Estimating Water Quality, Air Quality, and Soil Carbon Benefits of the Conservation Reserve Program

FAPRI-UMC Report #01-07

FAPRI
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UNIVERSITY OF MISSOURI-COLUMBIA

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Executive Summary

Established by Congress with the passage of the Food Security Act in 1985, the Conservation Reserve Program (CRP) is America's premier voluntary conservation effort to protect and restore fragile natural resources, as well as the world's largest. Since 1986, millions of acres of cropland have been retired into long-term grass and tree covers under the CRP. Over 36 million acres of cropland were enrolled in October 2006 (USDA 2006). The benefits of the program are not limited to increased agricultural productivity from replenished soils, they include the well-being that enhanced wildlife populations, improved water quality, improved air quality, and carbon sequestered in soil and biomass provide. Accurate and meaningful measures of changes in environmental quality are necessary if the CRP is to provide considerable environmental benefit cost effectively.

This report improves our understanding of the benefits of CRP by estimating how field and buffer practices affect the amount of soil and nutrients leaving the field. These estimates provide an indication of the benefits due to enhanced water and air quality and increased carbon sequestration. This report differs from previous studies in one or more of the following ways:

- The amounts of soil and nutrients actually leaving the field or watershed are estimated rather than the amounts mobilized on the field, some of which may not actually leave the field. These provide a better indicator of the CRP benefits that accrue in neighboring waters or adjoining lands.
- The model uses daily weather events and day-to-day management decisions to capture the variability introduced by weather.
- The report enables comparison between field and buffer practice effects.
- The study is national in scope.

Our estimates confirm that enrollment of marginal cropland in CRP virtually eliminates soil and nutrient loss and increases the amount of organic matter on enrolled fields: For the wetter, eastern half of the United States (those states adjoining and east of the Mississippi River), soil, nitrogen, and phosphorus losses in runoff or percolate from field-practice enrollments are estimated to be 6.5 tons, 20.7 pounds, and 5.4 pounds, respectively, per acre lower than what they might otherwise be, given current production practices. The impact of buffer practices on losses via runoff in this region is likewise considerable, with 3.1 tons, 8.1 pounds, and 1.4 pounds less, respectively, coming off each acre of cropland situated on a buffered watershed. In the drier, western half of the nation, field practices serve to reduce wind erosion, with 13.1 tons, 21.7 pounds, and 6.0 pounds less soil, nitrogen, and phosphorus stripped off fields. Regarding carbon sequestration, the effect of field practices on soil loss translates to an average nationwide net increase in total organic carbon of 0.7 tons per acre annually.

The estimates in this report are based on model runs involving the soil types associated with more than half of enrolled acreage. In order to refine our ability to set and meet goals, an effort is currently underway to construct a more representative national estimate by explicitly linking modeled soils to the remaining CRP soils.

Introduction

Established by Congress with the passage of the Food Security Act in 1985, the Conservation Reserve Program (CRP) is America's premier conservation effort to protect fragile natural resources and enhance environmental quality. Since 1986, millions of acres of cropland have been retired into long-term grass and tree covers under the CRP. In October 2006, over 36 million acres of cropland were enrolled (USDA 2006).

The considerable benefits of the program are not limited to the enhanced agricultural productivity that replenished soils may afford, but include the well-being that increased wildlife populations, improved water quality and associated impacts on aquatic species, improved air quality, and carbon sequestered in soil and biomass (that would otherwise have been released into the atmosphere) provide. Monetizing conservation benefits or quantifying changes in ecosystem services that provide them is important because benefits can then be explicitly compared to program costs.[1] Doing so accurately and with meaningful metrics allows stakeholders and decision makers to assess the overall merit of the program. Quantification also improves program performance because goals can be expressed as benchmarks and progress toward them assessed. Practices that work well can be distinguished from those that do not and encouraged. Practices that do not meet objectives can be discontinued or refined to increase effectiveness. Moreover, land characteristics associated with the greatest benefits can be identified, allowing USDA to encourage adoption of conservation practices on the best-suited lands.

Historically, conservation benefits have often been expressed in terms of the number of practices installed or the acres enrolled (USDA OCFO 2002, 2005; USDA NRCS 2005). For the CRP, acres enrolled were initially used as a measure of program performance in part because the Food Security Act of 1985 specified enrollment levels for 1986 through 1990. Acres, however, are not a *measure* but rather an *indicator* of conservation benefits, one that requires either awareness by the decision maker of the relationship between acres enrolled and benefits provided, or the strong assumption that the benefit of each additional acre is constant. These assumptions ignore the variation from place to place in the stress to the environment from fiber and food production and the environment's resilience in the face of stress. Some cropland is both highly productive and resilient, while other land is highly susceptible to erosion and degrades over time from crop production.

A somewhat more refined indicator of CRP benefits that has been used is the change in the amount of soil erosion that occurs on a field. The focus on erosion resulted from a series of analytical and policy developments:

- The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) and Wind Erosion Equation (WEQ) (Woodruff and Siddoway 1965) enabled estimation of changes in sheet and rill erosion and wind erosion.
- The 1982 National Resource Inventory (NRI), provided the wherewithal to apply these equations to cropland nationally (USDA SCS 1984) by quantifying the overall severity of soil erosion (2.1 billion tons per year), and identified where unsustainable levels of soil erosion occurred.
- Several assessments of conservation programs, policies, and soil erosion pointed to the potential for a targeted approach to soil erosion.[2] These analyses focused attention on the effect of commodity programs on land use

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[1] Ecosystem services refer to the natural processes that benefit people in one or more ways, e.g., the provision of suitable habitat for recreational fish species. Conservation, or ecological, benefits are the specific ways in which increased wellbeing is generated, e.g., better angling.

[2] Anticipating this work, the Agricultural Conservation Program in 1982 did provide assistance to landowners that adopted procedures to target measures most effective in reducing soil erosion.

change and soil erosion (Colacicco, et al. 1987, Reichelderfer 1985), the high proportion of soil erosion from a relatively small amount of cropland with high soil vulnerability to erosion (Bills and Heimlich 1984), and the high off-site damages from soil erosion and sedimentation (Clark et al. 1985, Crosson 1986, Ribaudo 1986).

The Conservation Reserve Program

The CRP is a voluntary program where producers with eligible land may enter into 10 to 15 year contracts to establish long-term covers on land to reduce soil erosion, improve water quality, and enhance wildlife habitat. In return for establishing and maintaining conservation covers, landowners receive

- annual rental payments,
- cost share assistance, not to exceed 50 percent of the eligible costs, and
- under certain conditions, incentives for enrolling land, undertaking particular practices, and performing certain maintenance practices.

Farmers can apply to re-enroll land for additional ten- or fifteen-year contracts.

Eligibility criteria for the CRP have evolved over time. Currently, to be eligible to be enrolled, land must be

- cropland that has been planted or considered planted to an agricultural commodity or in conserving use four of the six years between 1996 through 2001, and that is physically and legally capable of being planted in a normal manner to an agricultural commodity, or
- marginal pasture land.

In addition, cropland must

- have a weighted average erosion index of 8 or greater,
- be expiring CRP,
- be located in a national or state CRP conservation priority area, or
- be eligible for continuous sign-up (see below).

The CRP contains four programs: the general signup CRP, Continuous CRP (CCRP), Conservation Reserve Enhancement Program (CREP) and the Farmable Wetlands Program (FWP).

- The best known and largest (32.5 million acres) component, the general signup CRP, is competitive, using an environmental benefits index (EBI) to evaluate, rank, compare, and select offers.

- The Continuous CRP accepts eligible land, offering to install practices such as riparian buffers, grass filters, bottomland hardwood, and wetland restoration. Because these practices are deemed to be highly beneficial, they are accepted continuously without competition.

- Conservation Reserve Enhancement Program (CREP) is a state and federal partnership designed to address state and/or national conservation issues. An individual CREP project is developed when a state, Indian tribe, local government, or non-government entity identifies a priority agriculture-related environmental issue of state or national significance, such as impacts to water supplies, loss of critical habitat for threatened and endangered wildlife species, soil erosion, and reduced habitat for fish populations.

- The Farmable Wetlands Program (FWP) enrolls small non-floodplain wetlands under continuous sign-up provisions.

- The Food Security Act of 1985 contained a Conservation Title including several programs and provisions to reduce soil erosion. These programs specifically targeted soil erosion on cropland that had a high inherent capacity to erode.
- Conservation tillage technologies became economically viable and the conservation provisions in the Food Security Act spurred their adoption.

The ability to measure erosion has allowed conservation programs to be targeted towards cropland vulnerable to erosion and the effect has been considerable: a 43 percent reduction in the amount of cropland erosion between 1982 and 2003 (USDA NRCS 2006).

Indicators such as total acres enrolled and field-level erosion reductions certainly contribute to an argument that conservation program benefits are very real and potentially large. Yet, they offer limited insight in terms of just how large because they cannot account for the fact that some fields may be better than others in terms of wildlife habitat provision or water quality improvement. The absence of reliable indicators that would better convey the full spectrum of benefits and could be applied systematically presents a dilemma when assessing conservation program effectiveness and attempting to make refinements. While the shift toward comprehensive accounting of benefits means that selecting between conservation alternatives requires greater effort, considering the tradeoffs across multiple objectives leads to better decisions.

While the spectrum of benefits has been carefully documented on research plots, consideration of CRP benefits on a national scale has been frustrated by limited data and understanding of biophysical processes and modeling capabilities. Nevertheless, several attempts have been made and are worth mentioning: these assessments have typically relied on CRP contracts data and the NRI to estimate land-use change and reduced soil erosion on the field. Table 1 reports NRI estimates of the effect on soil erosion of CRP relative to the pre-CRP erosion rates. The following are often-cited benefit assessments.

- Ribaudo (1989) used the NRI to estimate the cost of erosion per acre of cropland. This estimate was converted to a CRP benefits estimate using CRP contract data based on NRCS staff assessments of offers. The monetized benefits related primarily to freshwater recreation and reduced damages to infrastructure.
- Among the most comprehensive efforts to date, Young and Osborn (1990) estimated the water quality, recreational, wildlife, and soil productivity benefits of the CRP using NRI data. Additionally, the economic impacts on commodity markets, government payments, and rural economies were examined.
- Feather et al. (1999) estimated the value for CRP-related impacts on outdoor recreation, including water-based recreation, hunting, and nature viewing. Although their indicator-based approach to infer water quality excluded consideration of non-recreational benefits, the authors indicated that these could be substantial.

Table 1. NRI estimates of CRP impact on water erosion by region (tons/acre/year)

USDA production region	Reduction
Appalachia	-16.73
Corn Belt	-16.26
Delta	-13.94
Great Lake	-5.36
Mountain	-3.43
Northeast	-7.46
Northern Plains	-4.16
Pacific	-6.46
Southeast	-8.40
Southern Plains	-2.26

NRI estimates are relative to pre-CRP conditions (USDA SCS 2000).

- Sullivan et al. (2004) conducted a Congressionally mandated examination of CRP impacts on rural economies. While the analysis largely focused on economic impacts (e.g., farm incomes), the study offered estimates on such physical effects as reduced wind (134 million tons) and sheet and rill (89 million tons) erosion due to the CRP.
- FSA cost-benefit analyses (USDA FSA 2003b, 2004) estimated soil erosion reductions from a 34.2 million acre CRP to be nearly 450 million tons per year compared to the 1982 level (or 321 million tons compared to 1997), with wind erosion and sheet and rill erosion each contributing equally to the total. The analyses also estimated reduced nitrogen (681,000 tons) and phosphorus (104,000 tons) fertilizer usage on land currently enrolled in CRP.

These efforts share a few caveats: Because of their reliance on USLE (or the revised version, RUSLE) they estimate erosion on the field and rely on delivery rates to move beyond it. Nitrogen and phosphorus losses are not explicitly modeled and the estimates did not distinguish among the various pathways off the field though the impacts of each may differ. Finally, the models used are not dynamic and cannot reflect the influence of events and decisions made throughout the growing cycle on results, or the cumulative effect of previous years' practices on the one in question.

The Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI), and USDA's Farm Service Agency (FSA), and Office of Risk Assessment and Cost-Benefit Analysis are collaborating on an effort to improve the modeling of the processes that are affected by the CRP and that lead to water-quality, air-quality, and carbon-sequestration benefits. The effort estimates the effect of establishing long-term conservation covers in terms of changes in

- soil, nitrogen, and phosphorus transported off the field (including below the root zone) with water,
- soil, nitrogen, and phosphorus trapped by buffer practices,
- windblown soil, nitrogen, and phosphorus transported off the field, and
- carbon levels in roots, surface residue, standing biomass and soil.

This report details the modeling performed and presents the results.

Background on Physical Processes

Assessing the CRP's impact on water quality requires an understanding of some of the basic physical properties and processes that link land use to pollutants leaving the field.

Erosion

Composed of minerals, air, water, and organic matter, soil particles are dislodged and transported by water and wind action. Sediment borne by water beyond the edge of field travels toward surface waters, whose quality will be affected if the sediment is not deposited en route. To the extent wind blown particles are deposited in waterways and on nearby surfaces where they are likely to be washed into nearby waterways, wind erosion also affects water quality.

The mineral and organic components of soil include nutrients such as nitrogen and phosphorus that can act as pollutants when excessive amounts are deposited in rivers, streams, and other water bodies. Soil movement plays an important role in nutrient movement because considerable nutrient loss is due to nitrogen and phosphorus attached to eroded soil particles (85 and 88 percent, respectively, according to this study). Because carbon is also closely associated with soil particles, erosion also reduces soil carbon levels.

Water Erosion

The energy of water as it flows over soil can dislodge it and cause erosion. The many processes contributing to water erosion start with precipitation: the impact energy of rain droplets dislodges soil particles. Ground cover, soil type, droplet size, and precipitation intensity all affect this process. After reaching the ground, water either percolates through the soil, runs off, or is absorbed by vegetation. When water moves with sufficient speed it can carry sediment that, if deposited in a lake or stream, will impact water quality. As water and sediment move across the landscape, additional soil particles can be dislodged and carried as sediment. Water flow diminishes if ground cover impedes the flow or the slope decreases. If water flow slows, energy is reduced and sediment is deposited in the field before it reaches a stream. Water erosion factors are influenced by conservation practices, vegetative cover, and length of slope. Figure 1 shows the results of water erosion.

Wind Erosion

Wind erodes soil by dislodging soil particles that then creep along, saltate (jump), or are suspended in the air. As Figure 2 illustrates, wind erosion occurs in regions with high wind velocity and exposed soils. It is a function of wind speed, soil texture and cohesiveness, surface soil moisture, crop and residue cover, and obstacles that provide breaks in air flow. Airborne sediment is picked up when wind velocity increases and deposited when the air flow is broken or wind velocity decreases.

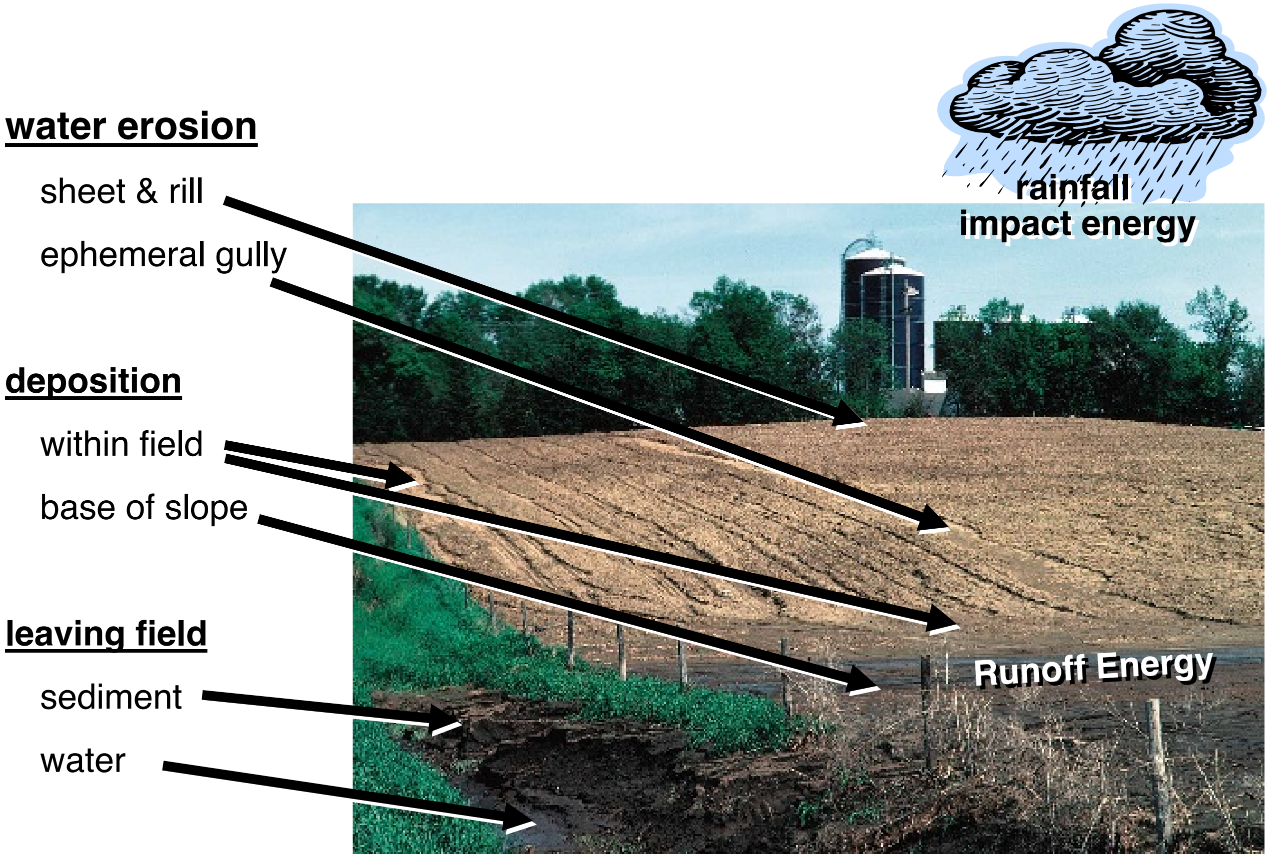

Photo courtesy of USDA Natural Resources Conservation Service

Figure 1. Water erosion processes at work in Iowa

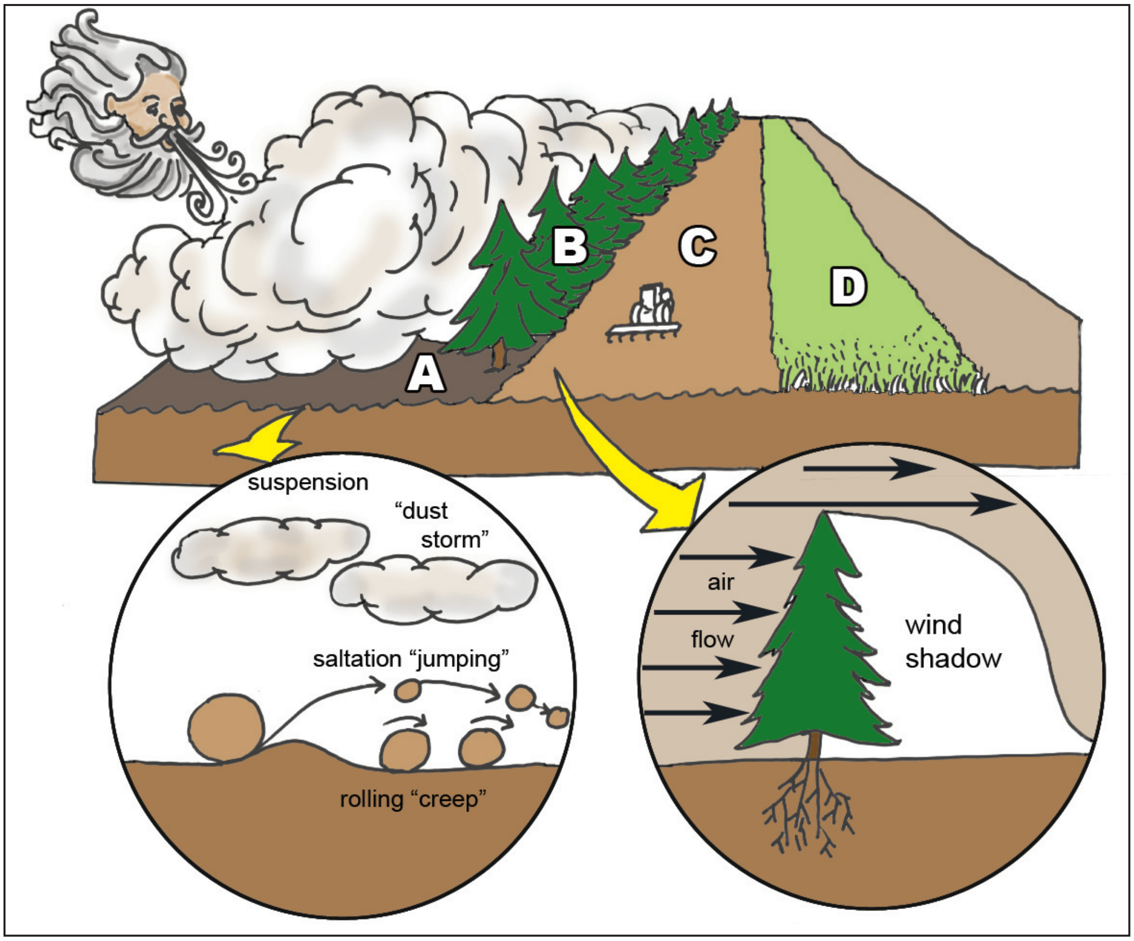

Figure 2. Wind erosion and deposition

A: Unsheltered tilled cropland
B: Windbreak
C: Sheltered tilled cropland
D: Conservation cover

Fertilizers

While soil contains the nutrients necessary for plant growth, supplementing this amount can boost yields and increase profits. The principal fertilizers needed are nitrogen, phosphorous, and potassium. Applying the right amount of fertilizer is a critical process: too little and yields decrease, too much and production costs exceed returns and the potential for air and water pollution increases. This study examines nitrogen and phosphorus, the two most commonly polluting nutrients.

Nitrogen

Occurring in the environment as ammonia, nitrate, mineralized nitrogen, or in organic residue, nitrogen inputs to a field arrive by way of fertilizer application, atmospheric deposition, nitrogen fixation, and residue decomposition (Figure 3). Although applications are usually in the form of nitrate and/or ammonia compounds, some, e.g., manure, also contain organic nitrogen compounds. The nitrogen in rainfall and irrigation water also adds to total nitrogen input. Nitrogen fixation occurs when microbes associated with legume crops, such as soybeans and alfalfa, convert atmospheric nitrogen into plant-available nitrogen.[3] Plant residues remaining after harvest contain organic nitrogen that returns to the soil as the residue decomposes.

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[3] Microbes are essential actors in these processes, converting nitrogen from one form to another and making it available for plants. As well as fixing and denitrifying nitrogen, they mineralize organic nitrogen, immobilizing it in the process.

Nitrogen moves and changes form on the field. It is absorbed by plants, removed with crops, lost to the atmosphere, dissolved in water leaving the field, and attached to eroded soil particles (Figure 4). Crops take up available nitrogen from the soil and this nitrogen is contained in the proteins of the harvested crops. Ammonia applied as fertilizer and ammonia released in the mineralization process can be volatilized. Nitrate can be converted to gaseous nitrogen molecules through denitrification, or volatilized as nitrous oxide. Organic and mineralized nitrogen are adsorbed to and move with eroded soil particles. Some forms of nitrogen, such as nitrate, are water soluble and available for plant uptake, while others are not. Water-soluble forms of nitrogen can leave the field in runoff or leach into groundwater. Because of their bioavailability, they contribute disproportionately to eutrophication of surface waters (Lal and Stewart 1994).[4]

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[4] Eutrophication is the process of excessive algae growth, dieoff, and oxygen depletion that results in aquatic species mortality.

