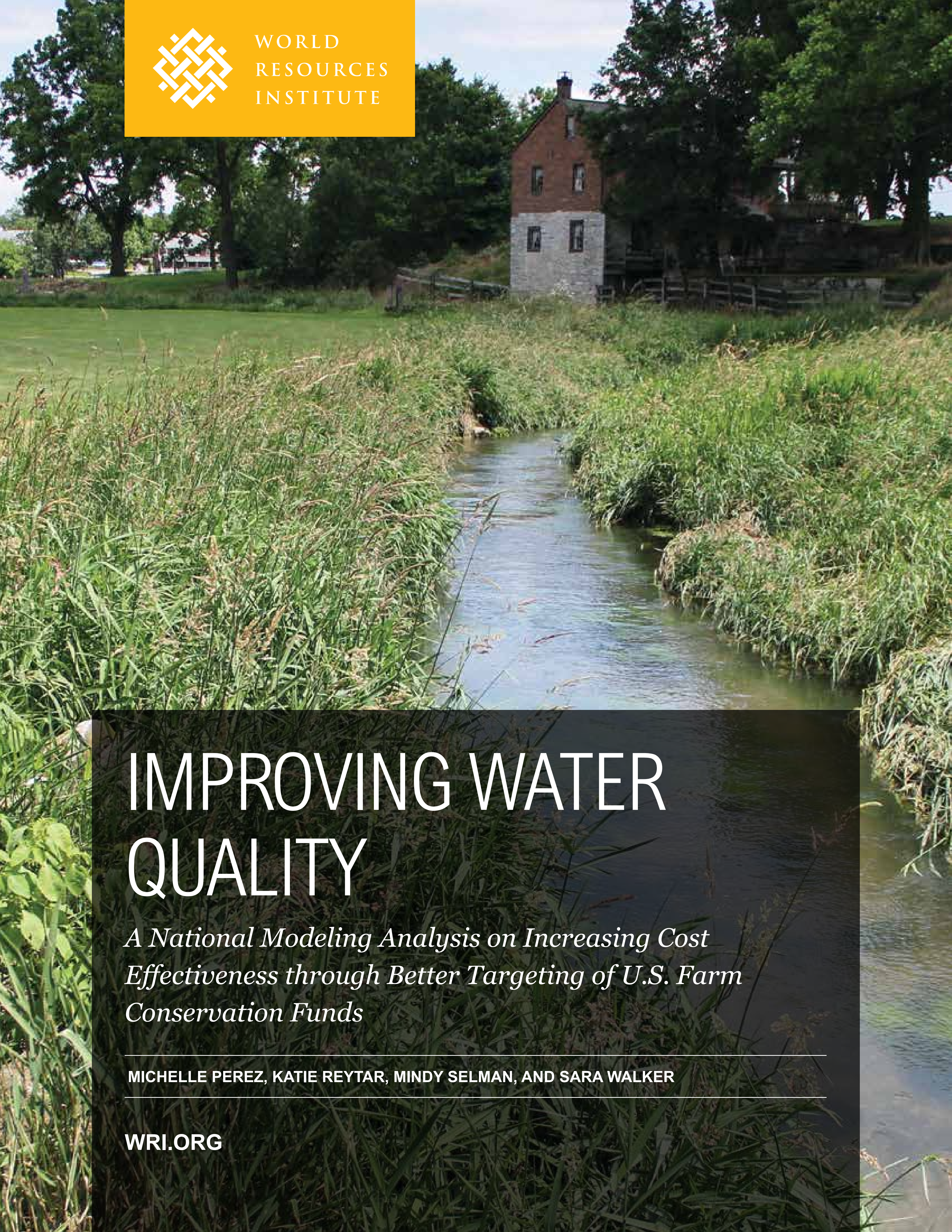


WORLD RESOURCES INSTITUTE

IMPROVING WATER QUALITY

A National Modeling Analysis on Increasing Cost Effectiveness through Better Targeting of U.S. Farm Conservation Funds

MICHELLE PEREZ, KATIE REYTAR, MINDY SELMAN, AND SARA WALKER

WRI.ORG

Design and layout by:
Jen Lockard
jlockard@ariacreative.net

TABLE OF CONTENTS

3 Foreword

4 Acknowledgments

7 Executive Summary

17 Introduction

21 Methods
22 Overview
24 Business-as-Usual Approach
24 Targeting Approaches and Optimization Scenarios
28 Assumptions and Limitations

31 Results and Discussion
32 Cost Effectiveness
35 Environmental Benefits
40 Acres Treated
41 Distribution of Practice Treatments
42 Regional Allocation of Funding

51 Conclusion

55 Recommendations

58 Appendix

65 Endnotes

67 References


RIVE

FOREWORD

This report presents good news. At a time when more resources are required to address environmental damage and fewer resources are available, it shows that better targeting of existing U.S. conservation funds could potentially improve environmental results more than seven-fold.

In more than 15,000 freshwater bodies in the United States, fertilizer runoff has deprived aquatic species of the oxygen they need to survive. In addition, despite progress in reducing soil erosion in recent years, 960 million tons—around 2.6 tons per acre of cropland—are still lost every year, contributing to poor water quality. These are not just environmental hazards; they cost American farmers money in wasted fertilizer purchases, wasted time spreading manure fertilizer, and reduced soil fertility.

Compounding the problem is the 69 percent increase in global food calories needed by midcentury. Agriculture is both vulnerable to climate change and a major cause of it. How can farmers in the United States and around the world grow more food and solve existing and evolving environmental problems?

Improving Water Quality: A National Modeling Analysis on Increasing Cost Effectiveness through Better Targeting of U.S. Farm Conservation Funds draws on detailed modeling analysis of different conservation funding allocation schemes. This report shows that targeting funds based on geographic and benefit-cost analysis offers 7 to 12 times more environmental benefits than a business-as-usual approach. In contrast, existing voluntary programs to mitigate the water quality problems associated with agriculture spread funds very broadly across the rural landscape, rather than targeting to where the impact per dollar would be maximized.

With funding shrinking for water quality and other environmental issues, the pressure is on to use federal funds more effectively. This report highlights one important opportunity to address agricultural environmental concerns in ways that are both cost effective and environmentally sound.

Andrew Steer
President
World Resources Institute

ACKNOWLEDGMENTS

This project was made possible by grants from the Packard Foundation, the Walton Family Foundation, and the McKnight Foundation. WRI could not have completed this study without the gracious collaboration of Jay Atwood and Lee Norfleet, staff on the Conservation Effects Assessment Project (CEAP) Team with the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) at the Texas A&M AgriLife Blackland Research and Extension Center. Jay Atwood developed the cost estimates and performed the optimization analysis on which the results are based. NRCS provided data and technical support while the approach, interpretation, analysis, and policy implications in this report belong to WRI.

We would like to thank the reviewers who contributed valuable feedback and thoughtful suggestions which made this report stronger. Internal reviewers at WRI included Rebecca Gasper, Lisa Johnston, Jamey Mulligan, and Paul Reig. External reviewers included Otto Doering, Purdue University; Richard Woodward, Texas A&M University; John Stierna and Jeremy Peters, American Farmland Trust; and Bruce Knight, Strategic Conservation Solutions, LLC and former chief of NRCS (2002–2006).

