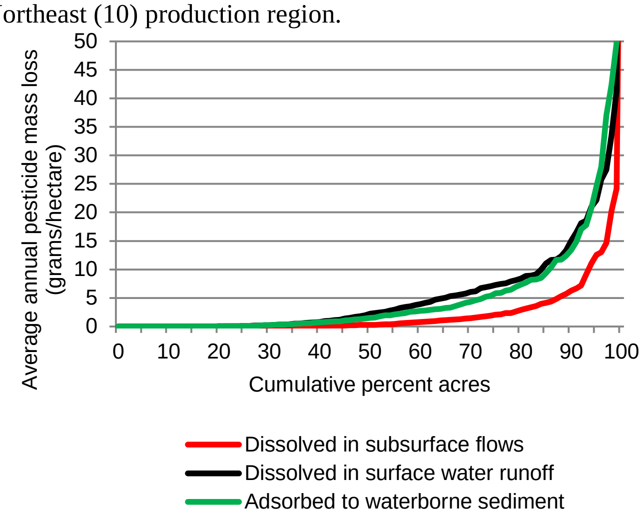
Note: 9 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 30. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Southern Plains (6) production region.



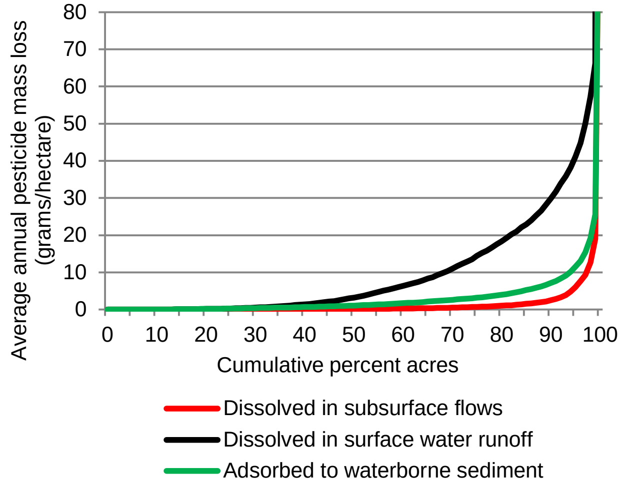
Note: 27 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 31. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Northeast (10) production region.



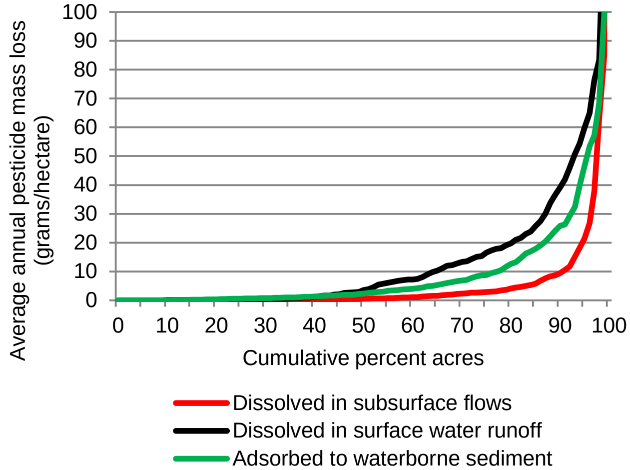
Note: 15 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 32. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), North Central and Midwest (7) production region.



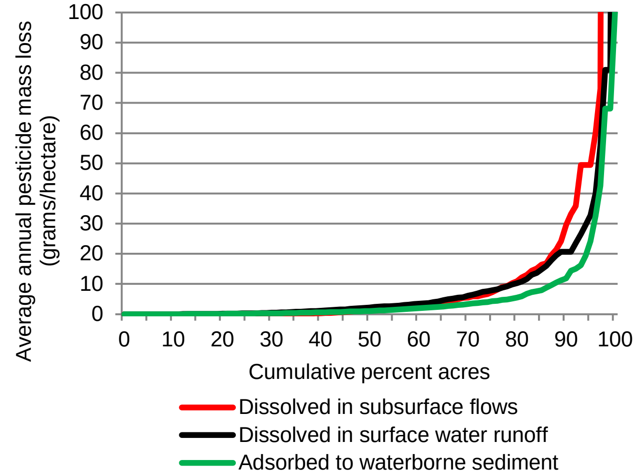
Note: 4 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 33. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), East Central (11) production region.



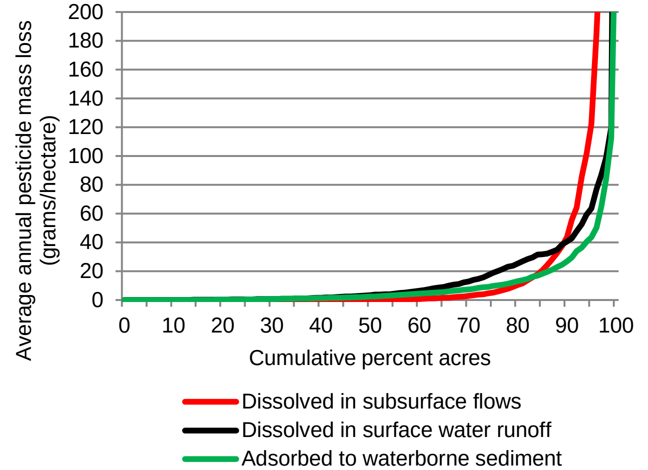
Note: 9 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 34. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Southeast Coastal Plain (12) production region.



Note: 9 percent of cultivated cropland acres in this region had no pesticides applied.

Figure 35. Distributions of average annual grams of active ingredient per hectare lost from cultivated cropland acres for three loss pathways (mass loss of all pesticides combined), Lower Mississippi and Texas Gulf Coast (9) production region.



Note: 3 percent of cultivated cropland acres in this region had no pesticides applied.

The APEX model simulations showed that, of the 305 different pesticides applied to cultivated cropland throughout the eight regions, 15 pesticides accounted for 85 percent of the total quantity of pesticides lost from farm fields (table 11). Of these, 7 pesticides were among those in the top 15 with the largest quantities of pesticides applied (table 6)—atrazine, glyphosate, S-metolachlor, acetochlor, metolachlor, pendimethalin, and 2,4-D dimethylamine salt.

Atrazine stands out as the pesticide with the largest quantities lost from farm fields—27 percent of the total amount of pesticides lost in all eight regions (table 11). Moreover, atrazine is among the pesticides with the largest quantities lost in each of the eight regions, shown in table 12. Atrazine dominated pesticide loss in 4 regions:

- the Southern Plains (6) region, where atrazine accounted for 50 percent of total pesticide loss from farm fields in the region,
- the North Central and Midwest (7) region, where atrazine accounted for 42 percent of total pesticide loss,
- the East Central (11) region, where atrazine accounted for 35 percent of total pesticide loss, and
- the Northeast (10) region, where atrazine accounted for 32 percent of total pesticide loss.

Glyphosate (isopropylamine salt) dominated loses in 2 regions—the Northern Plains (5) region, where glyphosate accounted for 20 percent of pesticide losses, and the Northwest Non-Coastal (3) region, where glyphosate accounted for 15 percent of pesticide losses. Glyphosate also had a significant percentage of total losses in the remaining 6 regions, ranking either second, third, or fourth highest in each region.

In the Southeast Coastal Plain (12) region, the insecticide methoxyfenozide dominated pesticide loss, accounting for 29 percent of total pesticide loss. The herbicide sodium chlorate dominated losses in the Lower Mississippi and Texas Gulf Coast (9) region, accounting for 44 percent of total pesticide loss.

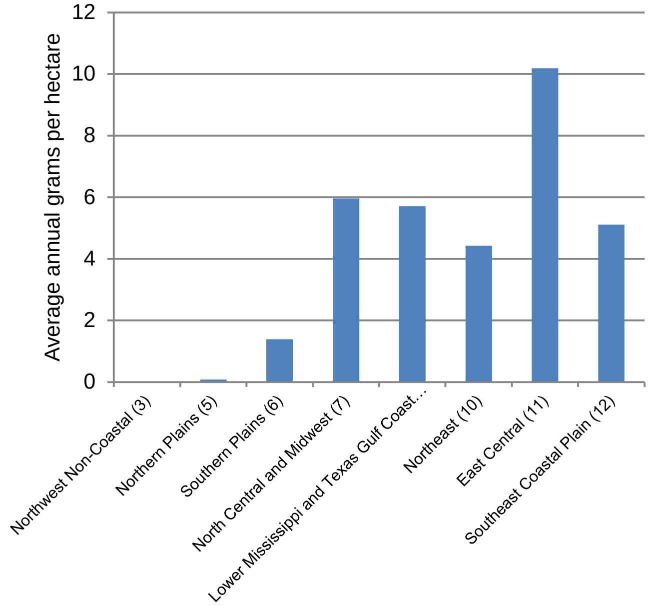
Table 11. Top 15 pesticides lost from farm fields in the largest quantities on cultivated cropland acres, percent of total amount of all pesticides lost.

Pesticide (active ingredient)	Pesticide type	Percent
Atrazine	Herbicide	27.0%
Sodium chlorate	Herbicide	16.0%
Glyphosate, isopropylamine salt	Herbicide	9.0%
S-Metolachlor	Herbicide	6.0%
Acetochlor	Herbicide	6.0%
Quinclorac	Herbicide	4.4%
Methoxyfenozide	Insecticide	3.1%
Metolachlor	Herbicide	3.1%
Sulfentrazone	Herbicide	2.8%
Paraquat dichloride	Herbicide	2.1%
Pendimethalin	Herbicide	1.4%
Simazine	Herbicide	1.4%
2,4-D, dimethylamine salt	Herbicide	0.9%
Copper hydroxide	Fungicide	0.8%
2,4-D, 2-ethylhexyl ester	Herbicide	0.7%
Total		84.8%

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

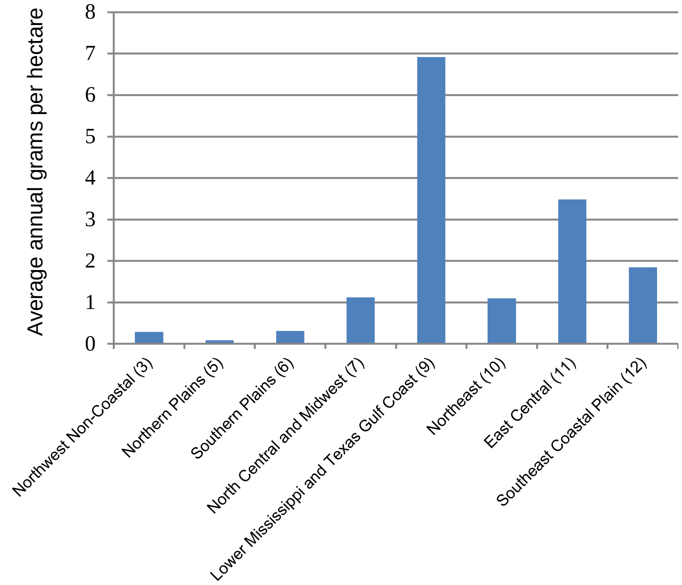
Per-hectare losses of atrazine and glyphosate from farm fields are shown in figures 35 and 36. These two pesticides had the largest amount applied throughout the eight regions (table 8) and dominated pesticide loss in most regions. Rates represent all cultivated cropland acres, including acres that did not receive those pesticides. The per-hectare loss of atrazine averaged 3.8 grams over all eight regions. Per-hectare loss of atrazine averaged highest in the East Central (11) region (fig. 35). Per-acre rates were lowest in the drier western regions, also seen in figure 25 for rates of loss for all pesticides combined. The per-hectare loss of glyphosate averaged 1.3 grams per hectare over all eight regions. The average per-hectare loss of glyphosate (isopropylamine salt) was highest in the Lower Mississippi and Texas Gulf Coast (9) region, the region with the highest rate of loss for all pesticides combined (fig. 36).

Figure 36. Mean of the average annual grams of atrazine (active ingredient) per hectare lost from cultivated cropland acres.



Note: Per-hectare rates represent all cultivated cropland acres in each region, including acres that did not receive atrazine applications.

Figure 38. Mean of the average annual grams of glyphosate (isopropylamine salt, active ingredient) per hectare lost from cultivated cropland acres.



Note: Per-hectare rates represent all cultivated cropland acres in each region, including acres that did not receive glyphosate (isopropylamine salt) applications.

Figure 37. Grassed contour buffer strips protect this field from erosion and sediment loss. The runoff and any pollutants from the cropped portion of the field is trapped by the grass buffers.

Figure 39. Native grasses and forbs are part of the planting mixture in this conservation buffer system. In addition to wildlife benefits, the buffers intercept, filter and process any pollutants that might be contained in the runoff water and sediments.

Table 12. Pesticides lost from cultivated cropland acres, percent of total amount of all pesticides lost by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides lost from farm fields in region
Northwest Non-Coastal (3)			
	Glyphosate, isopropylamine salt	Herbicide	15.0%
	Sulfur	Fungicide	13.1%
	Metam-sodium	Multi-Target	12.1%
	Metribuzin	Herbicide	6.8%
	1,3-Dichloropropene	Fungicide	5.3%
	2,4-D, dimethylamine salt	Herbicide	4.6%
	Paraquat dichloride	Herbicide	3.9%
	Aldicarb	Insecticide	2.5%
	2,4-Dichlorophenoxyacetic acid	Herbicide	2.5%
	2,4-D, 2-ethylhexyl ester	Herbicide	2.2%
	MCPA	Herbicide	1.7%
	Cycloate	Herbicide	1.5%
	Ethoprop	Nematicide	1.2%
	S-Metolachlor	Herbicide	1.1%
	Phorate	Insecticide	1.1%
	Triallate	Herbicide	1.1%
	MCPA, 2-ethylhexyl ester	Herbicide	1.1%
	Atrazine	Herbicide	1.0%
	Terbufos	Insecticide	1.0%
	Flufenacet	Herbicide	1.0%
	MCPA, sodium salt	NA	1.0%
Total			80.6%
Northern Plains (5)			
	Glyphosate, isopropylamine salt	Herbicide	20.0%
	Atrazine	Herbicide	18.0%
	Sulfentrazone	Herbicide	11.5%
	Metolachlor	Herbicide	6.2%
	Dicamba, dimethylamine salt	Herbicide	3.5%
	Acetochlor	Herbicide	3.5%
	Tebuconazole	Fungicide	2.6%
	Tetraconazole	Fungicide	2.5%
	Clopyralid	Herbicide	2.5%
	2,4-D, dimethylamine salt	Herbicide	2.4%
	Triallate	Herbicide	2.1%
	Ethofumesate	Herbicide	1.6%
	Quinclorac	Herbicide	1.5%
	MCPA	Herbicide	1.5%
	2,4-DP, dimethylamine salt	Herbicide	1.5%
	S-Metolachlor	Herbicide	1.5%
	Pendimethalin	Herbicide	1.3%
Total			83.9%
Southern Plains (6)			
	Atrazine	Herbicide	49.7%
	Glyphosate, isopropylamine sal	Herbicide	11.0%
	Metolachlor	Herbicide	5.7%
	S-Metolachlor	Herbicide	5.5%
	Alachlor	Herbicide	4.7%
	Sulfentrazone	Herbicide	2.4%
	Pendimethalin	Herbicide	1.9%
	Trifluralin	Herbicide	1.3%
	Diuron	Herbicide	1.3%
	Paraquat dichloride	Herbicide	1.2%
	Chlorsulfuron	Herbicide	1.1%
	Dimethenamide-P	Herbicide	1.1%
	2,4-Dichlorophenoxyacetic acid	Herbicide	0.9%
Total			88.1%

Table 12.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides lost from farm fields in region
North Central and Midwest (7)			
	Atrazine	Herbicide	41.6%
	Acetochlor	Herbicide	13.3%
	S-Metolachlor	Herbicide	11.3%
	Glyphosate, isopropylamine salt	Herbicide	7.8%
	Metolachlor	Herbicide	4.5%
	Sulfentrazone	Herbicide	3.9%
	Simazine	Herbicide	2.3%
	Dimethenamide-P	Herbicide	1.2%
	Pendimethalin	Herbicide	1.1%
	2,4-D, 2-ethylhexyl ester	Herbicide	1.0%
	Alachlor	Herbicide	1.0%
	Flufenacet	Herbicide	0.8%
	Paraquat dichloride	Herbicide	0.7%
	Dimethenamid	Herbicide	0.7%
	2,4-Dichlorophenoxyacetic acid	Herbicide	0.7%
	Mesotrione	Herbicide	0.5%
	Metam-sodium	Multi-Target	0.5%
Total			92.7%
Lower Mississippi and Texas Gulf Coast (9)			
	Sodium chlorate	Herbicide	44.4%
	Quinclorac	Herbicide	12.7%
	Glyphosate, isopropylamine salt	Herbicide	10.5%
	Atrazine	Herbicide	8.7%
	Paraquat dichloride	Herbicide	2.5%
	2,4-D, dimethylamine salt	Herbicide	1.7%
	Triclopyr	Herbicide	1.3%
	Metolachlor	Herbicide	1.1%
	S-Metolachlor	Herbicide	1.1%
	Diuron	Herbicide	1.1%
	Sulfentrazone	Herbicide	1.0%
	Pendimethalin	Herbicide	0.8%
	MSMA	Herbicide	0.8%
	Mepiquat chloride	Herbicide	0.7%
	Fluometuron	Herbicide	0.7%
	Acephate	Insecticide	0.6%
	Propanil	Herbicide	0.6%
Total			90.3%
Northeast (10)			
	Atrazine	Herbicide	31.6%
	S-Metolachlor	Herbicide	14.2%
	Pendimethalin	Herbicide	12.8%
	Glyphosate, isopropylamine salt	Herbicide	7.8%
	Paraquat dichloride	Herbicide	6.8%
	Metolachlor	Herbicide	4.5%
	Mancozeb	Fungicide	4.2%
	Dimethenamid	Herbicide	2.5%
	Acetochlor	Herbicide	2.4%
	Simazine	Herbicide	1.7%
	Chlorothalonil	Fungicide	1.4%
	Sulfentrazone	Herbicide	1.1%
	Alachlor	Herbicide	0.8%
	Copper hydroxide	Fungicide	0.7%
	Mesotrione	Herbicide	0.7%
	2,4-Dichlorophenoxyacetic acid	Herbicide	0.6%
	2,4-D, 2-ethylhexyl ester	Herbicide	0.5%
Total			94.1%

Table 12.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Percent of total quantity of pesticides lost from farm fields in region
East Central (11)			
	Atrazine	Herbicide	35.0%
	Glyphosate, isopropylamine salt	Herbicide	12.0%
	Paraquat dichloride	Herbicide	9.5%
	Sulfentrazone	Herbicide	6.4%
	Sodium chlorate	Herbicide	4.9%
	Metolachlor	Herbicide	4.5%
	Acetochlor	Herbicide	4.1%
	S-Metolachlor	Herbicide	4.1%
	Simazine	Herbicide	3.3%
	Pendimethalin	Herbicide	2.8%
	Chloropicrin	Fumigant	1.4%
	2,4-D, 2-ethylhexyl ester	Herbicide	1.0%
	Chlorothalonil	Fungicide	0.7%
	MSMA	Herbicide	0.7%
	Copper hydroxide	Fungicide	0.7%
	Carbofuran	Insecticide	0.5%
	Fluometuron	Herbicide	0.5%
Total			92.2%
Southeast Coastal Plain (12)			
	Methoxyfenozide	Insecticide	29.1%
	Atrazine	Herbicide	15.8%
	Glyphosate, isopropylamine salt	Herbicide	5.7%
	Copper hydroxide	Fungicide	5.5%
	Sodium chlorate	Herbicide	4.8%
	Chlorothalonil	Fungicide	4.1%
	1,3-Dichloropropene	Fungicide	3.0%
	Tebuconazole	Fungicide	3.0%
	Sulfentrazone	Herbicide	2.8%
	Mancozeb	Fungicide	2.3%
	Aldicarb	Insecticide	1.5%
	S-Metolachlor	Herbicide	1.5%
	2,4-D, dimethylamine salt	Herbicide	1.4%
	MSMA	Herbicide	1.4%
	Paraquat dichloride	Herbicide	1.3%
	Metolachlor	Herbicide	1.3%
	Pendimethalin	Herbicide	1.2%
Total			85.7%

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

Pesticide Risk

In the previous section, pesticide loss from farm fields was represented in terms of the *quantity* of pesticides lost. In most cases, the quantity lost was small, representing 1 percent or even less of what had been applied.

Moreover, results were presented for *combinations* of pesticides to simplify the analysis, as it is impractical to evaluate separately each of the 305 pesticides used in the eight regions. To combine pesticides, the quantity lost (active ingredient) was simply summed over all the pesticides at each sample point. This biases the assessment by overestimating the presence of the safer pesticides applied at higher rates and underestimating the presence of pesticides applied at low rates that are often less safe if over-applied or mishandled.

The environmental risk posed by the loss of pesticide residues from farm fields depends not only on the amount of pesticide lost, but also on the toxicity of the pesticide to non-target species that may be exposed to the pesticide.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As ratios of two concentrations, these risk indicators do not have units. The ratios are called Aquatic Risk Factors, or ARFs. ARF values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge of the field.

The final indicators are obtained by adding the ARFs over all the pesticides used at a sample point in each year, and then calculating the average annual value for each point by taking the mean over the 47 years in the model simulation. Average annual indicator values greater than 1 are multiples of the "safe" level.[5] A value of 2, for example, indicates that the pesticide (or pesticide mix) is 2 times the "safe" level, and a value of 10 is 10 times the "safe" level.

Since the assumptions underlying the estimation of the pesticide risk indicators would almost never be met in actual environmental settings (see box inset on following page), the indicators are suitable primarily for evaluation of ***potential*** risk under one set of conditions ***relative to*** another set of conditions, such as comparisons from field to field, comparisons of different farming activities on the same field, or comparisons from one region or area to another. The "safe" threshold value of 1 for the pesticide risk indicator is a useful benchmark, as it would be unlikely that ecosystem dysfunction or species mortality would occur in any nearby environmental setting where the edge-of-field risk indicator was less than 1. In actual environmental settings, where dilution from other sources of water occurs, a "safe" edge-of-field risk indicator would be expected to be greater than 1, perhaps much greater.

Three separate edge-of-field risk indicators are used for reporting:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow).

The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and invertebrates and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not yet been set.

These indicators provide a consistent measure that is comparable from field to field and are thus ideally suited for purposes of estimating potential risk reduction due to the use of conservation practices.