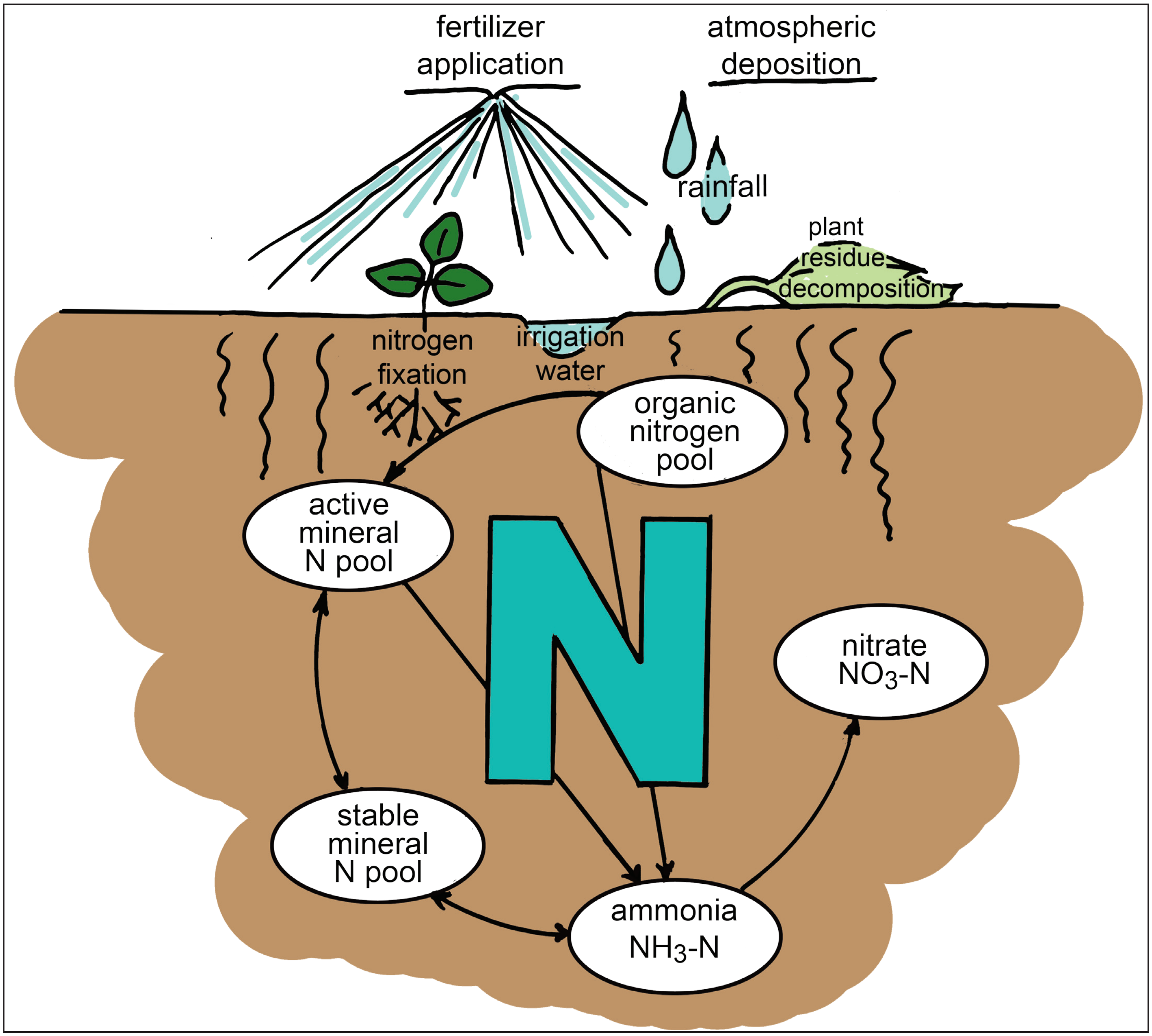

Figure 3. Nitrogen input processes

Phosphorus

Phosphorus occurs in the environment in both mineral and organic forms. There are multiple sources of phosphorus input to a field, primarily fertilizer application and residue decomposition (Figure 5). Fertilizer applications are usually in the form of phosphate compounds, rock phosphate, or manure.

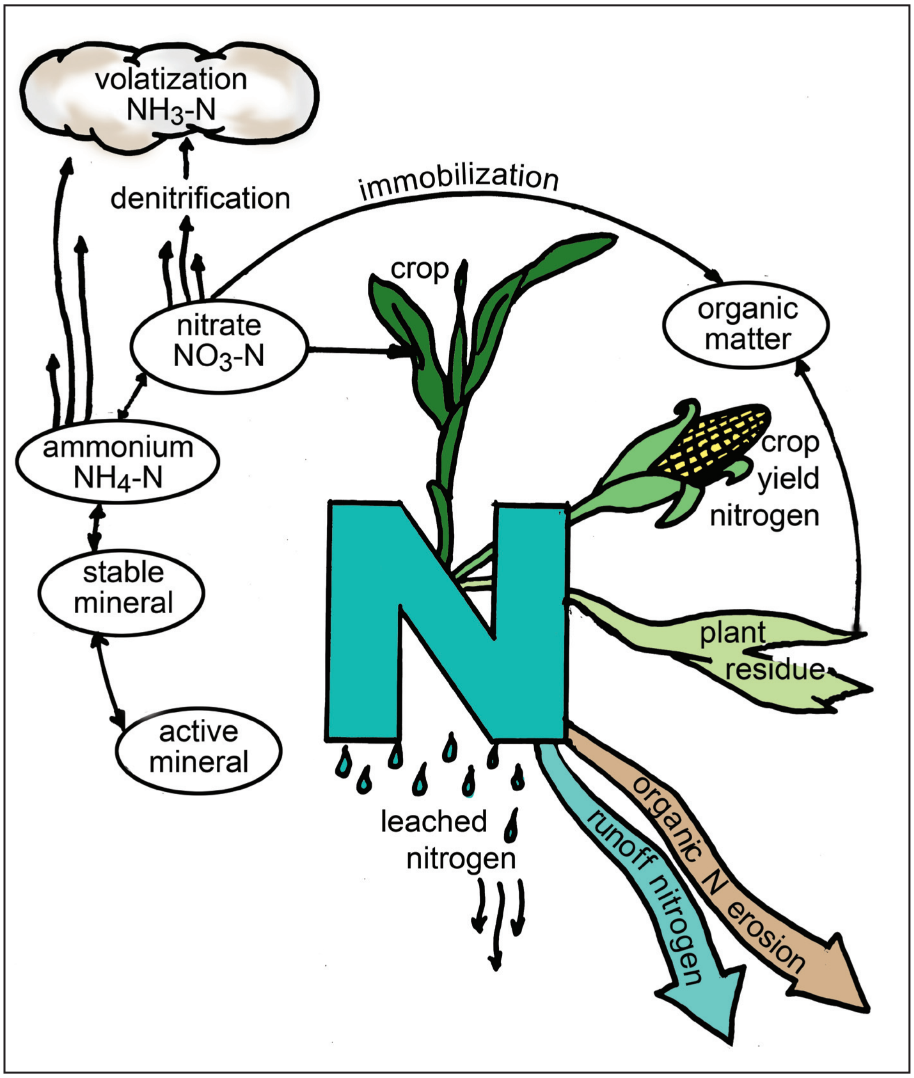

Figure 4. Nitrogen removal processes

As they do with nitrogen, crops take up available phosphorus from soil and it is removed as crops are harvested (Figure 6). Plant residues remaining after harvest contain organic phosphorus that returns to the soil as the residue decomposes. Water soluble phosphorus is available for plant uptake, runoff, and percolation. Dissolved phosphorus can leave the field in runoff or leach from it.[5] Organic and mineralized phosphorus can also be carried away from the field attached to eroded soil particles. Water soluble phosphorus is a much smaller proportion of the total phosphorus pool than water soluble nitrogen is of total nitrogen, but is the most available to aquatic plant life.

Like nitrogen, phosphorus causes problems when introduced to surface waters in excessive amounts due to the role it plays in the eutrophication process, which impacts the services and benefits these waters provide. Although nitrogen and carbon are also associated with eutrophication, most attention has focused on phosphorus because of the difficulty in controlling the exchange of nitrogen and carbon between the atmosphere and surface waters and the fixation of atmospheric nitrogen by some blue-green algae. Moreover, because of its relative scarcity, phosphorus is typically the limiting factor that determines whether eutrophication occurs and its control is of prime importance (Sharpley and Halverson 1994).

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[5] Leached phosphorus is of concern when groundwater flows into surface waters.

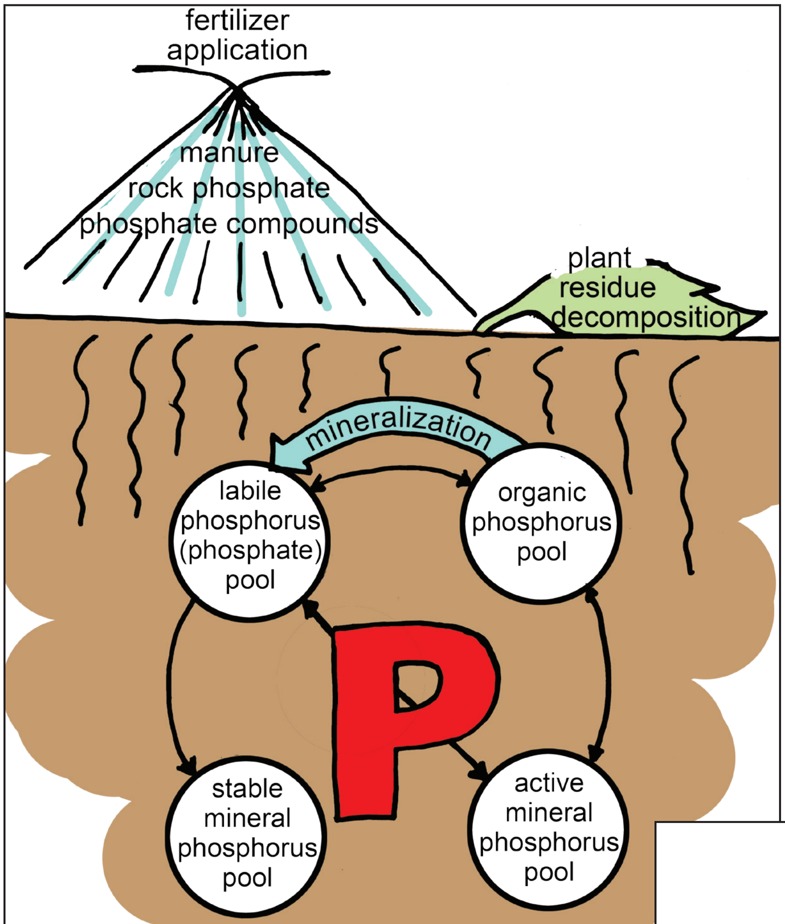

Figure 5. Phosphorus input processes

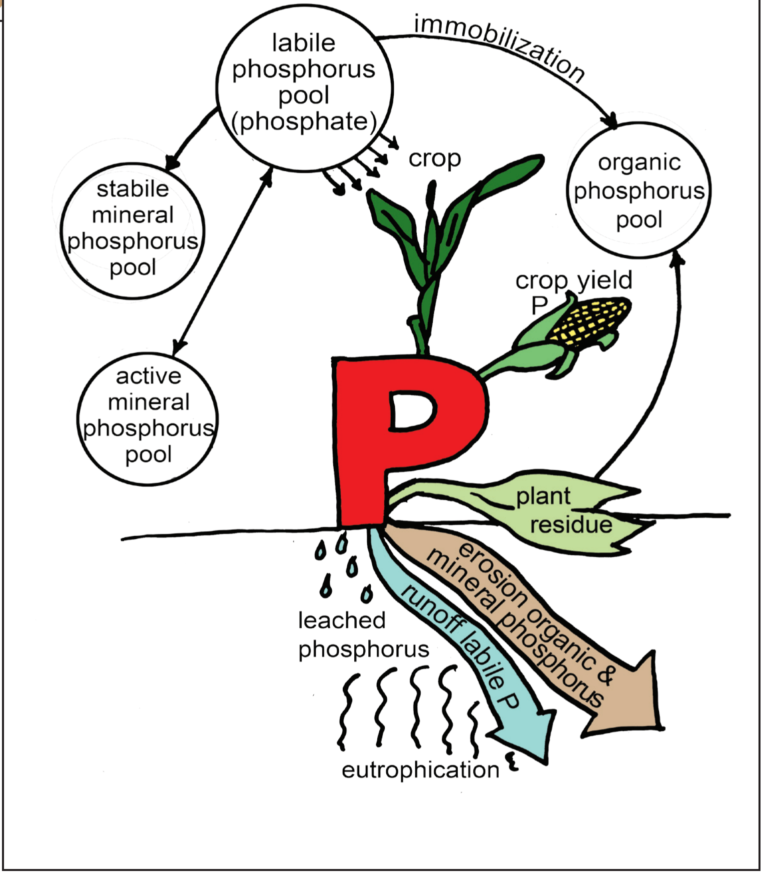

Figure 6. Phosphorus removal processes

Organic Carbon and Carbon Sequestration

Carbon is taken from the air by the photosynthesis process and is stored temporarily in growing plants, roots and organic material in the soil, plant residue following harvest, and microbes and, ultimately, incorporated into soil (Figure 7).

Carbon leaves the field through crop and soil microbe respiration, with sediment, and in harvested crops. Soil and surface plant residue are broken down by microbes converting carbon, nitrogen, and phosphorus into more mobile molecular forms. Microbes that break down organic material require sources of nitrogen and phosphorus as well as carbon, which (along with living plant material) ties up nitrogen and phosphorus.

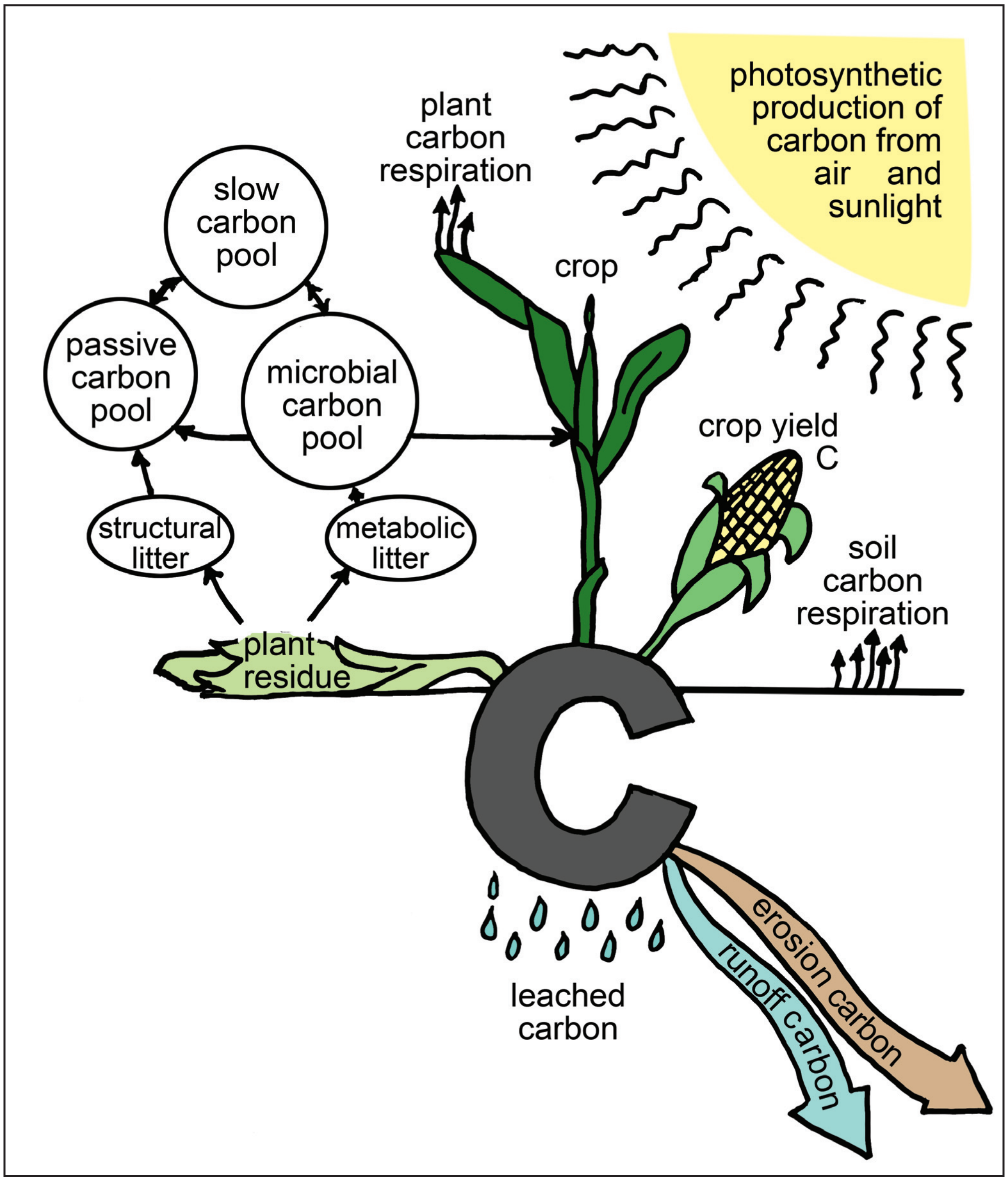

Figure 7. Carbon cycling processes

CRP Effects

CRP practices reduce water and wind erosion by establishing vegetative covers that improve soil structure and increase the standing live biomass and crop residues. The vegetation reduces runoff velocity (as well as wind velocity at ground level) and intercepts sediment before it enters surface waters.

Except to establish cover, CRP acres rarely receive fertilizer applications, reducing nutrients in percolation and runoff. CRP acres also reduce nitrogen and phosphorus runoff and percolation by establishing and maintaining a year-round vegetative cover that both intercepts nutrients before they enter surface waters and uses nutrients for growth. By restoring wetlands, the CRP also creates the anaerobic conditions conducive to nitrogen removal via denitrification.

Conservation covers such as trees, grass, and wetlands increase soil carbon by decreasing oxidation and increasing the amount of residue, roots, and standing live plant material.

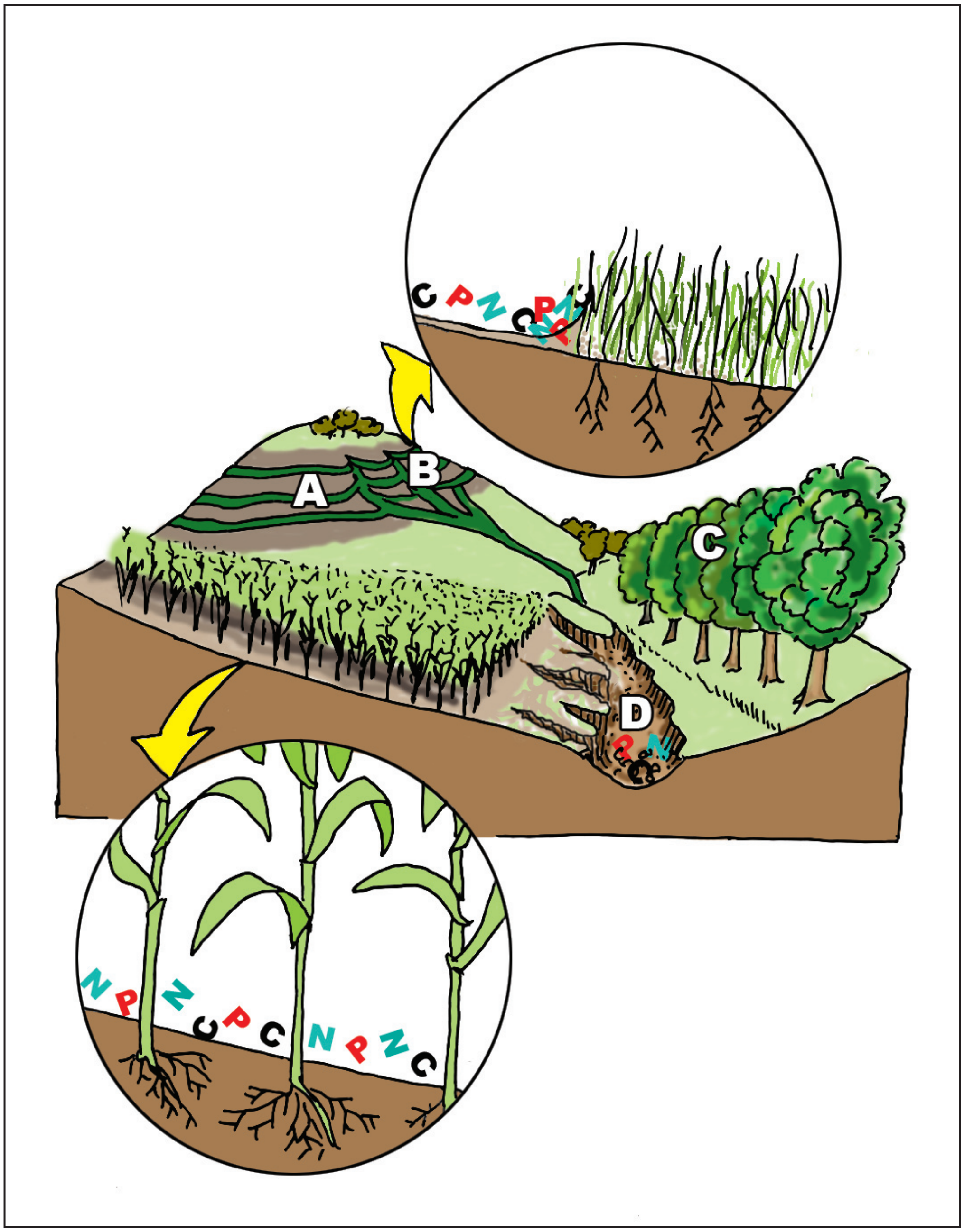

Figure 8. Buffer processes

A: Cropland buffer
B: Grass buffer strips
C: Timber buffer strip
D: Erosion of sediment, nitrogen, phosphorus and carbon

Buffers

Buffers are borders of grass or trees or both along rivers, streams, and other waterways. In addition to providing wildlife habitat, buffers improve water quality by intercepting the sediment and nutrients in runoff from adjacent cropland. Their relatively modest size belies their impact. The buffer vegetation slows water movement, enabling sediment to precipitate and nutrients to leach or be absorbed by plants before they reach surface waters. They further enhance aquatic habitat by moderating water temperatures, stabilizing stream banks, and restoring floodplains. USDA practice standards call for buffers ranging from 20 to 180 feet in width, depending on the slope, soil, adjacent land use, and other conditions. Figure 8 shows buffer strips and the off-field deposition that can occur in the absence of buffers.

Methodology

The effect of CRP on the movement of several key nutrients and sediment is determined by comparing estimates from computer simulations of various types of crops, agricultural practices, and conservation covers. We model 10 years into the future, with and without CRP practices, for selected soils currently enrolled. Individual assessments by soils, locations, weather stations, and alternative management systems are extrapolated to the state and then to the regional and national levels. The general approach taken balances the practical constraints of research, resources, and data availability, with the desire to produce both regional and national estimates of CRP effects.

Over a 10-year time frame, soil loss, nutrient loss, and carbon sequestration are estimated for CRP-enrolled lands as they currently exist and as they would be used absent the program. The with-CRP, or baseline, scenario reflects the current mix of conservation grass and tree covers utilized for the program in a given soil's State. Similarly, the without-CRP scenario reflects the mix of crop rotations and tillage systems (conventional and conservation) currently seen in the State.

The without-CRP scenario should and will differ from a before-CRP scenario. Over 19 million acres of CRP-enrolled land have been out of crop production for at least 10 years. If this land returned to crop production, the crop produced and the tillage system used would not likely be the same as when the land entered the CRP. Because different crop rotations have different implications for sediment and nutrient movement from a field, we do not assume the impact of no CRP today would be equivalent to pre-CRP impacts.