We are grateful to the following WRI staff for the review and editing assistance they provided: David Tomberlin, Craig Hanson, Betsy Otto, Hyacinth Billings, and Andrew Maddocks. Thank you to Caroline Taylor for copy editing services. For design and layout, thank you to Jen Lockard and WRI's Bill Dugan. All errors of fact or interpretation belong to the authors.

ABOUT THIS REPORT

This report is the second in a series of three papers analyzing ways to improve water quality through better targeting of federal farm conservation program funds.

Suggested citation:

Perez, M., K. Reytar, M. Selman, and S. Walker. 2014. "Improving Water Quality: A National Modeling Analysis on Increasing Cost Effectiveness through Better Targeting of U.S. Farm Conservation Funds." Report. Washington, DC: World Resources Institute. http://www.wri.org/publication/national-targeting-modeling-study

The other two papers in this series are:

- Perez, M., and S. Walker. 2014. "Improving Water Quality: A Review of the Mississippi River Basin Healthy Watershed Initiative (MRBI) to Target U.S. Farm Conservation Funds." Working Paper. Washington, DC: World Resources Institute. http://www.wri.org/publication/MRBI
- Walker, S., and M. Perez. 2014. "Improving Water Quality: Overcoming Barriers to Better Targeting of U.S. Farm Conservation Funds." Issue Brief. Washington, DC: World Resources Institute. http://www.wri.org/publication/targeting-barriers-us-farm-conservation-funds

ABOUT THE AUTHORS

Michelle Perez is a senior associate at WRI whose work focuses on farm conservation targeting, farm- and watershed-scale nutrient reduction assessment tools, and market-based approaches to improving water quality.
Contact: mperez@wri.org

Katie Reytar is a research associate at WRI who specializes in using geographic information systems (GIS) to analyze and inform environmental policy and management decisions.
Contact: kreytar@wri.org

Mindy Selman is a senior associate at WRI who leads the organization's work on water quality. She is a leading expert in water quality trading and other market-based mechanisms for improving water quality.
Contact: mselman@wri.org

Sara Walker is an associate at WRI whose work focuses on NutrientNet, WRI's online water quality trading tool, and cost-effective and market-based approaches to reducing nutrient pollution.
Contact: swalker@wri.org

EXECUTIVE SUMMARY

Greater use of both geographic and benefit-cost targeting has the potential to significantly increase the cost effectiveness of taxpayer investments in federal conservation programs addressing water quality.

The federal government's current approach to addressing the environmental issues associated with agriculture is to provide financial and technical assistance to farmers to install conservation practices on their farms to improve air, water, and soil quality, wildlife habitat, wetlands and other natural resource concerns. Specifically for water quality, the federal programs help to reduce excess nutrient (nitrogen and phosphorus) runoff and soil erosion stemming from individual farm fields. However, the current approach to allocating conservation dollars does not maximize environmental outcomes per dollar spent as it falls short on allocating taxpayer dollars to geographic priority areas or to farms and practices that are the most cost effective in achieving these environmental benefits (i.e., that have the greatest nitrogen, phosphorus, and sediment reductions per dollar spent).

Given increasing fiscal budget constraints, federal programs are under pressure to increase effectiveness and reduce costs. There is also growing demand for estimates of actual environmental benefits that the public is receiving for the investment of taxpayer funds. Likewise, members of Congress and federal conservation program managers are seeking to improve funding allocation options to achieve a greater return on public investment.

Over the years, recommendations for improving the effectiveness of federal conservation programs have included using the principles of targeting. Targeting can take many forms and have several dimensions. Targeting can seek to optimize environmental benefits and costs and/or seek to concentrate conservation activities in a certain location. Targeting might seek to combine two or more principles by using a combination of geography, expected benefits, and costs to identify priorities. Two important targeting approaches are geographic targeting and benefit-cost targeting.

Targeting Approaches

Geographic targeting involves establishing environmental or natural resource priorities and then committing funds to regions or watersheds exhibiting those priorities. For example, geographic targeting could prioritize areas that (a) are experiencing the greatest environmental and natural resource impairments, (b) exhibit "pristine" conditions worth preserving, or (c) could offer the greatest change in environmental or natural resource conditions.

Benefit-cost targeting involves identifying and treating the individual farms or conservation practices that can produce the most environmental benefits per dollar spent (i.e., those that are the most cost effective). Programs can aim for cost effectiveness in a variety of ways including, in the case of water quality programs, paying for the most cost-effective nutrient reduction outcomes measured either via direct monitoring or through indirect modeling estimates. Thus, benefit-cost targeting requires knowledge of relative or estimated environmental losses from individual acres, relative or estimated effectiveness of various treatment options, and treatment costs.

Our Analysis

To explore how the current approach to allocating federal conservation funding could be improved, the World Resources Institute (WRI) approached the Conservation Effects Assessment Project (CEAP) team of the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) to complete a national-level modeling analysis of different conservation funding allocation schemes. WRI developed the research questions while NRCS used its CEAP data, results from previous nationwide scientific analysis, and new economic optimization analysis to answer those research questions. NRCS provided the data results from that effort to WRI for further analysis, interpretation, and exploration of policy improvement options. Despite these different functional and institutional roles, the report uses the term "we" for readability's sake.

This study estimates the current level of cost effectiveness of the conservation programs and explores how financial assistance could be better allocated if areas were targeted using the principles of geographic and benefit-cost targeting to maximize environmental benefits per dollar spent. Using program payment data from 2006 to 2011 for cropland conservation practices nationwide, the National Resources Inventory (NRI)-CEAP farmer survey sample point dataset, and results from the Agricultural Environmental Policy Extender

(APEX) model, we estimated the current national level of cost effectiveness of federal spending on water quality-related practices. The results of this analysis represent the study's business-as-usual (BAU) approach. (See the first row of table ES-1.)

We found that $335 million was the annual average cost of the cropland-related nutrient and soil erosion control practices implemented nationwide under BAU from 2006 to 2011 in all the federal conservation programs. This cost estimate reflects practice installation, maintenance, and technical assistance costs and does not distinguish between the portion paid for by the financial assistance programs or by the farm producers. We limited our study to these cropland-related practices because the focus of our analysis is on maximizing environmental benefits like nitrogen (N), phosphorus (P), and sediment reductions. Because of the APEX model's ability to also simulate the soil carbon (C) sequestration co-benefits from some of these water quality-related practices, we included changes in soil C in the analysis, given the importance of climate change.

We added an economic optimization model to estimate how much more cost effective programs could be in comparison to BAU if the $335 million budget were allocated via a geographic targeting approach, a benefit-cost targeting approach, and a dual targeting approach that combined the two. The nationwide analysis was conducted at the farmer survey sample point scale along with those points' statistically expanded acres (that shared similar environmental and management conditions). Results were aggregated to the 201 4-digit watersheds in the contiguous United States and to 13 regions. Note that 4-digit watersheds are very large and average about 15,800 square miles.

A brief discussion of the methods and limitations of this study can be found in Box ES-1.

BOX ES-1 | TARGETING APPROACHES AND STUDY ASSUMPTIONS AND LIMITATIONS

The dual targeting approach, as modeled in our study, combined geographic targeting with benefit-cost targeting by allowing the model to optimize funding allocations nationwide. The economic optimization model determined the optimal amount of the $335 million budget to spend in each of the 201 4-digit watersheds by evaluating and selecting the acres and practices that achieved the greatest environmental benefits per dollar spent nationwide.