[5] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide for long-term exposure at the edge of the field. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides.

Pesticide Risk Indicators

Three *edge-of-field* pesticide risk indicators were used to assess the effects of conservation practices:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

Pesticide risk indicators were calculated for each pesticide as the ratio of the concentration in water leaving the field to the "safe" concentration (toxicity thresholds) for each pesticide, where both are expressed in units of parts per billion. This ratio is called the Aquatic Risk Factor (ARF). ARFs are unit-less numbers that represent the relative toxicity of pesticides in solution. A risk indicator value of less than 1 is considered "safe" because the concentration is below the toxicity threshold for exposure at the edge-of-the field.

$$ARF = \frac{\text{(Annual Concentration)}}{\text{(Toxicity Threshold)}} < 1 \quad \rightarrow \text{Little or no potential adverse impact}$$

Two aquatic toxicity threshold databases were used in estimating potential risk:

- <u>Human drinking water lifetime toxicity thresholds</u>. These thresholds are either taken from the EPA Office of Water Standards, or derived from EPA Reference Doses or Cancer Slopes using the methods employed by the EPA Office of Water.
- <u>Aquatic ecosystem toxicity thresholds</u>. The lowest (most sensitive) toxicity is used from the fish chronic NOEL (No Observable Effect Concentration), invertebrate chronic NOEL, aquatic vascular plant acute EC50 (Effective Concentration that is lethal to 50 percent of the population) and aquatic nonvascular plant acute EC50.

These edge-of-field indicators do not represent risk that non-target species would be subjected to in actual environmental settings. Consequently, they cannot be used to predict environmental impacts. The pesticide risk indicators are treated as ***potential*** risk indicators for purposes of making ***relative comparisons*** from field to field.

Environmental risk is a function of both exposure concentration and the time of exposure. In an actual environmental setting, both exposure concentration and time of exposure vary throughout the year and from year to year. The risk indicators do not estimate realistic exposure concentrations or realistic times of exposure because of the following assumptions and protocols:

1. The exposure concentration used in the development of the indicators represents an annual exposure, calculated as the sum of the annual pesticide loss divided by annual volume of water flow. In an actual environmental setting, concentrations would range from near zero during some time periods to highest concentrations during the early stages of runoff events.

2. For aquatic ecosystems, the exposure is assumed to be long-term at the edge of the field in an environmental setting that receives water only from the cropped field. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. With the data and information currently available, it is not possible to realistically estimate the extent to which water from fields has been diluted by base-flow, upstream water sources, and/or groundwater of various ages in actual environmental settings where ecosystems that support aquatic life would exist.

3. For drinking water, the assumption is that humans would be using runoff water from a cropped field as their only source of drinking water throughout the year, or in the case of groundwater, using water from a very shallow well that was recharged by percolation only from the cropped field. In contrast, drinking water supplies are typically treated prior to use and often are from water sources that are at least partially protected from contamination by water flows from cropped fields (such as deep wells and watersheds with land use restrictions).

For a complete documentation of the development of the pesticide risk indicators, see "Pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/.

The surface water pesticide risk indicator for aquatic ecosystems had larger values than either of the two indicators for humans, indicating that risks to the aquatic ecosystem from pesticide residues in runoff from farm fields was greater than the risk to humans from drinking water. The average of the surface water indicator for aquatic ecosystems over all eight regions was 2.368, compared to a value of 0.568 for the surface water indicator for humans and a value of 0.156 for the groundwater indicator for humans (table 13).

However, all three indicators have highly skewed distributions, indicating that most acres had low levels of risk while a few acres had higher levels of risk. The median indicator for aquatic ecosystems was only 0.181, compared to the mean of 2.368 and the 80th percentile of 2.995 (table 13). The medians for the two indicators for human risk were much lower—0.017 for the surface water indicator and less than 0.001 for the groundwater indicator. The two human risk indicator distributions are even more skewed than the distribution for aquatic ecosystems. For the surface water indicator for humans, the mean—0.568—was nearly as large as the 80th percentile value—0.645. For the groundwater indicator for humans, the mean—0.156—was greater than the 80th percentile value—0.060.

Regional differences among the three indicators are pronounced, as shown in figures 39-41, table 13, and figures 42-44. The surface water pesticide risk indicator for aquatic ecosystems was highest for the East Central (11) region, averaging 4.259. The surface water pesticide risk indicator for humans was highest in the Lower Mississippi and Texas Gulf Coast (9) region, averaging 1.423. The groundwater pesticide risk indicator for humans was highest in the Southeast Coastal Plain (12) region, averaging 0.633.

All three indicators were lowest in the Northern Plains (5) region, which also had the smallest amounts of field-level surface water runoff, loss of water through subsurface flows, and sediment loss (figs. 6, 7, and 9).

The distributions of the pesticide risk indicators by region in figures 42-44 show more clearly how the pesticide risk indicator values vary among the regions.

- For the surface water indicator for aquatic ecosystems, about half of the acres in both the East Central (11) region and the North Central and Midwest (7) region have average annual indicators greater than 1, whereas only 8-10 percent of acres have indicators greater than 1 in the Northwest Non-Coastal (3) region and Northern Plains (5) region (fig. 24).
- For the surface water indicator for humans, about 20-22 percent of the acres in three regions—the East Central (11) region, the Northeast (10) region, and the Lower Mississippi and Texas Gulf Coast (9) region—have average annual indicators greater than 1, whereas only 1-3 percent of acres have indicators greater than 1 in the Northwest Non-Coastal (3) region and Northern Plains (5) region (fig. 43).

Figure 40. Mean of the average annual surface water pesticide risk indicator for aquatic ecosystems.

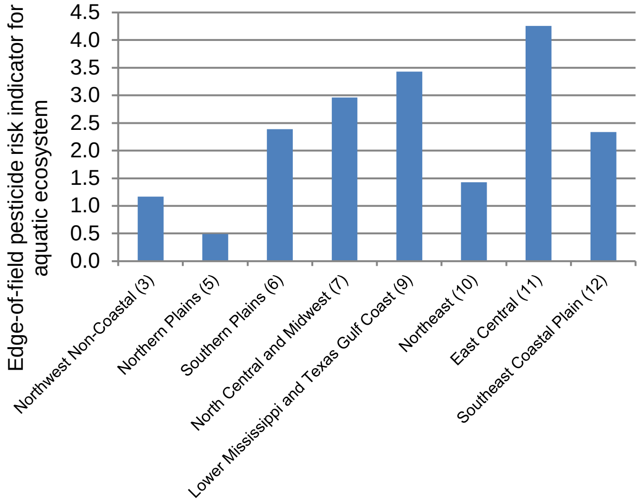


Figure 41. Mean of the average annual surface water pesticide risk indicator for humans.

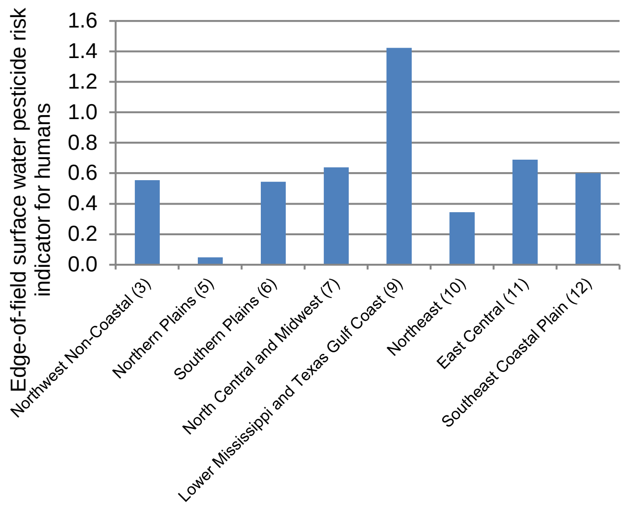
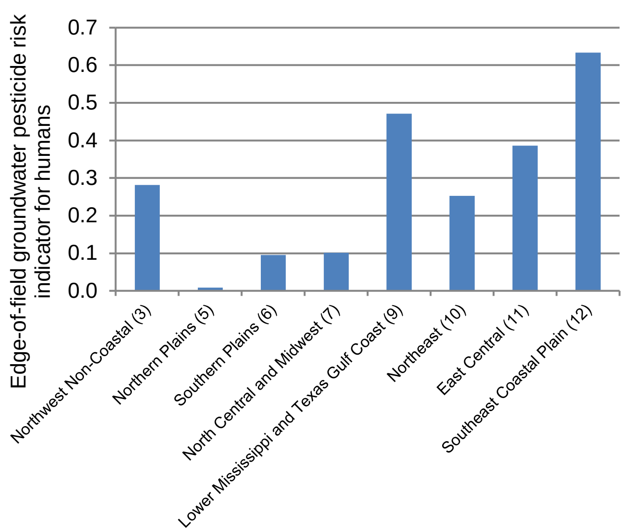


Figure 42. Mean of the average annual groundwater pesticide risk indicator for humans.



- For the groundwater indicator for humans, about 14 percent of the acres in the Southeast Coastal Plain (12) region have average annual indicators greater than 1, whereas only 1-2 percent of acres have indicators greater than 1in four regions—the Northwest Non-Coastal (3) region, the Northern Plains (5) region, the Southern Plains (6) region, and the North Central and Midwest (7) region (fig. 44).

Table 13. Edge-of-field pesticide risk indicators, cultivated cropland.

	Mean	Median	20th percentile	80th percentile
Average annual surface water pesticide risk indicator for aquatic ecosystems				
Northwest Non-Coastal (3)	1.169	0.007	<0.001	0.161
Northern Plains (5)	0.491	0.005	<0.001	0.189
Southern Plains (6)	2.386	0.047	<0.001	1.278
North Central and Midwest (7)	2.963	1.061	0.010	4.900
Lower Mississippi and Texas Gulf Coast (9)	3.427	0.169	0.001	3.853
Northeast (10)	1.429	0.536	<0.001	2.256
East Central (11)	4.259	1.135	<0.001	4.559
Southeast Coastal Plain (12)	2.333	0.581	0.002	2.645
All eight regions	2.368	0.181	<0.001	2.995
Average annual surface water pesticide risk indicator for humans				
Northwest Non-Coastal (3)	0.554	0.001	<0.001	0.017
Northern Plains (5)	0.047	0.001	<0.001	0.018
Southern Plains (6)	0.543	0.002	<0.001	0.169
North Central and Midwest (7)	0.639	0.187	0.001	1.148
Lower Mississippi and Texas Gulf Coast (9)	1.423	0.033	<0.001	1.204
Northeast (10)	0.345	0.135	<0.001	0.515
East Central (11)	0.688	0.172	<0.001	1.057
Southeast Coastal Plain (12)	0.601	0.092	<0.001	0.915
All eight regions	0.568	0.017	<0.001	0.645
Average annual groundwater pesticide risk indicator for humans				
Northwest Non-Coastal (3)	0.282	<0.001	<0.001	<0.001
Northern Plains (5)	0.009	<0.001	<0.001	<0.001
Southern Plains (6)	0.096	<0.001	<0.001	0.005
North Central and Midwest (7)	0.101	0.013	<0.001	0.110
Lower Mississippi and Texas Gulf Coast (9)	0.471	0.000	<0.001	0.074
Northeast (10)	0.253	0.019	<0.001	0.296
East Central (11)	0.387	0.023	<0.001	0.360
Southeast Coastal Plain (12)	0.633	0.027	<0.001	0.552
All eight regions	0.156	<0.001	<0.001	0.060

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

Figure 43. Distributions of average annual surface water pesticide risk indicator for aquatic ecosystems, representing CEAP sample points in eight production regions.

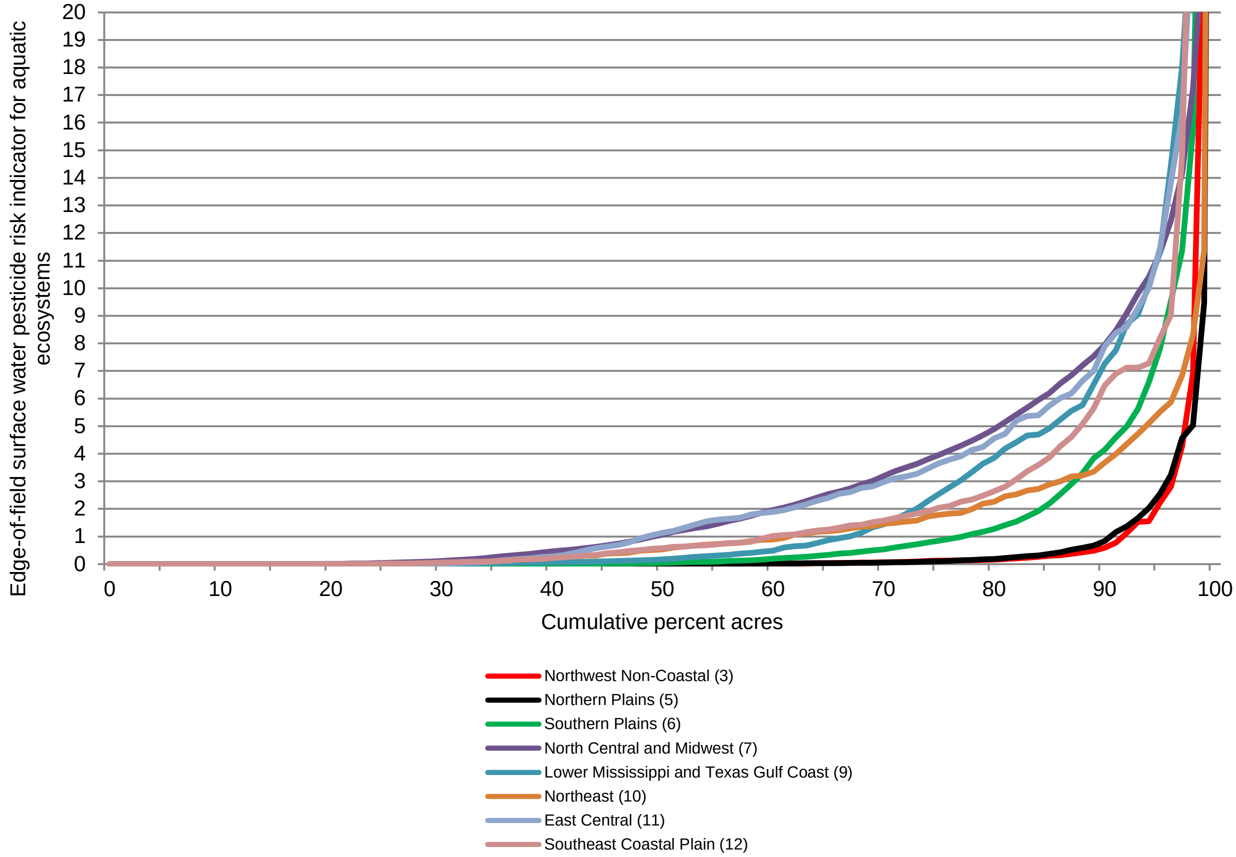


Figure 44. Distributions of average annual surface water pesticide risk indicator for humans, representing CEAP sample points in eight production regions.

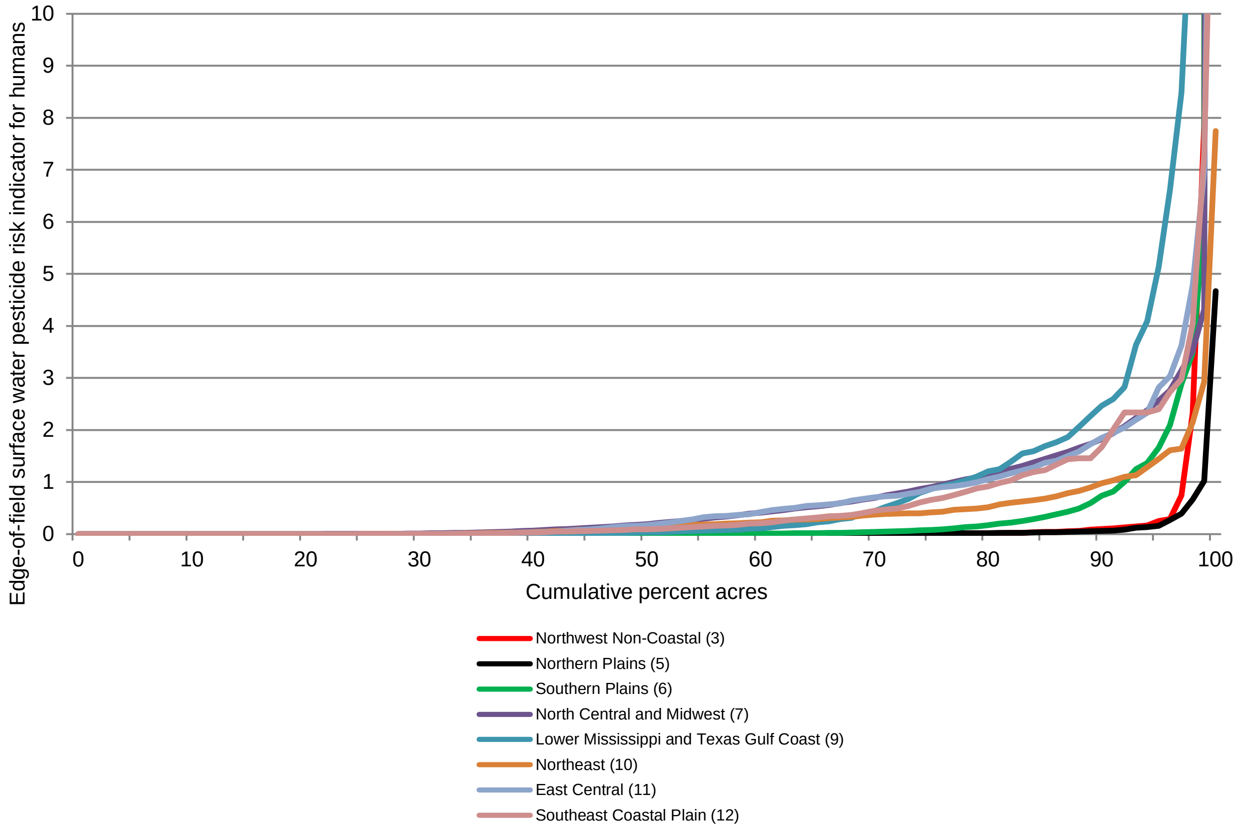
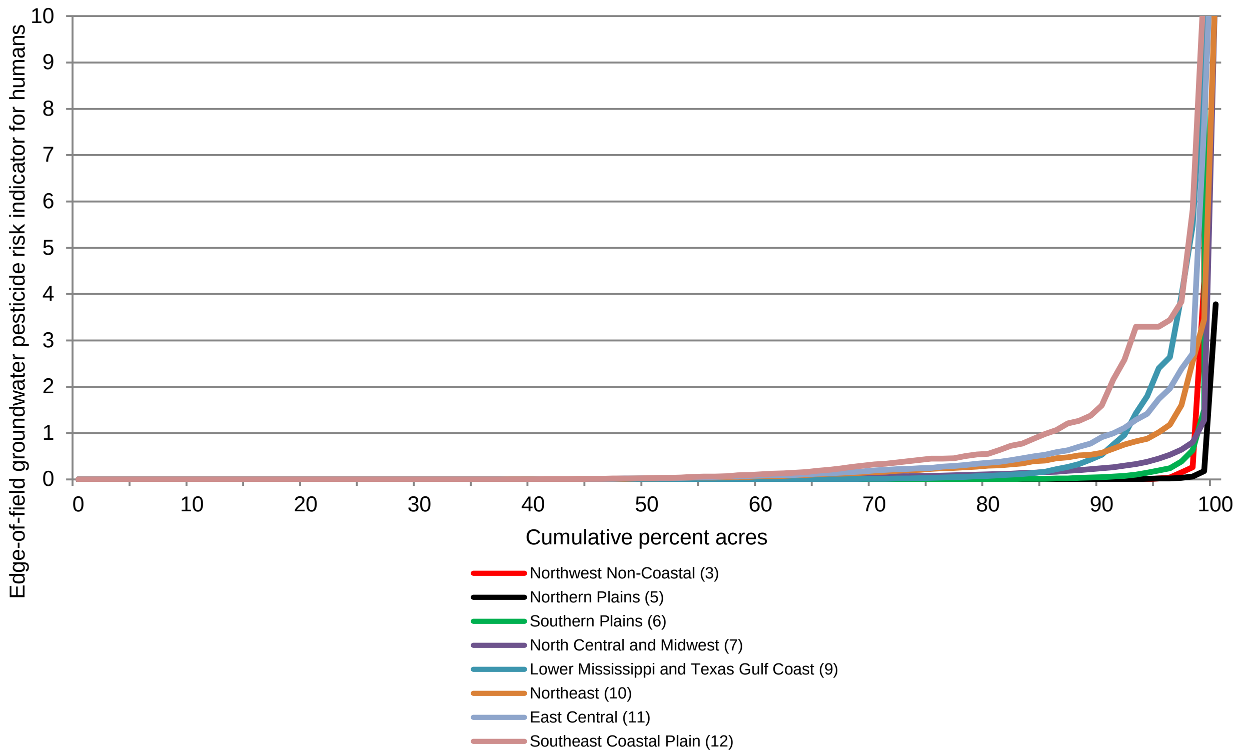


Figure 45. Distributions of average annual groundwater pesticide risk indicator for humans, representing CEAP sample points in eight production regions.



Pesticide risk indicators were greater than 1 for only about one-third of the 305 pesticides used on cultivated cropland in 2003-06. Of the pesticides with occurrences of risk indicators greater than 1, most occurred on only a few cultivated cropland acres.

The top pesticides with a risk indicator greater than 1 for all eight regions combined are listed for each of the three indicators in tables 14, 15, and 16. As shown in these tables, only a few pesticides were estimated to have the potential for environmental risk with long-term exposure at the edge of the field. The lists exclude pesticides applied on only a few acres throughout the eight regions. Not included in the lists are pesticides with risk indicators greater than 1 for fewer than 700,000 acres (0.2 percent of cultivated cropland in all eight regions) for the surface water indicator for aquatic ecosystems), pesticides with risk indicators greater than 1 for fewer than 200,000 acres (0.1 percent of cultivated cropland in all eight regions) for the surface water indicator for humans), and pesticides with risk indicators greater than 1 for fewer than 100,000 acres (0.05 percent of cultivated cropland in all eight regions) for the groundwater indicator for humans.

The herbicide atrazine was the dominant pesticide contributing to all three risk indicators at the national level. Based on the model simulations, the pesticide risk indicator for atrazine exceeded 1 for 23 percent of the cropped acres for risk to aquatic ecosystems, 11 percent of the cropped acres for surface water risk to humans, and 2 percent of the cropped acres for groundwater risk to humans (tables 14-16).

Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb)**.**

Atrazine also has a high incidence of occurrence of field level losses resulting in a risk indicator greater than 1. Results show that about 59 percent of the acres treated with atrazine had an average annual surface water risk indicator for aquatic ecosystems greater than 1 (table 14), and 29 percent of treated acres with an average annual surface water risk indicator for humans greater than 1 (table 15). As noted previously, however, these risk indicators are not suitable for assessment of impact, but rather represent the potential for risk for exposure to losses at the edge of the field.

Other pesticides that were shown by the modeling to have a relatively high incidence of occurrence of risk indicators greater than 1 are:

- the insecticide phostebupirim, for which 82 percent of the acres treated had an average annual surface water risk indicator for aquatic ecosystems greater than 1 (table 14);
- the insecticide malathion, for which 65 percent of the acres treated had an average annual surface water risk indicator for aquatic ecosystems greater than 1 (table 14);
- the fungicide fentin hydroxide, for which 65 percent of the acres treated had an average annual surface water risk indicator for aquatic ecosystems greater than 1 (table 14);
- the herbicide sulfentrazone, for which 61 percent of the acres treated had an average annual surface water risk indicator for aquatic ecosystems greater than 1 (table 14); and
- the insecticide dicrotophos, for which 61 percent of the acres treated had an average annual surface water risk indicator for humans greater than 1 (table 15).

When pesticide losses and potential risk are evaluated at the regional level instead of the national level, atrazine remains the dominant contributor to the risk indicators in most regions, but there are some exceptions. The top pesticides with a risk indicator greater than 1 for each region are listed for the three indicators in tables 17, 18, and 19.

At the regional level, atrazine was the dominant pesticide contributing to the surface water indicator for aquatic ecosystems in all but two regions (table 17):

- the Northwest Non-Coastal (3) region, where the dominant pesticide contributing to risk was the herbicide 2,4-D, 2-ethylhexyl ester (2 percent of cultivated cropland acres in the region had indicator values greater than 1), and
- the Northern Plains (5) region, where the dominant pesticide contributing to risk was also the herbicide 2,4-D, 2-ethylhexyl ester (3 percent of cultivated cropland acres in the region had indicator values greater than 1).

Atrazine was also the dominant pesticide contributing to the surface water indicator humans in all but one region—the Northwest Non-Coastal (3) region (table 18). In that region, the dominant pesticide contributing to risk was the multi-target pesticide metam-sodium, but only 0.8 1 percent of cultivated cropland acres in the region had indicator values greater than 1 for this pesticide.

And finally, atrazine was the dominant pesticide contributing to the groundwater indicator for humans in all but one region (table 19)—the Northwest Non-Coastal (3) region, where the dominant pesticide contributing to risk was the fungicide 1,3-Dichloropropene (0.6 percent of cultivated cropland acres in the region had indicator values greater than 1 for this pesticide).

Table 14. Top 15 pesticides with a surface water pesticide risk indicator for aquatic ecosystems greater than 1 for all eight regions combined.

Pesticide (active ingredient)	Pesticide type	Acres treated in 2003-06	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Atrazine	Herbicide	113,826,955	67,553,984	23.3%	59%
Acetochlor	Herbicide	35,869,313	14,745,802	5.1%	41%
2,4-D, 2-ethylhexyl ester	Herbicide	21,015,557	8,417,939	2.9%	40%
Metolachlor	Herbicide	12,796,487	7,053,585	2.4%	55%
Sulfentrazone	Herbicide	10,056,420	6,141,980	2.1%	61%
Phostebupirim	Insecticide	4,797,026	3,931,202	1.4%	82%
Chlorpyrifos	Insecticide	9,454,917	2,138,511	0.7%	23%
Aldicarb	Insecticide	4,455,568	1,521,457	0.5%	34 %
Alachlor	Herbicide	4,556,857	1,385,581	0.5%	30%
Malathion	Insecticide	2,098,590	1,363,142	0.5%	65%
Chlorothalonil	Fungicide	4,058,061	991,471	<0.5%	24%
Terbufos	Insecticide	2,686,052	926,346	<0.5%	34%
Fentin hydroxide	Fungicide	1,207,526	783,298	<0.5%	65%
S-Metolachlor	Herbicide	35,408,108	724,970	<0.5%	2%
Tefluthrin	Insecticide	5,577,336	704,690	<0.5%	13%

Notes: An additional 75 pesticides had acres with the average annual risk indicator greater than 1, but each represented less than 0.2 percent of cultivated cropland in the eight regions. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Table 15. Top pesticides with a surface water pesticide risk indicator for humans greater than 1 for all eight regions combined.

Pesticide (active ingredient)	Pesticide type	Acres treated in 2003-06	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Atrazine	Herbicide	113,826,955	32,472,064	11.2%	29%
Dicrotophos	Insecticide	3,477,102	2,125,590	0.7%	61%
Alachlor	Herbicide	4,421,239	1,120,212	0.4%	25%
Simazine	Herbicide	5,312,938	821,488	0.3%	15%
Terbufos	Insecticide	1,697,093	356,232	0.1%	21%
Dimethoate	Insecticide	1,811,937	337,850	0.1%	19%

Notes An additional 25 pesticides had acres with the average annual risk indicator greater than 1, but each represented less than 0.1 percent of cultivated cropland in the eight regions. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Table 16. Top pesticides with a groundwater pesticide risk indicator for humans greater than 1 for all eight regions combined.

Pesticide (active ingredient)	Pesticide type	Acres treated in 2003-06	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Atrazine	Herbicide	113,826,955	5,154,791	1.8%	5%
Dicrotophos	Insecticide	3,477,102	1,176,317	0.4%	34%
Aldicarb	Insecticide	4,455,568	338,414	0.1%	8%
Fluometuron	Herbicide	1,379,759	206,597	0.1%	15%
Simazine	Herbicide	1,767,242	123,149	<0.1%	7%

Notes: An additional 17 pesticides had acres with the average annual risk indicator greater than 1, but each represented less than 0.05 percent of cultivated cropland in the eight regions. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Table 17. Pesticides with a surface water pesticide risk indicator for aquatic ecosystems greater than 1, by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Acres treated	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Northwest Non-Coastal (3) region	2,4-D, 2-ethylhexyl ester	Herbicide	2,105,254	252,578	2.2%	12%
	Metribuzin	Herbicide	1,428,655	121,679	1.1%	9%
	Atrazine	Herbicide	221,040	98,842	0.9%	45%
	Aldicarb	Insecticide	319,823	73,718	0.6%	23%
	Chlorpyrifos	Insecticide	256,370	69,620	0.6%	27%
	Terbufos	Insecticide	211,188	61,629	0.5%	29%
	Flufenacet	Herbicide	57,875	57,875	0.5%	100%
	Phorate	Insecticide	270,775	56,409	0.5%	21%
	Metam-sodium	Multi-Target	295,800	53,646	0.5%	18%
Northern Plains (5) region	2,4-D, 2-ethylhexyl ester	Herbicide	5,708,865	1,332,141	2.8%	23%
	Atrazine	Herbicide	3,508,393	1,059,520	2.2%	30%
	Fentin hydroxide	Fungicide	1,207,526	783,298	1.6%	65%
	Sulfentrazone	Herbicide	2,189,025	631,120	1.3%	29%
	Metolachlor	Herbicide	531,942	397,182	0.8%	75%
Southern Plains (6) region	Atrazine	Herbicide	19,821,145	8,149,830	12.8%	41%
	2,4-D, 2-ethylhexyl ester	Herbicide	4,504,116	1,348,270	2.1%	30%
	Metolachlor	Herbicide	2,552,222	789,992	1.2%	31%
	Chlorsulfuron	Herbicide	4,196,261	648,922	1.0%	16%
	Malathion	Insecticide	1,097,732	645,561	1.0%	59%
	Chlorpyrifos	Insecticide	1,393,823	521,846	0.8%	37%
	Sulfentrazone	Herbicide	967,991	516,441	0.8%	53%
	Alachlor	Herbicide	1,510,640	399,950	0.6%	27%
	Trifluralin	Herbicide	6,707,824	393,339	0.6%	6%
	Phostebupirim	Insecticide	461,642	385,374	0.6%	84%
North Central and Midwest (7) region	Atrazine	Herbicide	72,679,212	46,357,509	39.5%	64%
	Acetochlor	Herbicide	31,196,526	13,648,830	11.6%	44%
	2,4-D, 2-ethylhexyl ester	Herbicide	6,680,617	4,435,673	3.8%	66%
	Sulfentrazone	Herbicide	5,657,909	4,266,798	3.6%	75%
	Metolachlor	Herbicide	6,854,109	4,137,673	3.5%	60%
	Phostebupirim	Insecticide	4,107,078	3,380,376	2.9%	82%
	Chlorpyrifos	Insecticide	5,799,622	1,235,627	1.1%	21%
	Alachlor	Herbicide	2,009,423	775,434	0.7%	37%
	Tefluthrin	Insecticide	4,929,193	680,819	0.6%	14%
Lower Mississippi and Texas Gulf Coast (9) region	Atrazine	Herbicide	5,260,512	3,857,893	18.2%	73%
	Malathion	Insecticide	900,703	640,706	3.0%	71%
	Metolachlor	Herbicide	745,823	516,320	2.4%	69%
	Aldicarb	Insecticide	921,183	469,869	2.2%	51%
	Dicrotophos	Insecticide	2,254,137	385,189	1.8%	17%
	2,4-D, 2-ethylhexyl ester	Herbicide	640,224	369,137	1.7%	58%
	Acetochlor	Herbicide	315,683	267,797	1.3%	85%
	Diuron	Herbicide	2,525,318	261,789	1.2%	10%
	Sulfentrazone	Herbicide	607,078	201,179	1.0%	33%
	Zeta-Cypermethrin	Insecticide	1,006,889	184,340	0.9%	18%
	Halosulfuron-methyl	Herbicide	1,101,642	169,158	0.8%	15%
	Permethrin, mixed cis,trans	Insecticide	325,278	164,952	0.8%	51%
	Prometryn	Herbicide	443,625	104,968	0.5%	24%
	Pyrithiobac-sodium	Herbicide	584,006	99,215	0.5%	17%

Table 17.—continued.

Production region	Pesticide (active ingredient)	Pesticide type	Acres treated	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1
Northeast (10) region	Atrazine	Herbicide	3,955,003	1,895,854	29.0%
	Metolachlor	Herbicide	534,655	286,367	4.4%
	2,4-D, 2-ethylhexyl ester	Herbicide	348,281	153,521	2.3%
	Acetochlor	Herbicide	390,327	102,158	1.6%
	Sulfentrazone	Herbicide	77,708	68,459	1.0%
	Chlorpyrifos	Insecticide	249,709	39,907	0.6%
	Diazinon	Insecticide	33,934	33,934	0.5%
East Central (11) region	Atrazine	Herbicide	4,328,182	3,346,461	38.4%
	Metolachlor	Herbicide	784,601	608,000	7.0%
	Acetochlor	Herbicide	809,842	380,895	4.4%
	2,4-D, 2-ethylhexyl ester	Herbicide	415,073	319,054	3.7%
	Sulfentrazone	Herbicide	327,515	317,161	3.6%
	Chlorpyrifos	Insecticide	305,968	107,706	1.2%
	Chlorothalonil	Fungicide	156,867	80,378	0.9%
	Aldicarb	Insecticide	243,422	77,529	0.9%
	Disulfoton	Insecticide	60,737	60,737	0.7%
	Phostebupirim	Insecticide	53,144	53,144	0.6%
	Endosulfan	Insecticide	214,747	48,596	0.6%
	Carbofuran	Insecticide	165,966	47,377	0.5%
Southeast Coastal Plain (12) region	Atrazine	Herbicide	4,053,469	2,788,074	20.6%
	Aldicarb	Insecticide	2,183,486	856,066	6.3%
	Chlorothalonil	Fungicide	2,748,890	664,461	4.9%
	Metolachlor	Herbicide	793,134	318,050	2.4%
	Endosulfan	Insecticide	324,873	284,677	2.1%
	Mancozeb	Fungicide	301,589	280,325	2.1%
	Methoxyfenozide	Insecticide	318,136	280,325	2.1%
	2,4-D, 2-ethylhexyl ester	Herbicide	613,127	207,565	1.5%
	Chlorpyrifos	Insecticide	665,016	150,479	1.1%
	Sulfentrazone	Herbicide	229,194	140,823	1.0%
	Terbufos	Insecticide	364,925	96,909	0.7%
	Diflubenzuron	Insecticide	177,462	79,919	0.6%

Note: Additional pesticides in each region had acres with the average annual risk indicator greater than 1, but each represented less than 0.5 percent of cultivated cropland in that region. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Table 18. Pesticides with a surface water pesticide risk indicator for humans greater than 1, by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Acres treated	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Northwest Non-Coastal (3) region	Metam-sodium	Multi-Target	295,800	86,534	0.8%	29%
	1,3-Dichloropropene	Fungicide	153,418	58,476	0.5%	38%
	Dimethoate	Insecticide	340,380	46,370	0.4%	14%
	Aldicarb	Insecticide	319,823	46,353	0.4%	14%
	Atrazine	Herbicide	221,040	45,646	0.4%	21%
	Terbufos	Insecticide	211,188	36,492	0.3%	17%
Northern Plains (5) region	Atrazine	Herbicide	3,508,393	279,339	0.6%	8%
Southern Plains (6) region	Atrazine	Herbicide	19,821,145	4,059,567	6.4%	20%
	Alachlor	Herbicide	1,510,640	316,421	0.5%	21%
	Dimethoate	Insecticide	565,589	235,258	0.4%	42%
North Central and Midwest (7) region	Atrazine	Herbicide	72,679,212	22,430,036	19.1%	31%
	Alachlor	Herbicide	2,009,423	687,941	0.6%	34%
	Simazine	Herbicide	3,545,695	625,085	0.5%	18%
	Terbufos	Insecticide	879,637	230,997	0.2%	26%
Lower Mississippi and Texas Gulf Coast (9) region	Atrazine	Herbicide	5,260,512	2,484,423	11.7%	47%
	Dicrotophos	Insecticide	2,254,137	1,529,100	7.2%	68%
	Molinate	Herbicide	475,658	155,292	0.7%	33%
	Acephate	Insecticide	3,608,760	137,476	0.6%	4%
	Propanil	Herbicide	2,547,296	99,555	0.5%	4%
	Alachlor	Herbicide	211,382	68,429	0.3%	32%
	Fluometuron	Herbicide	700,681	63,343	0.3%	9%
	Disulfoton	Insecticide	106,238	56,005	0.3%	53%
Northeast (10) region	Atrazine	Herbicide	3,955,003	478,147	7.3%	12%
	Alachlor	Herbicide	152,312	19,875	0.3%	13%
East Central (11) region	Atrazine	Herbicide	4,328,182	1,541,690	17.7%	36%
	Simazine	Herbicide	605,479	102,151	1.2%	17%
	Disulfoton	Insecticide	60,737	50,808	0.6%	84%
Southeast Coastal Plain (12) region	Atrazine	Herbicide	4,053,469	1,153,215	8.5%	28%
	Dicrotophos	Insecticide	1,015,965	485,187	3.6%	48%
	1,3-Dichloropropene	Fungicide	312,315	102,473	0.8%	33%
	Simazine	Herbicide	566,326	45,904	0.3%	8%
	Terbufos	Insecticide	364,925	42,927	0.3%	12%

Note: Additional pesticides in each region had acres with the average annual risk indicator greater than 1, but each represented less than 0.2 percent of cultivated cropland in that region. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Table 19. Pesticides with a groundwater pesticide risk indicator for humans greater than 1, by production region.

Production region	Pesticide (active ingredient)	Pesticide type	Acres treated	Acres with average annual risk indicator > 1	Percent of cultivated cropland acres with average annual risk indicator > 1	Percent of treated acres with average annual risk indicator > 1
Northwest Non-Coastal (3) region	1,3-Dichloropropene	Fungicide	153,418	63,901	0.6%	42%
	Atrazine	Herbicide	221,040	56,093	0.5%	25%
	Aldicarb	Insecticide	319,823	40,689	0.4%	13%
	Metam-sodium	Multi-Target	295,800	31,552	0.3%	11%
	Dimethoate	Insecticide	340,380	5,274	<0.1%	2%
Northern Plains (5) region	Atrazine	Herbicide	3,508,393	23,281	<0.1%	1%
Southern Plains (6) region	Atrazine	Herbicide	19,821,145	669,590	1.1%	3%
	Fluometuron	Herbicide	223,294	37,207	0.1%	17%
	Dimethoate	Insecticide	565,589	33,527	0.1%	6%
	Aldicarb	Insecticide	782,256	29,524	<0.1%	4%
North Central and Midwest (7) region	Atrazine	Herbicide	72,679,212	1,471,546	1.3%	2%
Lower Mississippi and Texas Gulf Coast (9) region	Atrazine	Herbicide	5,260,512	908,014	4.3%	17%
	Dicrotophos	Insecticide	2,254,137	619,785	2.9%	27%
	Fluometuron	Herbicide	700,681	118,718	0.6%	17%
	Aldicarb	Insecticide	921,183	53,667	0.3%	6%
	Molinate	Herbicide	475,658	32,264	0.2%	7%
	Acephate	Insecticide	3,608,760	30,008	0.1%	1%
	Simazine	Herbicide	206,009	25,509	0.1%	12%
	Dicamba, dimethylamine salt	Herbicide	350,257	14,928	0.1%	4%
	Metribuzin	Herbicide	742,337	14,928	0.1%	2%
	2,4-D, dimethylamine salt	Herbicide	1,654,312	14,928	0.1%	1%
Northeast (10) region	Atrazine	Herbicide	3,955,003	318,847	4.9%	8%
	Simazine	Herbicide	389,428	25,250	0.4%	6%
East Central (11) region	Atrazine	Herbicide	4,328,182	669,668	7.7%	15%
	Dicrotophos	Insecticide	67,546	40,083	0.5%	59%
	Simazine	Herbicide	605,479	26,034	0.3%	4%
	Fluometuron	Herbicide	98,502	15,672	0.2%	16%
	Dinoseb	Herbicide	9,562	9,562	0.1%	100%
	Aldicarb	Insecticide	243,422	4,349	<0.1%	2%
Southeast Coastal Plain (12) region	Atrazine	Herbicide	4,053,469	1,037,751	7.7%	26%
	Dicrotophos	Insecticide	1,015,965	494,548	3.7%	49%
	Aldicarb	Insecticide	2,183,486	204,788	1.5%	9%
	Simazine	Herbicide	566,326	46,356	0.3%	8%
	Fluometuron	Herbicide	357,282	35,001	0.3%	10%
	Sulfentrazone	Herbicide	229,194	15,089	0.1%	7%
	Tebuconazole	Fungicide	1,242,715	13,003	0.1%	1%

Note: Additional pesticides in each region had acres with the average annual risk indicator greater than 1, but each represented less than 0.05 percent of cultivated cropland in that region. Indicators were developed using APEX simulation modeling results based on 2003-06 CEAP survey information on farming practices.

Effects of Conservation Practices

Management practices that reduce the potential for loss of pesticides from farm fields primarily consist of a combination of:

- water erosion control practices and
- Integrated Pest Management (IPM) techniques

Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations.

The baseline results presented in previous sections include the benefits and effects of these and other 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. Annual practices such as tillage are also simulated. Pesticide management practices are reflected in the rate, timing, and method of application as well as the number of applications used to control or prevent pest infestations.

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 total pesticide loss, for example, is the total pesticide loss value for the no-practice scenario minus the total pesticide loss value 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 value.

The no-practice scenario also included specific features to remove or reverse the effects of other practices not targeted specifically at reducing pesticide loss, but which could have some effect on pesticide loss:[6]

- Nutrient management practices, which could affect pesticide loss through the relationship between crop growth (canopy development) and soil erosion.
- Cover crops, which could also affect soil erosion, but were not in common use in 2003-06.
- Irrigation management, which could increase pesticide losses in the no-practice scenario where less efficient irrigation systems are simulated.

In the next section, the use of soil erosion control practices will be summarized at the national level and at the regional level, as well as how their removal was simulated in the no-practice scenario. The following section does the same for pesticide management practices.

These two sections are then followed by a summary of the effects of conservation practices on water and sediment loss and the report concludes with an assessment of the effects of conservation practices on pesticide loss and associated environmental risk.

Erosion Control Practices

Erosion control practices include residue and tillage management (annual practices) and structural practices which, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field pesticide loss.

Structural practices evaluated that effect pesticide loss 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); and
- 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.)

Erosion control practice use in 2003-06. Structural practices for erosion control are in widespread use on cultivated cropland acres (fig. 45). Overall, about 38 percent of cultivated cropland acres had one or more water erosion control practice in 2003-06 (table 20). 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.

[6] 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.

Structural practices were most prevalent in the East Central (11) region (table 20), 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.

Not all cultivated cropland acres require erosion control practices. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable than other acres to erosion and sediment losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to infiltration of water and have a low potential for erosion. Of the 62 percent of cultivated cropland acres without one or more water erosion control practice in use in 2003-06, 71 percent had field slopes less than 2 percent, some of which would not need to be treated with structural practices.

Some form of conservation tillage was being used on all but 10 percent of the cultivated cropland acres in 2003-06 (table 21).

The Soil Tillage Intensity Rating (STIR) was used to assess tillage intensity. STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point. The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage as reported in the CEAP survey for 2003-06. STIR values were calculated for each crop and for each of the 3 years covered by the survey and accounted for multiple crops and cover crops.

About 32 percent of cultivated cropland acres in all eight regions met the tillage intensity criteria for no-till, and about 50 percent met the tillage intensity criteria for mulch till (table 21). 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. About 10 percent of the cropped acres in the eight regions were conventionally tilled in 2003-06.

Table 20. Structural erosion control practices in use in 2003-06, by region and for all regions combined, percent of cultivated cropland acres.

Production region	Overland flow control practices*	Concentrated flow control practices**	Edge-of-field buffering and filtering practices***	One or more water erosion control practices
Northwest Non-Coastal (3)	22%	14%	6%	34%
Northern Plains (5)	13%	12%	2%	22%
Southern Plains (6)	41%	17%	2%	44%
North Central and Midwest (7)	23%	29%	9%	45%
Lower Mississippi and Texas Gulf Coast (9)	12%	11%	3%	20%
Northeast (10)	36%	14%	5%	43%
East Central (11)	41%	32%	8%	58%
Southeast Coastal Plain (12)	24%	13%	6%	31%
All eight regions	26%	21%	5%	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 subsequently used in the APEX simulation modeling.