The models used to conduct the simulations are a key aspect of the methodology. Over the last 40 years, many models have been developed to estimate erosion and sediment delivery from the landscape. We used the Environmental Policy Integrated Climate (EPIC) (Gassman et al. 2005) and the Agricultural Policy Environmental eXtender (APEX) (Williams and Iazurralde 2005) models to estimate the environmental impacts. To realistically reflect the cumulative impacts of random weather events and the endogeneity of daily management decisions, the models were run for each day of the ten-year period.

EPIC and APEX are analytically powerful because they integrate the various processes that connect agricultural production to the movement of water, soil, and nutrients. The EPIC model estimates the mass of nitrogen, phosphorus, carbon, and sediment transported from the field via multiple pathways, such as in surface water runoff. EPIC predicts the effects of management decisions on soil, water, nutrient, and pesticide movement and the resulting impact on soil loss, water quality, and crop yields for areas with homogeneous soils and management. The APEX model embodies EPIC processes and has the added capability to estimate the amount of sediment leaving multiple fields and simulate the sediment trapping impacts of CRP buffers. Detailed tables of input parameters and model output for EPIC and APEX are shown in the Appendix, Tables A.1 and A.2.

Several specifications exist for water erosion, with the main difference among the equations being the emphasis on rainfall versus runoff energy. The equation used by this study is the Modified USLE (MUSLE), which uses runoff energy to simulate erosion and sediment yield. The focus on runoff energy provides for explicit estimation of the amount of soil transported to the edge of the field, eliminating the need to specify a delivery ratio, and allows relatively small time steps to be modeled (enabling, for example, simulation of single storms). Because these equations are based on sediment delivery in research watersheds rather than small experimental plots, they implicitly capture ephemeral gully erosion.

Both EPIC and APEX use the Wind Erosion Continuous Simulation (WECS) model that requires the daily distribution of wind speed to take advantage of the more mechanistic erosion equation. This approach uses wind speed distribution to continuously estimate potential wind erosion for a smooth bare soil. Potential erosion is adjusted using four factors: soil properties, surface roughness, cover (including residue), and distance across the field in the wind direction (Williams et al. 2000).

Initial Conditions

The initial conditions—slope, elevation, soil composition, soil water content, nutrient content, and residue cover—are held constant over the runs for each set of practices. For all scenarios, it is assumed there are no functioning tile drains in place. Initial soil nitrogen and phosphorus concentrations for each soil are estimated by simulating 10 years of the current cropping practice with conservation tillage and recording the resulting soil nutrient contents.[6]

Soil Characteristics

Because it is not practical to simulate every soil-state combination where CRP enrollments occur, the 363 most common—i.e., dominant—soils on CRP lands are modeled. Coverage is relatively sparse for the Northeast region, where soils are more variable and no soil series dominated CRP enrollments. In the Northeast, five soil series from Maryland and Pennsylvania are used to represent the CRP acreage. Table A.3 lists the soil characteristics used in this analysis. EPIC and APEX integrate soil slope, hydrologic soil type, water and nutrient storage capacity, carbon, soil chemical properties, water conductivity, soil texture, and carbon pools to estimate daily water quality impacts.

Agricultural Practices

The two CRP covers simulated are a four grass species plus legume mixture and a mixture of tree seedlings and weeds. The four grass species plus legume mix includes big blue stem, Indian grass, brome grass, switch grass, and alfalfa. These species were selected based on discussions with NRCS and information supplied by U.S. Geological Survey personnel (Allen and Vandever 2003). Two plant population densities are simulated: the higher of the two pertaining to east of the Great Plains States and the lower to the Great Plains and west. Initial population fractions for the five species vary by state and reflect recommended mixes. The densities do not change throughout the run, but the crop height and leaf area development respond to plant competition for light, water, and nutrients. The leaf area index (LAI) changes over time in response to the natural processes of succession at work during the ten-year CRP enrollment.

Trees are simulated based on the principal species planted for each state (Table A.4). In general, southern pine or oak are simulated in Southern and Delta States, oak or cottonwood in the Corn Belt, cottonwood in the Great Plains and Mountain States, and pine or fir in the Lake and Western States. Densities selected are based on CRP conservation practice standards (USDA FSA 2003a). Because weed species volunteer and provide ground cover until the canopy develops, weed cover is included with tree simulations to capture site conditions after tree planting.

Multiple simulations of rotation and tillage combinations are used to construct the without-CRP scenarios. A sequence of management practices is associated with each of the crops grown for these simulations. The timing of each practice is determined by soil temperature and the assimilation of heat units. These crop-specific management practices are used each year of the simulated rotation for that crop. The management practices used for conservation and conventional tillage for a corn-soybean rotation in central Iowa, as well as the CRP cover practice that would be used, are shown as an example in Table A.5.

Weather Generation

Weather, especially rainfall, is a random series of events strongly influencing runoff volumes and the off-site transport of nutrients and sediment. This stochasticity is incorporated in the model by plugging into it thirty different ten-year weather sequences. The starting points for these sequences

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[6] The current cropping practices were determined after consultation with crop production specialists. Some form of conservation tillage is now the standard practice for most rotations (cotton may be an exception).

are randomly generated from a distribution based on historic weather observations from an appropriate weather station. The ten-year sequences of weather variables used in EPIC and APEX are then generated by a precipitation model developed by Nicks (1974) and a temperature and solar radiation model developed by Richardson (1981). The same set of weather patterns is applied to the various cover types and practices that contribute to the two scenarios for each soil type.[7] Depicting nitrogen loss with sediment for an Iowa soil, Figure 9 illustrates the considerable variability across the thirty simulations due to the weather seeds.

CRP Field Characteristics

For simplicity, fields are assumed to be square. The size of the field planted to a conservation cover is based on the state average CRP contract for grass cover conservation practices (CP).[8] The same size is used for each crop type and management practice. The slope is based on the average slope for the soil or expert judgment by FAPRI if average slope was not available. Elevation is based on the elevation of the weather station used. This treatment minimized differences in the simulation results due solely to differences in field characteristics.

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[7] In light of the sensitivity of simulation results to crop-weather interactions, 60 runs were conducted for crops grown in rotation, such as corn and soybeans. Half started with one crop, half with the other.

[8] These included introduced grasses and legumes (CP 1), native grasses (CP 2), permanent wildlife habitat (CP 4) and existing grasses and legumes (CP 10). See the Appendix for a list of conservation practices.

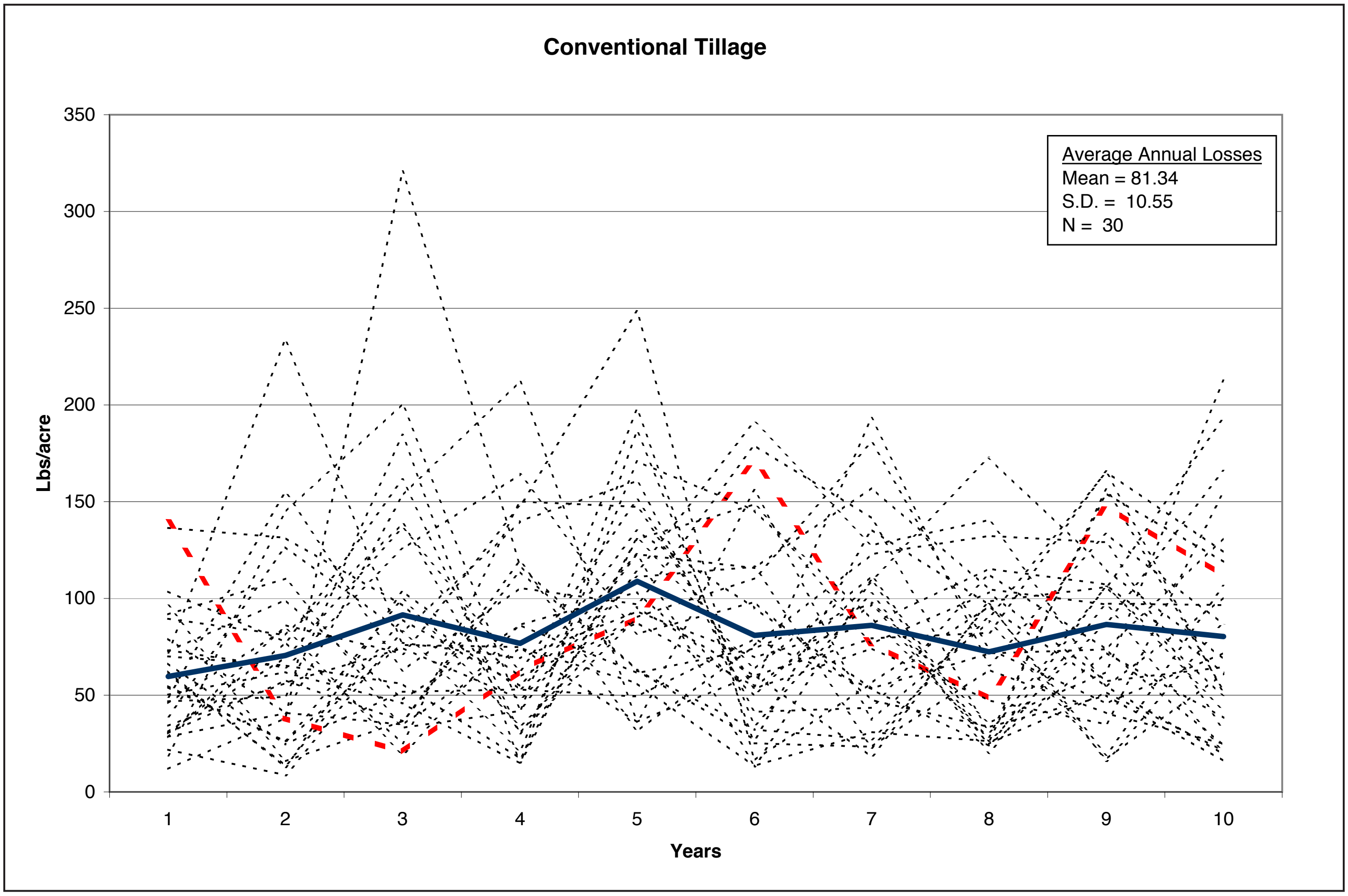

Figure 9a. Conventional tillage edge-of-field nitrogen losses with sediment for Iowa soil, "Ida" according to 30 different weather sequences

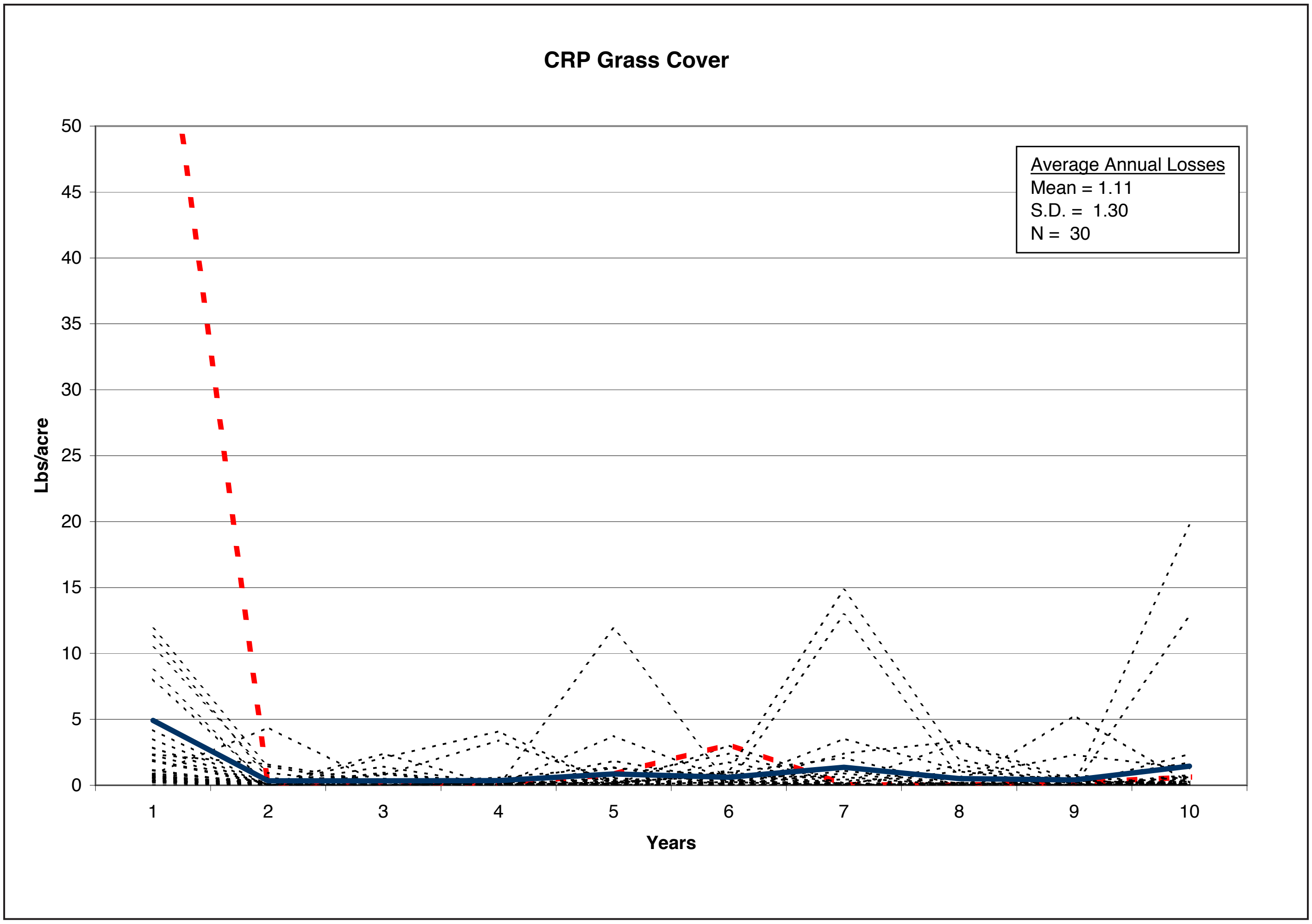

Figure 9b. CRP grass cover edge-of-field nitrogen losses with sediment for Iowa soil, "Ida," according to 30 different weather sequences

Individual sequences are dashed lines. The mean is a solid line. To illustrate correspondence between the two scenarios, one particular sequence is indicated in red.

Some interesting points come to light by comparing at the soil-type level nitrogen loss under crop production with nitrogen loss with a conservation grass cover:

- Extreme weather events account for a large portion of the overall impact.
- Relative to crop production, a conservation grass cover reduces the average annual N loss, the variation in N loss from year to year, the variation in N loss due to weather, and the peak losses due to extreme weather events.
- The first year of CRP experiences the highest losses because the soil is exposed to erosive forces until cover is established. Re-enrollments are likely to have even lower annual losses.

CRP Buffer Characteristics

Because the typical size of the watershed draining through buffers was not known, we assumed the watershed would be the same size as the state average CRP field. The extent of the buffer needed for each field was based on EPIC RUSLE erosion rates estimated for conventionally tilled cropland. Table A.6 shows the acreage needed in the buffer to achieve a 75 percent trapping efficiency that would trap 15 cm of sediment in 10 years (Dillaha and Hayes 1991). APEX used the same soil and weather as was used in the EPIC simulations.

Data

Considerable data are needed to model the interrelationships between the various factors affecting the effectiveness of the CRP in reducing sedimentation, enhancing soil productivity, improving water quality, and sequestering carbon. Data necessary to complete this study were acquired from a variety of sources. Figure 10 indicates the scope of data inputs required for this study and Figure 11 illustrates categories of outputs produced.

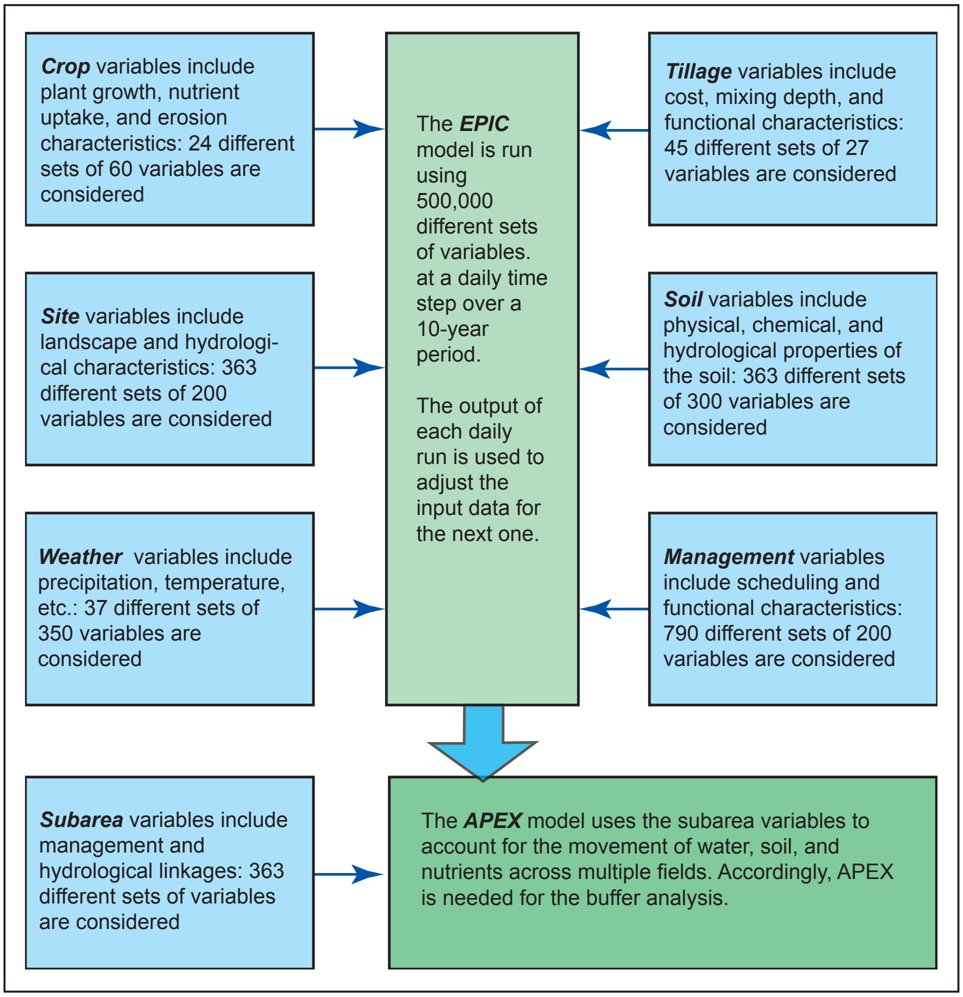

Figure 10. Inputs to EPIC and APEX

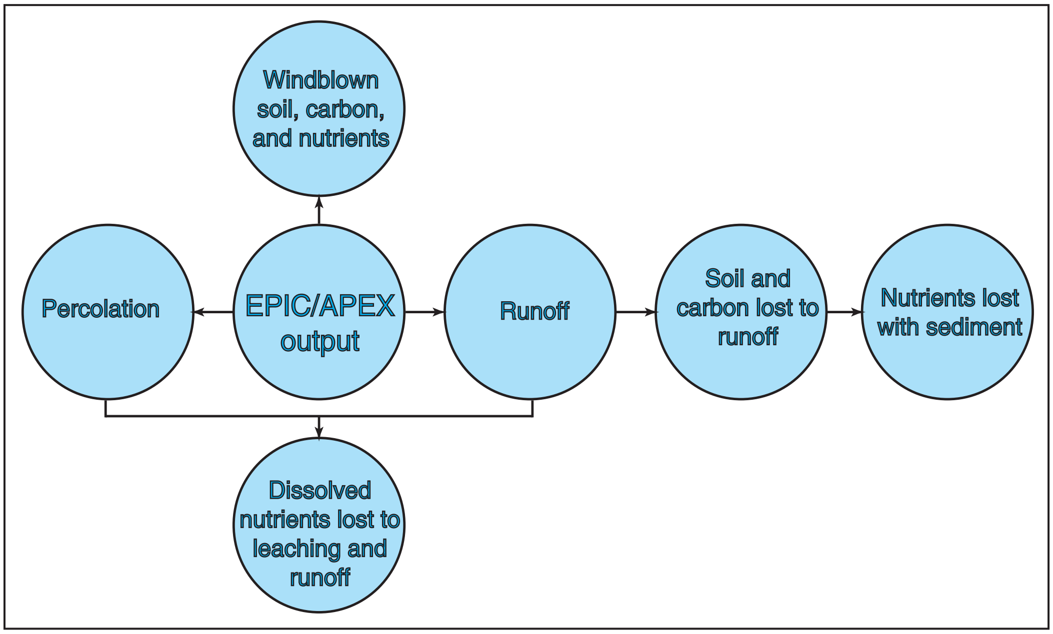

Figure 11. Outputs from EPIC and APEX

CRP Contract Information

CRP contract data provide much of the information needed to begin an examination of the conservation benefits from the CRP. Contract data include the conservation practice installed, state, county, year of installation, soil type, and acreage.

Crop Production and Farm Management Data

Crop rotations for each state (Table 2) are determined by examination of the spatial distribution of CRP enrollment and an NRCS analysis of the NRI database used in the Hydrologic Unit Model of the United States and other national assessments (Atwood et al. 1997).

Data from NASS (2005) are used for major crop acreage by state. One or two of three different rotations (corn-soybean, wheat-fallow, and cotton-sorghum) are assumed to sufficiently characterize current agricultural production for each state and allow for extrapolation of scenarios to aggregate scales.

Table 2. Crop Rotations by state

Region	State	Primary Crop Rotation	Secondary Crop Rotation	Surrogate Rotations
Northeastern				
	CT			Corn/Soybean
	DE			Corn/Soybean
	NH			Corn/Soybean
	ME			Corn/Soybean
	MA			Corn/Soybean
	NJ			Corn/Soybean
	NY			Corn/Soybean
	VT			Corn/Soybean
	RI			Corn/Soybean
	PA	Corn/Soybean		
	MD	Corn/Soybean		
Appalachian				
	TN	Cotton/Sorghum	Corn/Soybean	
	KY	Corn/Soybean		
	VA			Corn/Soybean
	VA			Cotton/Sorghum
	WV			Corn/Soybean
	WV			Cotton/Sorghum
	NC			Corn/Soybean
	NC			Cotton/Sorghum
Southeast				
	FL	Cotton/Sorghum	Corn/Soybean	
	GA	Cotton/Sorghum	Corn/Soybean	
	AL	Cotton/Sorghum	Corn/Soybean	
	SC	Cotton/Sorghum	Corn/Soybean	
Delta				
	AR	Cotton/Sorghum	Corn/Soybean	
	LA	Cotton/Sorghum	Corn/Soybean	
	MS	Cotton/Sorghum	Corn/Soybean	
Lake States				
	MN	Summer Wheat/Fallow		
	WI	Corn/Soybean		
	MI			Spring Wheat/Fallow
	MI			Corn/Soybean
Corn Belt				
	IN			Corn/Soybean
	IA	Corn/Soybean		
	IL	Corn/Soybean		
	MO	Corn/Soybean		
	OH	Corn/Soybean		

Table 2 continued on following page

Crop management practices are based on a national tillage, fertilizer, and pesticide database compiled by NASS and the Conservation Tillage Information Center for each cropping system by state, or in some cases parts of states, to match the Agricultural Sector Model areas (Atwood et al.1997).