To simulate benefit-cost targeting, our study restricted the conservation budgets in each watershed to the funding levels that had been available under BAU. The model was then allowed to allocate that budget in each watershed to treat acres (identified as having a high or medium need of treatment for nutrient or erosion losses) in a way that maximized reductions for the selected parameter (e.g., N, P, sediment, or soil C).

To simulate geographic targeting, we adopted the same conservation budget in each watershed that the dual targeting approach had determined was the most cost-effective use of the project funds. Next, the model sought out acres in need of treatment but was restricted to the same average level of cost effectiveness experienced in each watershed's BAU case to address those concerns.

Within each of the three targeting approaches, we evaluated five different optimization scenarios. Four scenarios optimized N, P, and sediment reductions and soil C sequestration individually; and one scenario, called the multiple benefits optimization scenario, optimized N, P, and soil C benefits simultaneously. Most conservation practices not only provide the intended environmental benefit for the targeted parameter (e.g., P reduction) but also provide additional co-benefits (e.g., sediment reduction, soil C sequestration) alongside the primary benefit. Thus, the model also reported the co-benefits gained in each of the five optimization runs, thereby allowing us to identify trade-offs (i.e., decreases in co-benefits) that can occur when different targeting priorities are selected.

The assumptions and limitations of the study are briefly introduced here:

- The study focuses only on water quality concerns, specifically nutrients and soil erosion, while many other environmental and natural resource concerns are addressed by federal conservation programs.
- The study only assesses cropland. It does not address grazing, pasture, hay, or forestland, or livestock operations.
- The study uses a budget constraint of $335 million, which reflects costs associated with cropland nutrient and erosion control practices implemented under the federal conservation programs from 2006 to 2011.
- The environmental benefits resulting from the conservation practices are estimated at the edge of the field only. Thus, this study does not account for the effect of practices in water bodies, nor does it account for the location of priority water bodies, a factor that is often the focus of geographic targeting.
- The study assumes full participation from producers associated with the statistical acres in the model. In reality, conservation programs are voluntary, and participation is subject to producer preference.
- BAU cost-effectiveness estimates and potential gains from targeting are derived from the CEAP farm survey data from 2003 to 2006 and do not take into account any of the most recent conservation efforts of the 2008 farm bill, including targeted approaches like the Mississippi River Basin Initiative. While the conservation gains made during the years since data collection have yet to be fully estimated, those gains reduce the remaining potential gains from targeting.
- While this study does consider technical assistance costs, it does not consider any additional transaction costs that may be involved in adoption of a targeting approach (e.g., costs to assess and identify the most cost-effective cropland acres and practices, additional outreach costs, etc.). Incorporation of such transaction costs will shrink the expected gains modeled in this study accordingly.

Table ES-1 | **Nationwide estimates of cost effectiveness and environmental benefits from BAU and the three targeting approaches under the multiple benefits optimization scenario**

TARGETING APPROACH	$/LB. NITROGEN REDUCED (1,000 LBS. N REDUCED)	$/LB. PHOSPHORUS REDUCED (1,000 LBS. P REDUCED)	$/TON SEDIMENT REDUCED (1,000 LBS. SEDIMENT REDUCED)	$/LB. SOIL CARBON SEQUESTERED (1,000 LBS. C SEQUESTERED)
Business-As-Usual (BAU)*	**$3.65** (91,843)	**$19.82** (16,891)	**$28.27** (11,845)	**$1.05** (317,565)
Geographic + Benefit-Cost (Dual Targeting)	**$0.36** (934,517)	**$2.82** (118,993)	**$7.02** (47,709)	**$0.38** (881,588)
Benefit-Cost Only	**$0.48** (692,694)	**$3.84** (87,289)	**$10.94** (30,622)	**$0.32** (1,048,015)
Geographic Only	**$4.26** (78,656)	**$17.56** (19,073)	**$24.01** (13,950)	**$1.28** (261,284)

Note: The BAU approach reflects the average annual costs ($335 million) associated with the cropland nutrient and erosion control practices implemented nationwide from 2006 to 2011 in all the federal conservation programs. This cost estimate reflects practice installation, maintenance, and technical assistance costs and does not distinguish between the portion paid for by the financial assistance programs or by the farm producers.

Findings

Our analysis provided several major findings:

Targeting Approaches

Finding 1. Combining geographic targeting with a benefit-cost targeting approach is most effective at improving cost effectiveness. The dual targeting approach yielded 7 to 12 times more environmental benefits for the same conservation budget as compared to the business-as-usual approach, depending on the optimization scenario (see table ES-1 for the multiple benefits optimization scenario and Tables 3 and 4a in the report for the other four scenarios). While it is unlikely that this magnitude of gains would be achievable in a real-world scenario (given transaction costs and other barriers to targeting), these results illustrate the potential for targeting approaches to improve the overall cost effectiveness of conservation payments, compared to business as usual.

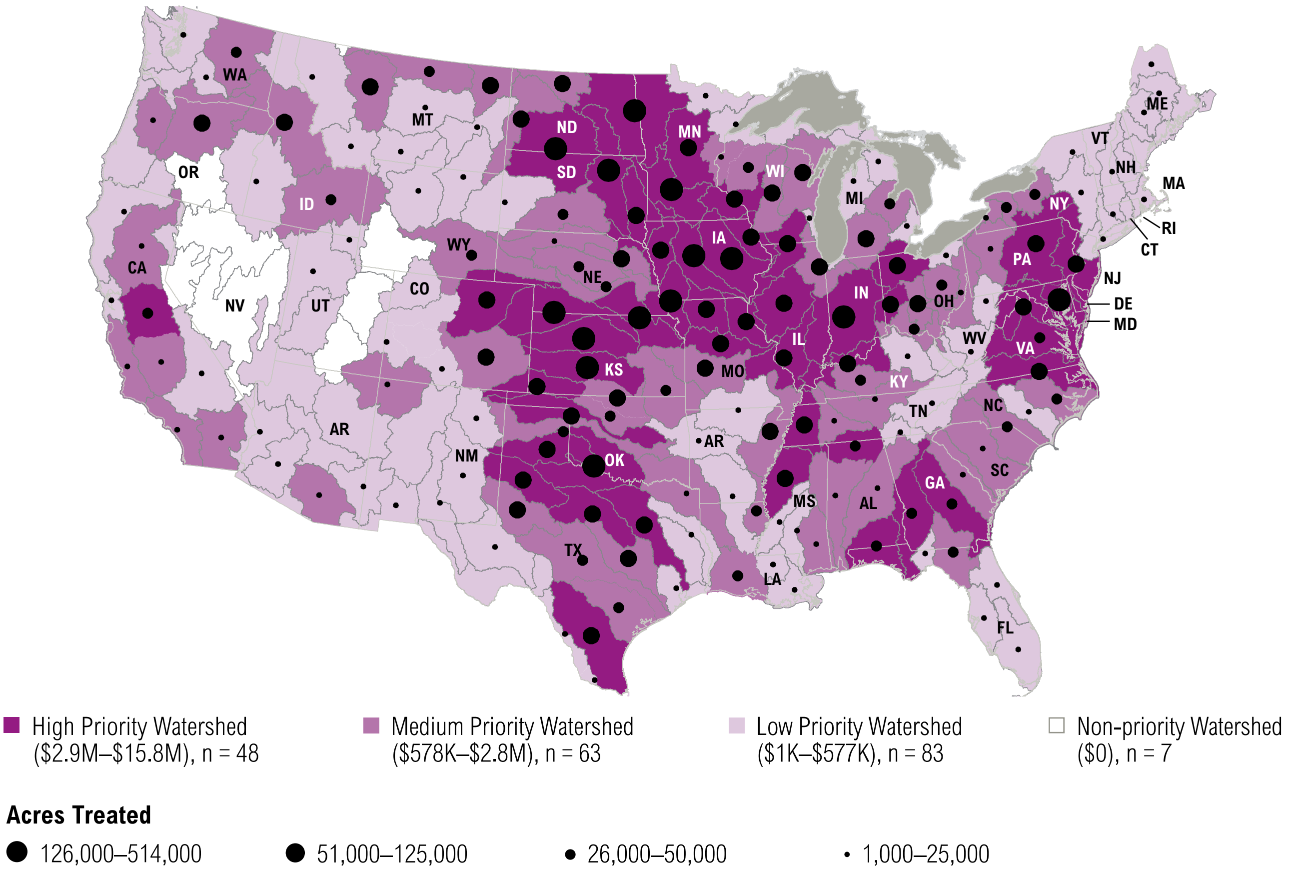
Finding 2. Even adopting a benefit-cost approach without geographic targeting vastly improves the environmental outcomes that can be achieved for a given budget. Our analysis found that a benefit-cost approach results in four to nearly nine times more environmental benefits as compared to BAU. These modeling results suggest, that even when regional funding allocations remain unchanged, there are still opportunities for improving the cost effectiveness of conservation payments.