Table 21. Conservation tillage use in 2003-06, by region and for all regions combined, percent of cultivated cropland acres.

Production region	Average annual tillage intensity for crop rotation meets criteria for no-till*	Average annual tillage intensity for crop rotation meets criteria for mulch till**	Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	Continuous conventional tillage in every year of crop rotation***
Northwest Non-Coastal (3)	19%	62%	11%	8%
Northern Plains (5)	47%	40%	9%	4%
Southern Plains (6)	19%	46%	9%	26%
North Central and Midwest (7)	34%	57%	5%	4%
Lower Mississippi and Texas Gulf Coast (9)	24%	54%	7%	14%
Northeast (10)	23%	55%	10%	12%
East Central (11)	52%	35%	8%	5%
Southeast Coastal Plain (12)	32%	49%	8%	11%
All eight regions	32%	50%	7%	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.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found on the NRCS website.
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.

No-till was in most use in two regions:

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

Mulch till was most prevalent in the Northwest Non-Coastal (3) region, where 62 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.

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 and act to mitigate sediment losses from the field, the no-practice protocol removes these areas and 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.)

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.[7]

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.[8] 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 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.

Figure 46. Aerial view of contour buffer strips on highly erodible cropland. Strips of alfalfa help curb erosion by providing breaks between the more erodible corn fields. The green strips filter and process runoff water and sediments that might contain pollutants.

[7] To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]

[8] 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.

Pesticide Management Practices

Other than soil erosion control, pesticide management practices for conservation purposes include:

- Pesticide use and application practices that minimize the risk that pesticide residues pose to the surrounding environment.
- Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

The first activity, for the most part, cannot be simulated in large-scale modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[9] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on evidence of IPM activity derived from farmer responses to a series of IPM-related survey questions.

Spot treatment. One of the choices for methods of pesticide application on the survey was "spot treatment." Overall for the eight regions combined, 1.3 percent of the cropped acres reported use of spot treatments. Typically, spot treatment applies to a small area within a field and is often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. To account for this in our point-level modeling schema, the average application rate reported in the survey for the field associated with the sample point was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field.

Partial field treatment. Partial field treatment was simulated in a manner similar to spot treatment. Partial field treatment was identified using information reported in the survey on the percentage of the field that was treated and where there was no indication of spot treatment as an application method.[10] Overall for the eight regions combined, it was determined that 1.8 percent of the cropped acres had partial field treatments. For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field.

The IPM indicator. The extent to which operators were using IPM techniques was determined using CEAP survey questions specifically designed to address IPM. An IPM indicator for use in the CEAP modeling was developed based on the four components in the PAMS framework for evaluating IPM practices, previously developed by USDA—Prevention, Avoidance, Monitoring, and Suppression. (See box inset on the following page.)

Responses to the CEAP survey questions on IPM activity were assigned scores that were used to quantify each of the four PAMS categories. These four scores were then combined into a single IPM indicator that was used to characterize each sample point as having either:

1. a high level of IPM activity,
2. a moderate level of IPM activity, or
3. a low level of IPM activity.

Overall for the eight regions, 9 percent of the cultivated cropland acres had a high level of IPM activity based on the 2003-06 survey responses (table 22). About 44 percent had a moderate level of IPM activity.

Table 22. Percent of cultivated cropland acres with a high, moderate, or low IPM indicator score.

	Percent high level	Percent moderate level	Percent low level
Northwest Non-Coastal (3)	11%	51%	37%
Northern Plains (5)	12%	49%	38%
Southern Plains (6)	6%	40%	54%
North Central and Midwest (7)	8%	45%	48%
Lower Mississippi & Texas Gulf Coast (9)	11%	40%	49%
Northeast (10)	5%	34%	61%
East Central (11)	5%	38%	58%
Southeast Coastal Plain (12)	16%	41%	43%
All eight regions	9%	44%	48%

(For more information on the development and application of the IPM indicator, see the CEAP documentation report "Integrated Pest Management (IPM) Indicator Used in CEAP Cropland Modeling," on the CEAP website at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/.)

[9] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated directly.

[10] It is possible that some partial field treatments had nothing to do with IPM. Partial field treatment was considered to be an IPM practice only where acres treated represented one-third or fewer of the acres in the field.

A Framework for Characterizing IPM Practices—PAMS

(Taken from Coble, H. "Measuring the Resilience of IPM Systems—The PAMS Diversity Index." Unpublished manuscript. U.S. Department of Agriculture. 1998)

Adoption of IPM systems normally occurs along a continum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches, and is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach). In order to qualify as IPM practitioners, growers would use tactics in all four PAMS components.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls exist, where they exist, are important IPM tools. *Chemical pesticides* can be important components of IPM programs. As with any tactic, pesticides should be used when they are the best available tactic considering all risk issues.

The questions from the survey that were used to derive the IPM indicator are shown below for each of the four PAMS categories.

Questions related to **prevention**:

1. Were pesticides with different mechanisms of action rotated or tank mixed for the primary purpose of keeping pests from becoming resistant to pesticides?
2. Did you plow down crop residues (using conventional tillage) specifically for the purpose of managing pests or reducing the spread of pests?
3. Did you chop, spray, mow, plow, or burn field edges, lanes, ditches, roadways or fence lines specifically for the purpose of managing pests or reducing the spread of pests?
4. Did you clean equipment and field implements after completing field work specifically for the purpose of managing pests or reducing the spread of pests?
5. Did you remove crop residue from the field specifically for the purpose of managing pests or reducing the spread of pests?
6. Were water management practices (such as irrigation scheduling, controlled drainage or treatment of retention water), used on this field to manage pests or toxic producing fungi and bacteria (i.e. aflatoxin)?

Questions related to **avoidance**:

1. Did you rotate crops in this field during the past 3 years specifically for the purpose of managing pests or reducing the spread of pests?
2. Did you use no-till or minimum till specifically for the purpose of managing pests or reducing the spread of pests?
3. Did you choose any crop variety to be planted in this field because it had resistance to a specific pest?
4. Were planting locations planned to avoid infestation of pests?
5. Were planting or harvesting dates adjusted for this field to manage pests?

Questions related to **monitoring**:

1. Which descriptor represents whether and how this field was primarily scouted for pests and/or beneficial organisms?
    a. By conducting general observations while performing routine tasks.
    b. By deliberately going to the field specifically for scouting activities.
    c. This field was not scouted for pests.
2. Was an established scouting process used (systematic sampling, recording counts, etc.) or were insect traps used in this field?
3. Was scouting for pests done in this field due to a pest development model?
4. Was scouting for pests done in this field due to a pest advisory warning?
5. Who did the majority of the scouting (choose one)?
    a. Operator, partner or family member
    b. An employee
    c. Farm supply or chemical dealer
    d. Independent crop consultant or commercial scout
6. Were written or electronic records kept for this field to track the activity or numbers of weeds, insects, or diseases?
7. Were scouting data compared to published information on thresholds to determine when to take measures to manage pests in this field?
8. Were the services of a diagnostic laboratory used for pest identification or soil or plant tissue pest analysis for this field?
9. Were weather data used to assist in determining either the ‘need for’ or ‘when to’ apply a pest management practice?

Questions related to **suppression**:

1. Were weather data used to assist in determining the ‘need for’, or ‘timing of’ when to make pesticide applications?
2. Were any biological pesticides such as Bt (Bacillus thuringiensis), insect growth regulators, neem, or other natural/biologically based products sprayed or applied to manage pests? [Exclude use of Bt corn or cotton Seed.]
3. Were pesticides with different mechanisms of action rotated or tank mixed for the PRIMARY PURPOSE of keeping pests from becoming resistant to pesticides? (This question is also related to prevention.)
4. Pesticides applied to this field were based *mostly* on (choose one):
    a. Preventive schedule – Routine treatments?
    b. Scouting data compared to published threshold guidelines?
    c. Scouting data and your established thresholds?
    d. Field mapping or GPS data on pests?
    e. Recommendations from a chemical dealer?
    f. Recommendations from an independent crop consultant?
    g. Recommendations from University extension?
    h. Recommendations from a neighbor?
5. Did you maintain ground covers, mulches, or other physical barriers specifically for the purpose of managing pests or reducing the spread of pests?
6. Did you adjust spacing, plant density, or row directions specifically for the purpose of managing pests or reducing the spread of pests?
7. Did you release beneficial organisms (insects, nematodes, fungi) in the field specifically for the purpose of managing pests or reducing the spread of pests?
8. Did you cultivate for weed control during the growing season specifically for the purpose of managing pests or reducing the spread of pests?

The IPM indicator was used to adjust pesticide application methods and to increase the frequency of applications in the no-practice scenario.

- For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications in the no-practice scenario.
- For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, 1 week and 2 weeks after its original application.
- For moderate IPM cases, the first application event was replicated one time for each crop, 1 week after its original application.

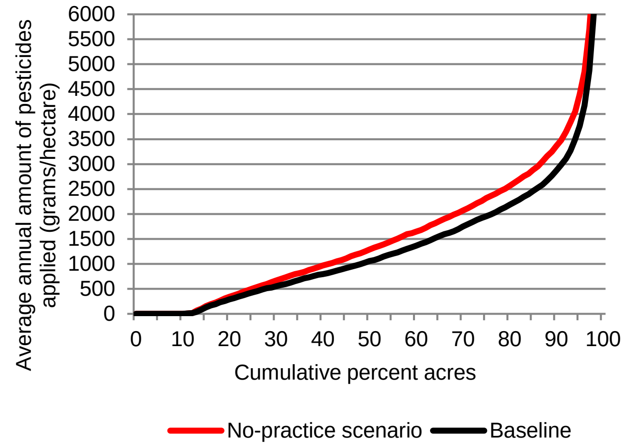
Some pesticide applications that would not be expected to be repeated sequentially were exempt from the above protocols.

For all eight regions combined, 10.3 percent of the cultivated cropland acres did not receive any pesticide applications. Some of these acres were classified as having a high or moderate level of IPM based on prevention, avoidance, or monitoring activities. Since no pesticides were applied, it was not possible to create a no-practice representation for these sample points as described above.

The cumulative distribution of the average annual amount of pesticides applied (grams per hectare of active ingredient for all pesticides combined) in both the baseline and the no-practice scenario are compared in figure 47. Overall, pesticide application rates in the no-practice scenario were increased above those in the baseline scenario for 43 percent of the cultivated cropland acres, as shown in figure 48. Included are the repeated applications related to the IPM indicator score as well as increased application rates associated with spot treatments and partial field treatments.

Figure 47. Contour stripcropping, grassed waterways, and a riparian buffer conserve water, protect the soil, and help reduce the risk of contaminated water leaving the farm.

Figure 48. Distributions of average annual amount of pesticides applied (grams per hectare of active ingredient for all pesticides combined).



Note: Ten percent of cultivated acres did not have pesticide applications.

Figure 49. Distributions of average annual amount of additional pesticides applied in the no-practice scenario to represent IPM activities.

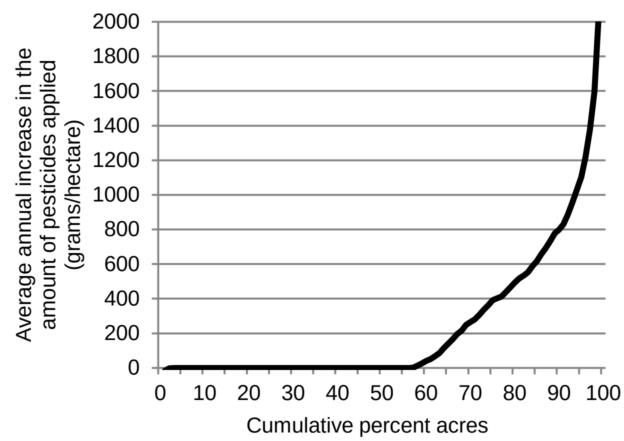


Figure 50. No-till drilling of soybeans into wheat stubble provides uninterrupted soil protection compared to conventional tillage systems. This practice significantly reduces soil erosion and potential water pollution from pesticides and soil sediments.

Effects of Conservation Practices on Water and Sediment Loss

As discussed in previous chapters, water loss and sediment loss from farm fields is a principle determinant of pesticide loss. The effect of conservation practices on water loss and sediment loss is summarized in this section to provide a perspective on the results presented for pesticide loss and potential environmental risk in the next section.

National-level results. 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 23). The distributions of the average annual estimates of surface water runoff in the baseline scenario and the no-practice scenario are contrasted in figure 50. 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. 51). 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 51 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 51. In general, these gains in surface water runoff due to practices 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.

Figure 51. Distributions of average annual surface water runoff for the baseline and no-practice scenarios, all eight regions combined.

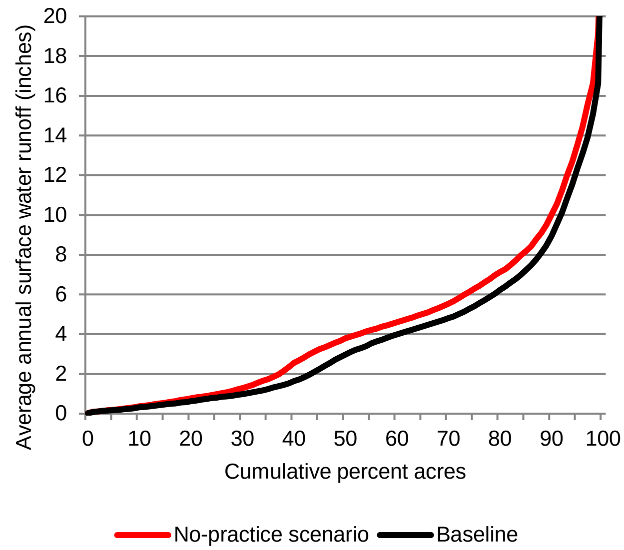


Figure 52. Distribution of average annual reductions in surface water runoff due to the use of conservation practices, all eight regions combined.

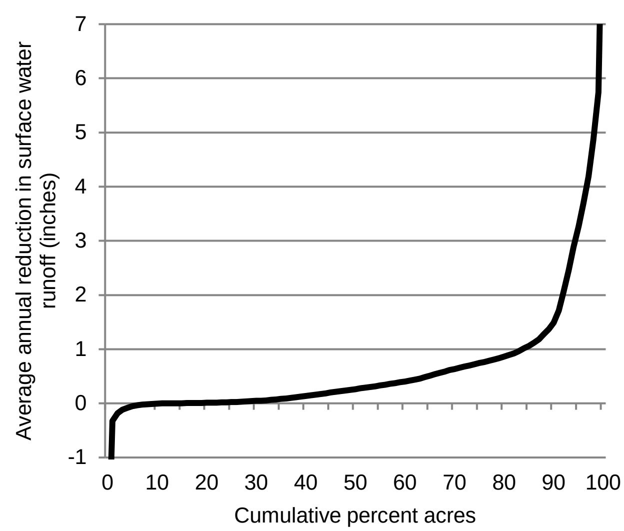


Table 23. Effects of conservation practices on water, sediment, and pesticide loss from farm fields, all eight regions combined.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.79	1.74	0.95	54%

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

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 23).

The re-routing of surface water to subsurface flows is shown graphically in figures 52 and 53. The baseline scenario curve in figure 35 shows higher subsurface flows than the no-practice curve. Figure 53 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. 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. 53).

Model simulations showed that reductions in subsurface water flows (shown as negative gains in fig. 53) 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.

Figure 53. Distributions of average annual subsurface water flow for the baseline and no-practice scenarios, all eight regions combined.

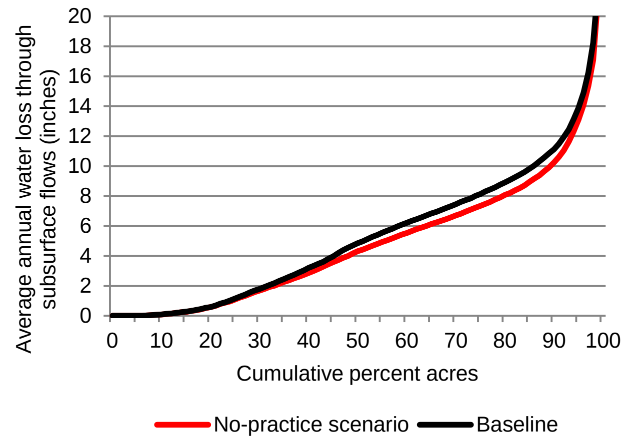
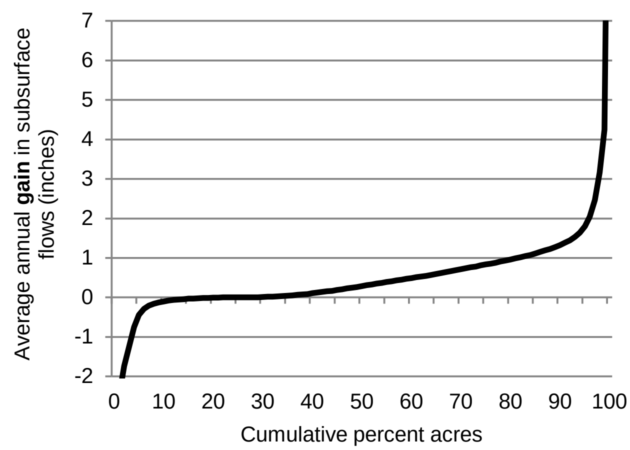


Figure 54. Distribution of average annual gain in subsurface water flows due to the use of conservation practices, all eight regions combined.



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 23). Without conservation practices, the average annual sediment loss for these acres would have been 1.7 tons per acre per year compared to 0.8 ton per acre average for the baseline conservation condition. The reduction in sediment loss due to the use of conservation practices averaged about 1 ton per acre per year.

The distributions of the average annual estimates of sediment loss in the baseline scenario and the no-practice scenario are contrasted in figure 54. Figure 54 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 (fig. 55). In contrast, about 25 percent had average annual reductions in sediment loss greater than 1 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. 55). These negative reductions in sediment loss are the result of tradeoffs in benefits of conservation practices previously discussed with respect to figure 51, where a small number of acres had negative reductions in surface water runoff due to use of conservation practices.

Figure 55. Distributions of average annual edge-of-field sediment loss from water erosion for the baseline and no-practice scenarios, all eight regions combined.

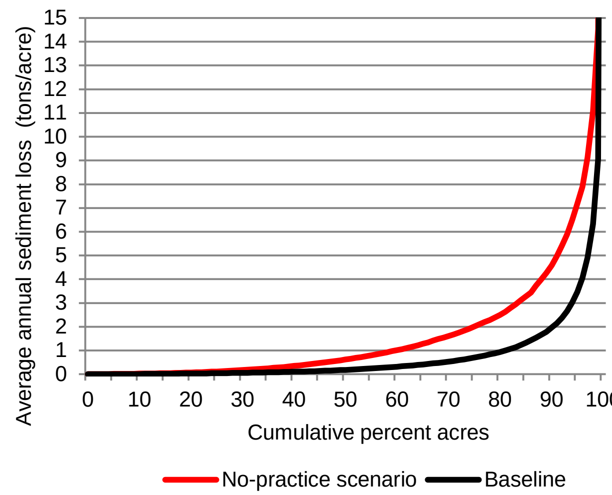
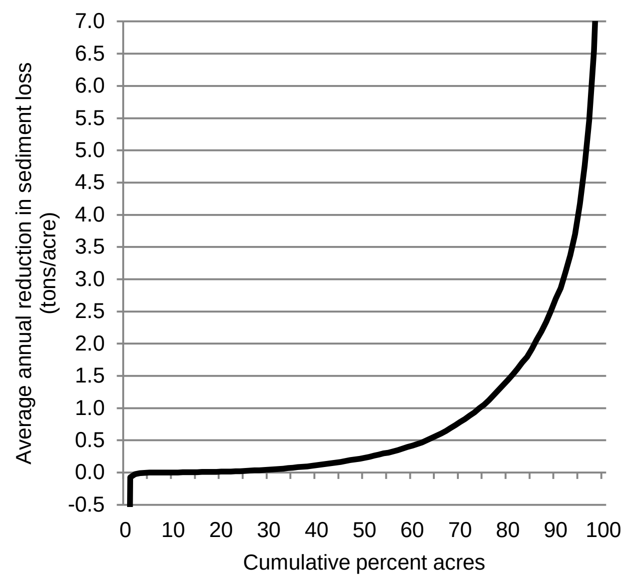


Figure 56. Distribution of average annual reduction in edge-of-field sediment loss from water erosion due to the use of conservation practices, all eight regions combined.



Regional results. The effects of conservation practices on water and sediment loss from farm fields vary substantially across the eight production regions, as shown in table 24, figures 56-58, and figures 59-61.

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 24 and fig. 56). This region also had the largest amount of surface water runoff in the baseline scenario. Figure 59 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 24, figs. 56 and 59):

- 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.

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 59 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 24, figs. 57 and 60). 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 24 and fig. 40).

Three regions were the least effective in attaining gains in subsurface water flows due to conservation practice use (table 24, figs. 57 and 60):

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

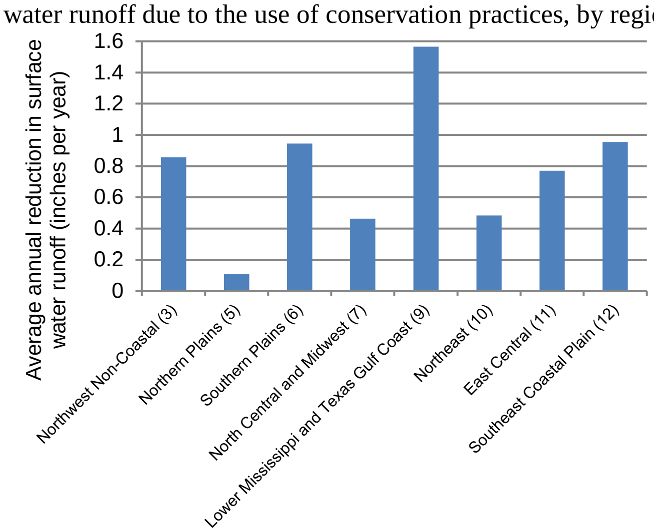
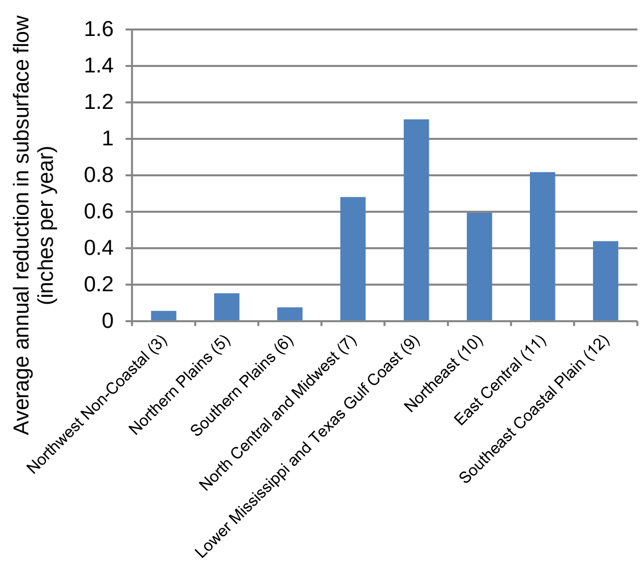


Figure 58. Mean of the average annual gains in subsurface water flows due to the use of conservation practices, by region.