Table 2. Crop rotations by state (continued)

Region	State	Primary Crop Rotation	Secondary Crop Rotation	Surrogate Rotations
Northern Plains				
	SD	Winter Wheat/Fallow	Corn/Soybean	
	ND	Summer Wheat/Fallow	Corn/Soybean	
	NE	Winter Wheat/Fallow	Corn/Soybean	
	KS	Winter Wheat/Fallow	Corn/Soybean	
Southern Plains				
	TX	Cotton/Sorghum	Winter Wheat/Fallow	
	OK	Winter Wheat/Fallow		
Mountain States				
	MT	Winter Wheat/Fallow		
	CO	Winter Wheat/Fallow		
	ID	Winter Wheat/Fallow		
	NM	Winter Wheat/Fallow		
	UT	Winter Wheat/Fallow		
	WY	Winter Wheat/Fallow		
	AZ			Winter Wheat/Fallow
	NV			Winter Wheat/Fallow
Pacific				
	CA	Winter Wheat/Fallow		
	OR	Winter Wheat/Fallow		
	WA	Winter Wheat/Fallow		

Environmental variables are estimated for each rotation simulated in a State using a weighted average across soils. Surrogate rotations for States in the region not simulated use weighted regional estimates with crops grown in those States.

Soils Data

Soil characteristics for the 363 soils are based on a database of over 20,000 different soils assembled by Dr. Otto Baumer for the Blacklands Texas Agricultural Experiment Station (TAES) in the late 1990s for use in the EPIC, APEX, and Soil and Water Assessment Tool process models. To make the modeling effort tractable, the 363 dominant soil series on CRP-enrolled land—accounting for over 53 percent of the acreage—were assessed (Table A.7). Table 3 shows the fraction of CRP acreage by state on which the assessed soils are located.

Farm Chemical Data

Chemical data for this study are limited to nitrogen and phosphorus applications. The application rates are based on recent NASS surveys by crop and state. The nitrogen and phosphorus application rates for each soil are based on an index of the amount of these nutrients required for near-optimal growth that is estimated via a 100-year simulation in EPIC. The fertilizer index is used to adjust the average nitrogen fertilizer application rates reported by National Agricultural Statistics Service (NASS) for the state (or a nearby state in some cases) to soil-specific rates.[9] A different fertilizer index is derived for each cropping-practice, soil-series combination.[10] The phosphorus application rates are derived directly from the NASS Chemical Use Survey.

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[9] A constant application rate is used for all five soil series representing the Northeast region.

[10] The index-based fertilizer application rate may be a more accurate reflection of farmers' behavior than the reported values in a statewide NASS Chemical Use Survey because the index provides soil-specific fertilizer application while the survey values are averages across several different soil types.

Table 3. Percentage of CRP acres assessed by State

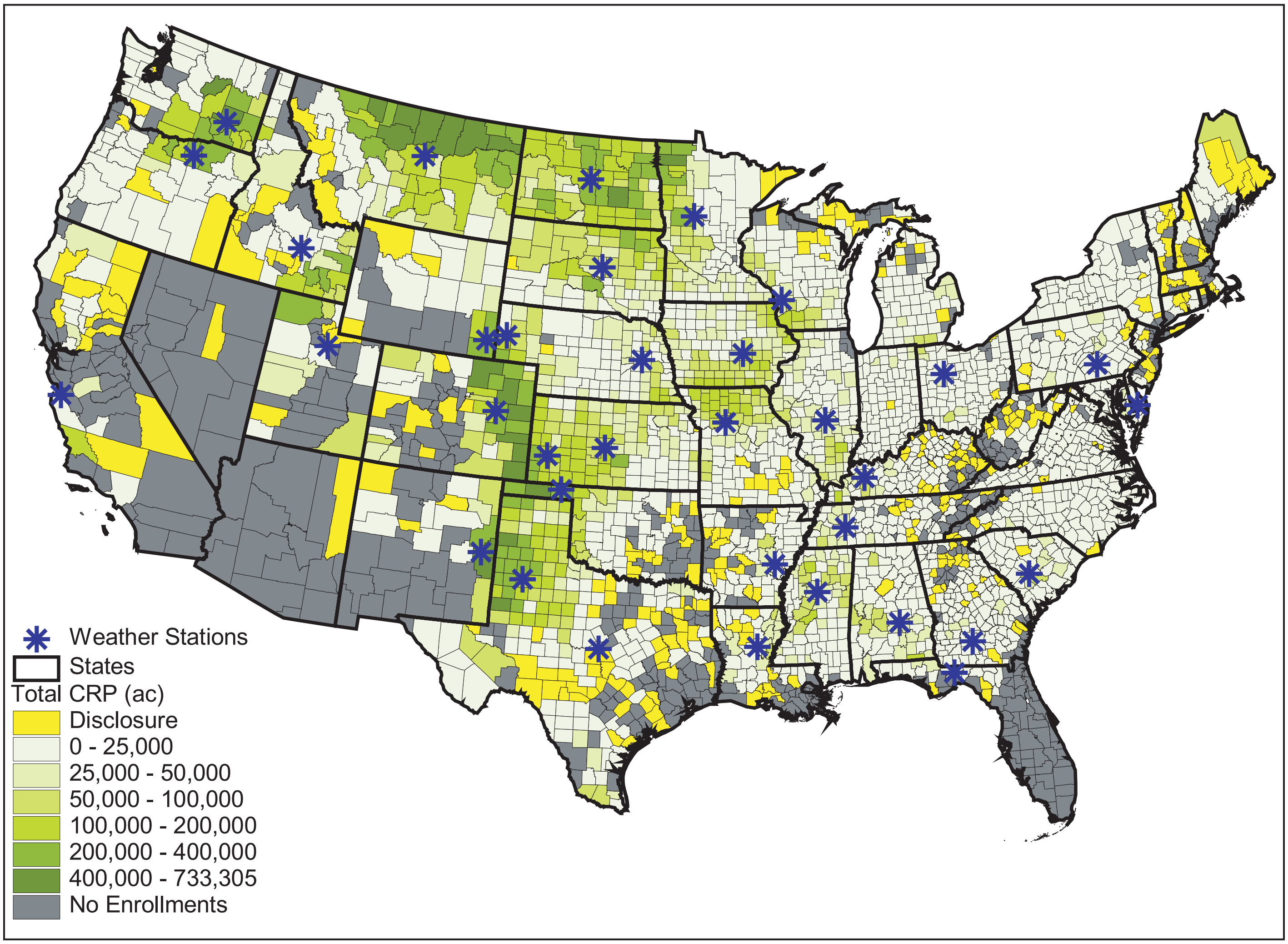
State	CRP acres with dominant soils	CRP acres	Percentage
AL	136,805	482,230	28.40%
AK	0	29,476	0.00%
AZ	0	33	0.00%
AR	24,373	160,631	15.20%
CA	22,097	138,997	15.90%
CO	1,243,427	2,203,436	56.40%
CT	0	318	0.00%
DE	0	6,632	0.00%
DC	0	0	0.00%
FL	22,218	88,487	25.10%
GA	149,902	313,437	47.80%
HI	0	21	0.00%
ID	340,943	795,172	42.90%
IL	240,069	964,110	24.90%
IN	0	301,609	0.00%
IA	701,638	1,865,301	37.60%
KS-east	1,037,639	1,516,646	68.40%
KS-west	974,546	1,142,955	85.30%
KS	2,012,185	2,659,601	75.70%
KY	136,296	312,863	43.60%
LA	44,006	205,351	21.40%
ME	0	24,273	0.00%
MD	12,874	60,889	21.14%
MA	0	121	0.00%
MI	0	310,119	0.00%
MN	567,436	1,668,551	34.00%
MS	372,270	866,944	42.90%
MO	798,668	1,552,986	51.40%
MT	2,246,550	3,413,165	65.80%
NE-east	139,110	693,591	20.00%
NE-west	200,899	451,091	44.50%
NE	340,009	1,144,682	29.70%
NV	0	151	0.00%
NH	0	195	0.00%
NJ	0	2,294	0.00%
NM	459,724	594,512	77.30%
NY	0	60,261	0.00%
NC	0	113,523	0.00%
ND	2,341,286	3,325,864	70.40%
OH	26,069	304,902	8.50%
OK	751,757	1,024,423	73.40%
OR	289,421	455,504	63.50%
PA	7,298	118,052	6.18%
RI	0	0	0.00%
SC	21,999	218,841	10.10%
SD	598,714	1,432,213	41.80%
TN	95,634	249,079	38.40%
TX-east	339,402	501,437	67.70%
TX-west	2,770,356	3,542,410	78.20%
TX	3,109,758	4,043,847	76.90%
UT	41,712	198,173	21.00%
VT	0	1,011	0.00%
VA	0	55,795	0.00%
WA	681,478	1,280,708	53.20%
WV	0	1,077	0.00%
WI	125,459	634,889	19.80%
WY	63,935	278,967	22.90%
Total	18,026,010	33,964,386	53.10%

October 2003 data

Weather Data

The EPIC and APEX models contain statistical weather data developed by USDA scientists Arlin Nicks and Gene Gander (USDA ARS, US Forest Service 2006). The key weather parameters are monthly precipitation, minimum and maximum temperature, radiation, relative humidity, and wind velocity and direction. The original source of the data is the National Oceanic and Atmospheric Administration's National Climatic Data Center. For this study, each alternative combination of the previously mentioned characteristics is simulated over a ten-year period thirty times by using thirty different weather-generator seeds. The resulting distribution for the estimated impact of a 10-year CRP contract characterizes the sensitivity of nutrient and sediment movement to weather variability.

At least one weather station per state is selected to provide the weather inputs required in the model. For most states, the weather station selected is the one nearest to the centroid of the CRP enrollments for that state (Figure 12). With two distinct weather patterns to consider, two stations are used for Texas, Kansas, and Nebraska: enrollments east of -100 degrees longitude are assigned to one station and those west to another.



disclosure – acres not reported when the number of contracts is too few to protect confidentiality of program participants

Figure 12. Weather stations

Model Output

The water and air quality benefits of CRP are reflected in comparisons of soil, nitrogen, and phosphorus leaving the field under with- and without-CRP scenarios. The change in the amount of organic carbon in soil and biomass is examined as well.

Model output starts out as a multitude of annual estimates. For CRP field practices, the benefit indicators are estimated for each assessed soil, 30 different simulations of 10-year weather sequences, and up to 6 agricultural practices: grass conservation cover, tree conservation cover, and conventional and conservation tillage of one or two predominant crop rotations.

For CRP buffer practices, a pair of agricultural practices is considered for each assessed soil's model watershed: One assumes the watershed is devoted entirely to the production of the state's predominant crop rotation, conventionally tilled. The other assumes a grass buffer of appropriate design and size is situated in the watershed and is trapping sediment and nutrients that move off the cropped portion of the watershed.

The indicators reported are limited to the most relevant and insightful portion of the otherwise substantial model output: water and wind erosion, nitrogen and phosphorus transported off the field in water and by wind, and total carbon sequestration.[11] There is also limited discussion of the pathways that contribute to the total amount of nitrogen and phosphorus transported off the field in water. All annual estimates are edge-of-field save carbon sequestration, which is an on-the-field estimate of the annual change over the contract period.

Nitrogen pathways include dissolved nitrate lost in runoff, adsorbed nitrogen lost with sediment, adsorbed nitrogen attached to windblown soil, dissolved nitrate leached into the groundwater or lost through subsurface flow, and denitrification and volitization to the air. In light of their differing impacts on water and air quality, respectively, nitrogen attached to windblown soil and the total amount of nitrogen leaving the field in water are reported separately.[12] The variation in bioavailability of the nitrogen aggregated into the latter means that a portion of the overall impact will be felt quickly, the result of dissolved nitrate, and a portion will be delayed, the result of nitrogen attached to soil.[13]

Phosphorus pathways include phosphorus dissolved in runoff, phosphorus adsorbed to sediment particles and lost with water and wind erosion, and phosphorus leached to the groundwater. As with nitrogen, phosphorus leaving the field due to wind erosion is separated out from phosphorus in the other pathways, which are totaled to indicate an overall effect from—and on—water.

The change in the total amount of organic carbon sequestered in the field is also reported. The total includes carbon in standing biomass, root structures, plant residues and in soil.

Summarizing and Aggregating Model Output

The disaggregate estimates are weighted by CRP acreage that currently exists on the respective soil. State-level per-acre averages are calculated for each benefit indicator and for each conservation cover and each rotation-tillage combination. An ongoing effort will improve upon this simple step by matching assessed soils to those not modeled according to similarity of soil characteristics.

A pair of estimates associated with the scenarios of interest is then constructed: one assuming current CRP acreage remains in the program and the other assuming the land is instead used for crop production. For the without-CRP scenario,

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[11] See Table A-2 for a complete list of outputs.

[12] Nitrogen makes up approximately 80 percent of the atmosphere and we assume that the denitrification occurring is primarily in terms of the transformation of nitrogen into molecular nitrogen (rather than nitrous oxide), which is environmentally benign.

[13] Bioavailability means the availability of a chemical for plant and animal uptake. The impact of nitrogen attached to soil particles is less swift than that of dissolved nitrates in runoff and leachate. Leached nitrogen can take decades to reach groundwater.

the estimate for each rotation-tillage combination is weighted by the relative extent to which that combination occurs on farms today in the respective states, as well as the degree to which the tillage technique is employed. Similarly, the baseline is an average of the estimates for each conservation cover weighted by the relative extent to which it has been planted on a state's enrolled land. For water erosion and nutrient loss, results are reported for both field and buffer practices with the weights of each based on their respective acreages.[14]

For reporting purposes, state averages are then scaled up to the agricultural production region and national levels.[15] Estimates are expressed in both per-acre and absolute (pounds or tons) terms. For the latter, one set of estimates takes into account only the spatial extent of assessed soils. Another set assumes that the assessed soils are representative of the total spatial extent of CRP enrollment, including the 16 states not reflected in the soil series modeled.

Results

Water and air quality impacts in terms of soil, nitrogen, and phosphorus losses in a 10-year CRP-enrollment scenario are compared to the impacts of agricultural production that would otherwise occur. The impacts of field and buffer practices on water quality are considered separately. Finally, the amount of carbon sequestered in the two scenarios is reported.

Water Quality

Water quality is affected by soil and nutrients transported off the field in water. Both field and buffer practices affect these processes.

Field Practices

Across all assessed soil types, the amount of soil moving off the field in runoff is 99 percent lower for CRP conservation cover than for crop production that might otherwise occur (the mix of rotations and tillage practices reflective of current market conditions). Averaging 2.1 tons/acre nationally and 6.5 tones/acre for states adjoining and east of the Mississippi river, 29 million fewer tons of soil leave the field annually as water erosion on the soils modeled (Table 4). Extrapolating to

Table 4. Estimated average annual effect of CRP field practices on soil and nutrients leaving field and carbon sequestered on field

	Per acre	Sample total (millions)	Extrapolation (millions)
Water quality			
Water erosion (tons)	-2.13	-29	-71
Nitrogen loss (lbs)	-7.73	-113	-259
Attached to sediment	-4.21	-57	-141
Dissolved in runoff	-1.29	-17	-43
Dissolved in subsurface flow	-0.67	-11	-22
Leached	-1.57	-28	-53
Phosphorus loss (lbs)	-1.67	-23	-56
Attached to sediment	-1.17	-16	-39
Dissolved in runoff	-0.59	-8	-20
Leached	0.10	1	3
Air quality			
Wind erosion (tons)	-9.99	-213	-335
Nitrogen loss (lbs)	-17.89	-381	-600
Phosphorus loss (lbs)	-4.70	-107	-157
Total organic carbon (tons)	0..67	12	23

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[14] Buffer acreages used in the state-level reporting include CP 13, 21, and 22. See the Appendix for a partial list of conservation practices.

[15] Additional summary tables and maps were created, but are too extensive to include in this report. These tables and maps will be made available on the FSA CRP website.

all CRP field-practice land, we estimate an annual national impact of 71 million fewer tons. While the largest per acre effects are observed in the Delta, Appalachia, and the Northeast, the percentage difference relative to the crop production scenario is considerable across all regions (Figure 13).

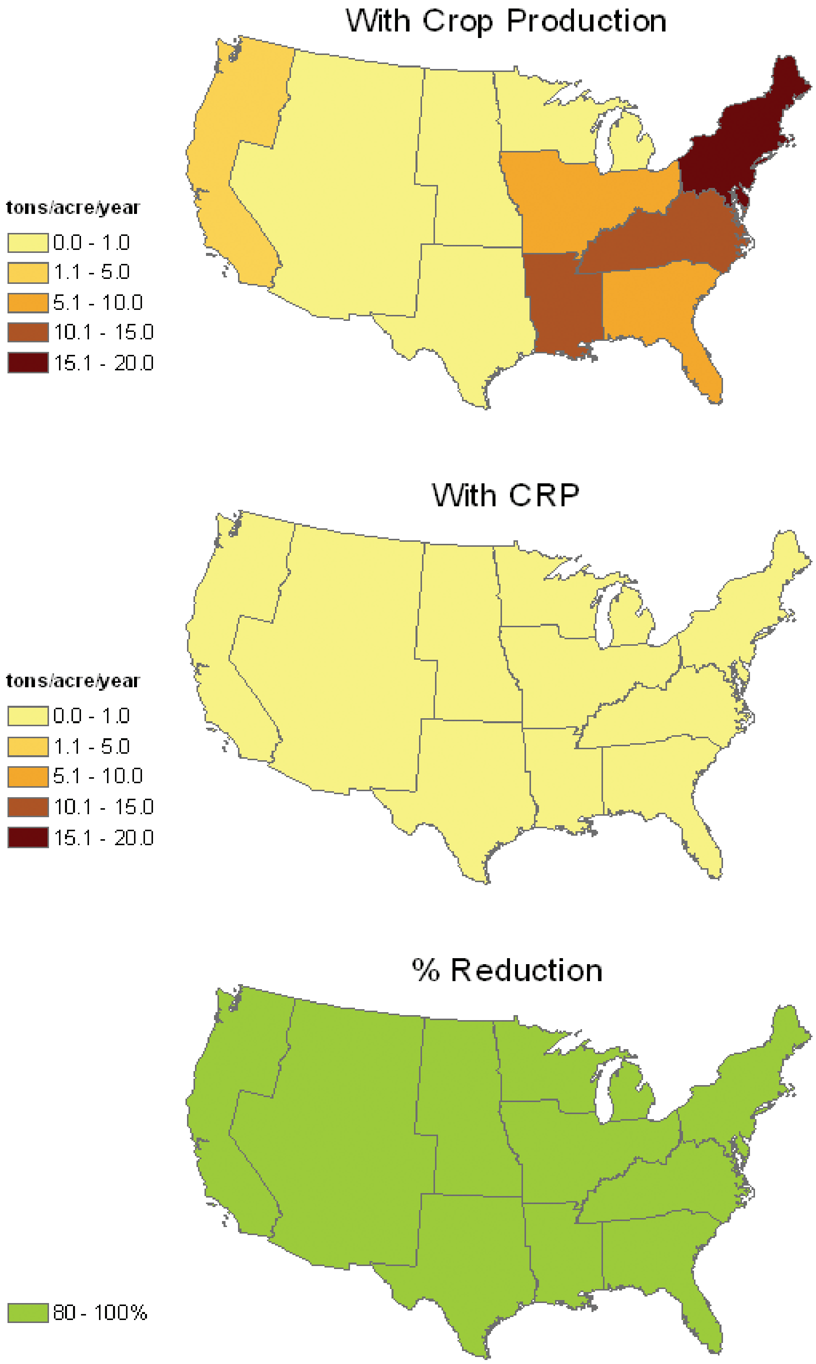

Figure 13. Effect of CRP field practices: water erosion at edge of field

Not only are losses of nitrogen attached to sediment dramatically lower in the CRP scenario than in the without-CRP scenario, so, too, is the amount of dissolved nitrogen moving off the field in runoff and percolate. Overall, nitrogen losses are 95 percent lower for CRP conservation cover compared to the without-CRP scenario, with nitrogen attached to sediment accounting for nearly half of this impact. Averaging 7.7 pounds/acre nationally and 20.7 pounds/acre for eastern states, 113 million fewer pounds of nitrogen leave the field annually in water erosion (Table 4). Extrapolating to all CRP field-practice land, we estimate a national impact of 259 million fewer pounds. The largest per acre effects are observed in the Delta, Appalachia, and the Northeast regions, and the percentage difference is considerable across all regions (Figure 14).

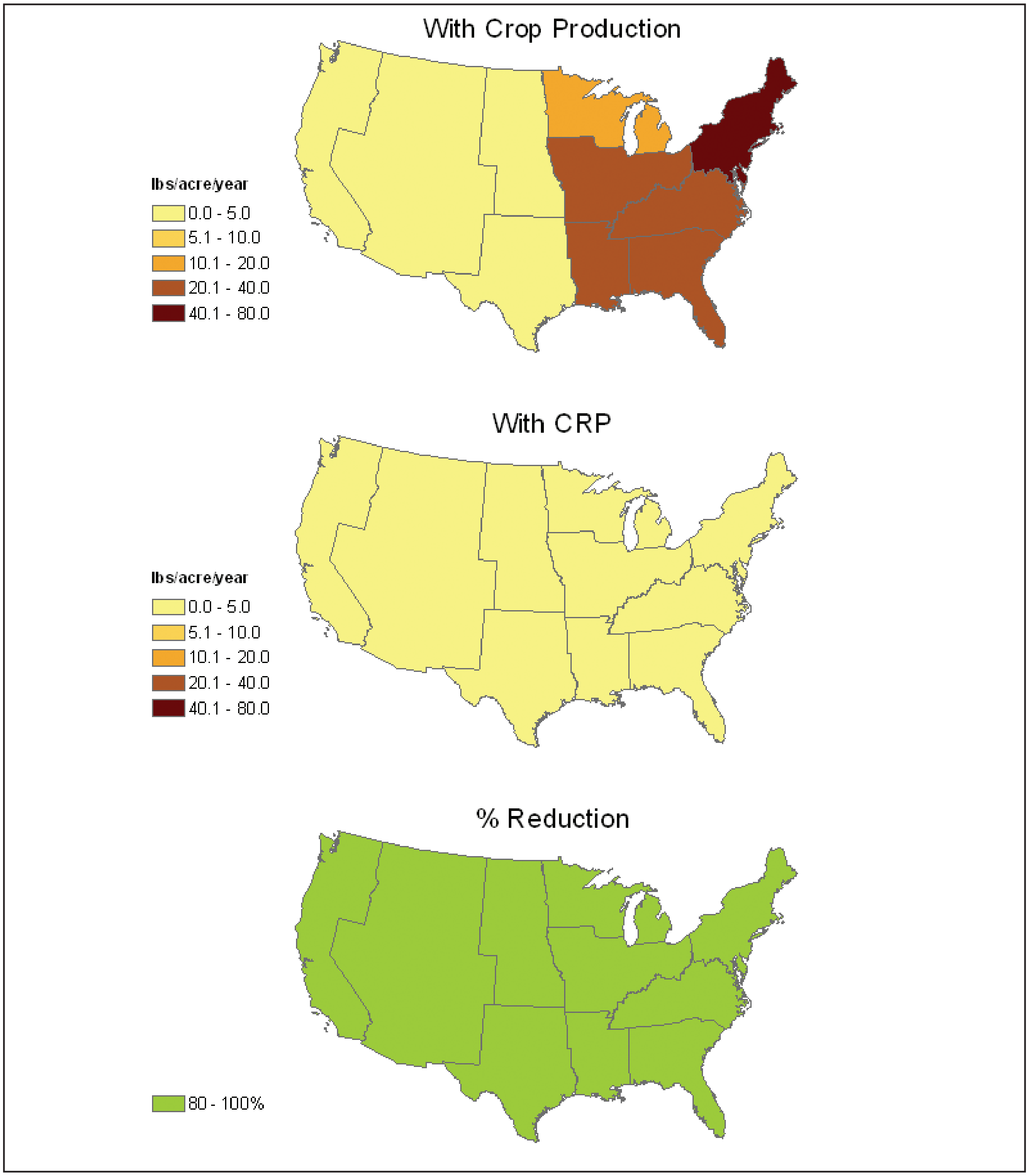

Figure 14. Effect of CRP field practices: Nitrogen loss off field in water

The effect on phosphorus of field practices is similar: Across all assessed soil types, the amount of phosphorus moving off the field in runoff and percolate is 86 percent lower for CRP conservation cover compared to the without-CRP scenario, with phosphorus attached to sediment accounting for nearly three-quarters of this impact. Averaging 1.7 pounds/acre nationally and 5.4 pounds/acre for eastern states, 23 million fewer pounds of phosphorus leave the field annually in water erosion (Table 4). Extrapolating to all CRP field-practice land, we estimate a national impact of 56 million fewer pounds. The largest per acre effects are observed in the Delta, Appalachia, and the Northeast regions, and the percentage difference is considerable across all regions, although noticeably less for the Great Lakes region (Figure 15).