Finding 3. Geographic targeting alone achieves little improvement in environmental outcomes per dollar spent. At a large watershed scale, geographic targeting alone appears to be generally no more effective than BAU.

Optimization Scenarios

Finding 4. Optimizing multiple environmental benefits simultaneously achieves better outcomes overall than does optimizing just one benefit individually. Optimizing multiple environmental benefits allows for the greatest

Figure ES-1 | **Funding allocations for cropland-related nutrient and soil erosion control practices under the business-as-usual approach to federal conservation program spending**



number of co-benefits and the fewest trade-offs among the four environmental benefit categories (N, P, sediment, and C sequestration) than does optimizing each benefit independently.

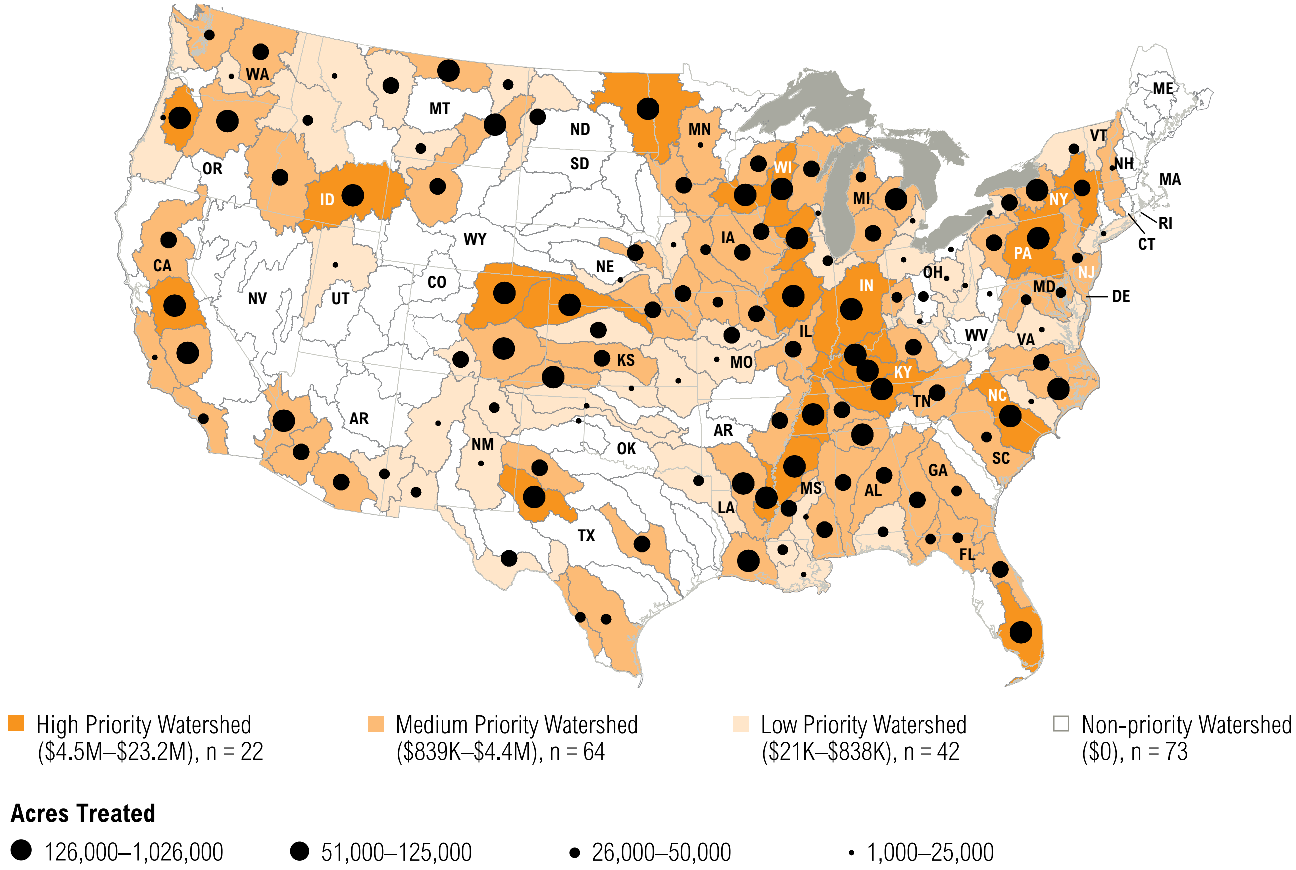
Finding 5. Optimizing phosphorus reductions provides more co-benefits than does optimizing any other environmental benefit individually. If only one environmental benefit can be targeted at once, an optimization focused on phosphorus reductions results in the most co-benefits and the fewest trade-offs among other environmental benefits as compared to optimizing for N, sediment, or soil C individually.

Implications

Finding 6. Targeting may actually result in a greater number of acres receiving conservation practices at less cost per acre. Because the dual and benefit-cost targeting approaches use funds far more cost effectively than business as usual, about 1.5 times more acres can be treated, suggesting that more farmers, not fewer, may be able to participate when targeting occurs.

Finding 7. If conservation dollars were reallocated based on both geographic and benefit-cost targeting principles, spending would be optimized in fewer, more cost-effective watersheds than under BAU, and funding levels and acres treated would be higher in those watersheds. See Figure ES-1 for the funding allocation under BAU and Figure ES-2 for the funding allocation when the multiple benefits optimization scenario is run under the dual targeting approach. Figures of the analyses under the N, P, sediment, and soil C individual optimization scenarios are presented in the report.

Figure ES-2 | **Funding allocations for cropland-related nutrient and soil erosion control practices under the dual targeting approach when multiple benefits are simultaneously optimized**



Recommendations

Based on the findings of this study and the potential to improve environmental outcomes per dollar spent, WRI recommends that USDA consider the following options for maximizing conservation program benefits.