Conservation practices were most effective in reducing sediment loss from water erosion in the East Central (11) region (table 24, and figs. 58 and 61), where the mean of the average annual reductions in sediment loss was 2.83 tons per acre per year. In this region, 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 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 tons 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. 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.61).

The remaining regions had mean average annual reductions in sediment loss ranging from 0.66 tons per acre per year for the Southern Plains (6) region to 1.74 tons per acre per year in the Northeast (10) region. Figure 44 shows that the distributions of the average annual reductions were generally similar for these 6 regions. All had little or no benefit from use of conservation practices for over half of the acres. Reductions 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 59. Mean of the average annual reduction in edge-of-field sediment loss from water erosion due to the use of conservation practices, by region.

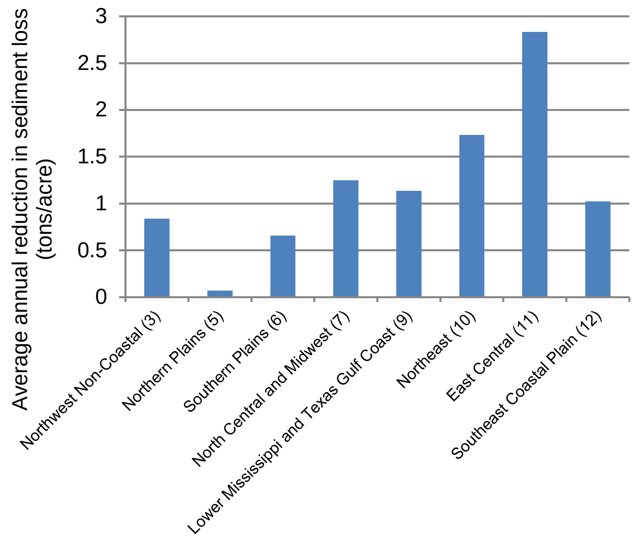


Table 24. Effects of conservation practices on water and sediment loss from farm fields, by production region.

	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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.90	1.74	0.84	48%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.06	0.14	0.07	53%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.26	0.92	0.66	72%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.80	2.04	1.25	61%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	2.66	3.80	1.13	30%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	2.36	4.10	1.74	42%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	2.52	5.36	2.83	53%
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%
Average annual sediment loss at edge or field due to water erosion (tons/acre)	0.96	1.98	1.02	52%

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

Figure 60. Distributions of average annual reductions in surface water runoff due to the use of conservation practices, representing CEAP sample points in eight production regions.

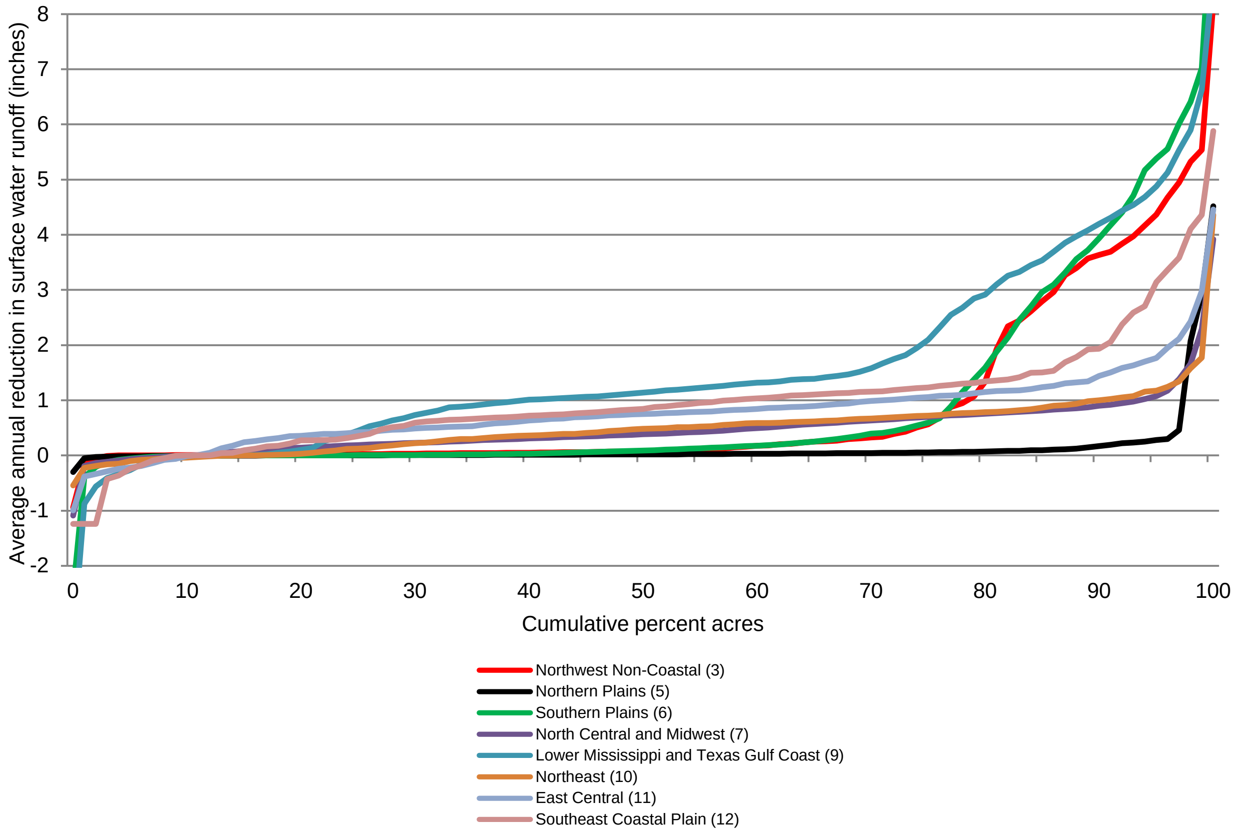


Figure 61. Distributions of average annual gains in subsurface flows due to the use of conservation practices, representing CEAP sample points in eight production regions.

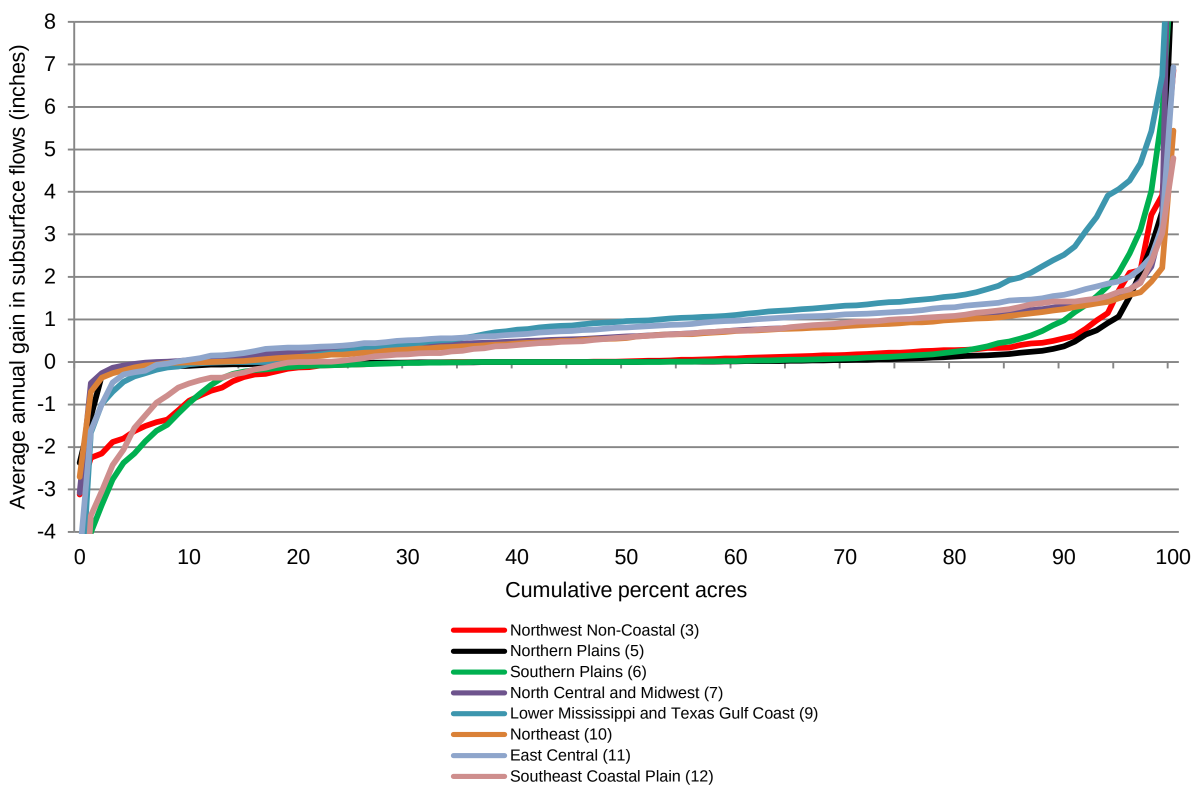
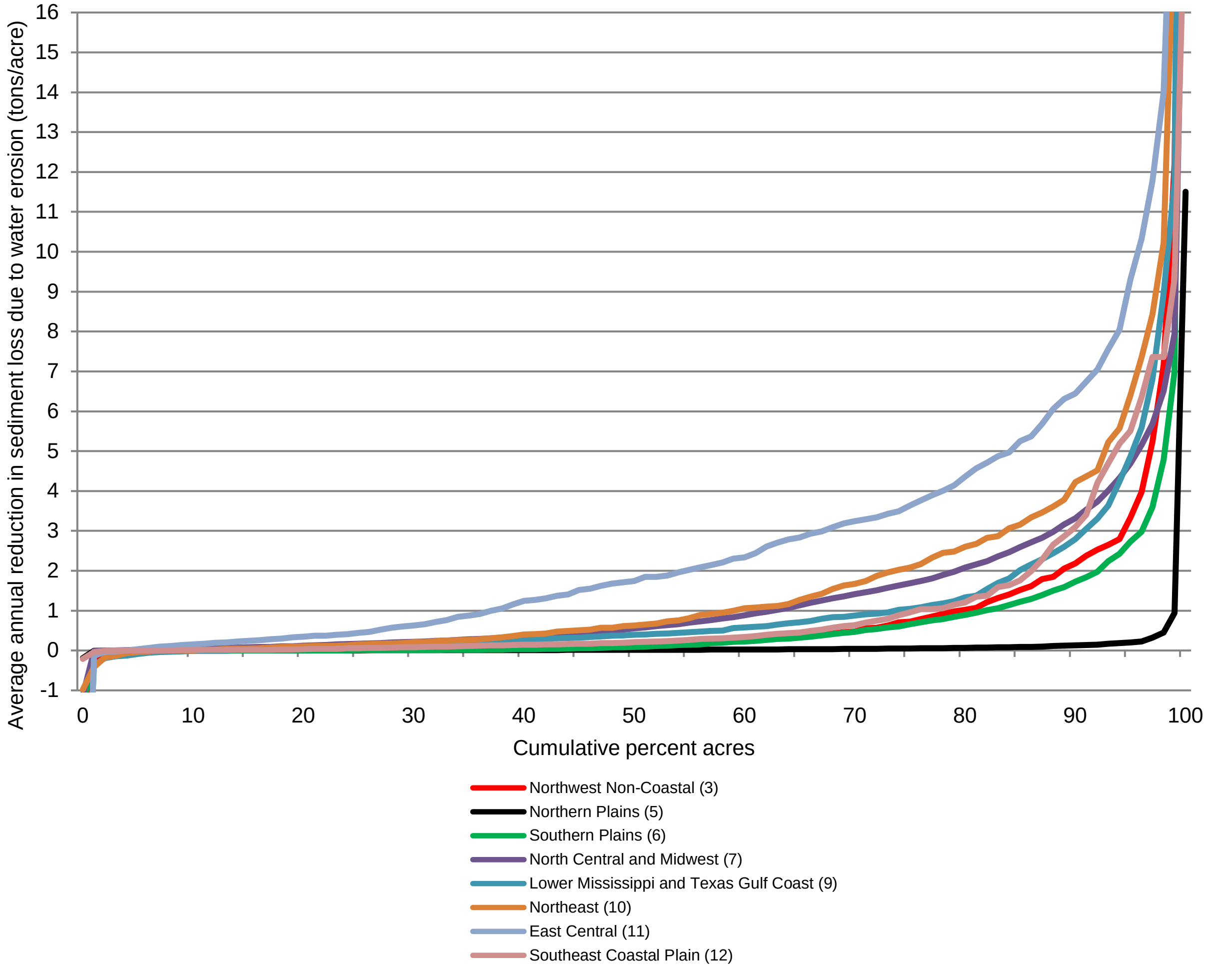


Figure 62. Distributions of average annual reductions in sediment loss from water erosion due to the use of conservation practices, representing CEAP sample points in eight production regions.



Effects of Conservation Practices on Pesticide Loss

The effects of conservation practices on water loss and sediment loss from farm fields translate to the effects of practices on loss of pesticides from farm fields, modified by the benefits due to use of IPM practices as represented by increased pesticide applications in the no-practice scenario, discussed previously. For all eight regions combined, the increase in the amount of pesticide applied in the no-practice scenario averaged 255 grams of active ingredient per hectare (table 25). Thus, the benefit of IPM activities as determined from the CEAP survey for 2003-06 was equivalent to a 13-percent reduction in the amount of pesticides applied, on average.

National-level results. Model simulation results indicate that use of conservation practices—including IPM practices—has reduced the loss of pesticides (summed over all pesticides) by an average of 5 grams of active ingredient per hectare per year, reducing the average amount lost from 19 grams per hectare in the no-practice scenario to 14 grams per hectare in the baseline scenario (table 25). This represents a 27-percent reduction, on average, relative to the amount lost in the no-practice scenario.

The baseline and no-practice distributions of total pesticide loss at sample points in all eight regions are shown in figure 62. Both distributions show that losses are very low for the majority of sample points, but then increase for the more vulnerable and less treated acres and/or acres with higher application rates. For example, the average annual amount of pesticide loss was less than 4 grams per hectare for 50 percent of the cultivated cropland acres in both scenarios.

Similarly, the reduction in pesticide loss due to the use of conservation practices was also restricted to a minority of cultivated cropland acres (fig. 63). About 42 percent of the cropped acres had reductions in pesticide loss above 1 gram per hectare per year. About half of the cultivated cropland acres had zero or negligible reductions, and 8 percent had negative reductions (i.e. gains) in pesticides lost due to use of conservation practices. These negative reductions correspond primarily to acres that had negative reductions in the loss of surface water runoff due to use of conservation practices, shown in figure 51. Small negative reductions in pesticide loss can also occur on these landscapes that are not tilled, resulting in the concentration of residues for some pesticide types near the soil surface where they are more susceptible to loss with surface water runoff.

Figure 63. Distributions of average annual amount of pesticide lost, total for all three loss pathways, for the baseline and no-practice scenarios, all eight regions combined.

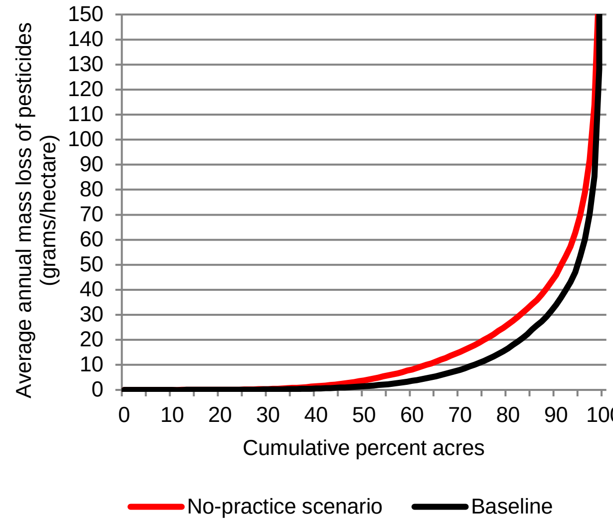


Figure 64. Distribution of average annual reduction in the total amount of pesticide lost due to the use of conservation practices, total for all three loss pathways, all eight regions combined.

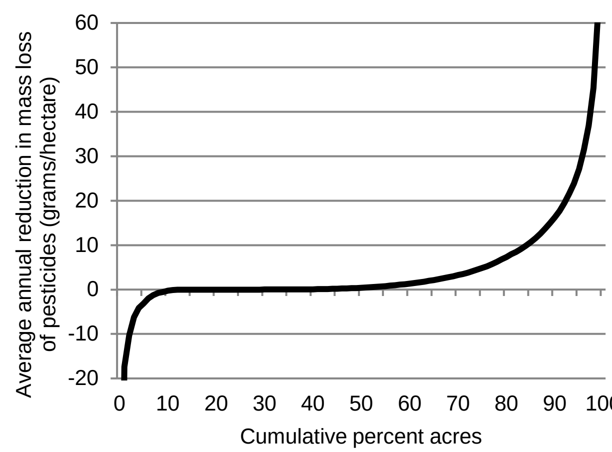


Table 25. Effects of conservation practices on pesticide loss from farm fields for all eight regions combined.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,653	1,908	255	13%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	2.76	5.07	2.31	46%
Loss of pesticides dissolved in surface water runoff at the edge of field	6.63	9.22	2.59	28%
Loss of pesticides dissolved in subsurface flow pathways	4.66	4.88	0.22	5%
Loss of pesticides to all three loss pathways	14.04	19.17	5.12	27%

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

Only a small amount of pesticides dissolved in subsurface flows are affected by conservation practices (table 25 and fig. 64). Model simulation results show that reductions in pesticide loss in subsurface flows average only 0.22 grams per hectare averaged over all cultivated cropland acres in the eight regions. Figure 64 shows that only 4 percent of cropped acres had reductions in the loss of pesticides in subsurface flows of more than 1 gram per hectare per year. Another 4 percent had negative reductions in the loss of pesticides in subsurface flows of more than 1 gram per hectare per year, which results from the re-routing of surface water runoff to subsurface flows as shown in figure 53.

Reductions from pesticide loss from farm fields due to the use of conservation practices mostly occur for pesticides dissolved in surface water runoff or pesticides lost with waterborne sediment (table 25 and figs. 65 and 66). The average annual reduction in pesticides lost in surface water runoff was 2.6 grams per acre per year, representing a 28-percent reduction relative to the no-practice scenario. The average annual reduction in pesticides lost with waterborne sediment was about the same—2.3 grams per acre per year, representing a 46-percent reduction.

These reductions, however, were limited to a minority of the cropped acres for both loss pathways. Only 30 percent of the cultivated cropland acres had reductions of more than 1 gram per acre per year in the loss of pesticides dissolved in surface water runoff due to conservation practice use (fig. 56). Similarly, 32 percent of the cultivated cropland acres had reductions of more than 1 gram per acre per year in the loss of pesticides with waterborne sediment due to conservation practice use (fig. 66).

The negative reductions in the loss of pesticides dissolved in surface water runoff for about 10 percent of cultivated cropland acres, shown in figure 65, reflects the reductions in surface water runoff due to the use of conservation practices, previously shown in figures 51 and 59.

Figure 65. Distribution of average annual reduction in loss of pesticides dissolved in subsurface flows due to the use of conservation practices, all eight regions combined.

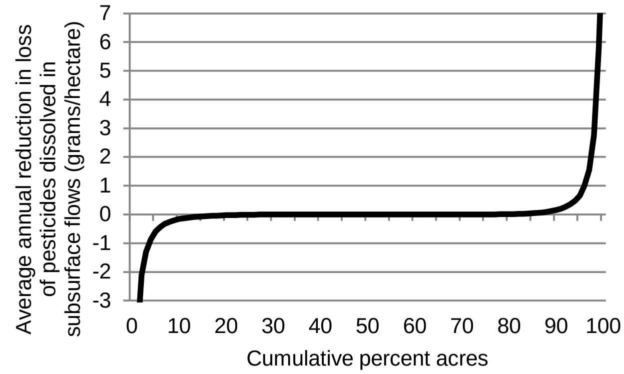


Figure 66. Distribution of average annual reduction in the loss of pesticides dissolved in surface water runoff due to the use of conservation practices, all eight regions combined.

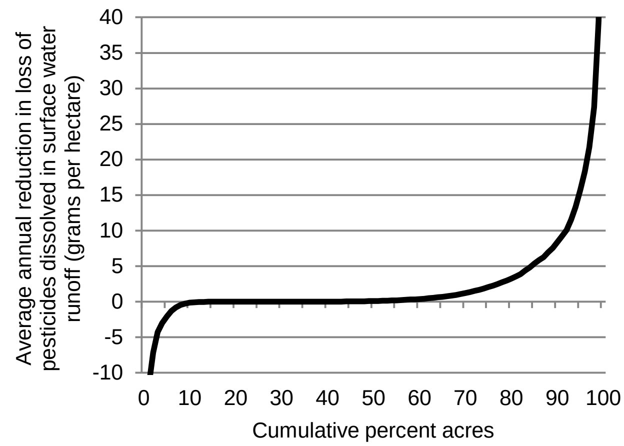
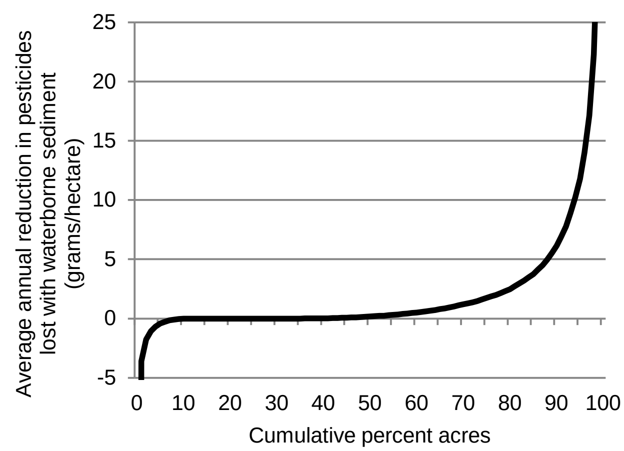


Figure 67. Distribution of average annual reduction in loss of pesticides with waterborne sediment due to the use of conservation practices, all eight regions combined.