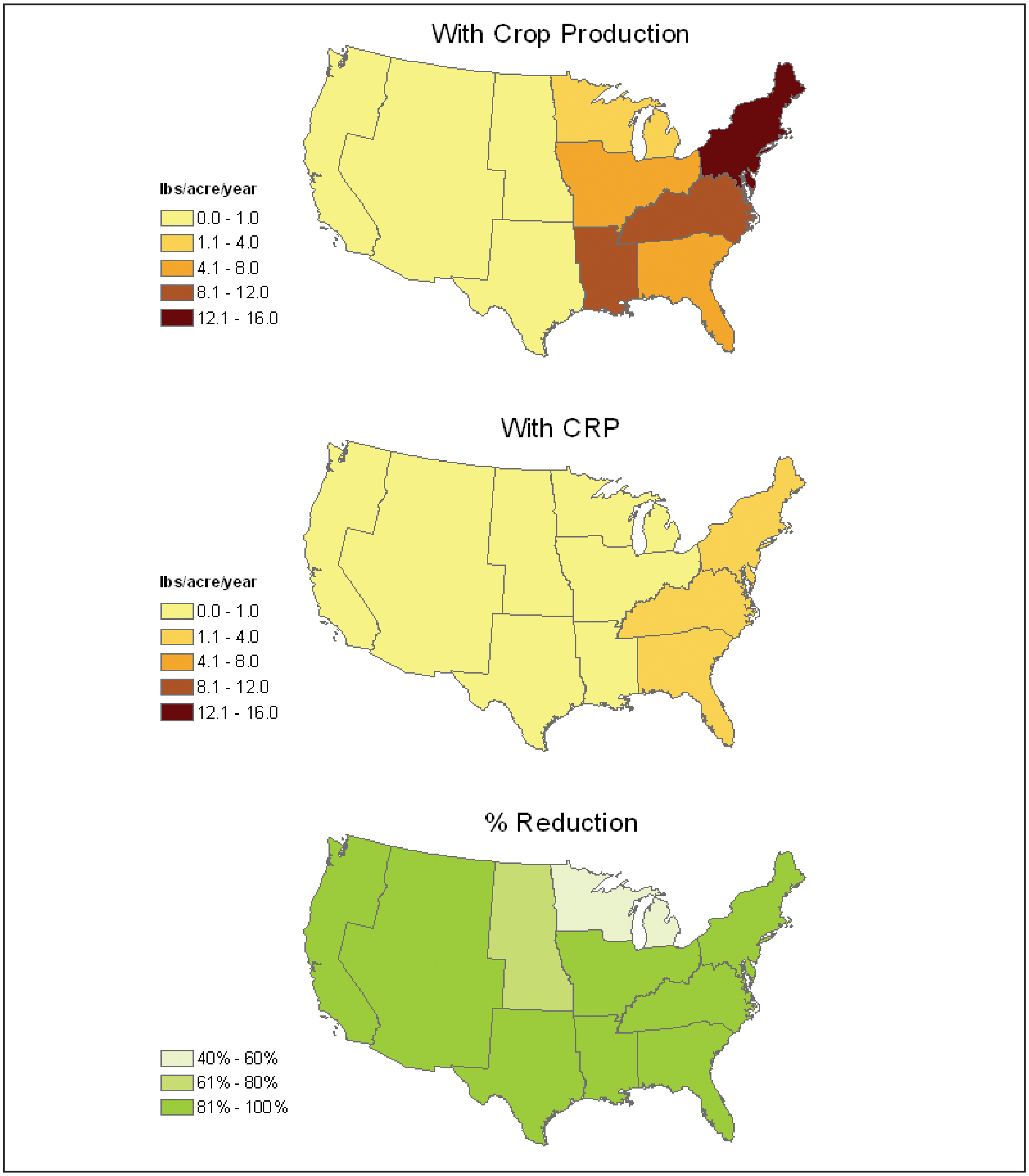

Figure 15. Effect of CRP field practices: Phosphorus loss off field in water

Buffer Practices

CRP also filters sediment and nutrients that flow across established buffer covers, trapping soil and nutrients that enter from adjoining fields before they reach waterways. Because buffers are situated and designed to intercept runoff from other fields in the watershed, an acre of buffer has a greater impact than an acre of CRP field.[16] The buffer estimates are a more direct indicator of water quality benefits than the field estimates. Because buffers are strategically located to intercept soil and nutrients before they reach surface waters, any soil and nutrients not trapped by the buffer are likely loaded into the waterbody.

Nearly 96.0 tons of waterborne soil are trapped by each acre of buffer, or 2.5 tons of soil per acre of field the CRP practice is intended to buffer (Table 5). These alternative ways of looking at the effect of buffers should bracket the estimated impact of field practices. That they are both higher than our estimated 1.6 tons/acre field-practice effect on water erosion is because buffer estimates assume conventional tillage only, rather than the current mix of conventional and conservation tillage. As Figure 16 shows, the effect per acre of buffered field is highest in the Delta and Appalachia regions.

Table 5 shows that 247.2 pounds of nitrogen are trapped by each acre of buffer, or 6.4 pounds per acre of field the CRP practice is intended to buffer (versus a 6.2 pounds per acre reduction due to field practices). As Figure 16 shows, Great Lakes and Northeast regions realize the largest effect per acre of buffered field.

Nearly 41.2 pounds of phosphorus are also trapped by each acre of buffer, which translates to 1.1 pounds per acre of the affected watershed (field practices reduce losses by 1.3 pounds per acre on average). The Delta and Appalachia regions realize the largest effect per acre of buffered field.

For the states adjoining and east of the Mississippi River where buffer enrollments predominate, the 3.1 tones, 8.1 pounds, and 1.4 poinds of soil, nitrogen, and phosphorus are being trapped per acre of buffered field.

Table 5. Estimated average annual effect of CRP buffer practices

	Reductions per acre of buffer	Reductions per acre of field affected by buffer
Water erosion (tons)	96.03	2.48
Nitrogen loss in water (lbs)	247.15	6.38
Phosphorus loss in water (lbs)	41.55	1.07

Note: Reductions per acre of buffer are strongly related to the size of watershed filtered by the buffer.

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[16] To the extent that CRP land is between cropland and waterways this buffering effect occurs on all practices; however, modeling this effect was beyond the scope of this study.

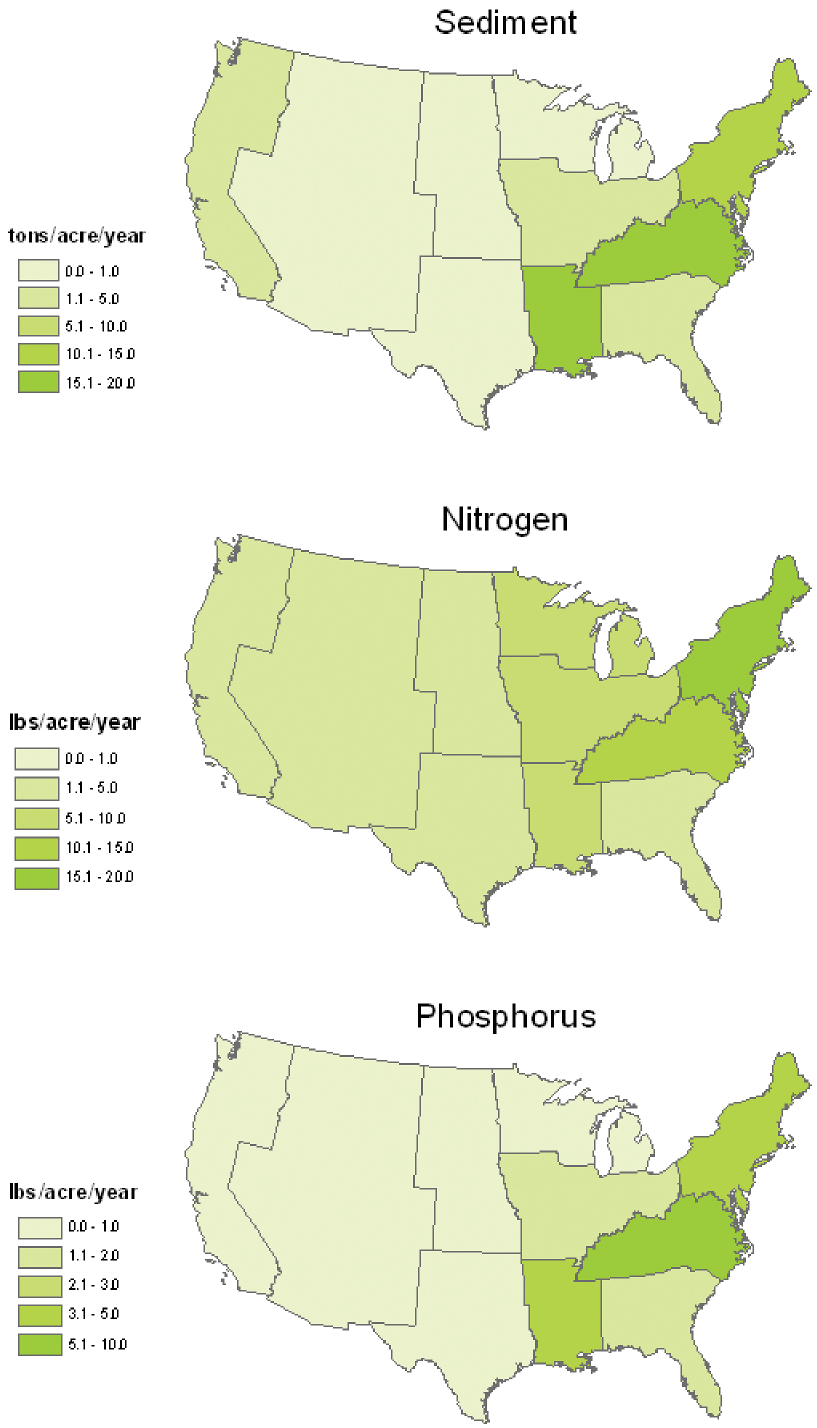

Figure 16. Effect of CRP buffer practices: The amount of sediment and nutrients trapped from each acre of buffered watershed

Air Quality

Air quality is affected by particulates carried off the field by wind. CRP conservation cover effectively eliminates wind erosion across all assessed soil types. With reductions averaging 10.0 tons/acre nationally and 13.1 tones/acre for Pacific, Mountain, and Plains states, 213 million fewer tons of soil leave the field annually as wind erosion (Table 4). Extrapolating to all CRP field-practice land, we estimate a national impact of 335 million fewer tons. The largest per acre effects are observed in the Southern Plains and the percentage difference is considerable across all regions with wind erosion (Figure 17).

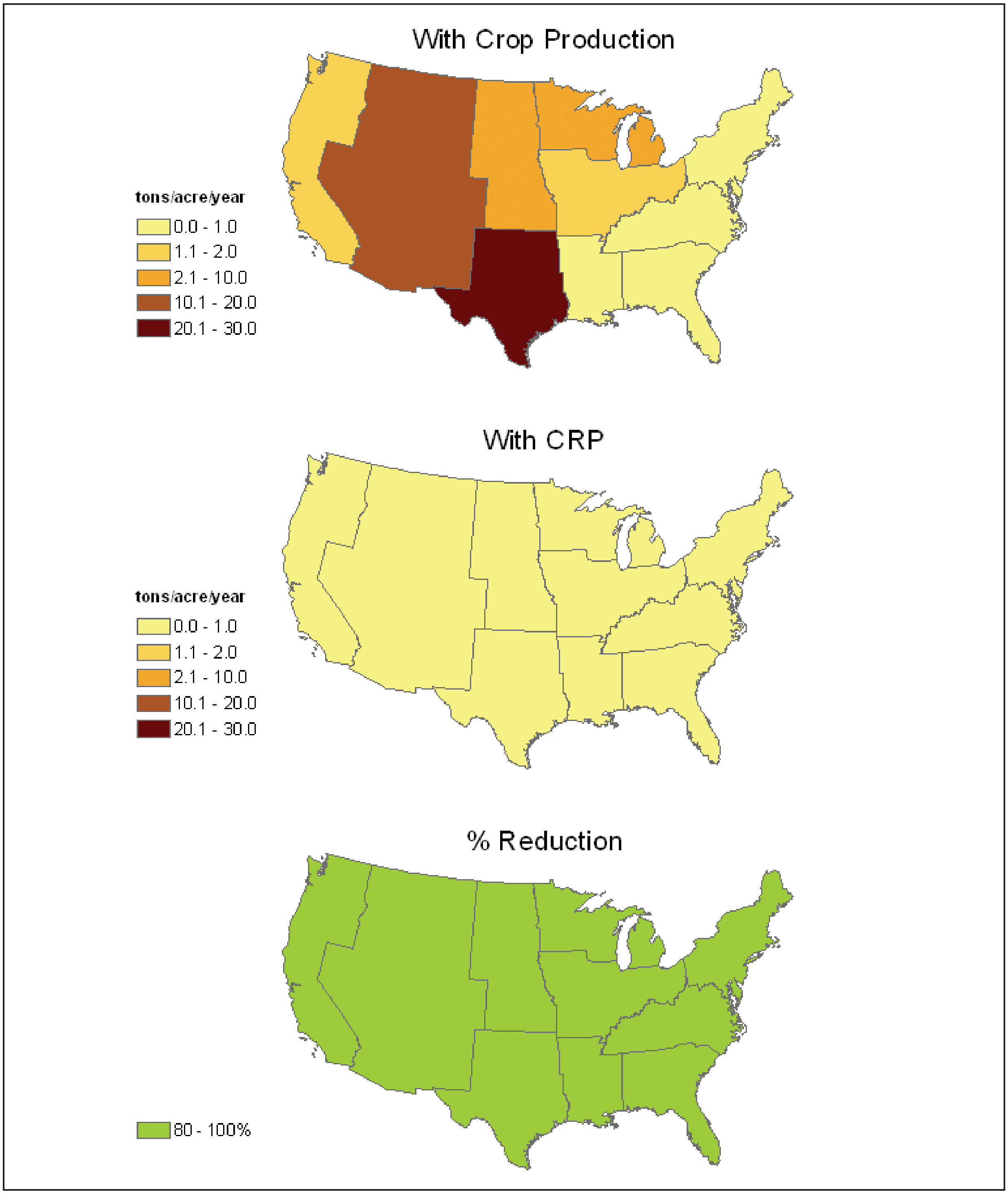

Figure 17. Effect of CRP practices: wind erosion at edge of field

Because nutrients are attached to wind-borne soil particles, the effect of CRP conservation cover on them is nearly identical to that on wind erosion. Averaging 17.9 pounds/acre nationally and 21.7 pounds/acre for western states, 381 million fewer pounds of nitrogen are borne off the field by wind (Table 4). Extrapolating to all CRP field-practice land, we estimate a national impact of 600 million fewer pounds. The largest per acre effects are observed in the Southern Plains and Great Lakes regions, and the percentage difference is considerable across all regions (Figure 18).

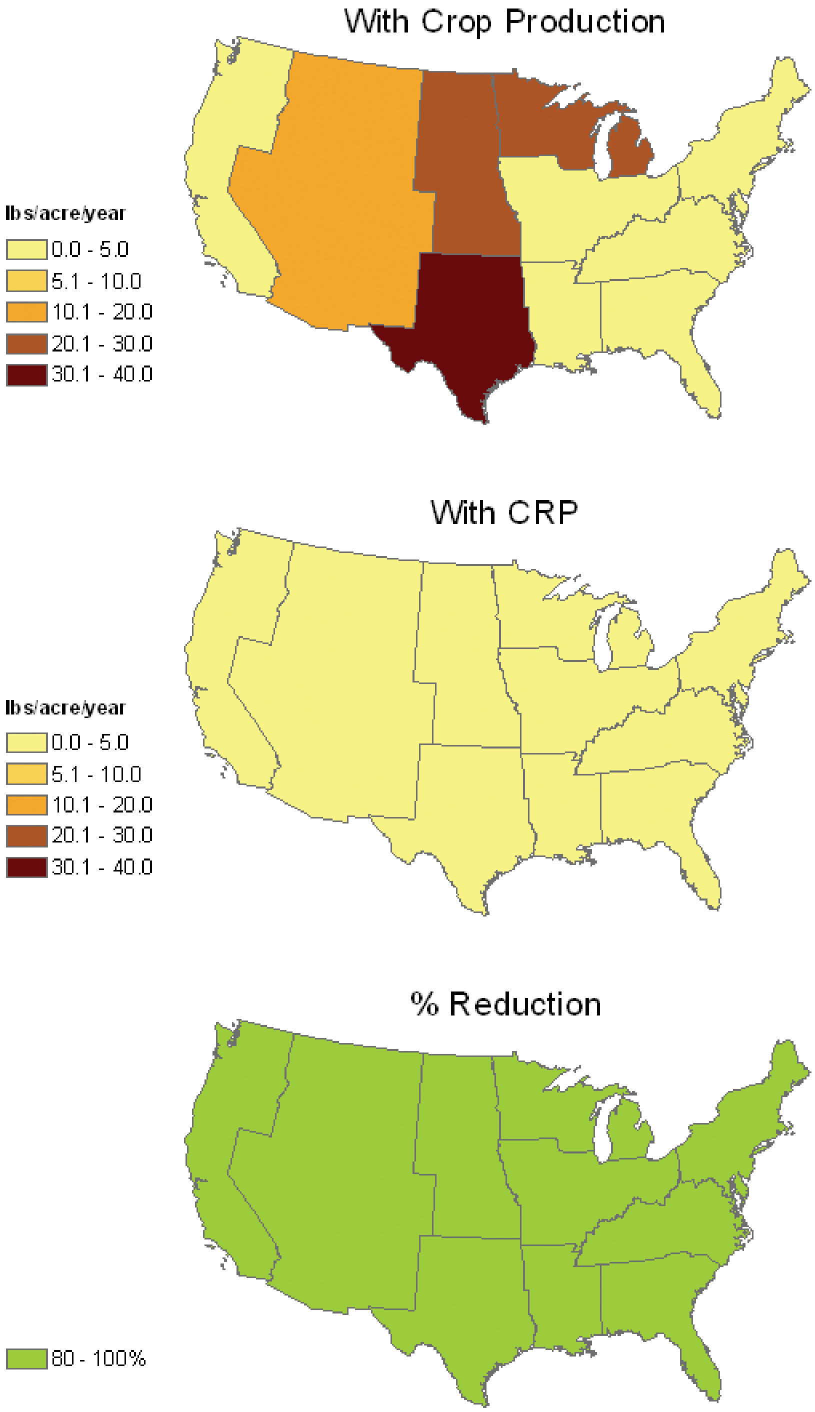

Figure 18. Effect of CRP practices: Nitrogen loss off field via wind

Averaging 4.7 pounds/acre nationally and 6.0 pounds/acre for western states, 107 million fewer pounds of phosphorus are borne off the field by wind (Table 4). Extrapolating to all CRP field-practice land, we estimate a national impact of 157 million fewer pounds. The largest per acre effects are observed in the Southern Plains and the percentage difference is considerable across all regions (Figure 19).

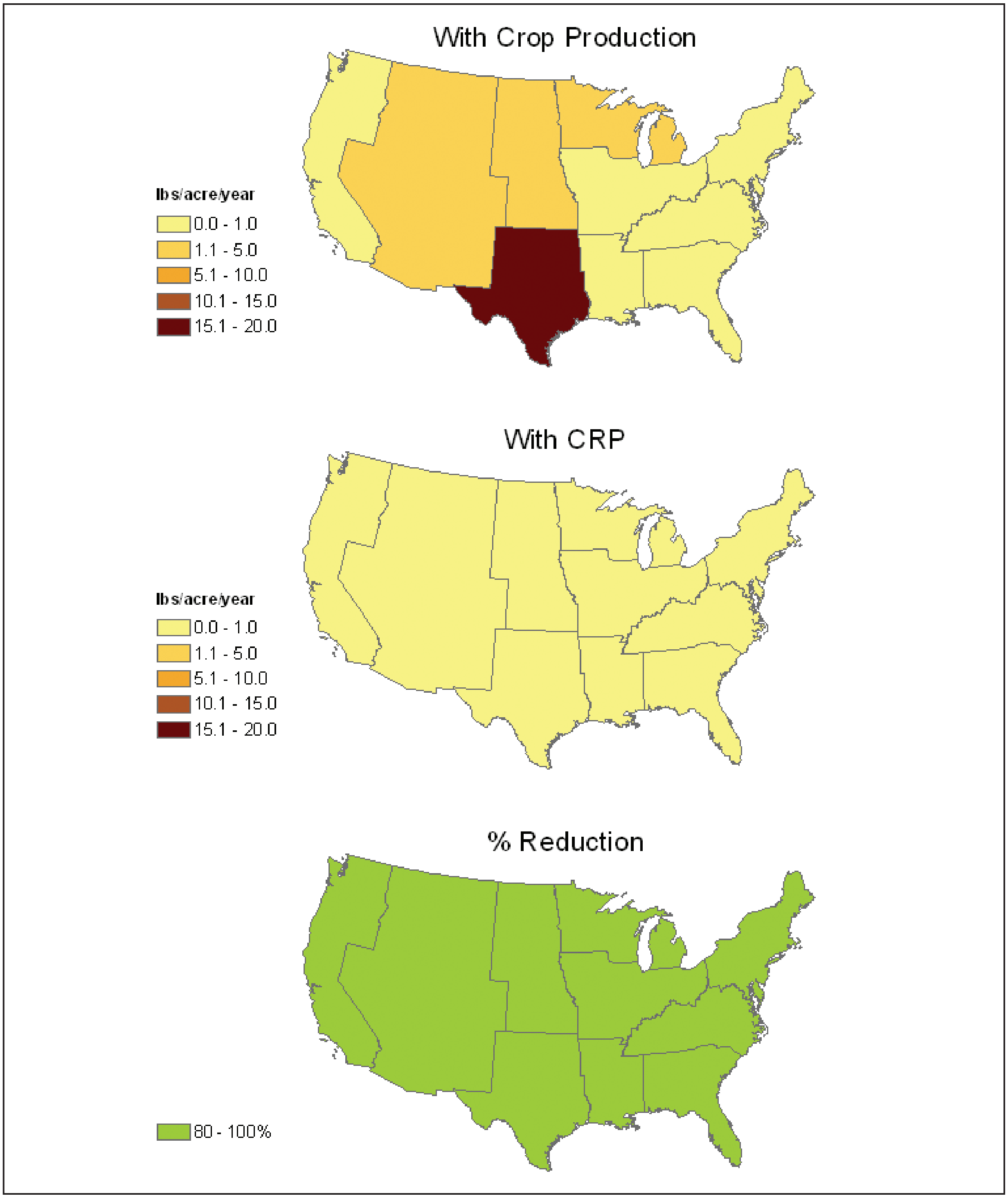

Figure 19. Effect of CRP practices: phosphorus loss off field via wind

Carbon Sequestration

CRP has a profound impact on organic carbon levels in a field. Across all assessed soil types and over a 10-year period after initial conditions (see above) in the without-CRP scenario, the amount of organic carbon contained in soil, as well as in live vegetation and standing crop residue, is estimated to fall 6 percent. In contrast, carbon levels increase 7 percent over 10 years in the CRP scenario. As shown on Table 4, this effect amounts to an annual average of 12 million tons (44 million tons of CO_2 equivalent) or 0.7 tons/acre more carbon sequestered. Extrapolating to all CRP field-practice land, we estimate a national impact of an additional 23 million tons (84 million tons of CO_2 equivalent) per year. The greatest effect is observed in the Delta and Southeastern States (Figure 20).