1. **Begin tracking the water quality-related environmental benefits of federal conservation programs.**

   Current federal conservation programs related to water quality track administrative metrics, such as practices implemented, dollars spent, or conservation contracts signed. By also tracking environmental benefits, the agency will be taking a critical step toward being able to assess the cost effectiveness of these programs. In so doing, the agency will be able to improve program transparency and enhance its ability to track progress toward meeting stated water quality-related goals. Over time, this will ensure that government programs are gaining the most environmental improvement from limited taxpayer resources.

2. **Incorporate benefit-cost principles into existing farmer application ranking criteria used to allocate funding in the conservation programs.**

   To effectively incorporate and operationalize principles of benefit-cost targeting into current programs, NRCS must invest in tools and technologies to better estimate and quantify environmental benefits and costs from conservation at the farm scale. These tools should be used in lieu of or as supplements to existing conservation application ranking systems associated with nutrient and soil erosion control practices. Funding should then be allocated to farmers based on total expected environmental benefit(s) and project costs. Finally, when possible, NRCS should consider co-benefits and trade-offs when selecting the environmental benefits used in the ranking tool in order to ensure that the ranking tools and criteria reflect desired regional, state, or local environmental goals.

3. **Conduct pilot projects that combine geographic and benefit-cost targeting, and/or begin including benefit-cost criteria into existing geographic targeting initiatives like the Mississippi River Basin Healthy Watersheds Initiative (MRBI), the National Water Quality Initiative (NWQI), and the new Regional Conservation Partnership Program (RCPP).**

   To achieve measurable improvements in various water bodies (e.g., streams, rivers, and lakes) suffering from nutrient pollution, NRCS and its conservation partners should continue and increase the number of targeted watershed projects they undertake in small watersheds under the MRBI, NWQI, and RCPP initiatives. To ensure that the funds dedicated to these geographic targeting initiatives are used as cost effectively as possible, the agency should include benefit-cost criteria in the conservation planning process to aid farmer decision making and in the conservation contract selection process to select the most cost-effective contracts. The agency should also consider developing pilot projects that road test the new benefit-cost ranking criteria to identify problems that may materialize and develop solutions to overcome those problems.

4. **Improve federal funding allocation formulas for distributing conservation program funds to the states.**

   Should USDA invest the resources needed to pursue the three previous options, the agency will be laying the groundwork needed to improve the federal conservation funding formulas. Efforts to improve the formulas should take advantage of the CEAP datasets and models but also take into account other sources of relevant data such as on-the-ground best professional judgment, appropriate water quality datasets, and information generated from field-scale and watershed-scale tools. In so doing, the formulas should result in better targeting of funds to watersheds, acres, and practices within states that can achieve the greatest environmental benefits per dollar spent.

Many barriers to implementing targeting approaches exist, including scientific, economic, technical, institutional, and political hurdles. The third paper in this series delves into the various barriers to better targeting and explores options for overcoming them. As a result of these barriers, USDA is not likely to achieve the same magnitude of potential gains found in this study. However, this report illustrates that it is possible to achieve more environmental outcomes per dollar spent than business as usual. WRI believes that USDA can and should strive to maximize the positive impact taxpayer conservation dollars have on water quality. We hope that this report generates many productive conversations among the various conservation community stakeholders in order to realize as much of the modeled improvements in environmental benefits and cost effectiveness as possible.

INTRODUCTION

This study examines the potential gains in cost effectiveness that may be achieved if federal conservation funding addressing water quality on cropland were targeted using geographic priorities and/or benefit-cost approaches.

Although there are many different conservation program priorities, this report is focused primarily on water quality.

Taxpayer-funded federal conservation programs have been resolving environmental and natural resource problems on individual farms for decades. By engaging farm producers and rural landowners on a voluntary basis, the USDA Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) oversee programs that provide financial and technical assistance to farmers for the installation and maintenance of conservation practices. These practices help farmers address a variety of environmental and natural resource issues on agricultural land (e.g., soil quality, water quality, air quality, water quantity, and wildlife habitat), as well as production management issues (e.g., soil fertility, irrigation) and regulatory issues like manure management from confined animal operations.

Although there are many different conservation program priorities, this report is focused primarily on water quality. Eutrophication is a widespread condition in the United States that afflicts freshwater streams, rivers, and lakes as well as estuarine systems such as bays and gulfs in which excess nutrients—nitrogen (N) and phosphorus (P)—cause algae blooms that deplete the water of oxygen and harm aquatic life. In the United States, more than 15,000[1] inland water bodies remain impaired due predominantly to excess agricultural nutrients from synthetic fertilizers and manure and also from sediment from cropland soil erosion.

The current formula for allocating federal conservation dollars to the states includes many important factors to address environmental and natural resource concerns. However, USDA's current approach for allocating conservation dollars does not adequately enable prioritization of funds to watersheds or regions with critical water quality concerns. For example, in one of the largest federal programs, the Environmental Quality Incentives Program (EQIP), 31 factors make up the allocation formula. Although a few factors provide additional weight for the presence of impaired water bodies, the formula does not guarantee that funding flows to areas with the highest priority water quality problems.[2] A Government Accountability Office (GAO) report found that "NRCS's funding process is not clearly linked to EQIP's purpose of optimizing environmental benefits; as such, NRCS may not be directing EQIP funds to states with the most significant environmental concerns arising from agricultural production."[3]

Within states, conservation dollars are awarded to individual farms based on ranking criteria. These criteria vary significantly by state, reflecting different state or local priorities, with some factors reflecting national priorities. One component of the application ranking systems is the cost-efficiency factor. Though cost effectiveness is called for in the farm bill[4] and required by the EQIP Manual,[5] in reality, the cost-efficiency factor is poorly calculated because it is based on qualitative rather than quantitative estimates of environmental benefits and includes generalized rather than actual cost information.[6] Indeed, even the remaining components of the EQIP ranking criteria systems have yet to demonstrate that the use of points, weights, and multipliers to prioritize applications actually results in funding solutions for the highest priority problems.[7]

While the prevailing approach to conservation funding allocation does help address water quality and other environmental problems on individual farms, it does not necessarily result in the improvement of water quality in streams, rivers, and lakes more broadly. This is because the current approach results in dispersing funds widely across the agricultural landscape. The predominant approach to conservation spending creates a patchwork quilt of solutions on distantly located farm fields. Instead, what is needed to improve water quality is sufficient concentration of funds in the drainage area above an impaired water body to reduce the N, P, or sediment runoff ailing that body of water. The current approach also does not prioritize funding allocations to farms that maximize the environmental benefits achieved per dollar spent.[8]

Given increasing fiscal budget constraints, federal programs are under pressure to increase effectiveness and reduce costs. There is also growing demand for estimates of actual environmental benefits that the public is receiving for the investment of taxpayer funds. Likewise, members of Congress and federal conservation program managers are seeking to improve funding allocation options to achieve a greater return on public investment.

Over the years, recommendations for improving the effectiveness of federal conservation programs have included using the principles of targeting.[9] Targeting can take many forms and have several dimensions. Targeting can seek to optimize environmental benefits, optimize costs, and/or seek to concentrate conservation activities in a certain location. Targeting might seek to combine two or more principles by using both benefits and costs to identify priorities. Two important targeting approaches are geographic targeting and benefit-cost targeting.