Regional results. Regional results generally followed the same trends as shown for all eight regions combined, and closely mirrored the reductions in water loss and sediment loss by region (table 26 and fig. 67). The mean of the average annual reductions in total pesticide loss (all three pathways combined) due to the use of conservation practices was highest for two regions (table 26):

- 11.0 grams per hectare per year for the Lower Mississippi and Texas Gulf Coast (9) region, representing a 14-percent reduction relative to the no-practice scenario.
- 10.5 grams per hectare per year for the Southeast Coastal Plain (12) region, representing a 24-percent reduction relative to the no-practice scenario.

Two other regions also had significant reductions in total pesticide loss due to the use of conservation practices:

- 7.3 grams per hectare per year for the East Central (11) region, representing a 20-percent reduction relative to the no-practice scenario.
- 6.8 grams per hectare per year for the North Central and Midwest (7) region, representing a 32-percent reduction relative to the no-practice scenario.

These four regions also have the largest percentage of cultivated cropland acres that benefit significantly from erosion control and IPM practices, as shown in figures 68 and 52. The largest percentage of acres are in the North Central and Midwest (7) region, where 53 percent of the cultivated cropland acres had reductions greater than 2 grams per hectare of total pesticide loss due to use of conservation practices.

Benefits are low in the Northern Plains (5) region, shown clearly in both figures 68 and 69. Reductions in the loss of pesticides in this region due to the use of conservation practices are low primarily because surface water runoff and sediment loss from water erosion are also very low, as are the reductions in these losses due to the use of conservation practices, shown previously.

Figure 69 also shows that the remaining three regions also have significant reductions in total pesticide losses due to conservation practices, but these are limited to a smaller proportion of cultivated cropland acres than in the four regions with the highest average reductions.

A few acres in each region have relatively large reductions in total pesticide loss due to use of conservation practices (fig. 69). Reductions of more than 20 grams per hectare of active ingredient (all pesticides combined) occur on up to 15 percent of the cultivated cropland within the region. Reductions of more than 50 grams per hectare occur on up to 5 percent in some regions. These are acres where the pesticides in use are applied at higher rates than other pesticides, and where erosion control and IPM practices are being used effectively. Acres with large negative reductions are similar, but have field characteristics and combinations of conservation practices and farming practices that increase the losses of pesticides from farm fields, as discussed previously.

Figure 69 also shows that erosion control and IPM practices have little or no benefit on a significant proportion of cropped acres in all regions. The percentage of cropped acres with reductions of -1 to 1 gram per hectare per year ranged from 26 percent for the North Central and Midwest (7) region and the Lower Mississippi and Texas Gulf Coast (9) region to more than 70 percent for the three western-most regions—the Northwest NonCoastal (3) region, the Northern Plains (5) region, and the Southern Plains (6) region.

Figure 68. Mean of the average annual reduction in total pesticide lost due to use of conservation practices, all 3 pathways combined, grams per hectare for all pesticides combined.

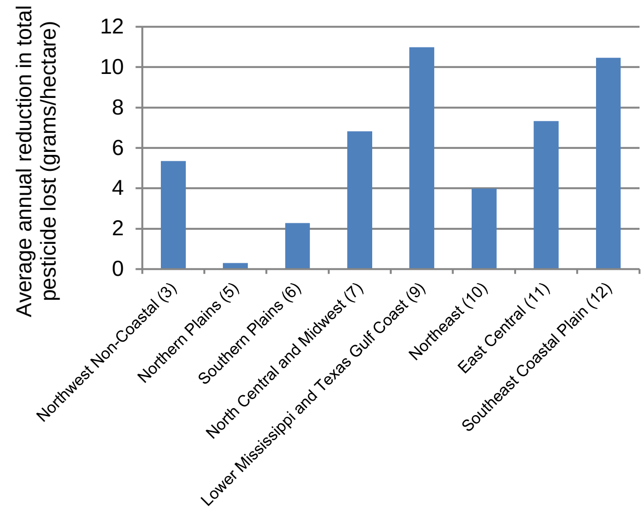


Figure 69. Percent of cultivated cropland acres in each region with reductions greater than 2 grams per hectare of total pesticide loss due to use of conservation practices, all pesticides combined.

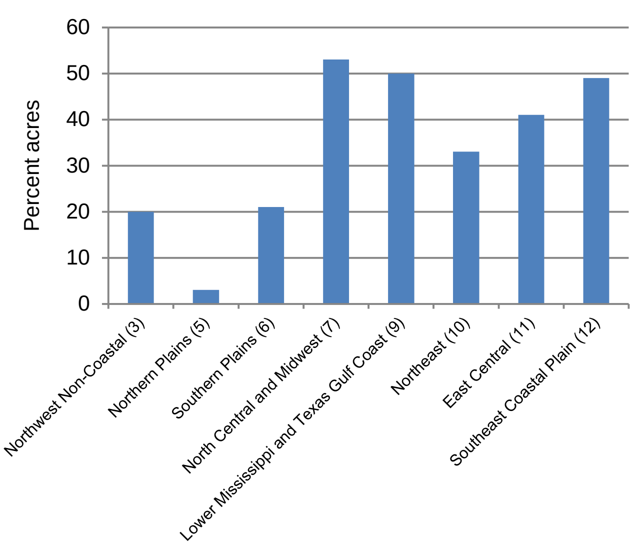


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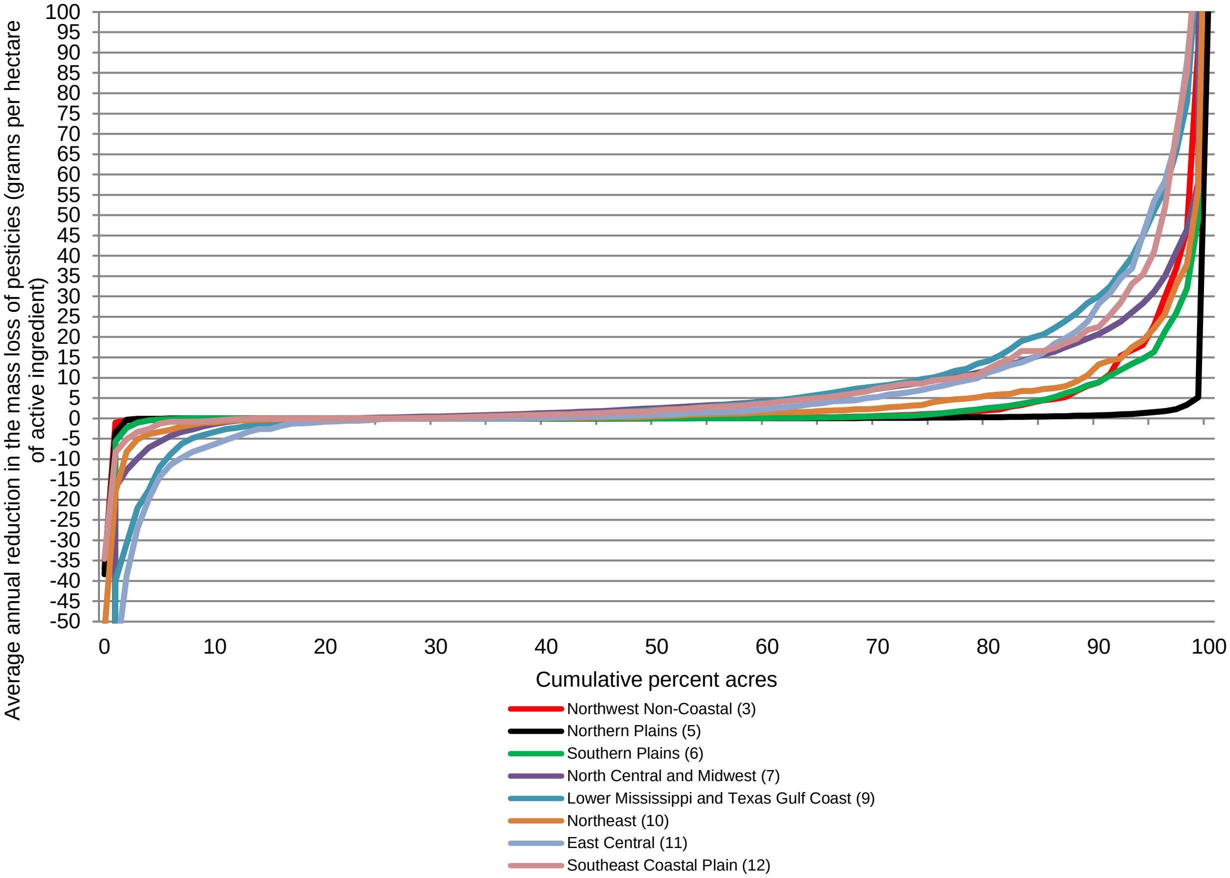
Table 26. Effects of conservation practices on pesticide loss from farm fields, by production region.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
Northwest Non-Coastal (3) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	3,091	3,368	277	8%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	0.71	2.33	1.62	70%
Loss of pesticides dissolved in surface water runoff at the edge of field	0.90	4.40	3.50	80%
Loss of pesticides dissolved in subsurface flow pathways	0.34	0.57	0.22	39%
Loss of pesticides to all three loss pathways	1.95	7.30	5.35	73%
Northern Plains (5) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	752	952	200	21%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	0.13	0.32	0.19	60%
Loss of pesticides dissolved in surface water runoff at the edge of field	0.17	0.29	0.12	41%
Loss of pesticides dissolved in subsurface flow pathways	0.13	0.13	0.00	-1%
Loss of pesticides to all three loss pathways	0.43	0.74	0.31	42%
Southern Plains (6) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	870	957	87	9%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	0.52	2.14	1.62	76%
Loss of pesticides dissolved in surface water runoff at the edge of field	1.93	2.51	0.59	23%
Loss of pesticides dissolved in subsurface flow pathways	0.35	0.43	0.08	18%
Loss of pesticides to all three loss pathways	2.79	5.08	2.28	45%
North Central and Midwest (7) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,571	1,885	314	17%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	2.92	5.83	2.91	50%
Loss of pesticides dissolved in surface water runoff at the edge of field	10.16	14.00	3.85	27%
Loss of pesticides dissolved in subsurface flow pathways	1.24	1.31	0.07	5%
Loss of pesticides to all three loss pathways	14.32	21.15	6.83	32%
Lower Mississippi and Texas Gulf Coast (9) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	2,542	2,971	429	14%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	10.31	14.63	4.32	30%
Loss of pesticides dissolved in surface water runoff at the edge of field	15.09	19.85	4.76	24%
Loss of pesticides dissolved in subsurface flow pathways	40.26	42.17	1.91	5%
Loss of pesticides to all three loss pathways	65.66	76.64	10.98	14%
Northeast (10) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,484	1,638	153	9%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	5.68	8.48	2.79	33%
Loss of pesticides dissolved in surface water runoff at the edge of field	6.00	6.84	0.84	12%
Loss of pesticides dissolved in subsurface flow pathways	2.32	2.68	0.36	13%
Loss of pesticides to all three loss pathways	14.00	18.00	4.00	22%
East Central (11) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	3,062	3,291	229	7%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	9.47	13.69	4.22	31%
Loss of pesticides dissolved in surface water runoff at the edge of field	13.81	16.83	3.01	18%
Loss of pesticides dissolved in subsurface flow pathways	5.78	5.87	0.09	2%
Loss of pesticides to all three loss pathways	29.06	36.39	7.32	20%
Southeast Coastal Plain (12) region				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	5,794	6,289	495	8%
Average annual mass loss of pesticides, all pesticides combined (grams of active ingredient per hectare)				
Loss of pesticides adsorbed to sediment lost at the edge of field due to water erosion	5.32	9.19	3.87	42%
Loss of pesticides dissolved in surface water runoff at the edge of field	8.26	14.47	6.21	43%
Loss of pesticides dissolved in subsurface flow pathways	18.84	19.22	0.38	2%
Loss of pesticides to all three loss pathways	32.41	42.88	10.46	24%

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

Figure 70. Distributions of the average annual reduction in the total amount of pesticide lost from farm fields due to the use of conservation practices, representing CEAP sample points in eight production regions.



Effects of Conservation Practices on the Potential for Environmental Risk Associated with Pesticide Loss

The pesticide risk indicators are used to extend the assessment of the effects of conservation practices beyond the quantity of pesticides lost from farm fields to include the potential for harmful environmental effects from the loss of the pesticide residues that are the most toxic to non-target species.

National-level results. For all eight regions combined, conservation practices have (table 27):

- Reduced the average annual surface water pesticide risk indicator for aquatic ecosystems from 4.3 without conservation practices to 2.4 with conservation practices, a 44-percent reduction,
- Reduced the average annual surface water pesticide risk indicator for humans from 0.83 without conservation practices to 0.57 with conservation practices, a 32-percent reduction, and
- Reduced the average annual groundwater pesticide risk indicator for humans from 0.19 without conservation practices to 0.16 with conservation practices, an 18-percent reduction.

Conservation practices have been more effective at reducing potential environmental risk to aquatic ecosystems than to humans because, as shown in figures 39, 46, and 47, and table 13, the level of environmental risk to aquatic ecosystems from exposure to pesticide residues is much higher than for humans. Similarly, the potential for risk to humans through exposure to drinking water from groundwater sources is very low compared to exposure of humans and aquatic organisms to surface water.

The pesticide risk indicators reflect reductions in pesticide loss for the more toxic pesticides, listed in tables 14-17. Since some of these pesticides are not used as commonly as the other pesticides, most acres have no or little reduction in potential risk due to the use of conservation practices:

- 60 percent of the cropped acres have no or negligible reductions in the surface water pesticide risk indicator for aquatic ecosystems due to use of conservation practices (fig. 70),
- 70 percent of the cropped acres have no or negligible reductions in the surface water pesticide risk indicator for humans due to use of conservation practices (fig. 71), and
- 85 percent of the cropped acres have no or negligible reductions in the groundwater pesticide risk indicator for humans due to use of conservation practices (fig. 72).

Figure 71. Reduction in the surface water pesticide risk indicator for aquatic ecosystems due to use of conservation practices, all eight regions combined.

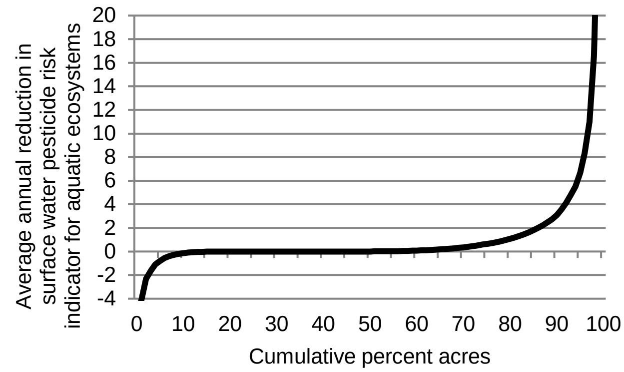


Figure 72. Reduction in the surface water pesticide risk indicator for humans due to use of conservation practices, all eight regions combined.

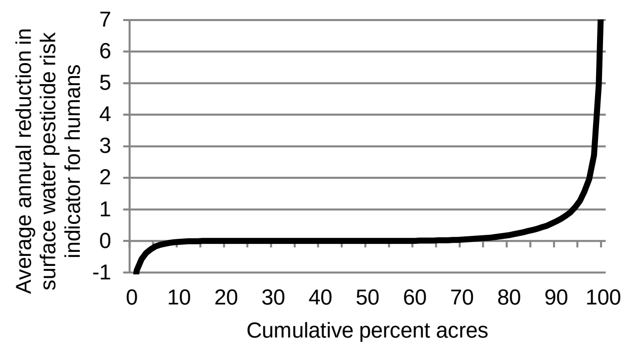


Figure 73. Reduction in the groundwater pesticide risk indicator for humans due to use of conservation practices, all eight regions combined.

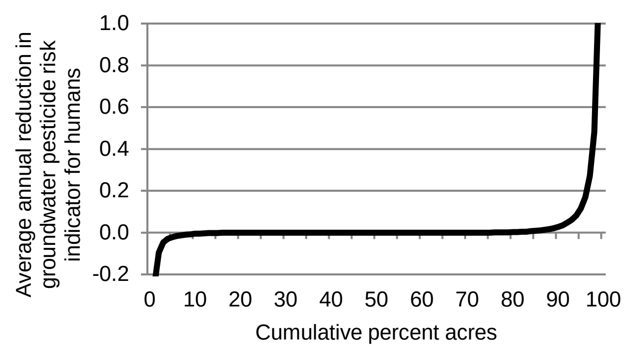


Table 27. Effects of conservation practices on edge-of-field potential environmental risk for all eight regions combined.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.37	4.26	1.89	44%
Average annual surface water pesticide risk indicator for humans	0.57	0.83	0.27	32%
Average annual groundwater pesticide risk indicator for humans	0.16	0.19	0.04	18%

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

However, conservation practices in use on the acres that had potential risks were effective in reducing those risks:

- Reductions in the surface water pesticide risk indicator for aquatic ecosystems due to use of conservation practices were greater than 1 for 20 percent of the cultivated cropland acres (fig. 70),
- Reductions in the surface water pesticide risk indicator for humans due to use of conservation practices were greater than 1 for 6 percent of the cultivated cropland acres (fig. 71), and
- Reductions in the groundwater pesticide risk indicator for humans due to use of conservation practices were greater than 1 for less than 1 percent of the cultivated cropland acres (fig. 72).

Figure 70 also shows that the top five percent of acres had large reductions in the surface water pesticide risk indicator for aquatic ecosystems—reductions of 7 or more units, which represents a factor of 7 times the safe level. These are acres where erosion control and IPM practices were effective in reducing the potential risk from use of pesticides that were more toxic to non-target species than other kinds of pesticides.

As seen for pesticide loss, a few acres had negative reductions in the surface water pesticide risk indicators. These are acres where the no-practice scenario had less surface water runoff than the baseline scenario, as shown in figures 54 and 64.

Regional results. The effectiveness of conservation practices in reducing the potential for environmental risk from pesticide residues is much higher in some regions than in others (table 28 and figures 73-77).

Average annual reductions in the surface water pesticide risk indicator for aquatic ecosystems due to the use of conservation practices were highest in two regions (table 28 and fig. 73):

- the Northwest Non-Coastal (3) region, with an average annual reduction of 3.4, representing a 74-percent reduction relative to the no-practice scenario, and
- the Southern Plains (6) region, with an average annual reduction of 2.8, representing a 54-percent reduction relative to the no-practice scenario.

Figure 75 shows that the North Central and Midwest (7) region also stands out in that it has the highest percentage of cropped acres with reductions in the surface water pesticide risk indicator for aquatic ecosystems greater than 1—about one-third of the cropped acres in that region.

The Northern Plains (5) region and the Northeast (10) region had the lowest average reduction in the surface water pesticide risk indicator for aquatic ecosystems—about 1 for the Northern Plains (5) region and less than 1 in the Northeast (10) region (table 28 and fig. 73).

The Lower Mississippi and Texas Gulf Coast (9) region has the highest average annual reduction of the surface water pesticide risk indicator for humans—0.88, representing a 38-percent reduction relative to the no-practice scenario (table 28 and fig. 74).

The average annual reduction in the surface water pesticide risk indicator for humans was lowest in three regions (table 28, fig. 74 and fig. 76)—the Northeast (10) region, the Southern Plains (6) region, and the Northern Plains (5) region.

The majority of acres in all regions have little or no reductions in the surface water pesticide risk indicator for humans, as shown in figure 76.

With the exception of a small number of acres, mostly in the Southeast Coastal Plain (12) region, reductions of the groundwater pesticide risk indicator for humans are negligible. The mean value of the reduction in the indicator was less than 0.2 for all regions (table 28). Figure 77 shows that the highest reductions exceeded 1 for less than 1 percent of the cropped acres in all regions except for the Southeast Coastal Plain (12) region, where the highest reductions exceeded 1 for only 4 percent of the cropped acres.

Figure 74. Mean of the average annual reduction in the surface water pesticide risk indicator for aquatic ecosystems due to the use of conservation practices.

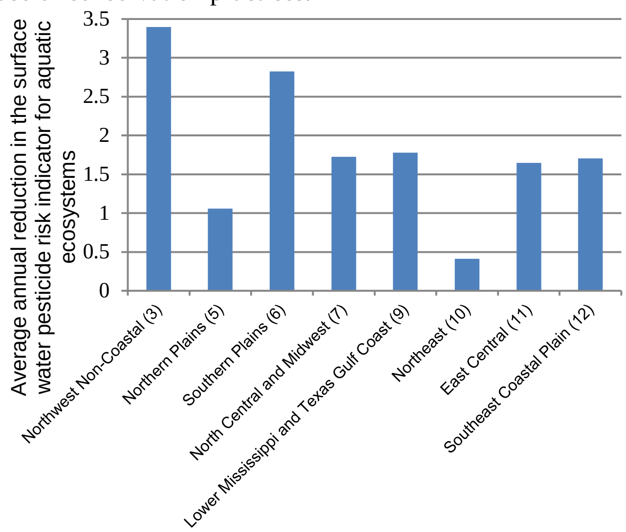


Figure 75. Mean of the average annual reduction in the surface water pesticide risk indicator for humans due to the use of conservation practices.

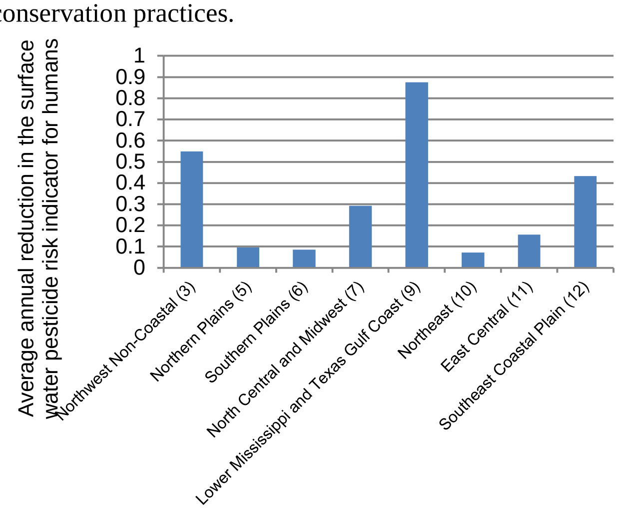


Table 28. Effects of conservation practices on edge-of-field potential environmental risk, by region.