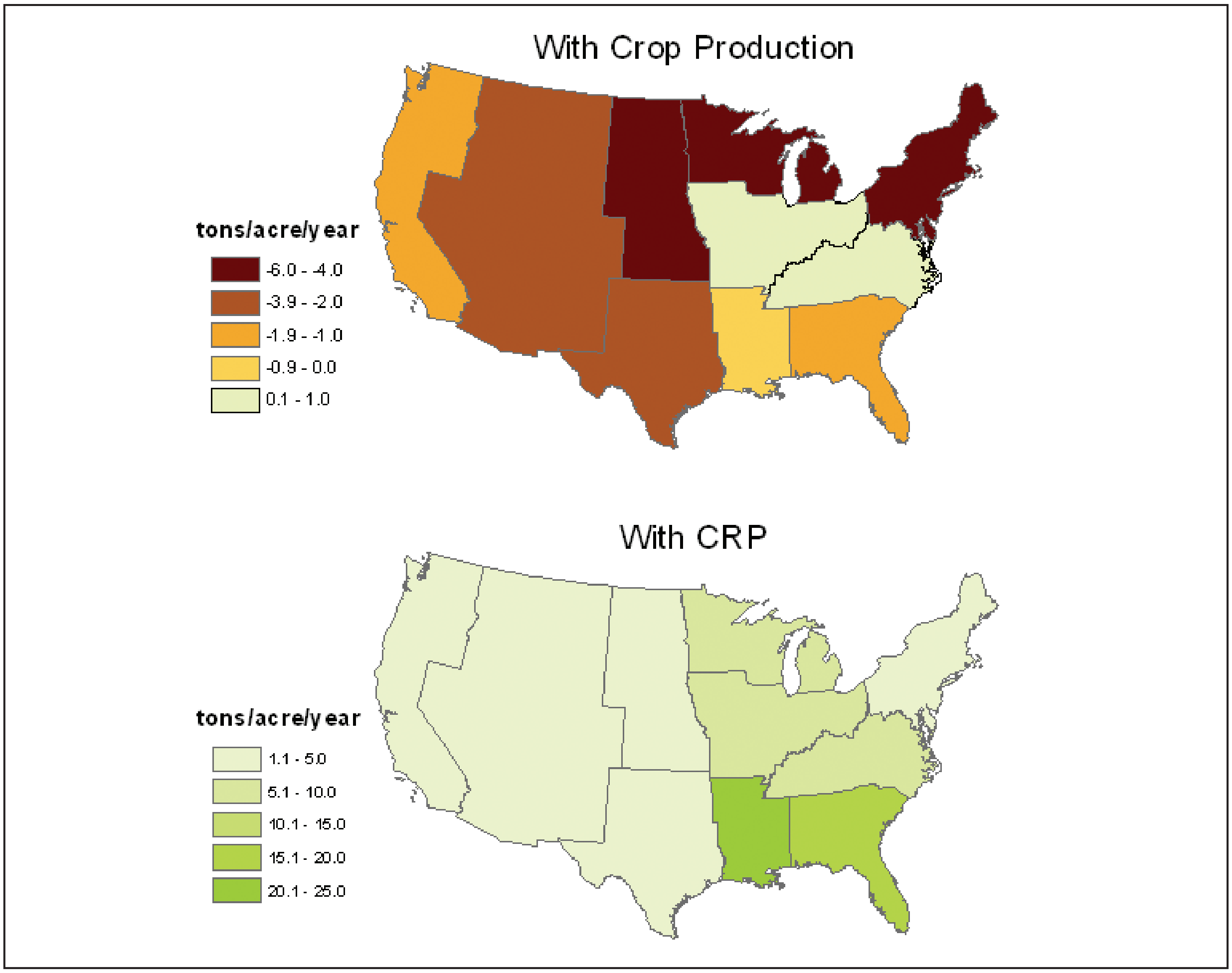

Figure 20. Effect of CRP practices: Change in carbon stored

Discussion

We now provide some useful context for the results. First, we compare our estimates to NRI estimates, as the latter are the basis for many CRP benefits studies to date. Second, we discuss some caveats to the results and point out where work to address them is proceeding. Third, we take a step back to explain in more detail the connection between CRP and the benefits it generates, water quality benefits in particular.

Comparison

For each agricultural production region, Table 6 compares MUSLE and USLE estimates from our model to USLE estimates reported in the NRI. The differences among them are both reasonable and understandable. The MUSLE estimates have been the focus of this study because they deal with what is leaving the field and can be expected to differ from USLE estimates. The processes at the field level differ sufficiently and in enough ways from the experimental plot level (to which USLE relates) that the magnitude and direction of difference between MUSLE and USLE estimates is an empirical question. Because, for some soils, MUSLE estimates will reflect larger scale erosion processes (e.g., ephemeral gully formation) than USLE estimates do, the former can exceed the latter. Conversely, MUSLE estimates can be lower than USLE estimates for other soils because residence time of water is longer for the larger observational unit, allowing soil and nutrients to be deposited back on the field rather than exit it.

Even differences between the two sets of USLE estimates are unsurprising: NRI estimates are based on several hundred thousand average annual observations. However, the greater spatial resolution is at the expense of temporal precision: the annual time step used cannot account for sensitivity of estimates to weather events, nor the responsiveness of day-to-day management decisions to these events. In contrast, our simulations both assume that 363 soil-type observations are sufficiently reflective of local conditions across the United States, and proceed at a daily time step, with the modeled results from each day feeding into the next.

Additionally, whereas our estimates of CRP effects are relative to a without-CRP baseline, the NRI estimates are relative to a before-CRP baseline. In light of the agricultural sector's transformation over the past few decades (the switch from wheat to soybean cultivation by many farmers, the widespread adoption of conservation tillage, etc.), these baselines are markedly different. Similarly, the NRI relates to the 1997 CRP, whereas this study models the somewhat different fields of the 2003 CRP.

Comparisons between earlier estimates of nutrient loss reductions—such as the 681,000 ton reduction in nitrogen fertilizer usage reported by FSA (USDA FSA 2003b, 2004)—and this study share the qualifications expressed, above.

Table 6. Comparison of estimates of CRP impact on water erosion by region (tons/acre/year)

USDA production region	NRI estimates USLE	FAPRI estimates USLE	FAPRI estimates MUSLE
Appalachia	-16.73	-11.31	-10.82
Corn Belt	-16.26	-10.12	-6.27
Delta	-13.94	-12.29	-13.59
Great Lake	-5.36	-1.47	-0.77
Mountain	-3.43	-1.98	-0.23
Northeast	-7.46	-18.42	-16.05
Northern Plains	-4.16	-5.49	-0.59
Pacific	-6.46	-4.75	-1.42
Southeast	-8.40	-6.63	-6.62
Southern Plains	-2.26	-2.71	-0.19

NRI estimates are relative to pre-CRP conditions (USDA SCS 2000). FAPRI estimates are relative to current, without-CRP conditions.

Caveats

The 363 soils assessed were selected to cover the largest area, not necessarily to be representative of the full CRP. Accordingly, state, regional, and national estimates may be biased toward what is occurring on soils of a large spatial extent. These tend to be in the Western Great Plains, where soils can have extensive coverage. Because this region is relatively dry, estimates may be biased upward for wind erosion and downward for water erosion as well as nutrient loss. An effort is currently underway to generate a more representative national estimate by explicitly linking modeled soils to the remaining CRP soils. The crosswalk uses key soil characteristics and is being conducted by FSA with guidance by FAPRI: draft results are expected spring 2007.

Second, for each soil, we can only speculate on how much of each rotation would be planted or the degree to which a particular tillage technique would be used absent the CRP. We use state-level data regarding current crop production patterns to construct the necessary weights.

Third, the estimated impact of buffers on nutrient trapping are best viewed as an upper bound because the model does not account for the potential for tile drains to be functioning on a buffered watershed, transporting dissolved nutrients past the buffer and into receiving surface waters.

Fourth, even using the indicators presented in this study, identifying where the greatest benefits accrue is not straightforward. Benefits will relate the degree to which soil and nutrient losses change in both absolute and relative terms. Because the without-CRP scenario differs by location, where the greatest absolute and relative effects of the CRP occur differs as well. In the context of erosion, for example, modest tons-per-acre reductions may generate significant benefits where soil surface layers are already extremely thin, such as the Southeastern Piedmont.

The magnitude of benefits is also highly dependent upon the off-site context. Our benefit indicators differ from true benefit measures because they do not reflect how sensitive receiving waterbodies are to stress and how valuable these waterbodies were before being degraded.

Fifth, in light of the focus on the CRP's benefits, the scope of the study and its output is limited to land enrolled in the CRP in September 2003. Because non-CRP land is not examined, this study does not address whether the CRP's impact is disproportionate to the amount of land it occupies (10 percent of what had been cropland), as one would hope to be the case.

Connection

CRP generates substantial conservation benefits both on and off site. On-site benefits accrue from enhanced potential agricultural productivity, reduced input costs, and increased wildlife habitat.[17] The well-being from the latter can be experienced directly by the producer or by those who compensate the producer for an experience (e.g., renting the land for hunting use).

Off-site benefits accrue from improved water quality as sedimentation and nutrient enrichment of waterways is kept in check. The recently conducted Wadeable Streams Assessment found that only 28 percent of U.S. stream miles are in good condition (EPA 2006). With industrial point sources already regulated (although compliance is not assured), enrolling marginal lands in the CRP could have a major influence on water quality.

Wildlife habitat provision also leads to off-site benefits as migratory or wide-ranging species are affected (e.g., wetlands restoration and waterfowl), as does controlling wind-blown dust

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[17] A concern for agricultural productivity may seem irrelevant to a program that takes land out of production. However, CRP lands may eventually return to crop production as alternative production methods are developed. For example, no-till has enabled sustainable production on millions of acres of erodible croplands. Also, CRP does allow for harvesting of conservation covers in limited circumstances.

and sequestering carbon in soil and vegetation lead to off-site benefits.[18]

Significant conservation benefits occur when soil and nutrients remain on a field rather than being transported to nearby surface waters via runoff and wind (i.e., deposition).[19] Excessive sediment and nutrients in lakes, streams, and estuaries can overwhelm them, reducing their capacity to provide the ecosystem services (e.g., recreational fisheries and nutrient cycling) that, in turn, provide wellbeing (e.g., better angling and enhanced aesthetics). Specifically, agricultural practices can lead to sedimentation and eutrophication.

- Sheet and rill erosion ultimately deposit soil in surface waters, which leads to increased turbidity (suspended solids) and eventually sedimentation. Turbidity impedes the growth of submerged aquatic vegetation, which has corresponding effects across the food web. Sedimentation kills benthic invertebrates (e.g., mayfly larvae) and hampers fish reproduction.
- Nitrogen and phosphorus fertilize surface waters in much the same way as they do cropland. However, increasing productivity in aquatic ecosystems is not always a good thing. The nutrient enrichment of surface waters in a watershed can result in algal blooms. When the algae die, the decomposition process uses up the dissolved oxygen that aquatic species require for survival. Phosphorus is especially relevant for freshwaters as productivity in these ecosystems tends to be limited and, thus, greatly affected by this nutrient. Marine ecosystems, on the other hand, tend to be nitrogen limited.

Ideally, the benefits would be quantified in terms of the changes in the ecosystem services affected (e.g., increase in fish stocks or the improvement in the scenic quality of the waterbody), or even monetized. This is no easy task: a sequence of complex analytical steps is required to shift emphasis from the fields enrolled to where the benefits manifest offsite. Figure 21 shows the

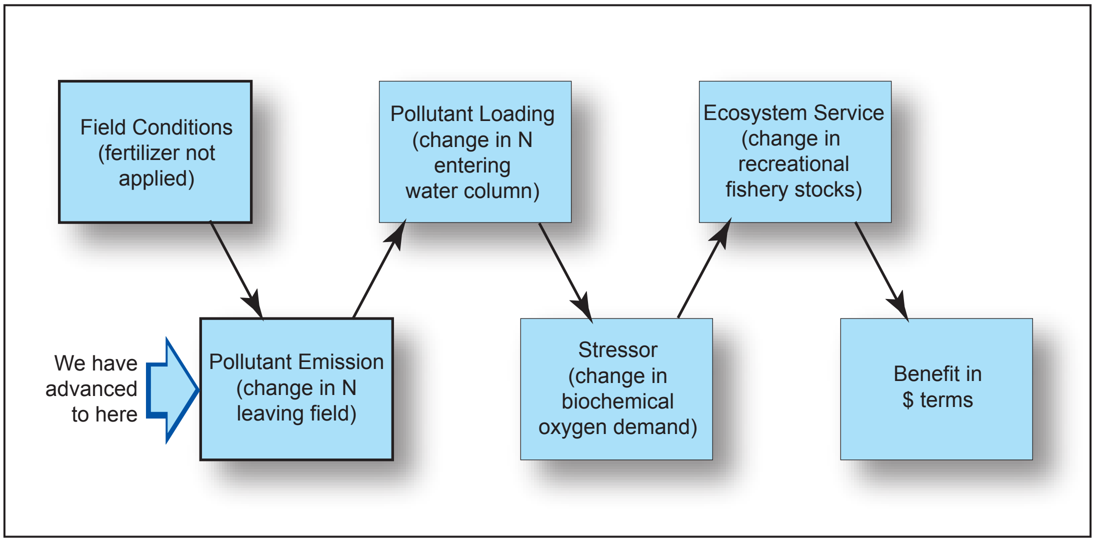

Figure 21. Conservation benefits assessment process

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[18] The former reduces health risks. The latter is an off-site benefit because carbon in soil or biomass is carbon that does not enter the atmosphere and contribute to climate change.

[19] A related benefit is the effect of CRP practices on the speed of water running off fields, which reduces stream flashing.

series of necessary steps in a complete benefits assessment process, with nitrogen loss offered as an example. Because of the context dependence of benefits, proceeding all the way to the right-hand side of the figure for all relevant benefits across the entire nation may be effectively impossible.

Conclusion

Comprehensively and accurately assessing benefits both highlights program accomplishments and helps identify ways in which the program can be made more cost effective; e.g., improved targeting of cropland in the greatest need of conservation covers.

This study increases our knowledge of CRP benefits by quantifying the differences that occur in movement of sediment and nutrients off the field under CRP and crop production. Rather than risk providing a false sense of precision by claiming to measure or even monetize benefits, this study instead develops improved indicators of many of the important benefits. Because they are a more accurate reflection of nutrient and sediment loadings that can adversely impact water quality, these estimates tell a more cogent story than indicators such as acres enrolled, fertilizer not applied, or erosion on the field. In terms of Figure 21, this report describes a significant step beyond the leftmost box.

Our estimates confirm that enrollment of marginal cropland in CRP virtually eliminates soil and nutrient loss and increases the amount of organic soils on fields. On average across the nation, we find that soil, nitrogen, and phosphorus losses (water and wind combined) are 12.1 tons, 25.6 pounds, and 6.4 pounds, respectively, per acre lower than what they might otherwise be. Conversely, in an acre of field, total organic carbon increases by 0.7 tons annually.

The impact of buffer practices on croplands is also considerable: 2.5 tons of soil, 6.4 pounds of nitrogen, and 1.1 pounds of phosphorus in runoff from buffered cropland are being held back from surface waters by these practices.

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Appendix

Glossary of conservation practices

CP1	new introduced grasses and legumes
CP2	new native grasses
CP3	new softwood trees (not longleaf)
CP3A	new longleaf pines
CP4	permanent wildlife habitat
CP5	field windbreaks
CP6	diversions
CP7	erosion control structures
CP8	grass waterways
CP9	shallow water areas for wildlife
CP10	existing grasses and legumes
CP11	existing trees
CP12	wildlife food plots
CP13	vegetative filter strips
CP15	contour grass strips
CP16	shelterbelts
CP17	living snow fences
CP18	salinity reducing vegetation
CP19	alley cropping
CP20	alternative perennials
CP21	filter strips (grass)
CP22	riparian buffers
CP23	wetland restoration
CP24	cross wind trap strips
CP25	rare and declining habitat
CP26	sediment retention
CP27	farmable wetland pilot (wetland)
CP28	farmable wetland pilot (upland)
CP29	wildlife habitat buffer (marg past)
CP30	wetland buffer (marg past)
CP31	bottomland hardwood
CP33	habitat buffers for upland birds

Table A.1. Input parameters used in EPIC

Parameter Name	Description	Value	Units	Data Source
Run Parameters EPICRUN.DAT				
ASTN	Run Name/number		1 to 1724	Model design
ISIT	Site Number		1 to 364	Model design
IPW1	Weather Station		1 to 35	Centroid station in each state or partial state
IPW5	Weather Station		N/A	Centroid station in each state
IWND	Wind Station		1 to35	Centroid station in each state
INPS	Soil #		1 to 364	Several soils per state
IOPS	Manage File #		1 to 1700	
Data Parameters EPICFILE.DAT				
FSITE	Site list and number file	SITE3060.DAT	1 to 364	Specific to this project
FWPM1	Weather data file	WPM1FSAC.DAT	1 to 35	Specific to this project
FWPM5	Multi-weather file option	WPM53050.DAT	N/A	N/A
FWIND	Wind data file	WINDFSAC.DAT	1 to 35	Specific to this project
FWIDX	Multi-weather file option	WIDX3050.DAT	N/A	N/A
FCROP	Crop parameters file	CROPCMNA.DAT	1 to 141	EPIC crop file, new trees and weeds, expert judgment
FTILL	Field operations file	TILLCMN.DAT	1 to 649	EPIC tillage file, NRCS database, expert judgment
FPEST	Pesticides characteristics file	PESTCOM.DAT	1 to 272	EPIC pesticide file, NRCS database, expert judgment
FFERT	Fertilizer characteristics file	FERTCOM.DAT	1 to 68	EPIC fertilizer file, NRCS database, expert judgment
FSOIL	Soil list file	SOIL306V.DAT	1 to 364	Built from CRP data, and Dr. Baumer's database
FOPSC	List of operation schedules file	OPSCFSAR.DAT	1 to 1700	Specific to this project
FTR55	Data for runoff	TR55COM.DAT	N/A	Standard Epic file
FPARM	Miscellaneous parameters file	PARM3060.DAT	N/A	Parameters set by expert judgment
FMLRN	Multiple erosion factor run file	MLRN3060.DAT	N/A	Option not used
FPRNT	Output option control file	PRNT3060.DAT	N/A	Options selected by FSA and ORACBA
FCMOD	Price changes file	CMOD3060.DAT	N/A	Option not used
FPMV	New file for sensitivity analyses	PMUN3060.DAT	N/A	New option-not used
Control Parameters EPICCONT.DAT				
NBYR	Number of years of simulation	10	years	Expert judgment
IYRO	Beginning year of simulation	1	years	Expert judgment
IMO	Month simulation begins	January	month	Expert judgment
IDA	Day of month simulation begins	1	day	Expert judgment
IPD	Output interval and type	13 (annually-monthly tables)	N/A	Expert judgment

Parameter Name	Description	Value	Units	Data Source
NGN	Daily weather input	Variables input	N/A	Expert judgment
IGN	Number of times each random number cycles before simulation starts	0	N/A	Expert judgment
IGSO	Real time weather simulation	0	N/A	Expert judgment
LPYR	Leap year or not	0-Yes	N/A	Expert judgment
IET	Potential evaporation/ transpiration method - Hargreaves	4	N/A	Expert judgment
ISCN	Stochastic curve	0-On	N/A	Expert judgment
ITYP	EQ peak rate estimate	0 – Modified rational	N/A	Expert judgment
ISTA	Erosion of soil profile calculations	0-Normal	N/A	Expert judgment
IHUS	Heat units established from month and day input schedule	0-Manually heat unit scheduled	N/A	Expert judgment
NCOW	Number of cows	0	Number	Expert judgment
NVCN	Curve Number generation	4-Variable CN based on soil moisture index	N/A	Expert judgment
INFL	Discharge (Q) estimation method	0-Curve number	N/A	Expert judgment
MASP	Mass/mass & concentration pesticide and nutrient output	0-Mass only	N/A	Expert judgment
LBP	Soluble P runoff estimation method	0-GLEAMS methodology	N/A	Expert judgment
NSTP	Real time day of year	0	Julian	Expert judgment
IGMX	Number times random generator seed initialized per site	30	Number	30 alternative sets of weather seeds used
IERT	Enrichment ratio	0-EPIC method	N/A	Expert judgment
ICG	Crop biomass conversion method	0-Radiation-biomass method	N/A	Expert judgment
LMS	Lime application automatically	0-Yes	N/A	Expert judgment
ICF	Erosion C-factor	0-RUSLE	N/A	Expert judgment
ISW	Soil field capacity wilting point estimation method	4-Rawls	N/A	Expert judgment
IRW	Weather with daily input options	0	N/A	Expert judgment
ICO2	Constant/dynamic CO2 method	0-Constant	N/A	Expert judgment
IUNS	Normal or sensitivity analysis	0-Normal	N/A	Expert judgment
NYRCLTOR	Years of cultivation over-ride	50	Years	Expert judgment

Parameter Name	Description	Value	Units	Data Source
RFNC	Average concentration of N in rainfall	0.8	ppm	Expert judgment
CNO3I	Concentration of NO3 in irrigation	0	ppm	N/A
CSLT	Concentration of salts in irrigation	750	ppm	N/A
PSTX	Pest damage scaling	1	N/A	Expert judgment
YWI	# years of record 0.5 rainfall intensity input	10	Years	N/A
BTA	Wet-dry probabilities	0	Fraction	N/A
EXPK	Exponential rainfall distribution	0	Scalar	Default
FL	Field length	0.63	Km	Expert judgment
FW	Field width	0.32	Km	Expert judgment
ANGO	Field length angle from North	0	Degrees	Expert judgment
STD	Standing dead crop residue	0	Ton/ha	Expert judgment
UXP	Wind speed exponent	0.3	Scalar	Expert judgment
DIAM	Diameter of soil particle	500	µm	Expert judgment
ACW	Wind erosion factor	1	Scalar	Expert judgment
BIR	Irrigation stress trigger	0	Fraction	Expert judgment
EFI	Irrigation runoff fraction	N/A	Fraction	Expert judgment
VIMX	Maximum annual	N/A	mm	Expert judgment
ARMN	Minimum irrigation application	N/A	mm	Expert judgment
ARMX	Maximum irrigation application	N/A	mm	Expert judgment
BFTO	Auto fertilizer trigger	0	Scalar	Expert judgment
FNP	Fertilizer application (Pick which 1 of 3)	0	Kg/ha	Expert judgment
FMX	Maximum N fertilizer application	500	Kg/ha	Expert judgment
DRT	Time required to drain	1	Days	Expert judgment
FDSO	Furrow dike factor	0.9	Fraction	Expert judgment
PEC	Conservation Practice Factor	0.6	Scalar	Expert judgment
VLGN	Lagoon volume ratio	N/A	Ratio	N/A
COWW	Lagoon input from wash water	N/A	M^3/cow/day	N/A
DDLG	Time to reduce lagoon from max to norm	N/A	Days	N/A
SOLQ	Liquid/solid manure ratio	N/A	Ratio	N/A
GZLM	Above ground grazing biomass limit	0.1	T/ha	N/A
FFED	Fraction of time herd in feeding area	0	Fraction	N/A
DRV	Water Erosion Driving Equation	3	N/A	Expert judgment