Geographic targeting involves establishing environmental or natural resource priorities and then committing funds to regions or watersheds exhibiting those priorities. For example, geographic targeting could prioritize areas that:

a. are experiencing the greatest environmental and natural resource impairments,[10]

b. exhibit “pristine” conditions worth preserving,[11] or

c. could offer the greatest change in environmental or natural resource conditions.[12]

Benefit-cost targeting involves identifying and treating the individual farms or acres that can produce the most environmental benefits per dollar spent (i.e., those that are the most cost effective).[13] Programs can aim for cost effectiveness in a variety of ways, including, in the case of water quality programs, paying for the most cost-effective nutrient reduction outcomes measured either via direct monitoring or through indirect modeling estimates. Thus, benefit-cost targeting requires knowledge of relative or estimated environmental losses from individual acres, relative or estimated effectiveness of various treatment options, and treatment costs.[14]

To date, there has been limited documentation by NRCS and other USDA agencies and academic institutions of the environmental effectiveness and the cost effectiveness of the conservation programs, especially when it comes to impacts on water quality.[15] Performance tracking has been restricted to counting administrative metrics such as practices, contracts, acres, and dollars. In addition, there have been limited attempts to evaluate how performance might be improved through targeting of funds both geographically, to areas with the greatest opportunities for changes in environmental outcomes, and cost effectively, to acres where the greatest environmental outcomes can be achieved for every dollar spent.[16]

This study examines the potential gains in cost effectiveness that may be achieved if federal conservation funding were targeted using geographic priorities and/or benefit-cost approaches.

Section I

METHODS

We completed a national-level modeling analysis of various conservation funding allocation schemes using farm survey data, conservation program data, economic optimization models, and Geographic Information Systems (GIS) mapping analysis.

With assistance from the NRCS Conservation Effects Assessment Project (CEAP) team, we conducted a national-level modeling analysis to determine the current cost effectiveness of conservation programs and how the effectiveness of these programs could be improved if financial assistance were better targeted to regions that could maximize environmental benefits per dollar spent. NRCS provided data and technical support while the approach, interpretation, analysis, and policy implications in this report belong to WRI.

We restricted our analysis of program environmental effectiveness to water quality, one of the most widespread and long-standing challenges related to agricultural production. Specifically, we focused our analysis on the reduction of N, P, and sediment losses and excluded other water quality issues such as pesticide losses. In addition to these parameters, we included soil carbon sequestration as part of our analysis.

Note that we use the term *environmental benefit* as a catchall term to refer to both the N, P, and sediment loss reductions as well as the soil C sequestrations. We do so because this is a term used by NRCS to describe the edge-of-field N, P, and sediment loss reductions, despite it also being a term in the economics literature to indicate the impact on human beings, e.g., the economic value of the loss reduction or the in-situ stream water quality value of the reduction.

Our analysis investigated the following questions:

1. How successful is the current business-as-usual (BAU) approach to federal conservation spending in reducing N, P, and sediment and sequestering soil C, both in terms of environmental benefit and cost effectiveness?

2. If federal conservation programs targeted funding using (a) geographic priorities, (b) benefit-cost ratios, or (c) both, how much more environmentally effective would they be in comparison to the BAU approach?

3. How do results of the targeting approaches vary depending on the environmental benefit targeted (N, P, and sediment reduction, soil C sequestration, or a combination thereof)?

4. If programs were designed to achieve the most cost-effective environmental benefits, where would the funds be spent, and how would that change existing conservation program funding allocations?

Overview

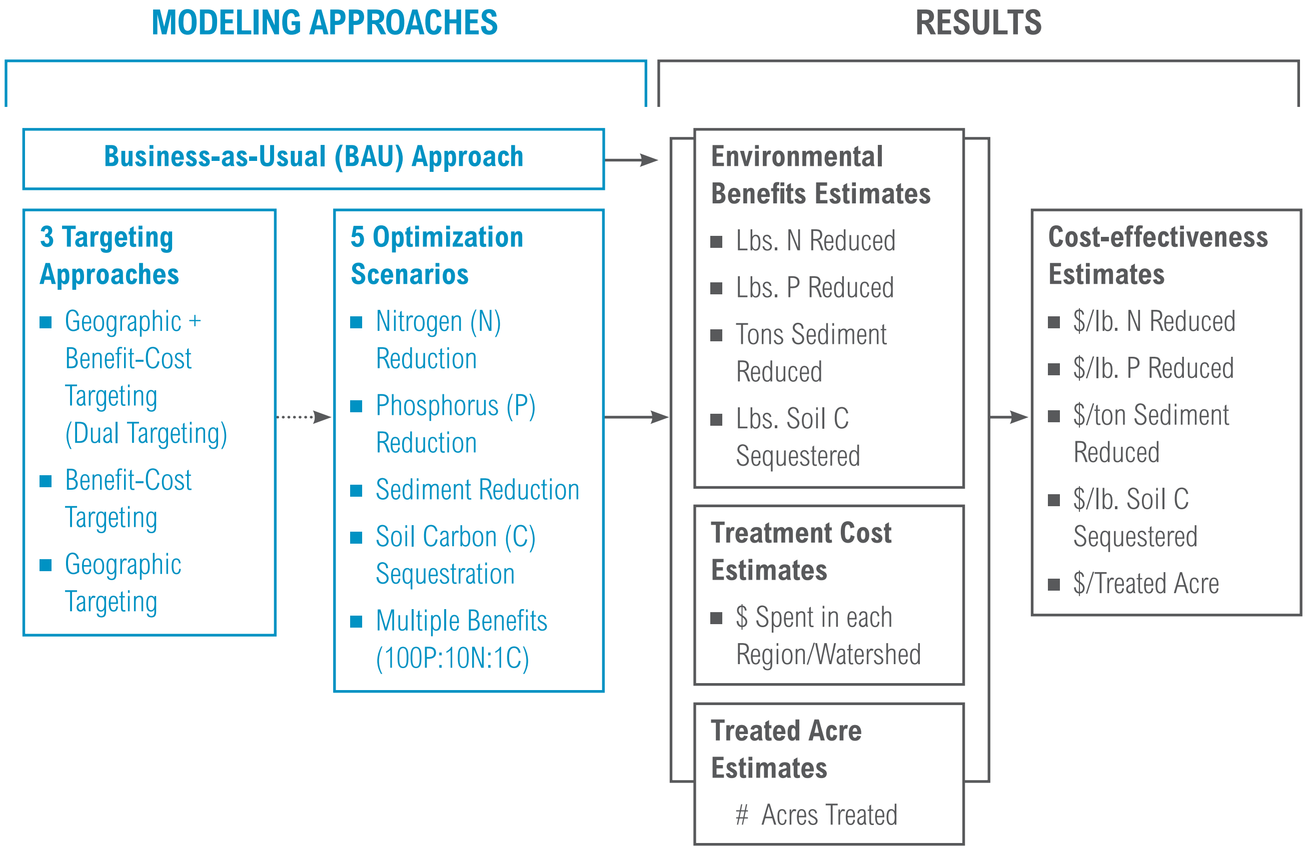
As the foundation of our analysis, we used the results of the CEAP National Assessment for Cropland. The CEAP study estimated the environmental impact of 18,691 sample points on farms across the country using soils, topography, and weather data from the National Resources Inventory (NRI), as well as crop management and conservation practice information from the CEAP farmer surveys conducted from 2003–2006. These NRI-CEAP sample points were modeled using the Agricultural Environmental Policy Extender (APEX) model.