	Baseline scenario	No-practice scenario	Reduction due to practices	Percent reduction
Northwest Non-Coastal (3) region				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.17	4.57	3.40	74%
Average annual surface water pesticide risk indicator for humans	0.55	1.10	0.55	50%
Average annual groundwater pesticide risk indicator for humans	0.28	0.42	0.14	33%
Northern Plains (5) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	0.49	1.55	1.06	68%
Average annual surface water pesticide risk indicator for humans	0.05	0.14	0.10	67%
Average annual groundwater pesticide risk indicator for humans	0.01	0.01	0.00	37%
Southern Plains (6) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.39	5.21	2.82	54%
Average annual surface water pesticide risk indicator for humans	0.54	0.63	0.09	14%
Average annual groundwater pesticide risk indicator for humans	0.10	0.11	0.02	15%
North Central and Midwest (7) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.96	4.69	1.72	37%
Average annual surface water pesticide risk indicator for humans	0.64	0.93	0.29	31%
Average annual groundwater pesticide risk indicator for humans	0.10	0.14	0.04	26%
Lower Mississippi and Texas Gulf Coast (9) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	3.43	5.21	1.78	34%
Average annual surface water pesticide risk indicator for humans	1.42	2.30	0.88	38%
Average annual groundwater pesticide risk indicator for humans	0.47	0.48	0.01	2%
Northeast (10) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.43	1.84	0.41	22%
Average annual surface water pesticide risk indicator for humans	0.35	0.42	0.07	17%
Average annual groundwater pesticide risk indicator for humans	0.25	0.31	0.06	19%
East Central (11) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	4.26	5.91	1.65	28%
Average annual surface water pesticide risk indicator for humans	0.69	0.85	0.16	19%
Average annual groundwater pesticide risk indicator for humans	0.39	0.40	0.02	4%
Southeast Coastal Plain (12) region			0.00	
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.33	4.04	1.70	42%
Average annual surface water pesticide risk indicator for humans	0.60	1.03	0.43	42%
Average annual groundwater pesticide risk indicator for humans	0.63	0.81	0.17	21%

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

Figure 76. Distributions of average annual reductions in the surface water pesticide risk indicator for aquatic ecosystems due to conservation practice use, representing CEAP sample points in eight production regions.

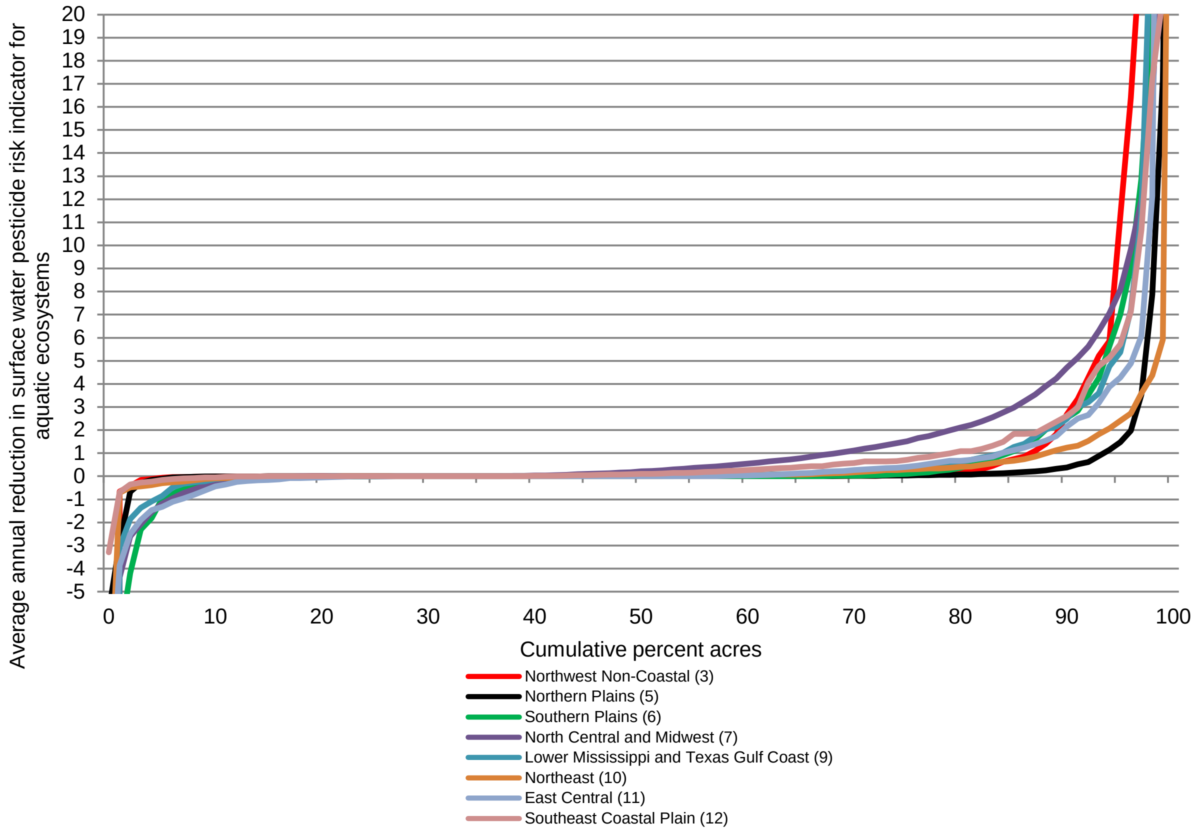


Figure 77. Distributions of average annual reductions in the surface water pesticide risk indicator for humans due to conservation practice use, representing CEAP sample points in eight production regions.

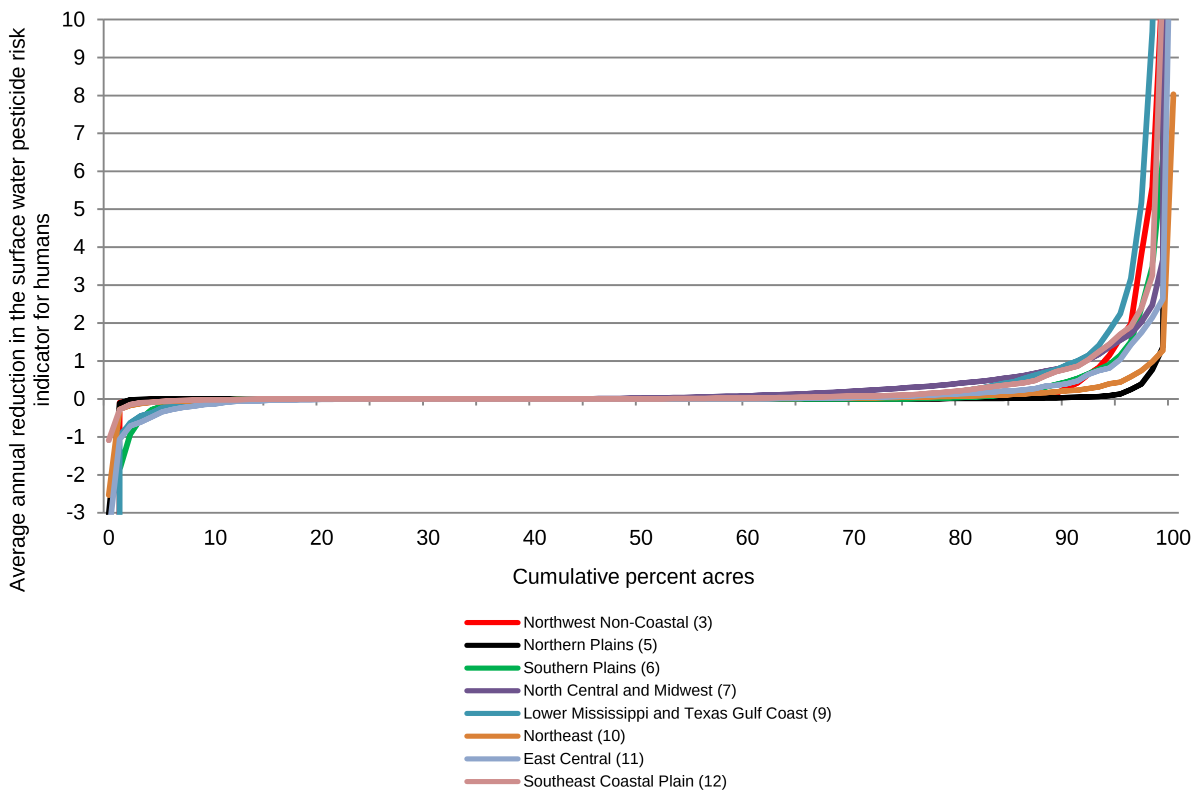
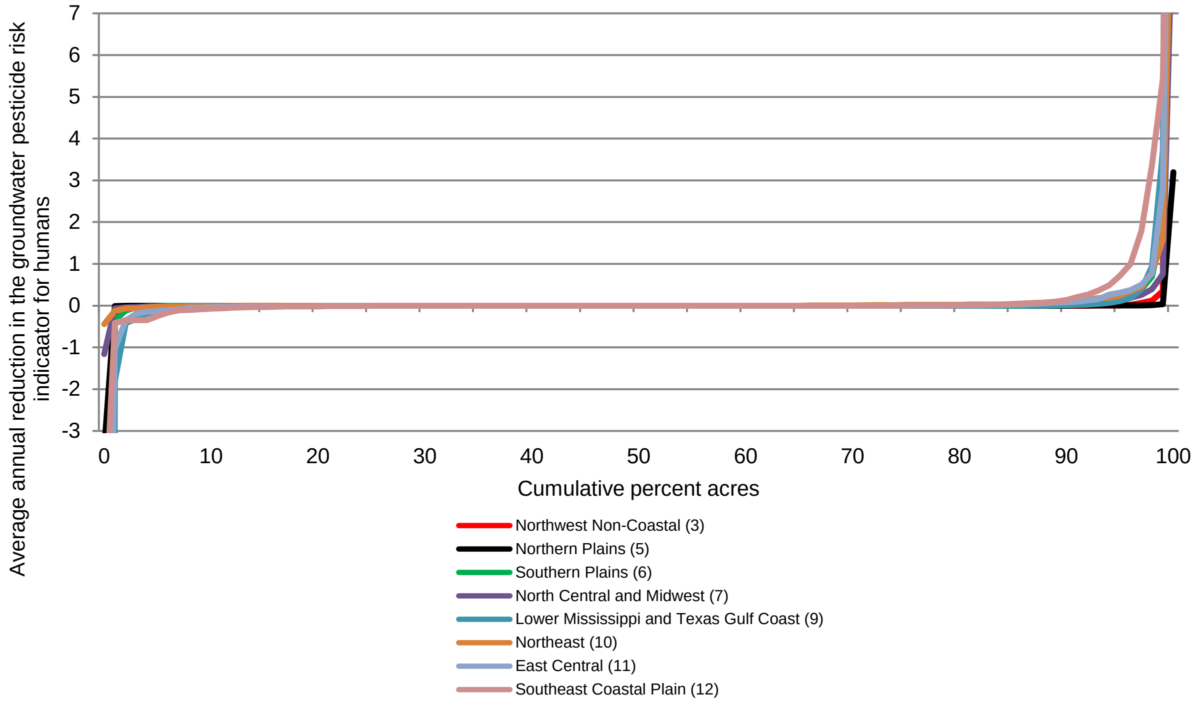


Figure 78. Distributions of average annual reductions in the groundwater pesticide risk indicator for humans due to conservation practice use, representing CEAP sample points in eight production regions.



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.[11] The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[12] 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 are 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.

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

[12] 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. Percent of acres treated with pesticides in each region in 2003-06.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
1,3-Dichloropropene	Fungicide	1.3	0	<0.1	0	0	0.1	0.6	2.3	0.2
2-(2,4-Dichlorophenoxy) propano	Herbicide	0	0	0	<0.1	0	0.1	0	<0.1	<0.1
2,4-D acid, triisopropanolamin	Herbicide	1.3	0.3	<0.1	<0.1	0	0	0	0	0.1
2,4-D, 2-ethylhexyl ester	Herbicide	18.3	12.0	7.1	5.7	3.0	5.3	4.8	4.5	7.2
2,4-D, butoxyethyl ester	Herbicide	1.6	2.7	0.4	0.8	0.3	0.6	0.9	0.5	1.0
2,4-D, diethanolamine salt	Herbicide	0.9	0.1	<0.1	<0.1	0.7	0	0.1	0	0.1
2,4-D, dimethylamine salt	Herbicide	11.2	6.2	6.6	1.4	7.8	3.3	2.1	6.9	4.5
2,4-D, isopropylamine salt	Herbicide	4.0	3.2	1.1	<0.1	0	0	0	0	0.9
2,4-DB, dimethylamine salt	Herbicide	0	0.3	0.4	0.1	0.2	0.6	0.5	6.6	0.5
2,4-Dichlorophenoxyacetic acid	Herbicide	14.0	13.5	8.1	3.4	3.6	2.9	1.5	3.1	6.5
2,4-DP, dimethylamine salt	Herbicide	3.3	3.6	1.6	1.1	2.2	1.4	0.6	0.7	1.8
Abamectin	Miticide	0	0	0	0	0.4	0	0.5	2.1	0.1
Acephate	Insecticide	0	0	1.6	0.2	17.1	1.1	7.7	9.8	2.4
Acetamiprid	Insecticide	0.3	0	0.9	0	2.5	0	0.1	0.1	0.4
Acetochlor	Herbicide	0.2	3.0	2.5	26.6	1.5	6.0	9.3	1.3	12.4
Acibenzolar-s-methyl	Fungicide	0	0	0	0	0	0	0.7	0	<0.1
Alachlor	Herbicide	1.7	0.3	2.4	1.7	1.0	2.3	0.3	2.3	1.6
Aldicarb	Insecticide	2.8	<0.1	1.2	0.1	4.4	0	2.8	16.2	1.6
Ametryn	Herbicide	0	0	<0.1	<0.1	0.1	0	0.2	1.3	0.1
Amitraz	Insecticide	0	0	0	0	0	0	0	<0.1	<0.1
Asulam	Herbicide	0	0	0	0	0.6	0	0	0	<0.1
Atrazine	Herbicide	1.9	7.4	31.2	61.9	24.9	60.4	49.6	30.0	39.2
Azadirachtin	Miticide	0.1	0	<0.1	0	0	0	0	0	<0.1
Azinphos-Methyl	Insecticide	0	0	<0.1	<0.1	0	0.1	0	0	<0.1
Azoxystrobin	Fungicide	3.7	0.3	0.3	0.5	9.9	0.3	1.3	6.2	1.5
Bacillus cereus strain BP01	Bacillus lic	0	0	0.7	0	3.7	0	1.4	6.0	0.7
Bacillus thuringiensis	NA	0	0	0	0	0.6	0	0.1	0.3	0.1
Bacillus thuringiensis subspec	NA	0	0	0	0	0	0.2	0	0.2	<0.1
Barban	Herbicide	0	0.1	0	<0.1	<0.1	0	0	0	<0.1
Benfluralin	Herbicide	<0.1	0	0	0	0	0	0	<0.1	<0.1
Benomyl	Fungicide	0	0	0	0	0	0.1	0.1	0	<0.1
Bensulfuron-methyl	Herbicide	0	0	0	<0.1	4.3	0	0	0.2	0.3
Bensulide	Herbicide	0	0	<0.1	<0.1	0	0	0	0	<0.1
Bifenox	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Bifenthrin	Insecticide	1.2	<0.1	1.4	1.3	1.0	0.4	1.7	0.7	1.1
Bispyribac-sodium	Herbicide	0	0	0	0	0.4	0	0	0	<0.1
boscalid	Fungicide	0.2	0.1	0.1	<0.1	0	0.1	0	0.2	0.1
Bromacil	Herbicide	0	0	0.1	<0.1	0	0	0	0	<0.1

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Bromoxynil	Herbicide	7.6	7.5	0.3	1.9	<0.1	0.3	0	0.1	2.4
Bromoxynil heptanoate	Herbicide	1.5	4.0	<0.1	0.2	<0.1	0	0.1	0	0.8
Bromoxynil octanoate	Herbicide	12.0	17.3	<0.1	0.7	<0.1	0.8	0.1	0.1	3.6
Butylate	Herbicide	0.2	0	0	<0.1	0	0	0	0	<0.1
Cacodylic acid	Herbicide	0	0	0	0	0.1	0	0.1	0	<0.1
Captan	Fungicide	0	0	<0.1	<0.1	0	0	0	0	<0.1
Carbaryl	Insecticide	0.4	0.2	0	0.1	0.1	1.0	0.1	1.0	0.2
Carbofuran	Insecticide	0.7	0.1	0.2	0.4	0.2	0.1	1.9	0.3	0.3
Carboxin	Fungicide	0.1	0.1	0	0	0	0	0	0	<0.1
Carfentrazone-ethyl	Herbicide	2.6	0.5	1.5	1.0	4.5	<0.1	0.9	2.9	1.4
Chloramben, ammonium salt	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Chlorethoxyfos	Insecticide	0.2	0	0	0.1	0	0	0	0	0.1
Chlorfenapyr	Miticide	0	0.1	0	0	0	0	0	<0.1	<0.1
Chlorimuron-ethyl	Herbicide	0	0.2	0.6	4.9	2.5	1.8	1.3	3.1	2.6
Chloropicrin	Fumigant	0.1	0	<0.1	0	0	0	0.6	1.6	0.1
Chlorothalonil	Fungicide	3.4	0.3	0.3	0.4	0.7	2.0	1.8	20.4	1.5
Chlorpyrifos	Insecticide	2.2	1.6	2.2	4.9	0.7	3.8	3.5	4.9	3.3
Chlorsulfuron	Herbicide	4.4	0.6	6.6	0.1	0.2	0	0	0.1	1.8
Chlorthal dimethyl	Herbicide	0	0	0	<0.1	<0.1	0	0	0	<0.1
Clethodim	Herbicide	1.2	7.8	0.4	2.3	1.0	0.5	0.8	1.7	2.5
Clodinafop-propargyl	Herbicide	6.2	8.5	0	0.1	0	0	0	0.3	1.7
Clomazone	Herbicide	0	0	<0.1	0.2	15.3	0.7	3.3	3.5	1.5
Clopyralid	Herbicide	5.3	9.3	0.5	9.2	0.7	0.7	1.8	0.5	5.7
Clopyralid, monoethanolamine	Herbicide	1.3	0.3	<0.1	<0.1	0	0	0	0	0.1
Cloransulam-methyl	Herbicide	0	0.4	0.1	1.9	0.9	0.2	2.2	1.9	1.1
Copper hydroxide	Fungicide	0.5	0	0.2	0.2	0	0.9	0.5	2.9	0.3
Copper oxychloride	Fungicide	0	0	0	0.1	<0.1	0	0	0	<0.1
Copper sulfate pentahydrate	Algicide	0	0	0	<0.1	0	0	0	0	<0.1
Cyanazine	Herbicide	<0.1	0	<0.1	0.4	0.5	0.1	0.3	0.1	0.2
Cyclanilide	Herbicide	0	0	0.8	0	3.0	0	2.8	7.1	0.8
Cycloate	Herbicide	0.6	0	0	0.1	<0.1	0	0	0	<0.1
Cyfluthrin	Insecticide	2.1	0.7	1.4	4.1	5.8	4.0	1.4	8.1	3.1
Cyhalofop-butyl	Herbicide	0	0	0	0	1.4	0	0	0.1	0.1
Cymoxanil	Fungicide	0.6	0	0.1	0.1	0	0.1	0	2.1	0.2
Cypermethrin	Insecticide	0	0.1	0.4	<0.1	5.9	0	1.0	4.0	0.8
Cytokinin (as kinetin)	Growth Regulator	0.1	0	0	0	<0.1	0	0	0	<0.1
Deltamethrin	Insecticide	0	0.1	0.5	0	0	0	0	0.9	0.2
Desmedipham	Herbicide	4.9	4.2	0.1	1.4	0.7	0	0	0	1.5

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Diazinon	Insecticide	0.3	0	0	0.1	<0.1	0.5	0.6	0.5	0.1
Dicamba	Herbicide	4.2	12.8	5.3	5.9	1.0	5.4	1.6	0.4	6.1
Dicamba, diglycoamine salt	Herbicide	0.8	2.1	0.4	1.0	1.8	0.6	0.4	<0.1	1.0
Dicamba, dimethylamine salt	Herbicide	4.3	3.7	4.0	3.2	1.7	2.5	1.0	0.1	3.2
Dicamba, potassium salt	Herbicide	0	0	0.8	3.3	<0.1	0.4	0.1	<0.1	1.5
Dicamba, sodium salt	Herbicide	0.9	1.7	3.0	1.9	0.3	1.4	2.1	0.1	1.9
Dichlobenil	Herbicide	0	0	<0.1	0	0	0	0	0	<0.1
Dichlorprop	Herbicide	0.2	0	0	<0.1	0	0	0.2	0.1	<0.1
Diclofop-methyl	Herbicide	0.6	0.1	<0.1	0	0.3	0.1	1.0	0.1	0.1
Dicloran	Fungicide	0.1	0	0	0	0	0	0	0	<0.1
Dicofol	Miticide	0	0	0	0	<0.1	0	0	0	<0.1
Dicrotophos	Insecticide	0	0	0.2	0	10.7	0	0.8	7.5	1.2
Difenzoquat methyl sulfate	Herbicide	2.8	0	0	0	0	0	0	0	0.1
Diflubenzuron	Insecticide	0	0.1	0	0	0.5	0	0	1.3	0.1
Diflufenzopyr sodium salt	Growth Regulator	0.6	1.3	1.0	3.8	0.2	0.9	2.7	0.1	2.1
Dimethenamid	Herbicide	0.2	0.1	1.4	2.0	0.4	1.7	0.8	0.2	1.2
Dimethenamide-P	Herbicide	1.8	0.9	1.5	4.9	0.9	0.7	1.4	0.3	2.6
Dimethipin	Herbicide	0	0	0	0	0	0	<0.1	0.6	<0.1
Dimethoate	Insecticide	3.0	<0.1	0.9	0.3	1.3	3.8	0	2.8	0.8
Dimethomorph	Fungicide	0.1	0	0	<0.1	0	0.2	0	0	<0.1
Dinocap	Fungicide	0	0	0	0	<0.1	0	0	0	<0.1
Dinoseb	Herbicide	0	0	0	<0.1	0	0	0.1	0	<0.1
Diquat dibromide	Herbicide	0.8	0.4	0	0.1	0	1.2	0	0.1	0.2
Disulfoton	Insecticide	0.1	0	<0.1	<0.1	0.5	0	0.7	0.8	0.1
Diuron	Herbicide	0.9	<0.1	2.3	0.1	11.9	0.2	1.3	9.3	1.9
Emamectin benzoate	Insecticide	0	0	0.3	0	0.3	0	0	0	0.1
Endosulfan	Insecticide	0.6	0	<0.1	0.1	0.2	0.4	2.5	2.4	0.3
Endothall	Herbicide	0	0.2	0	<0.1	0	0	0	0	<0.1
EPTC	Herbicide	3.9	1.1	0.1	1.0	<0.1	1.5	0	0.1	0.8
Esfenvalerate	Insecticide	1.8	4.2	0.5	1.1	1.0	0.3	0.8	6.5	1.7
Ethalfluralin	Herbicide	1.8	5.8	0.1	0.2	0.2	0.8	0.3	5.8	1.4
Ethephon	Herbicide	0.7	0.1	4.0	0	19.9	<0.1	5.7	22.8	3.6
Ethofumesate	Herbicide	4.5	2.5	0.1	0.5	0	0	0	0	0.8
Ethoprop	Nematicide	0.7	0	0	0	0.1	0	0.3	<0.1	<0.1
Etridiazole	Fungicide	0	0	0.2	0	0.4	0	0	0.4	0.1
Famoxadone	Fungicide	0.1	0	0.1	<0.1	0	0	0	0	<0.1
Fatty alcolhol	Growth Regulator	0	0	0	0	0	0	2.8	3.5	0.2
Fenamidone	Fungicide	0.2	0	0	0	0	0	0	0	<0.1