Parameter Name	Description	Value	Units	Data Source
BUS(1-4)	Option coefficients for MUSL equation	1.58,0.56,0.56,0.12	N/A	N/A
COIR	Cost of irrigation water	0	$\$/M^3$	N/A
COL	Cost of lime	0	$/ton	N/A
FULP	Cost of fuel	0	$/gallon	N/A
WAGE	Labor cost	0	$/hour	N/A
SITE-SPECIFIC	***.Sit (Only relevant parameters listed)**			
IRR	Irrigation practice factor	0	N/A	No irrigation
WSA	Watershed area	Varies by state	ha	Average size of CRP grass contract
YLAT	Latitude	Varies by state or sub-state area	Degree	Centroid weather station latitude
YLOG	Longitude	Varies by state or sub-state area	Degree	Centroid weather station longitude
ELEV	Elevation of watershed	Varies by state or sub-state area	m	Centroid weather station elevation
UPSL	Upland slope length	100	m	Expert judgment
UPS	Upland slope steepness	Varies by soil	m/m	Soil database mean & expert judgment
APM	Peak Rate	1	index	Expert judgment N/A
CHL	mainstem channel length	0	Km	Default to EPIC internal estimate
CHS	mainstem channel slope	0	m/m	Default to EPIC internal estimate
CHN	Mannings N value	0.05	Scalar	Default to EPIC internal estimate
SN	Surface N value	0.15	Scalar	Default to EPIC internal estimate
SNO	Water content of snow on ground at start of simulation	0	mm	Default to EPIC internal estimate
CHD	Channel Depth	0	m	Default to EPIC internal estimate
CO2X	CO2 concentration override for site	0	ppm	N/A
CNO3X	N concentration in irrigation water override for site	0	ppm	N/A
RFNX	Concentration of N in rainfall override for site	0	ppm	N/A
FWTH	Name of daily weather file input	N/A	File name	N/A
Field Operations	***.ops (Only relevant parameters listed)**			
LUN	Land Use Number	3, 9, 22, or 29	Line #	Curve # Lookup table by land use
XMTU (1)	Time from planting to maturity	Tree specific	Years	Expert judgment

Parameter Name	Description	Value	Units	Data Source
XMTU (2)	Time from planting to harvest	Trees specific	Potential heat units to maturity plus % drying	Expert judgment
OPV1 (1)	potential heat units for planting	Crop specific	Fraction	Five years of WAOB planting and harvest date, analyses of results, and fitting with potential heat unit program. Expert judgment
OPV1 (2)	application volume for irrigation	N/A	mm	N/A
OPV1 (3)	fertilizer application rate	Crop and soil specific by state	kg/ha	USDA Agricultural Chemical Usage 2003 Field Crops Summary indexed by soil based on simulated crop
OPV1 (4)	pest control factor for pest application	Crop specific	fraction of pests controlled	N/A
OPV2 (1)	SCS hydrologic soil group & land use runoff curve number table	Crop, soil, and management specific	SCS curve # table line number or SCS curve #	SCS curve number table & expert judgment
OPV2 (2)	pesticide application rate	Crop and management specific	kg/ha	N/A information from USDA cropping practices survey used but this input varies much with time
OPV2 (3)	application depth for fertilizer	0 to 75	mm	Expert judgment
OPV3 (1)	plant water stress factor	0-1	Fraction	N/A
OPV4 (1)	runoff	Irrigation system specific	Fraction of applied	N/A
OPV5 (1)	plant population	Crop and management specific	plants/m^2 or # trees/ Ha	Expert judgment
OPV6 (1)	max annual N fertilizer applied to a crop	Crop and management	Kg/Ha	Expert judgment
OPV7 (1)	time of operation as fraction of growing season	0 to 1.3 operation, weather station, and crop specific	Fraction	Five years of WAOB planting and harvest date, analyses of results, and fitting with potential heat unit program. Expert judgment

Table A.2. Output variables from EPIC

Output variables	Units
4 PRCP Rainfall	Inches
10 PET Potential ET	Inches
11 ET Evapotranspiration	Inches
14 Q Runoff	Inches
15 CN SCS Curve Number	Index/scalar
16 SSF Subsurface Flow	Inches
17 PRK Percolation	Inches
18 QDRN Drain Tile Flow	Inches
19 IRGA Irrigation	Inches
20 QIN In flow to shallow groundwater	Inches
C Index cover factor for erosion	Index/scalar
30 USLE Water erosion -USLE	Ton/Acre
31 MUSL Sediment leaving field-MUSLE	Ton/Acre
32 AOF Water erosion-Onstad-Foster	Ton/Acre
33 MUSS Sediment leaving field-MUSS	Ton/Acre
34 MUST Sediment leaving field-MUST	Ton/Acre
35 MUSI Sediment leaving field-MUSI	Ton/Acre
42 YW Wind erosion	Ton/Acre
43 YON N loss with sediment	Pounds/Acre
44 QNO3 NO3-N loss in runoff	Pounds/Acre
45 SSFN NO3-N loss in subsurface flow	Pounds/Acre
46 PRKN NO3-N leached	Pounds/Acre
55 QAP labile P loss in runoff	Pounds/Acre
49 DN Denitrification	Pounds/Acre
50 NFIX Nitrogen fixation	Pounds/Acre
HMN Fresh humus mineralization	Pounds/Acre
51 NITR Nitrification	Pounds/Acre
52 AVOL NH3-N volatilized	Pounds/Acre
53 DRNN Nitrogen in Drain tile flow	Pounds/Acre
54 YP P loss with sediment	Pounds/Acre
57 PRKP P leached	Pounds/Acre
59 FNO Fertilizer organic N	Pounds/Acre
60 FNO3 Fertilizer NO3-N	Pounds/Acre
61 FNH3 Fertilizer NH3-N	Pounds/Acre
62 FPO Fertilizer organic P	Pounds/Acre
63 FPL Fertilizer Labile P	Pounds/Acre
66 LIME Lime	Tons/Acre
77 YOC Organic carbon in sediment	Pounds/Acre
36 RUSL Water erosion (RUSLE)	Tons/Acre
OCPD Organic in plow depth (4-6inches)	Tons/Acre
TOC Total organic carbon in soil profile	Tons/Acre
ITOC Initial organic carbon in soil profile	Tons/Acre
STD Standing plant residue	Tons/Acre
DEC31STL Year end standing live biomass	Tons/Acre
AUG1LAI Leaf area index August 1st	Index
APBC Labile P in plow depth	Pounds/Acre
TAP Total labile P in soil profile	Pounds/Acre
TNO3 NO3-N in soil	Pounds/Acre
N-PRECIP NO3-N in rain	Pounds/Acre
N – YLD Total nitrogen in harvested crop	Pounds/Acre
P – YLD Total phosphorus in harvested crop	Pounds/Acre

Table A.3. EPIC and APEX soil characteristics

Soil Charactistics	Normal value range	Unit of measure	Source
soil albedo	0.01 to 0.2 soil specific	Fraction	Soil data base and expert judgment
soil hydrologic group	1, 2, 3, or 4 soil group A, B, C, or D respectively	Group	Soil hydrologic group lookup tables
Soil Charactistics for each of 10 soil layers			
Depth to bottom of layer	0.01 to 2.0	M	Soil database and expert judgment
Bulk density	1.3 to 1.7	t/m^3	Soil database
Water content at wilting point	Rawls equations in EPIC	m/m	ARS Hydrologic group Beltsville, MD & Expert judgmen
Water content at field capacity	Rawls equations in EPIC	m/m	ARS Hydrologic group Beltsville, MD & Expert judgmen
% sand	Soil specific	%	Baumer soil database
% silt	Soil specific	%	Baumer soil database
Initial Organic N	Soil and management	g/t	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Soil pH	Soil specific	4 to 9	Baumer soil database
sum of BASES	Soil specific	C mol/kg	Baumer soil database
organic carbon concentration	Soil specific	%	Baumer soil database
calcium carbonate	Soil specific	%	Baumer soil database or EPIC Default estimate
cation exchange capacity	Soil specific	C mol/kg	Baumer soil database or EPIC Default estimate
coarse fragments	Soil specific	% of vol	Baumer soil database
initial NO3 concentration	Soil & management specific	G/T	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
initial labile P concentration	Soil & management specific	G/T	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
crop residue	Soil & management specific	T/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
bulk density (oven dry)	Soil specific	t/m^3	Baumer soil database
P sorption ratio < 1 or active & stable P > 1	Soil specific	Fraction or kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Saturated conductivity	Soil specific	mm/h	Baumer soil database or EPIC Default estimate
fraction of storage interacting with NO3 leaching	Soil & management specific	Fraction	EPIC Default estimate
initial organic P concentration	Soil & management specific	G/T	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Exchangeable K concentration	Soil & management specific	G/T	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Electrical conductivity	Soil & management specific	MMHO/CM	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Initial Soil Water Storage	Soil & management specific	Fraction	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Metabolic Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Lignin Content Of Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Carbon Content Of Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
C Content Of Metabolic Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
C Content Of Lignin Of Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Lignin Of Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
C Content Of Biomass	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
C Content Of Slow Humus	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
C Content Of Passive Humus	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Structural Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Metabolic Litter	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Biomass	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Slow Humus	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
N Content Of Passive Humus	Soil & management specific	Kg/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data
Observed C Content At End Of Simulation	Soil & management specific	T/ha	Result of 10 year pre-crop and CRP runs based on N-index and NASS data

Table A.4. Trees simulated on CRP acres by State

Region	State Name	Tree
Northeastern		
	PENNSYLVANIA	Oak
	MARYLAND	Oak
Appalachian		
	TENNESSEE	Pine
	KENTUCKY	Oak
Southeast		
	FLORIDA	Pine
	GEORGIA	Pine
	ALABAMA	Pine
	SOUTH CAROLINA	Pine
Delta		
	ARKANSAS	Pine
	LOUISIANA	Oak
	MISSISSIPPI	Pine
Lake States		
	MINNESOTA	Pine
	WISCONSIN	Pine
Corn Belt		
	IOWA	Cottonwood
	ILLINOIS	Oak
	MISSOURI	Oak
	OHIO	Oak
Northern Plains		
	SOUTH DAKOTA	Cottonwood
	NORTH DAKOTA	Cottonwood
	NEBRASKA	Cottonwood
	KANSAS	Cottonwood
Southern Plains		
	TEXAS	Cottonwood
	OKLAHOMA	Cottonwood
Mountain States		
	MONTANA	Cottonwood
	COLORADO	Cottonwood
	IDAHO	Cottonwood
	NEW MEXICO	Cottonwood
	UTAH	Cottonwood
	WYOMING	Cottonwood
Pacific		
	CALIFORNIA	Pine
	OREGON	Pine
	WASHINGTON	Pine

Table A.5. Crop management practices for conventional and conservation till corn and mixed grasses (CRP)

Equipment	Scheduling by Fraction of Heat Units*	Fertilizer Application Rate (lbs/ac)	Mixing Efficiency	Percentage Residue Remaining
Conventional Corn				
Tandem Disk	0.02		0.75	25
Anhydrous Spreader	0.07	80 N	0.10	23
Dry Fertilizer Spreader	0.07	25 P^2O^5	0.00	23
Field Cultivator	0.10		0.30	16
Row Planter	0.12		0.10	14
Row Cultivator	0.20		0.25	11
Dry Fertilizer Spreader	0.30	50 N	0.00	11
Row Cultivator	0.43		0.25	8
Combine	1.15		0.00	8
Conventional Soybean				
Dry Fertilizer Spreader	0.07	10 N 15 P^2O^5	0.00	100
Tandem Disk	0.08		0.75	25
Field Cultivator	0.18		0.30	18
Row Planter	0.20		0.10	16
Combine	1.15		0.00	16
Conservation Till Corn				
Dry Fertilizer Spreader	0.08	80	0.00	100
Field Cultivator	0.08		0.30	70
Row Planter	0.12		0.10	63
Anhydrous Spreader	0.20	50 N	0.10	57
Row Cultivator	0.20		0.25	43
Row Cultivator	0.33		0.25	33
Combine	1.15		0.00	33
Conservation Till Soybean				
Dry Fertilizer Spreader	0.08	10 N 15 P^2O^5	0.00	100
Field Cultivator	0.18		0.30	70
Row Planter	0.20		0.10	63
Combine	1.15		0.00	63
Mixed Grasses				
Drill Planter	0.15		0.10	90

* If there is no crop growing, this fraction is the fraction of the heat units for the year with a base temperature of zero, about 3500 for Iowa. Conventional tilled corn is planted when 420 heat units are accumulated. The crop heat unit accumulation is calculated by subtracting the crop base temperature, 8°C for corn, from the average daily temperature once the crop begins growing (when soil temperature in soil layer two reaches base temperature). Heat unit scheduling is the fraction of the heat units from beginning of growth to physiological maturity, 1400 heat units in Iowa. Harvest takes place when 1630 heat units are accumulated. It is scheduled after maturity to allow some crop drying.

Table A.6. Simulated CRP field size and CRP buffer size

State abreviation	Soil number	Field Size acres	Buffer Size acres
AL	1	60	1.2
AL	2	60	12.0
AL	3	60	3.0
AL	4	60	3.0
AR	5	44	2.2
CA	6	316	6.3
CO	7	197	2.0
CO	8	197	2.0
CO	9	197	2.0
CO	10	197	2.0
CO	11	197	2.0
CO	12	197	2.0
CO	13	197	2.0
CO	14	197	2.0
CO	15	197	2.0
CO	16	197	2.0
CO	17	197	2.0
CO	18	197	2.0
CO	19	197	2.0
CO	20	197	2.0
CO	21	197	2.0
CO	22	197	2.0
CO	23	197	2.0
CO	24	197	2.0
CO	25	197	2.0
CO	26	197	2.0
CO	27	197	2.0
CO	28	197	2.0
CO	29	197	2.0
CO	30	197	2.0
CO	31	197	2.0
CO	32	197	2.0
FL	33	25	0.5
GA	34	27	0.3
GA	35	27	1.3
GA	36	27	0.3
GA	37	27	0.3
GA	38	27	2.7
GA	39	27	1.3
ID	40	160	1.6
ID	41	160	1.6
ID	42	160	1.6
ID	43	160	1.6
ID	44	160	1.6
ID	45	160	1.6
ID	46	160	1.6
ID	47	160	1.6
IL	48	28	5.7
IL	49	28	0.6
IL	50	28	2.8
IL	51	28	1.4
IL	52	28	0.6
IL	53	28	1.4
IL	54	28	1.4
IA	55	45	4.5
IA	56	45	2.2
IA	57	45	2.2
IA	58	45	2.2
IA	59	45	2.2
IA	60	45	2.2
IA	61	45	4.5
IA	62	45	2.2
IA	63	45	4.5
IA	64	45	4.5
IA	65	45	4.5
IA	66	45	0.4
IA	67	45	4.5
IA	68	45	4.5
IA	69	45	4.5
IA	70	45	4.5
IA	71	45	9.0
KS	72	82	0.8
KS	73	82	0.8
KS	74	82	1.6
KS	75	82	1.6
KS	76	82	0.8
KS	77	82	1.6
KS	78	82	0.8
KS	79	82	0.8
KS	80	82	1.6
KS	81	82	1.6
KS	82	82	0.8
KS	83	82	4.1
KS	84	82	4.1
KS	85	82	0.8
KS	86	82	0.8
KS	87	82	0.8
KS	88	82	0.8
KS	89	82	0.8
KS	90	82	1.6
KS	91	82	0.8
KS	92	82	0.8
KS	93	82	4.1
KS	94	82	0.8
KS	95	82	4.1
KS	96	82	1.6
KS	97	82	0.8
KS	98	82	1.6
KS	99	82	0.8
KS	100	82	8.2

State abreviation	Soil number	Field Size acres	Buffer Size acres
KS	101	82	1.6
KS	102	82	1.6
KS	103	82	4.1
KS	104	82	0.8
KY	105	40	7.9
KY	106	40	0.8
KY	107	40	4.0
KY	108	40	4.0
LA	109	49	2.5
LA	110	49	4.9
MN	111	53	0.5
MN	112	53	0.5
MN	113	53	1.1
MN	114	53	1.1
MN	115	53	0.5
MN	116	53	1.1
MN	117	53	0.5
MN	118	53	0.5
MN	119	53	0.5
MN	120	53	0.5
MN	121	53	0.5
MN	122	53	1.1
MN	123	53	1.1
MN	124	53	1.1
MN	125	53	0.5
MN	126	53	0.5
MS	127	38	0.8
MS	128	38	3.8
MS	129	38	1.9
MS	130	38	3.8
MS	131	38	7.6
MS	132	38	3.8
MS	133	38	7.6
MS	134	38	0.8
MS	135	38	7.6
MS	136	38	3.8
MS	137	38	1.9
MS	138	38	7.6
MO	139	59	5.9
MO	140	59	5.9
MO	141	59	5.9
MO	142	59	5.9
MO	143	59	5.9
MO	144	59	5.9
MO	145	59	11.7
MO	146	59	5.9
MO	147	59	11.7
MO	148	59	1.2
MO	149	59	5.9
MO	150	59	2.9
MO	151	59	2.9
MO	152	59	2.9
MO	153	59	5.9
MO	154	59	5.9
MO	155	59	5.9
MO	156	59	11.7
MO	157	59	5.9
MT	158	199	2.0
MT	159	199	2.0
MT	160	199	2.0
MT	161	199	2.0
MT	162	199	2.0
MT	163	199	2.0
MT	164	199	2.0
MT	165	199	4.0
MT	166	199	10.0
MT	167	199	2.0
MT	168	199	2.0
MT	169	199	2.0
MT	170	199	2.0
MT	171	199	2.0
MT	172	199	2.0
MT	173	199	2.0
MT	174	199	2.0
MT	175	199	2.0
MT	176	199	4.0
MT	177	199	2.0
MT	178	199	2.0
MT	179	199	2.0
MT	180	199	2.0
MT	181	199	2.0
MT	182	199	2.0
MT	183	199	2.0
MT	184	199	2.0
MT	185	199	2.0
MT	186	199	2.0
MT	187	199	2.0
MT	188	199	2.0
MT	189	199	2.0
MT	190	199	2.0
MT	191	199	2.0
MT	192	199	2.0
MT	193	199	2.0
MT	194	199	2.0
MT	195	199	2.0
MT	196	199	2.0
MT	197	199	2.0
NE	198	65	0.6
NE	199	65	1.3
NE	200	65	3.2

State abreviation	Soil number	Field Size acres	Buffer Size acres
NE	201	65	0.6
NE	202	65	0.6
NE	203	65	0.6
NE	204	65	0.6
NE	205	65	0.6
NE	206	65	0.6
NE	207	65	1.3
NE	208	65	0.6
NM	209	228	2.3
NM	210	228	2.3
NM	211	228	2.3
NM	212	228	2.3
NM	213	228	2.3
NM	214	228	2.3
NM	215	228	2.3
NM	216	228	2.3
ND	217	106	1.1
ND	218	106	1.1
ND	219	106	1.1
ND	220	106	1.1
ND	221	106	5.3
ND	222	106	1.1
ND	223	106	1.1
ND	224	106	1.1
ND	225	106	1.1
ND	226	106	1.1
ND	227	106	1.1
ND	228	106	1.1
ND	229	106	1.1
ND	230	106	1.1
ND	231	106	1.1
ND	232	106	1.1
ND	233	106	1.1
ND	234	106	1.1
ND	235	106	1.1
ND	236	106	1.1
ND	237	106	1.1
ND	238	106	1.1
ND	239	106	1.1
ND	240	106	2.1
ND	241	106	1.1
ND	242	106	1.1
ND	243	106	1.1
ND	244	106	2.1
ND	245	106	1.1
ND	246	106	1.1
ND	247	106	1.1
ND	248	106	1.1
ND	249	106	1.1
ND	250	106	1.1
ND	251	106	1.1
ND	252	106	1.1
ND	253	106	1.1
ND	254	106	1.1
ND	255	106	1.1
ND	256	106	1.1
ND	257	106	1.1
OH	258	32	0.3
OK	259	121	1.2
OK	260	121	1.2
OK	261	121	1.2
OK	262	121	1.2
OK	263	121	1.2
OK	264	121	1.2
OK	265	121	1.2
OK	266	121	1.2
OK	267	121	1.2
OK	268	121	1.2
OK	269	121	1.2
OK	270	121	1.2
OK	271	121	6.0
OK	272	121	1.2
OR	273	219	2.2
OR	274	219	2.2
OR	275	219	2.2
OR	276	219	2.2
OR	277	219	2.2
OR	278	219	2.2
SC	279	22	0.2
SD	280	83	0.8
SD	281	83	0.8
SD	282	83	0.8
SD	283	83	0.8
SD	284	83	0.8
SD	285	83	0.8
SD	286	83	0.8
SD	287	83	0.8
SD	288	83	0.8
SD	289	83	4.2
SD	290	83	4.2
SD	291	83	1.7
SD	292	83	0.8
SD	293	83	0.8
SD	294	83	0.8
SD	295	83	0.8
SD	296	83	0.8
TN	297	38	1.9
TN	298	38	3.8
TN	299	38	3.8
TN	300	38	3.8

State abreviation	Soil number	Field Size acres	Buffer Size acres
TX	301	169	1.7
TX	302	169	3.4
TX	303	169	1.7
TX	304	169	1.7
TX	305	169	1.7
TX	306	169	1.7
TX	307	169	1.7
TX	308	169	1.7
TX	309	169	1.7
TX	310	169	1.7
TX	311	169	1.7
TX	312	169	1.7
TX	313	169	1.7
TX	314	169	1.7
TX	315	169	1.7
TX	316	169	1.7
TX	317	169	3.4
TX	318	169	1.7
TX	319	169	1.7
TX	320	169	1.7
TX	321	169	1.7
TX	322	169	1.7
TX	323	169	1.7
TX	324	169	1.7
TX	325	169	1.7
TX	326	169	1.7
TX	327	169	1.7
TX	328	169	1.7
TX	329	169	1.7
TX	330	169	1.7
TX	331	169	1.7
TX	332	169	1.7
TX	333	169	1.7
TX	334	169	3.4
TX	335	169	1.7
TX	336	169	1.7
TX	337	169	1.7
UT	338	197	2.0
UT	339	197	2.0
WA	340	173	1.7
WA	341	173	1.7
WA	342	173	1.7
WA	343	173	1.7
WA	344	173	1.7
WA	345	173	1.7
WA	346	173	1.7
WA	347	173	1.7
WA	348	173	1.7
WA	349	173	1.7
WA	350	173	1.7
WA	351	173	1.7
WI	352	26	0.3
WI	353	26	0.3
WI	354	26	0.5
WI	355	26	0.3
WY	356	286	2.9
WY	357	286	2.9
WY	358	286	2.9
MD	359	21	1.0
MD	360	21	2.1
MD	361	21	1.0
PA	362	30	0.6
PA	363	30	3.0