APEX is a field-level model that can estimate the environmental losses (N, P, sediment, and soil C) for an agricultural operation given site-specific environmental and management conditions provided by the NRI-CEAP dataset. The results of the modeled sample points were then statistically extended to representative acres in order to provide a national-level dataset. Because the CEAP suite of data used in this study is limited to cropland, we included only cropland in our analysis and excluded other types of agricultural land such as pasture, hay, and rangeland or livestock feeding operations.

To answer our study questions, we estimated the current BAU approach to conservation payment allocation in addition to three alternative targeting approaches: geographic targeting, benefit-cost targeting, and a combination of the two that we refer to as the dual targeting approach. Each of these three modeled targeting approaches was run with the goal of optimizing four environmental benefits: N, P, and sediment reductions and soil C sequestration. These four benefits were optimized individually, as well as simultaneously in the multiple benefits scenario, which optimized N, P, and soil C benefits together.

Figure 1 offers a visual depiction of the overall modeling framework for this study while Box 1 lists the datasets and models that were used to conduct the analysis. The next section briefly summarizes the

Figure 1 | **Schematic showing the overall framework of this modeling study**



BOX 1 | DATA AND MODELS USED TO CONDUCT THIS STUDY

- Sample point survey data from the 2003 to 2006 Natural Resources Inventory Conservation Effects Assessment Project (NRI-CEAP) farm survey, which provides environmental information (e.g. soil, slope, and weather) as well as farmer production management and conservation data
- The Agricultural Environmental Policy Extender (APEX) model to estimate the four edge-of-field environmental losses, reductions, and sequestrations
- Conservation practice data from 2006 to 2011 from the NRCS ProTracts programs database to estimate the acreage treated by cropland-related nutrient and soil erosion control practices in the business-as-usual scenario
- An economic optimization model to identify and treat the most cost-effective acres
- A Geographic Information System (GIS) to map the funding allocations and treated acre results of the BAU and optimization scenarios (see Appendix A.6 for more details)
- Greenhouse gas emissions conversions data to estimate nitrous oxide emissions benefits (see Box 2 and Appendix A.7 for more information)

methods used to estimate environmental benefits and cost-effectiveness parameters under BAU and the three targeting approaches. For a more detailed and technical description of our methodology, please refer to the Appendix.

Business-as-Usual Approach

To estimate the current national level of effectiveness of conservation funding (or BAU approach), we identified the practices funded in the contiguous 48 states by the main conservation programs[17] over five years (2006 through 2011) that are tracked by the NRCS ProTracts program payments database. We limited our analysis to those practices[18] that were applicable to cropland for the control of nutrient losses and soil erosion and that could be modeled using the APEX model. We found that, over these five years, about 8.7 million cropland acres were treated on average every year with these practices; and the average annual spending on these practices was $335 million dollars, which included installation, maintenance, *and* technical assistance costs. Thus, we elected to set the national budget constraint for this modeling analysis at $335 million to provide a direct comparison between BAU and the targeting approaches.

The APEX model was used to estimate the four environmental benefits achieved under BAU from these adopted practices nationwide (N, P, and sediment reductions and soil C sequestration) and aggregated the results to two watershed scales: the 201 4-digit HUC watersheds as well as the 18 2-digit watersheds.[19] We generated an estimate of the nationwide average BAU cost effectiveness for each of the four benefits by dividing the total cost ($335 million) by each benefit (e.g., lbs. of N reduced), to derive a per-unit cost (e.g., $/lb. N reduced). See Appendix A.2 and A.3 for more details about the BAU approach.

For each optimization scenario, we estimated the environmental benefits, the cost effectiveness of achieving those benefits, and the acres treated by each of the targeting approaches.

Targeting Approaches and Optimization Scenarios

WRI developed three targeting approaches to serve as alternative options to the BAU approach for spending the $335 million national budget to achieve edge-of-field N, P, sediment, and soil C benefits: (1) geographic targeting, (2) benefit-cost targeting, and (3) a dual targeting approach that combined the two. NRCS applied these three approaches using a linear programming optimization model that was developed to determine (a) which of the available 18,691 cropland sample points across the contiguous 48 states to treat, (b) which of the six available practice treatments (See table 1) were the most cost effective to use, and (c) the portion of the statistically extended acreage represented by the sample point to treat.

The first two treatments, cover crops and drainage water management, constitute single-practice treatments. The four additional treatments are composed of a combination of one or more practices available for use by the APEX model for applying each treatment.

The optimization model was developed to maximize the four benefits individually (N reductions, P reductions, sediment reductions, and soil C sequestration) per dollar spent and then, in a fifth scenario, optimized three benefits simultaneously (N, P, and soil C) per dollar spent. For each scenario, we estimated the environmental benefits, the cost effectiveness of achieving those benefits, and the acres treated by each of the three targeting approaches. The results of each scenario were aggregated to each of the 201 4-digit watersheds and also the 18 2-digit watersheds in the contiguous United States. A brief description of the targeting and optimization methods is provided here, and more information can be found in Appendix A.4.

Table 1 | **Conservation practice options available for use by the six conservation treatment systems**

CONSERVATION PRACTICES	CONSERVATION TREATMENT SYSTEMS					
	COVER CROP (CC)	DRAINAGE WATER MANAGEMENT (DWM)	EROSION CONTROL (EC)	EROSION CONTROL & NUTRIENT MANAGEMENT (ENM)	ENM-CC	ENM-DWM
Cover Crop	x				x	
Drainage Water Management		x				x
Residue Management Tillage			x	x	x	x
Contour Farming			x	x	x	x
Wind Break or Shelter Belt			x	x	x	x
Field Border			x	x	x	x
Riparian Herbaceous Buffer			x	x	x	x
Riparian Forest Buffer			x	x	x	x
Filter Strip			x	x	x	x
Hedgerow			x	x	x	x
Contour Strip Cropping			x	x	x	x
Cross Wind Strips and Traps			x	x	x	x
Terrace			x	x	x	x
Herbaceous Wind Barrier			x	x	x	x
Surface Roughening			x	x	x	x
Nutrient Management Plan				x	x	x

Table 2 provides a simple reference displaying how the model either optimized or held constant the conservation budgets and the level of cost effectiveness for each of the 201 4-digit watersheds in the contiguous United States.

Table 2 | **Model specification for the three targeting approaches within the 201 4-digit watersheds nationwide**

TARGETING APPROACHES	MODELED VARIABLES	
	CONSERVATION BUDGETS PER WATERSHED	COST-EFFECTIVENESS LEVEL PER WATERSHED
Geographic + Benefit-Cost Targeting (a.k.a. Dual Targeting)	Optimized	Optimized
Geographic Targeting Only	Optimized	BAU
Benefit-Cost Targeting Only	BAU	Optimized

Geographic + Benefit-Cost Targeting Approach

To estimate benefits and cost effectiveness of conservation funding based on the geographic + benefit-cost targeting approach (the dual targeting approach), we assumed that the national budget ($335 million) was allocated to the acres and to six available practice treatments anywhere nationwide that the model identified as being able to achieve the greatest number of environmental benefits per dollar spent, thereby optimizing both the budget allocation and cost effectiveness of treatments. Once all project funds were expended, the results were aggregated and reported at the 4-digit HUC watershed level, revealing an optimal project budget for conservation spending in each of the 201 watersheds for each of the five optimization scenarios. The budget allocations adopted in the dual targeting approach are used in the geographic targeting approach (see below) to simulate a geographically targeted budget allocation.