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Fenamiphos	Insecticide	0	0	0	0	0	0	0	<0.1	<0.1
Fenbuconazole	Fungicide	0	0	0	0	0	0	0	0.1	<0.1
Fenbutatin-oxide	Miticide	0	0	0	0	0.1	0	0	0	<0.1
Fenoxaprop-ethyl	Herbicide	1.6	18.8	0.1	1.6	0.8	0.1	0.9	0	3.9
Fenoxaprop-p-ethyl	Herbicide	3.4	8.4	0	0.1	0	0	0	0.1	1.5
Fenpropathrin	Insecticide	0	0	0	0	0	0	0	<0.1	<0.1
Fentin hydroxide	Fungicide	0.1	2.5	<0.1	0.6	0	0.6	0	0	0.7
Fipronil	Miticide	0	0	0.9	0.6	0.2	0.6	0.2	0	0.5
Fluazifop-P-butyl	Herbicide	0	0.2	0.1	1.3	0.3	0.2	1.2	0.2	0.7
Fluazinam	Fungicide	1.1	0	0	0	0	0	0	0	<0.1
Flucarbazone-sodium	Herbicide	3.6	2.3	0	<0.1	0	0	0	0	0.5
Flucythrinate	Insecticide	0.1	0	0	0	0	0	0	0	<0.1
Fludioxonil	Fungicide	0	<0.1	0	0	0	0	0	0	<0.1
Flufenacet	Herbicide	0.5	0.1	0.9	2.5	0.5	0.3	0.2	0.2	1.3
Flumetralin	Growth Regulator	0	0	0	<0.1	<0.1	0	3.2	1.6	0.2
Flumetsulam	Herbicide	0	0.9	0.6	8.6	1.2	4.8	2.4	1.1	4.1
Flumiclorac-pentyl	Herbicide	0	0	<0.1	0.4	0.3	0	0.1	0.6	0.2
Flumioxazin	Herbicide	0	0.2	0.1	1.4	2.2	0	0.7	2.5	0.9
Fluometuron	Herbicide	0	0	0.4	<0.1	3.3	0	1.1	2.6	0.5
Fluroxypyr	Herbicide	8.1	7.3	0.2	0.2	<0.1	0	0	0.1	1.7
Fluroxypyr 1-methylheptyl ester	Herbicide	1.7	5.0	<0.1	<0.1	0	0	0	0	0.9
Flutolanil	Fungicide	0.8	0	0	<0.1	0	0	0	0.8	0.1
Fomesafen Sodium	Herbicide	0	0.8	0	2.3	1.4	1.5	0.8	0.9	1.3
Foramsulfuron	Herbicide	0.1	0.4	0.1	0.5	<0.1	0	0.2	0.2	0.3
GABA	NA	<0.1	0	0	0	0	0	0	0	<0.1
gamma-Cyhalothrin	Insecticide	0	<0.1	0	0.1	0.1	0	0.1	0.1	<0.1
Garlic oil	Biological	0	0	0	<0.1	0	0	0	<0.1	<0.1
Gibberellic acid	Growth Regulator	0	0	0	0	<0.1	0	0	0	<0.1
Glufosinate-ammonium	Herbicide	0.7	0.7	0.9	4.6	0.6	0.2	0.2	0.7	2.3
Glyphosate	Herbicide	0.1	1.6	0.9	2.5	2.0	2.2	1.8	2.4	1.8
Glyphosate, ammonium salt	Herbicide	0.1	<0.1	<0.1	0.1	0.3	0.4	0	0	0.1
Glyphosate, isopropylamine salt	Herbicide	31.2	61.3	39.9	77.2	77.1	36.0	65.2	69.5	62.9
Glyphosate-trimesium	Insecticide	0.2	0.9	0.8	1.7	2.2	1.1	1.7	1.9	1.4
Halosulfuron-methyl	Herbicide	0	0	0.2	0.7	5.2	1.3	0.2	2.2	0.9
Hexazinone	Herbicide	0.5	0	0	<0.1	0.1	0	0	0	<0.1
Imazamethabenz-methyl	Insecticide	3.1	2.8	<0.1	0	0.1	0	0	0	0.6
Imazamox	Herbicide	3.1	4.0	0.2	1.8	0.1	0.7	0.2	0	1.6
Imazapic	Herbicide	0	0	0.2	0	0	0	<0.1	6.0	0.3

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Imazapic ammonium	Herbicide	0.2	0	0	<0.1	0	0.2	0.2	4.4	0.2
Imazapyr	Herbicide	0	0.1	0.2	1.5	0.1	<0.1	4.8	0.2	0.8
Imazapyr, isopropylamine salt	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Imazaquin	Herbicide	0	0	0.1	0.6	0.5	<0.1	0.5	0.2	0.3
Imazaquin, monoammonium salt	Herbicide	0	0	0	<0.1	0	0	0	0.1	<0.1
Imazaquin, sodium salt	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Imazethapyr	Herbicide	2.5	1.8	0.7	5.5	3.6	2.0	6.3	0.9	3.3
Imazethapyr, ammonium salt	Herbicide	0.7	0.2	0	0.1	0.1	<0.1	0	0.3	0.1
Imidacloprid	Fungicide	2.0	0.3	0.3	0.2	5.4	0.7	3.0	3.3	0.9
Indole-3-butyric acid	Fungicide	0	0	0	0	0.1	0	0	0	<0.1
Indoxacarb	Insecticide	0	0	0.2	0	1.5	0	0	0.2	0.2
Iodosulfuron-methyl-sodium	Herbicide	0	0	0.1	<0.1	<0.1	0	0.1	0	<0.1
Iprodione	Fungicide	0.2	0	<0.1	0	0.3	0	0.2	0	<0.1
Isoxaflutole	Herbicide	0	0.5	1.7	6.7	<0.1	1.0	2.8	0	3.3
Kinetin (plant hormone)	Biological	0	0	0.1	0	0.6	0	0.4	2.0	0.2
Lactofen	Herbicide	0	0.2	<0.1	0.8	<0.1	0.1	0.3	0.1	0.4
lambda-Cyhalothrin	Insecticide	1.6	2.1	1.3	3.3	13.3	7.0	7.7	12.1	4.0
L-Glutamic acid	NA	<0.1	0	0	0	0	0	0	0	<0.1
Lindane	Insecticide	0	0	<0.1	0	0	0	0	0	<0.1
Linuron	Herbicide	0.1	0	0.1	0.2	0.3	0.5	<0.1	0.8	0.2
Live Chlamydospores of Phytoph	Biological	0	0	<0.1	0	0	0	0	0	<0.1
Malathion	Insecticide	1.2	0	1.7	0.1	4.3	0	0.3	0.1	0.8
Maleic hydrazide, potassium salt	Herbicide	0.4	0	<0.1	<0.1	0	0.2	6.1	2.6	0.4
Mancozeb	Fungicide	4.5	0.1	0.1	0.3	<0.1	1.6	0.2	2.2	0.5
Maneb	Fungicide	0.1	0	0	0	0	0	0	<0.1	<0.1
MCPA	Herbicide	12.2	23.1	0	1.1	0	0.4	0	<0.1	4.7
MCPA, 2-ethylhexyl ester	Herbicide	17.1	12.2	0.3	0.4	<0.1	1.0	0.1	0.1	2.9
MCPA, butoxyethyl ester	Herbicide	0	0.1	0	0	0	0	0	0	<0.1
MCPA, dimethylamine salt	Herbicide	4.3	1.8	<0.1	0.2	<0.1	0.5	0.5	0	0.6
MCPA, isooctyl ester	Herbicide	0	0.1	0	0	0	0	0	0	<0.1
MCPA, sodium salt	NA	0.3	0.2	<0.1	0.3	0.1	0.2	0.1	0.2	0.2
MCPB, sodium salt	Herbicide	<0.1	0	0	0	0	0.5	0	0	<0.1
MCPP, DMA salt	Herbicide	0	0	0	0	<0.1	0	0	0	<0.1
Mecoprop-P	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Mefenoxam	Fungicide	1.6	<0.1	<0.1	0.1	0.7	0.2	1.2	1.5	0.3
Mepiquat chloride	Herbicide	0	0	1.6	0	11.7	0	3.3	15.8	2.0
Mepiquat pentaborate	Herbicide	0	0	0.2	0	0.7	0	0.7	0.8	0.2
Mesosulfuron-methyl	Herbicide	1.9	0.2	0.5	0	0.1	0	0.1	0.1	0.2

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Mesotrione	Herbicide	0.1	1.3	2.6	13.9	0.8	16.9	4.0	1.2	7.0
Metalaxyl	Fungicide	0.4	0.1	0	<0.1	0.2	0	0.1	<0.1	0.1
Metaldehyde	Molluscicide	0	0	0	0	0	<0.1	0.2	0	<0.1
Metam-sodium	Multi-Target	2.6	0	0	<0.1	0	0	0.3	0.9	0.2
Methamidophos	Insecticide	1.2	0.2	0	0	0.3	0.5	0	2.1	0.2
Methanone, [3-(4,5-dihydro-3-i	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Methidathion	Insecticide	0.1	0	0	<0.1	0	0	0	0	<0.1
Methomyl	Insecticide	0.4	0	0.1	0.1	0.1	0.7	0	1.8	0.2
Methoxyfenozide	Insecticide	0	0	0.2	0	0.7	0	0	2.4	0.2
Methyl bromide	Sterilant	0	0	0	0	<0.1	0	0	0	<0.1
Methyl parathion	Insecticide	0.1	0.7	1.3	0.1	6.7	0.1	0	2.0	1.0
Metiram	Fungicide	0.3	0	0	0	0	0.1	0	0	<0.1
Metolachlor	Herbicide	0.2	1.1	4.0	5.8	3.5	8.2	9.0	5.9	4.4
Metribuzin	Herbicide	12.4	0.1	0.5	2.9	3.5	1.8	0.4	2.9	2.2
Metsulfuron-methyl	Herbicide	19.4	4.7	10.8	0.1	0.2	0	0	0.1	4.0
Molinate	Herbicide	0	0	0.1	<0.1	2.2	0.1	0	0.6	0.2
Monocarbamide	NA	0	0	0.2	<0.1	0.6	0	0.9	3.9	0.3
MSMA	Herbicide	0	0	0.1	0	2.7	0	1.2	4.7	0.5
Myclobutanil	Fungicide	0.1	0	0	<0.1	0	0.1	0	0	<0.1
Naled	Insecticide	0.3	0	0	0	0	0	0	0	<0.1
Napropamide	Herbicide	0	0	0	0	0	0.1	1.4	0.3	0.1
Naptalam, sodium salt	Herbicide	0	0	<0.1	<0.1	0.1	0	0	0	<0.1
Nicosulfuron	Herbicide	0.3	3.2	2.2	10.7	4.3	9.9	5.9	2.7	6.2
Nonanoic acid	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Norflurazon	Herbicide	0	0	<0.1	0.1	0.3	0	0.1	0	0.1
Novaluron	Miticide	0.2	0	0	0	0.3	0	0	0	<0.1
Oryzalin	NA	0	0	<0.1	0	0	0	0	0	<0.1
Oxamyl	Insecticide	1.7	0	0.5	0	1.4	0	0	2.4	0.4
Oxydemeton-methyl	Insecticide	0.4	0	0	0	0	0	0	0	<0.1
Oxyfluorfen	Herbicide	0.1	0	<0.1	<0.1	0.1	0.2	0	0.3	0.1
Paecilomyces fumosoroseus Apop	NA	0	0	0	<0.1	0	0	0	0	<0.1
Paraquat dichloride	Herbicide	2.4	0.6	3.1	0.8	7.4	7.2	8.5	13.5	2.8
Parathion	Insecticide	0.3	0	0.3	0	0.1	0	0	0.1	0.1
Pebulate	Herbicide	0	0	0	0	0	0	0.1	0	<0.1
Pendimethalin	Herbicide	5.5	3.2	4.6	6.2	8.5	19.9	9.4	21.4	6.6
Pentachloronitrobenzene	Fungicide	0.7	0.1	0.2	<0.1	0.9	0.1	0.2	0.7	0.2
Permethrin, mixed cis,trans	Insecticide	0.2	0.2	0.4	1.4	1.5	1.6	2.3	2.1	1.0
Phenmedipham	Herbicide	4.9	4.0	0.1	1.3	0.7	0	0	0	1.5

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Phorate	Insecticide	2.4	<0.1	0.1	<0.1	0.5	0.1	0.2	7.7	0.5
Phosmet	Insecticide	0.7	0	0	<0.1	0	0	0	0.4	0.1
Phostebupirim	Insecticide	0.1	0.3	0.7	3.5	0.1	0.4	0.6	0	1.7
Picloram, potassium salt	Herbicide	1.1	0.3	0.9	<0.1	0	0	0	0	0.3
Pinoxaden	Herbicide	<0.1	0.1	0	0	0	0	0	0	<0.1
Piperonyl butoxide	Insecticide	0	0	<0.1	0	0	0	0	0	<0.1
Pirimicarb	Insecticide	0.1	0	0	0	0	0	0	0	<0.1
Primisulfuron-methyl	Herbicide	1.1	0.4	0.6	2.9	0.2	1.5	2.0	0.1	1.5
Prodiamine	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Profenofos	Insecticide	0	0.1	0	0	0.4	0	0.1	0	<0.1
Prometryn	Herbicide	0	0	0.8	0.1	2.1	0	1.2	3.2	0.5
Propachlor	Herbicide	0	0.1	0.1	<0.1	0	0.2	0	0.2	0.1
Propamocarb hydrochloride	Fungicide	0	0	0	0	0	0.1	0	0	<0.1
Propanil	Herbicide	0.1	0	0	<0.1	12.0	0	0	0.3	0.9
Propargite	Insecticide	0.3	0	0.3	<0.1	0.2	0	0	0	0.1
Propazine	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Propiconazole	Fungicide	2.4	3.2	0.6	0.2	4.2	0.6	2.1	4.8	1.5
Propoxycarbazone-sodium	Herbicide	1.0	0.2	0.5	0	0	0	0	0	0.2
Prosulfuron	Herbicide	3.4	0.1	1.8	1.0	0.7	0.6	1.6	0.2	1.1
Pymetrozine	Insecticide	0.3	0	0	<0.1	0	0	0	0	<0.1
Pyraclostrobin	Fungicide	1.4	3.5	0.2	0.9	1.7	0.1	1.8	5.8	1.5
Pyraflufen-ethyl	Herbicide	0	0	0.3	0	<0.1	0	0.4	1.6	0.2
Pyrazon	Herbicide	0.3	0	0	0.1	<0.1	0	0	0	0.1
Pyrethrins	Insecticide	0.1	0	0	0	0	0	0.5	0	<0.1
Pyridate	Herbicide	0.1	0	0	<0.1	0	0	<0.1	0	<0.1
Pyriproxyfen	Insecticide	0	0	0	0	0	0	0	2.1	0.1
Pyrithiobac-sodium	Herbicide	0	0	1.2	<0.1	2.8	0	0.3	3.3	0.6
Quinclorac	Herbicide	0.8	<0.1	0.1	<0.1	8.0	0	0	0.1	0.6
Quizalofop-ethyl	Herbicide	0.6	0.4	<0.1	0.1	<0.1	0	0	0	0.1
Quizalofop-p-ethyl	NA	4.0	2.7	<0.1	0.3	<0.1	0.2	<0.1	0.1	0.8
Rimsulfuron	Herbicide	2.5	2.2	2.1	8.7	3.8	11.8	3.0	1.9	5.2
Rotenone	Insecticide	0.1	0	0	0	0	0	0	0	<0.1
Sethoxydim	Herbicide	0.7	4.8	<0.1	0.4	0.4	0.2	0.2	2.3	1.1
Simazine	Herbicide	0	0	0.1	3.0	1.0	5.9	6.9	4.2	1.9
S-Metolachlor	Herbicide	2.0	1.1	10.3	19.9	6.4	33.0	13.3	12.7	12.8
Sodium acifluorfen	Herbicide	0	0.1	0	0.5	2.0	0	0.6	3.1	0.5
Sodium asulam	Herbicide	0	0	0	0	0.6	0	0	0	<0.1
Sodium bentazon	Herbicide	0.7	4.1	<0.1	0.7	1.6	1.5	0.3	4.6	1.4

Appendix B.—continued.

Pesticide (active ingredient)	Pesticide type	Northwest Non-Coastal (3)	Northern Plains (5)	Southern Plains (6)	North Central and Midwest (7)	Lower Mississippi and Texas Gulf Coast (9)	Northeast (10)	East Central (11)	Southeast Coastal Plain (12)	All eight regions
Sodium chlorate	Herbicide	0	0	0.1	<0.1	3.2	0	0.4	0.8	0.3
Spinosyn A	Insecticide	0	0	0.1	<0.1	0.4	0.4	1.0	3.6	0.3
Spiromesifen	Insecticide	0.2	0	0	0	0	0	0	0	<0.1
Streptomycin	Microbiocide	0	0	0	<0.1	0	0	0	0	<0.1
Sulfentrazone	Herbicide	0.3	4.6	1.5	4.8	2.9	1.2	3.8	1.7	3.5
Sulfometuron methyl	Herbicide	0	0	<0.1	0	0	0	0	0	<0.1
Sulfosulfuron	Herbicide	3.8	0.5	1.4	0	0	0	0	0	0.5
Sulfur	Fungicide	0.9	0	<0.1	<0.1	0	0	0.1	0.2	0.1
Tebuconazole	Fungicide	0	4.8	0.4	0.2	0.1	0	0.8	9.2	1.4
Tebufenozide	Insecticide	0	0	0	<0.1	1.7	0	0	0	0.1
Tebuthiuron	Herbicide	0	0	0.1	<0.1	0	0	0	<0.1	<0.1
Tefluthrin	Insecticide	0.2	0.1	0.7	4.2	0	3.5	1.3	0.1	2.0
Terbacil	Herbicide	0.2	0	0	<0.1	0	0	0	<0.1	<0.1
Terbufos	Insecticide	1.8	1.6	0.4	0.7	0.9	0.4	0	2.7	0.9
Tetraconazole	Fungicide	0	2.9	0	1.0	0	0	0.1	0	0.9
Thiamethoxam	Fungicide	0.4	0.1	0.1	<0.1	6.0	0	0.4	0.8	0.6
Thiazopyr	Herbicide	0	0	0	<0.1	0	0	0	0	<0.1
Thidiazuron	Herbicide	0	0	2.3	0	14.6	0	1.6	9.9	2.1
Thifensulfuron methyl	Herbicide	31.4	12.4	2.9	2.8	4.9	8.9	7.7	6.9	6.1
Thiobencarb	Herbicide	0	0	0	<0.1	0.1	0	0	0	<0.1
Thiodicarb	Insecticide	0	0	<0.1	0	1.2	0.1	0	0.2	0.1
Thiophanate-methyl	Fungicide	0.5	0.6	0	0.1	0.5	0.3	0	0.1	0.2
Thiram	Fungicide	0	0	0	<0.1	0	0	0	0	<0.1
Tralkoxydim	Herbicide	6.0	1.3	0	0	0	0	0	0	0.5
Tralomethrin	Insecticide	0	0	0	0	0.3	0	0	0.8	0.1
Triallate	Herbicide	2.8	1.5	0	<0.1	0	0	0	0	0.4
Triasulfuron	Herbicide	1.5	2.5	4.2	0	0	0	0	0	1.4
Tribenuron-methyl	Herbicide	33.7	11.2	2.9	1.8	3.8	4.5	6.0	6.3	5.4
Tribuphos	Herbicide	0	0	1.4	<0.1	12.6	0	3.4	16.2	2.1
Triclopyr	Herbicide	0	0.1	<0.1	<0.1	2.9	<0.1	0	0.2	0.3
Trifloxystrobin	Fungicide	0.1	0.6	0	0.1	1.0	<0.1	0.2	1.0	0.3
Trifloxysulfuron-sodium	Herbicide	0	0	0	<0.1	1.5	0	0.6	0.9	0.2
Trifluralin	Herbicide	3.2	7.5	10.6	4.6	2.1	1.6	0.2	6.1	6.0
Triflusulfuron-methyl	Herbicide	2.7	3.7	0.1	1.1	0	0	0	0	1.2
Trinexapac-ethyl	Herbicide	0	0	0.1	0	0	0	0	0	<0.1
Vernolate	Herbicide	0	0	0	0.5	0	0	0	0	0.2
Vinclozolin	Fungicide	0	0.3	0	0	0	1.0	0	0	0.1
Zeta-Cypermethrin	Insecticide	2.3	0.7	1.3	1.7	4.8	0.3	1.5	3.9	1.8

Source: Pesticide use as reported in the 2003-06 NRI-CEAP Cropland Survey and subsequently used in the APEX simulation modeling.