Table A.7. Soils used in study by State and soil name

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
AL0010	AL	36,567	Dothan	60	MONTGOMERY WB AP
AL0011	AL	37,851	Sumter	60	MONTGOMERY WB AP
GA0029	AL	39,308	Orangebur	60	MONTGOMERY WB AP
MS0039	AL	23,079	Kipling	60	MONTGOMERY WB AP
TN0011	AR	24,373	Loring	44	STUTTGART 9ESE
CA0091	CA	22,097	Balcom	316	SALINAS 3E
CO0003	CO	107,720	Ascalon	197	LIMON
CO0054	CO	27,329	Weld	197	LIMON
CO0055	CO	169,893	Wiley	197	LIMON
CO0078	CO	60,050	Stoneham	197	LIMON
CO0213	CO	65,744	Planter	197	LIMON
CO0662	CO	78,279	Onley	197	LIMON
CO3296	CO	34,266	Platner	197	LIMON
CO3299	CO	17,169	Wages	197	LIMON
CO3353	CO	84,366	Weld	197	LIMON
CO3355	CO	38,439	Norka	197	LIMON
CO3357	CO	63,086	Baca	197	LIMON
CO3384	CO	49,797	Fort	197	LIMON
CO3390	CO	30,738	Vona	197	LIMON
CO3404	CO	37,757	Baca	197	LIMON
CO3432	CO	18,099	Kimst	197	LIMON
CO3450	CO	35,364	Haxtun	197	LIMON
CO3503	CO	17,256	Platner	197	LIMON
CO3693	CO	39,976	Campo	197	LIMON
CO3825	CO	90,816	Wiley	197	LIMON
CO3848	CO	36,674	Colby	197	LIMON
CO4089	CO	25,490	Manter	197	LIMON
CO7299	CO	53,089	Colby	197	LIMON
CO7308	CO	23,551	Renohill	197	LIMON
CO7328	CO	21,502	Keith	197	LIMON
CO7596	CO	16,977	Colby	197	LIMON
AL0010	FL	22,218	Dothan	26	TALLAHASSEE WB AP
AL0010	GA	16,277	Dothan	27	TIFTON 2 N
AL0071	GA	19,467	Cowarts	27	TIFTON 2 N
GA0001	GA	55,951	Tifton	27	TIFTON 2 N
GA0005	GA	16,995	Faceville	27	TIFTON 2 N
GA0027	GA	17,853	Carngie	27	TIFTON 2 N
NC0053	GA	23,359	Fuquay	27	TIFTON 2 N
ID0034	ID	77,029	Newdale	160	CRATERS OF MOON NM
ID0036	ID	19,921	Lanoak	160	CRATERS OF MOON NM
ID0039	ID	20,943	Neeley	160	CRATERS OF MOON NM
ID0083	ID	71,894	Rexburg	160	CRATERS OF MOON NM
ID0130	ID	17,409	Taney	160	CRATERS OF MOON NM
ID0217	ID	25,089	Tetoria	160	CRATERS OF MOON NM
ID0355	ID	91,203	Ririe	160	CRATERS OF MOON NM
ID0549	ID	17,455	Bancroft	160	CRATERS OF MOON NM
IA0564	IL	22,604	Bauer	29	PANA
IL0003	IL	48,575	Bluford	29	PANA
IL0026	IL	19,017	Blair	29	PANA
IL0057	IL	58,204	Ava	29	PANA
IL0065	IL	25,339	Rozetta	29	PANA
IL0099	IL	22,704	Grantsbur	29	PANA
IN0054	IL	43,626	Hosmer	29	PANA

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
IA0502	IA	68,342	Shelby	45	IOWA FALLS 1N
IA0505	IA	51,845	Ladoga	45	IOWA FALLS 1N
IA0509	IA	27,283	Pershing	45	IOWA FALLS 1N
IA0517	IA	26,963	Weller	45	IOWA FALLS 1N
IA0521	IA	16,571	Clarion	45	IOWA FALLS 1N
IA0542	IA	18,555	Downs	45	IOWA FALLS 1N
IA0544	IA	29,027	Clarinda	45	IOWA FALLS 1N
IA0546	IA	59,253	Clinton	45	IOWA FALLS 1N
IA0550	IA	27,576	Armstrong	45	IOWA FALLS 1N
IA0551	IA	32,927	Arispe	45	IOWA FALLS 1N
IA0553	IA	28,863	Adair	45	IOWA FALLS 1N
IA0554	IA	43,166	Sharpsbur	45	IOWA FALLS 1N
IA0559	IA	22,794	Lamoni	45	IOWA FALLS 1N
IA0562	IA	58,583	Gara	45	IOWA FALLS 1N
IA0564	IA	136,478	Fayette	45	IOWA FALLS 1N
IA0596	IA	36,409	Ida	45	IOWA FALLS 1N
MO0160	IA	17,003	Lindley	45	IOWA FALLS 1N
CO0031	KS-W	40,684	Manter	82	LAKIN
CO0052	KS-W	45,429	Vona	82	LAKIN
KS0001	KS-E	19,379	Albion	82	GREAT BEND
KS0003	KS-E	27,840	Armo	82	GREAT BEND
KS0004	KS-E	20,578	Attica	82	GREAT BEND
KS0022	KS-E	20,631	Clark	82	GREAT BEND
KS0024	KS-W	145,572	Colby	82	LAKIN
KS0038	KS-E	19,431	Farnum	82	GREAT BEND
KS0040	KS-E	20,231	Geary	82	GREAT BEND
KS0047	KS-E	237,190	Harney	82	GREAT BEND
KS0053	KS-E	31,740	Irwin	82	GREAT BEND
KS0058	KS-E	24,224	Kenoma	82	GREAT BEND
KS0072	KS-E	22,968	Martin	82	GREAT BEND
KS0081	KS-E	36,047	Naron	82	GREAT BEND
KS0091	KS-E	53,741	Penden	82	GREAT BEND
KS0093	KS-E	108,702	Pratt	82	GREAT BEND
KS0096	KS-W	287,546	Richfield	82	LAKIN
KS0102	KS-W	25,686	Santana	82	LAKIN
KS0103	KS-E	46,426	Shellabarg	82	GREAT BEND
KS0108	KS-W	21,340	Spearville	82	LAKIN
KS0113	KS-W	306,737	Ulysses	82	LAKIN
KS0116	KS-E	46,762	Wakeen	82	GREAT BEND
KS0127	KS-W	18,096	Bridgepor	82	LAKIN
NE0023	KS-E	58,993	Coly	82	GREAT BEND
NE0025	KS-E	56,124	Crete	82	GREAT BEND
NE0038	KS-W	18,387	Goshen	82	LAKIN
NE0044	KS-E	32,531	Holdrege	82	GREAT BEND
NE0049	KS-W	18,080	Keith	82	LAKIN
NE0076	KS-E	43,349	Pawnee	82	GREAT BEND
NE0090	KS-E	74,541	Uly	82	GREAT BEND
NE0095	KS-E	17,857	Wymore	82	GREAT BEND
OK0071	KS-E	18,354	Woodwar	82	GREAT BEND
OK0102	KS-W	46,989	Dalhart	82	LAKIN
KY0001	KY	49,541	Zanesville	40	MADISONVILLE
KY0029	KY	23,726	Sadler	40	MADISONVILLE
MS0001	KY	19,872	Grenada	40	MADISONVILLE
TN0011	KY	43,157	Loring	40	MADISONVILLE
LA0073	LA	21,870	Tensas	49	BELAH FIRE TOWER
MS0001	LA	22,136	Grenada	49	BELAH FIRE TOWER
MN0025	MN	27,433	Esthervill	53	WADENA
MN0037	MN	50,416	Ulen	53	WADENA
MN0048	MN	37,542	Percy	53	WADENA

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
MN0050	MN	31,154	Arveson	53	WADENA
MN0054	MN	18,202	Rockwell	53	WADENA
MN0055	MN	27,992	Vallers	53	WADENA
MN0068	MN	30,783	Flaming	53	WADENA
MN0072	MN	28,697	Kratka	53	WADENA
MN0076	MN	36,583	Rolise	53	WADENA
MN0083	MN	57,355	Grimstad	53	WADENA
MN0131	MN	22,654	Poppleton	53	WADENA
MN0134	MN	25,566	Mavie	53	WADENA
MN0395	MN	26,138	Clearwate	53	WADENA
MN0413	MN	64,055	Smiley	53	WADENA
MN0633	MN	31,850	Strathcom	53	WADENA
ND0219	MN	51,016	Barnes	53	WADENA
LA0050	MS	16,647	Sharkey	38	WINONA 3 ENE
LA0057	MS	21,873	Ruston	38	WINONA 3 ENE
MS0001	MS	17,498	Grenada	38	WINONA 3 ENE
MS0033	MS	64,686	Providenc	38	WINONA 3 ENE
MS0039	MS	19,772	Kipling	38	WINONA 3 ENE
MS0044	MS	32,834	Ora	38	WINONA 3 ENE
MS0050	MS	18,467	Smithdale	38	WINONA 3 ENE
MS0054	MS	16,116	Alligator	38	WINONA 3 ENE
MS0066	MS	27,606	Memphis	38	WINONA 3 ENE
MS0083	MS	29,928	Savannah	38	WINONA 3 ENE
MS0122	MS	22,380	Memphis	38	WINONA 3 ENE
TN0011	MS	84,463	Loring	38	WINONA 3 ENE
IA0142	MO	28,853	Shelby	59	CARROLLTON
IA0148	MO	18,107	Armstrong	59	CARROLLTON
IA0151	MO	29,214	Lamoni	59	CARROLLTON
IA0502	MO	48,404	Shelby	59	CARROLLTON
IA0550	MO	151,682	Armstrong	59	CARROLLTON
IA0553	MO	23,851	Adair	59	CARROLLTON
IA0559	MO	93,926	Lamoni	59	CARROLLTON
IA0561	MO	37,357	Keswick	59	CARROLLTON
IA0562	MO	64,842	Gara	59	CARROLLTON
MO0001	MO	41,221	Grundy	59	CARROLLTON
MO0020	MO	19,795	Lagonda	59	CARROLLTON
MO0032	MO	23,998	Barden	59	CARROLLTON
MO0046	MO	22,250	Menfro	59	CARROLLTON
MO0056	MO	39,214	Mexico	59	CARROLLTON
MO0059	MO	21,011	Gorin	59	CARROLLTON
MO0060	MO	18,854	Kilwinnin	59	CARROLLTON
MO0061	MO	33,696	Leonard	59	CARROLLTON
MO0071	MO	27,858	Armster	59	CARROLLTON
MO0358	MO	54,535	Lagonda	59	CARROLLTON
MT0008	MT	33,260	Dooley	199	ROY 8 NE
MT0009	MT	36,701	Farnuf	199	ROY 8 NE
MT0013	MT	25,350	Marias	199	ROY 8 NE
MT0019	MT	62,868	Tally	199	ROY 8 NE
MT0022	MT	120,883	Turner	199	ROY 8 NE
MT0024	MT	90,761	Vida	199	ROY 8 NE
MT0025	MT	30,483	Zahill	199	ROY 8 NE
MT0048	MT	23,356	Cabba	199	ROY 8 NE
MT0050	MT	21,123	Cabbart	199	ROY 8 NE
MT0065	MT	25,921	Chinook	199	ROY 8 NE
MT0076	MT	16,777	Abor	199	ROY 8 NE

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
MT0088	MT	19,224	Crago	199	ROY 8 NE
MT0093	MT	50,527	Ethridge	199	ROY 8 NE
MT0103	MT	18,560	Hillon	199	ROY 8 NE
MT0105	MT	57,543	Kevin	199	ROY 8 NE
MT0114	MT	17,795	Marvan	199	ROY 8 NE
MT0124	MT	206,212	Scobey	199	ROY 8 NE
MT0128	MT	26,062	Tanna	199	ROY 8 NE
MT0130	MT	24,276	Thebo	199	ROY 8 NE
MT0138	MT	27,310	Yamac	199	ROY 8 NE
MT0139	MT	50,257	Bearpaw	199	ROY 8 NE
MT0156	MT	76,268	Lonna	199	ROY 8 NE
MT0173	MT	21,534	Cambert	199	ROY 8 NE
MT0233	MT	287,476	Telstad	199	ROY 8 NE
MT0235	MT	169,188	Phillips	199	ROY 8 NE
MT0236	MT	20,002	Theony	199	ROY 8 NE
MT0271	MT	20,908	Delpoint	199	ROY 8 NE
MT0289	MT	86,964	Joplin	199	ROY 8 NE
MT0889	MT	32,660	Cambert	199	ROY 8 NE
MT0890	MT	17,259	Cambeth	199	ROY 8 NE
MT1081	MT	16,192	Delpoint	199	ROY 8 NE
MT1152	MT	31,436	Fortbento	199	ROY 8 NE
MT1474	MT	67,454	Scobey	199	ROY 8 NE
ND0257	MT	65,066	Shambo	199	ROY 8 NE
ND0258	MT	214,740	Williams	199	ROY 8 NE
ND0281	MT	17,034	Reeder	199	ROY 8 NE
ND0283	MT	17,678	Cherry	199	ROY 8 NE
ND0284	MT	30,811	Farland	199	ROY 8 NE
SD0394	MT	24,546	Bryant	199	ROY 8 NE
WY0280	MT	44,085	Evanston	199	ROY 8 NE
NE0019	NE-W	18,634	Canyon	65	SCOTTS BLUFF CAA AP
NE0023	NE-E	18,759	Coly	65	COLUMBUS
NE0026	NE-E	64,987	Crofton	65	COLUMBUS
NE0262	NE-W	47,556	Valentine	65	SCOTTS BLUFF CAA AP
NE0321	NE-W	21,986	Sidney	65	SCOTTS BLUFF CAA AP
NE0361	NE-W	33,808	Alliance	65	SCOTTS BLUFF CAA AP
NE0364	NE-W	17,240	Bridget	65	SCOTTS BLUFF CAA AP
NE0384	NE-W	44,315	Rosebud	65	SCOTTS BLUFF CAA AP
NE0451	NE-E	37,145	Lawet	65	COLUMBUS
SD0060	NE-E	18,219	Nora	65	COLUMBUS
WY1113	NE-W	17,360	Jayem	65	SCOTTS BLUFF CAA AP
NM0257	NM	17,383	Portales	228	MELROSE
NM0969	NM	29,150	Clovis	228	MELROSE
TX0118	NM	19,666	Brownfiel	228	MELROSE
TX0128	NM	50,402	Acuff	228	MELROSE
TX0129	NM	161,593	Olton	228	MELROSE
TX0130	NM	141,463	Amarillo	228	MELROSE
TX0133	NM	20,297	Arvana	228	MELROSE
TX0251	NM	19,770	Stegall	228	MELROSE
MN0099	ND	33,629	Buse	106	MC CLUSKY
MN0147	ND	37,187	Vallers	106	MC CLUSKY
MN0551	ND	25,569	Ulen	106	MC CLUSKY
MN0552	ND	17,442	Dovray	106	MC CLUSKY
MT0253	ND	17,081	Cabba	106	MC CLUSKY
ND0004	ND	29,248	Ruso	106	MC CLUSKY
ND0007	ND	88,802	Arvilla	106	MC CLUSKY

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
ND0009	ND	30,070	Embden	106	MC CLUSKY
ND0011	ND	23,647	Divide	106	MC CLUSKY
ND0012	ND	42,150	Maddock	106	MC CLUSKY
ND0015	ND	17,142	Gardena	106	MC CLUSKY
ND0022	ND	33,707	Towner	106	MC CLUSKY
ND0025	ND	17,248	Wyndmer	106	MC CLUSKY
ND0030	ND	23,884	Emrick	106	MC CLUSKY
ND0033	ND	224,094	Hamerly	106	MC CLUSKY
ND0037	ND	53,868	Wabek	106	MC CLUSKY
ND0042	ND	172,997	Williams	106	MC CLUSKY
ND0043	ND	145,964	Vebar	106	MC CLUSKY
ND0044	ND	27,411	Morton	106	MC CLUSKY
ND0046	ND	44,271	Parshall	106	MC CLUSKY
ND0048	ND	108,525	Zahl	106	MC CLUSKY
ND0056	ND	32,755	Max	106	MC CLUSKY
ND0068	ND	45,564	Heimdal	106	MC CLUSKY
ND0073	ND	18,870	Regent	106	MC CLUSKY
ND0078	ND	146,721	Svea	106	MC CLUSKY
ND0079	ND	39,310	Belfield	106	MC CLUSKY
ND0093	ND	32,388	Amor	106	MC CLUSKY
ND0104	ND	24,989	Moreau	106	MC CLUSKY
ND0115	ND	17,906	Lohnes	106	MC CLUSKY
ND0118	ND	32,250	Binford	106	MC CLUSKY
ND0119	ND	381,189	Barnes	106	MC CLUSKY
ND0124	ND	25,111	Lehr	106	MC CLUSKY
ND0137	ND	17,210	Forman	106	MC CLUSKY
ND0220	ND	37,223	Chama	106	MC CLUSKY
ND0227	ND	26,172	Biesigl	106	MC CLUSKY
ND0388	ND	22,275	Brantford	106	MC CLUSKY
ND0418	ND	21,377	Appam	106	MC CLUSKY
SD0052	ND	46,486	Sioux	106	MC CLUSKY
SD0411	ND	59,848	Hecla	106	MC CLUSKY
SD0467	ND	56,927	Swenoda	106	MC CLUSKY
SD0500	ND	42,779	Renshaw	106	MC CLUSKY
IL0014	OH	26,069	Blount	32	KENTON 2 W
KS0093	OK	28,512	Pratt	121	BEAVER
KS0096	OK	234,236	Richfield	121	BEAVER
KS0113	OK	70,045	Ulysses	121	BEAVER
OK0052	OK	16,860	Granfield	121	BEAVER
OK0057	OK	45,016	Nobscot	121	BEAVER
OK0058	OK	53,531	Mansic	121	BEAVER
OK0061	OK	25,015	Devol	121	BEAVER
OK0070	OK	16,633	StPaul	121	BEAVER
OK0071	OK	44,122	Woodwar	121	BEAVER
OK0102	OK	125,594	Dalhart	121	BEAVER
TX0245	OK	20,306	Miles	121	BEAVER
TX0246	OK	31,020	Mansker	121	BEAVER
TX0249	OK	19,313	Vernon	121	BEAVER
TX0422	OK	21,554	Carey	121	BEAVER
OR0021	OR	105,390	Condon	219	HEPPNER
OR0065	OR	63,677	Morrow	219	HEPPNER
OR0102	OR	39,131	Valby	219	HEPPNER
OR0481	OR	30,900	Mikklo	219	HEPPNER
WA0031	OR	27,113	Ritzville	219	HEPPNER
WA0260	OR	23,210	Waha	219	HEPPNER

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
VA0102	SC	21,999	Emporia	22	AIKEN
ND0041	SD	19,032	Niobell	83	HIGHMORE 1 W
ND0042	SD	46,365	Williams	83	HIGHMORE 1 W
ND0043	SD	29,703	Vebar	83	HIGHMORE 1 W
ND0086	SD	20,268	Reeder	83	HIGHMORE 1 W
ND0119	SD	35,448	Barnes	83	HIGHMORE 1 W
ND0137	SD	94,794	Forman	83	HIGHMORE 1 W
SD0021	SD	26,045	Clarno	83	HIGHMORE 1 W
SD0058	SD	16,836	Highmore	83	HIGHMORE 1 W
SD0071	SD	49,173	Ulen	83	HIGHMORE 1 W
SD0079	SD	37,266	Opal	83	HIGHMORE 1 W
SD0110	SD	20,142	Lakoma	83	HIGHMORE 1 W
SD0116	SD	52,561	Millboro	83	HIGHMORE 1 W
SD0142	SD	18,618	Renshaw	83	HIGHMORE 1 W
SD0171	SD	43,109	Houdek	83	HIGHMORE 1 W
SD0180	SD	51,338	Poinsett	83	HIGHMORE 1 W
SD0231	SD	18,977	Vienna	83	HIGHMORE 1 W
SD0248	SD	19,039	Ottumwa	83	HIGHMORE 1 W
MS0001	TN	19,952	Genada	38	LEXINGTON
MS0122	TN	18,636	Memphis	38	LEXINGTON
TN0011	TN	28,987	Loring	38	LEXINGTON
TN0027	TN	28,059	Lexington	38	LEXINGTON
NM0257	TX-W	40,285	Portales	169	LUBBOCK WB AP
OK0052	TX-E	38,833	Granfield	169	GOLDTHWAITE
OK0061	TX-E	20,579	Lofton	169	GOLDTHWAITE
OK0071	TX-E	32,036	Woodwar	169	GOLDTHWAITE
TX0072	TX-E	19,718	Lefton	169	GOLDTHWAITE
TX0089	TX-E	17,140	Abiline	169	GOLDTHWAITE
TX0090	TX-W	19,379	Mereta	169	LUBBOCK WB AP
TX0111	TX-W	44,549	Estacado	169	LUBBOCK WB AP
TX0115	TX-W	228,400	Patricia	169	LUBBOCK WB AP
TX0116	TX-W	83,747	Midessa	169	LUBBOCK WB AP
TX0118	TX-W	95,145	Brownfiel	169	LUBBOCK WB AP
TX0119	TX-W	16,747	Triomas	169	LUBBOCK WB AP
TX0128	TX-W	61,132	Acuff	169	LUBBOCK WB AP
TX0129	TX-W	181,177	Olton	169	LUBBOCK WB AP
TX0130	TX-W	487,239	Amarillo	169	LUBBOCK WB AP
TX0133	TX-W	47,207	Arvana	169	LUBBOCK WB AP
TX0134	TX-E	16,601	Springer	169	GOLDTHWAITE
TX0138	TX-W	19,988	Jalmar	169	LUBBOCK WB AP
TX0159	TX-E	25,662	Nowena	169	GOLDTHWAITE
TX0191	TX-E	18,786	Delfina	169	GOLDTHWAITE
TX0208	TX-E	19,121	Duval	169	GOLDTHWAITE
TX0243	TX-W	103,618	Sherm	169	LUBBOCK WB AP
TX0244	TX-W	36,990	Gruver	169	LUBBOCK WB AP
TX0245	TX-W	273,107	Miles	169	LUBBOCK WB AP
TX0246	TX-W	22,222	Mansker	169	LUBBOCK WB AP
TX0247	TX-W	782,725	Pullman	169	LUBBOCK WB AP
TX0250	TX-E	27,432	Tillman	169	GOLDTHWAITE
TX0253	TX-E	48,241	Sagerton	169	GOLDTHWAITE
TX0266	TX-W	66,721	Dallam	169	LUBBOCK WB AP
TX0326	TX-W	17,696	Zita	169	LUBBOCK WB AP
TX0418	TX-W	58,178	Sunray	169	LUBBOCK WB AP
TX0419	TX-W	28,359	Paduacah	169	LUBBOCK WB AP
TX0421	TX-W	19,361	Dumas	169	LUBBOCK WB AP

Site Name Soils V #	State	Land in CRP (acres)	Soil Name	Avg CRP Field (acres)	Weather Station
TX0422	TX-E	16,323	Carey	169	GOLDTHWAITE
TX0468	TX-E	19,551	Mcallen	169	GOLDTHWAITE
TX0500	TX-W	16,968	Quanah	169	LUBBOCK WB AP
TX1241	TX-W	38,795	Pep	169	LUBBOCK WB AP
UT0456	UT	21,082	Dalcan	197	HEBER
UT1428	UT	20,630	Kearns	197	HEBER
OR0002	WA	29,294	Athena	173	HATTON 10 E
OR0481	WA	20,444	Mikkab	173	HATTON 10 E
WA0026	WA	89,774	Wallawall	173	HATTON 10 E
WA0031	WA	283,533	Ritzville	173	HATTON 10 E
WA0041	WA	16,097	Palouse	173	HATTON 10 E
WA0261	WA	18,403	Willis	173	HATTON 10 E
WA0315	WA	100,966	Shano	173	HATTON 10 E
WA0329	WA	32,241	Touhey	173	HATTON 10 E
WA0416	WA	16,514	Adkins	173	HATTON 10 E
WA0419	WA	18,300	Renslow	173	HATTON 10 E
WA1868	WA	34,699	Touhey	173	HATTON 10 E
WA9039	WA	21,213	Ritzville	173	HATTON 10 E
IL0352	WI	31,570	Seaton	26	VIROQUA
WI0043	WI	36,692	Newglatus	26	VIROQUA
WI0099	WI	18,566	Lafarge	26	VIROQUA
WI0127	WI	38,631	Valton	26	VIROQUA
CO0003	WY	26,829	Ascaln	286	PHILLIPS
NE0097	WY	20,966	Altvan	286	PHILLIPS
WY9317	WY	16,140	Mitchell	286	PHILLIPS
MD0032	MD	7,288	Othello	21	GEORGETOWN DE
MD0053	MD	3,790	Fallsingto	21	GEORGETOWN DE
MD0052	MD	1,796	Elkton	21	GEORGETOWN DE
PA0066	PA	568	Atkins	30	HARRISBURG PA
MD0028	PA	3,735	Volusia	30	HARRISBURG PA

Photos courtesy of USDA Natural Resources Conservation Service

Front Cover:
Photo by Lynn Betts: *Filterstrip along a stream in western Iowa.*

Back Cover:
Photo by Jeff Vanuga: *Prairie species seeded under the Conservation Reserve Program, Kansas.*
Photo by Dennis Hadley: *Conservation practices combined to form a conservation system work together for the good of the land.*
Photo by Lynn Betts: *Native grasses in a field offered into the Conservation Reserve Program in Van Buren County, Iowa.*

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