Geographic Targeting Approach

In our analysis, we define geographic targeting as an approach that prioritizes funding to watersheds anywhere in the country that can achieve the

greatest reductions in N, P, and sediment losses and the greatest soil carbon sequestration as estimated at the field's edge. To estimate the environmental benefits and cost effectiveness of a geographic-only targeting approach, we used the optimal budgets previously allocated to each 4-digit watershed under the dual targeting approach (i.e., the optimal budget for each of the five optimization scenarios described above). Thus, for example, whatever budget the N optimization scenario in the dual targeting approach determined to allocate within each 4-digit watershed, that same "optimal" budget amount was used in the geographic targeting approach's N optimization run. Within each watershed, the model then allocated that optimal budget for conservation treatment but was constrained to the average BAU cost-effectiveness values previously estimated for each watershed.

For example, if the model allocated an optimal $100,000 to a given watershed based on the dual targeting approach, and the average cost to treat a single acre under BAU is $60 per acre with an average N benefit of 10 lbs. per acre, then the geographic targeting approach would be able to treat 1,667 acres and reduce 16,670 lbs. of N in that watershed. Therefore, under the geographic targeting approach, the model uses the optimal budget per watershed but assumes that the cost effectiveness of achieving environmental benefits per watershed is the same as BAU.

Benefit-Cost Targeting Approach

To estimate the environmental benefits and cost effectiveness of the benefit-cost only targeting approach, the model was constrained by how the conservation budgets were allocated to each of the 201 watersheds under BAU and did not allow for any reallocation of funds across watersheds. Within each 4-digit watershed, however, the model was unconstrained in its search to find the acres and practice treatments that resulted in the most environmental benefit per dollar spent (i.e., optimizing cost effectiveness). Acres continued to be treated until each watershed's BAU budget was exhausted. The benefit-cost scenario was run to optimize cost effectiveness of treatment practices and benefits for each of the five optimization scenarios. In essence, the benefit-cost targeting approach assumes that the same state funding allocation occurs in each watershed as was spent from 2006 to 2011 (i.e., BAU) but that these funds would now treat the most cost-effective acres using the most cost-effective practices.

Assumptions and Limitations

The CEAP dataset, APEX model, and economic optimization model reflect the best available data on farm production and conservation activities nationwide and the best available nationwide computer modeling systems to provide estimates of the environmental impact and economic costs of certain conservation practices. As with any study, this report's results should be reviewed with an understanding of the assumptions and limitations that restrict the analysis. The study's results offer an indication of the kinds of benefits and cost savings that may be realized from better targeting of conservation funds.

A list of the study's assumptions and limitations is provided here and discussed further in Appendix A.5:

- The analysis estimates the benefits of targeting a subset of conservation program funds for water quality concerns, which is one of the many environmental and natural resource concerns that are addressed by the conservation programs. Thus, the spatial distribution of optimal payments would likely be different if a different set of environmental outcomes were considered.

- The analysis is restricted to focusing only on cropland as these were the only lands considered in the 2006 CEAP assessment (though future CEAP analyses will focus on rangelands and wetlands). The CEAP data do reflect use of livestock manure on cropland through the nutrient management practice treatment but do not include manure management practices at livestock operations.

- Our analysis adopted a budget constraint of $335 million to provide a direct comparison to the BAU costs associated with the nutrient and soil erosion control practices, which is a fraction (7 percent) of the $5 billion per year or so that was spent on all conservation practices and all types of agricultural land over the same time period.

- Due to the budget restriction, our analysis was also restricted to treating between 8.7 million cropland acres in the BAU approach to at most 16.8 million cropland acres in the dual targeting approach. These acreages are just a fraction (3 to 6 percent) of the 304 million cropland acres across the country. As such, in each of the 201 4-digit watersheds, only between a few thousand to a few million acres could be treated. Some watersheds received no funds due to a variety of reasons, including limited cropland acres, limited NRI-CEAP survey sample points, or the fact that the acres were deemed by the model as not cost effective relative to cropland in other 4-digit watersheds.

- The APEX and optimization models use inputs and conduct the analysis at the sample point scale (and the point's statistically extended acres); but because some smaller watersheds have a limited availability of sample points, the results are reported at the much larger 4-digit watershed scale, which represents the smallest scale at which the data are statistically valid. Also, neither model can pinpoint exactly where the treated acres are located within the watersheds to provide more localized findings.

- The APEX model estimates environmental losses and reductions at the field's edge and thus does not reflect an analysis of the effects of conservation practices on ecological conditions in streams, nor does it take note of the presence or location of impaired water bodies within watersheds. Instead, this study focuses on the attainment of what NRCS calls "full treatment" wherein each sample point attains a combination of practices that addresses all the specific inherent vulnerability factors (e.g., soil hydrologic group, slope, erodibility, etc.) that determine the potential for sediment and nutrient losses.[20]

- By ignoring the presence of impaired (or pristine) water bodies that are ideally considered in policy discussions, the analysis, in turn, does not allow for incorporation of potential societal preferences for conservation efforts in certain locations or preferences for one environmental benefit (e.g., P) over another (e.g., N) to address the problems causing the water body impairments. These types of societal inputs are critical when trying to clean up impaired water bodies via targeted watershed projects that are usually implemented at the 8-digit or 12-digit watershed.[21]

- The study ignores the effect on yield, either positive or negative, from conservation practices and also ignores the cost savings from reduced fertilizer purchases that often accompany the nutrient management treatment. Both elements would be taken into account by producers when selecting which, if any, conservation practices to adopt in their farm operation to address the water quality concerns highlighted in this report.

- BAU cost-effectiveness estimates and potential gains from targeting are derived from the CEAP farm survey data from 2003 to 2006 and do not take into account any of the most recent conservation efforts of the 2008 farm bill, including targeted approaches like the Mississippi River Basin Initiative and the Chesapeake Bay Watershed Initiative nor the increased adoption of cover crops in many areas. While the conservation gains made during the years since data collection have yet to be fully estimated, those gains reduce the remaining potential gains from targeting.

- The study assumes full participation from producers associated with the statistical acres in the model. In reality, conservation programs are voluntary, and participation is subject to producer preference.

- The study does not consider additional transaction costs that may be involved in adoption of a targeting approach (e.g., costs to identify and assess cropland acres, outreach costs, etc.). Accordingly, incorporation of such transaction costs will shrink the expected gains modeled in this study.

Section II

RESULTS AND DISCUSSION

We analyze how the three different targeting approaches compare to BAU in terms of cost effectiveness, environmental benefits, acres treated, and allocation of funding across regions.

Cost Effectiveness

Table 3 provides the national-level estimates of cost effectiveness and environmental benefits from the BAU approach, the targeting approaches, and the optimization scenarios.* Cost effectiveness was calculated by dividing the total budget constraint of $335 million by the pounds or tons of environmental benefits achieved under each scenario. Cells with estimates highlighted in blue represent the results of the targeted benefit in each of the respective scenarios. Non-highlighted cells in the same row show the co-benefits for the non-targeted parameter. For example, in the N optimization scenario, the cell showing the N reduction benefits is highlighted, while the associated benefits for P, sediment, and soil C that were generated alongside the targeted N reductions are shown in the same row but are not highlighted.

Our analysis estimates that the **BAU level** of cost effectiveness of federal conservation program funds for cropland-focused conservation treatments ranges from about $1 to $28 per unit of environmental benefit, with sediment and P having the highest per unit reduction costs ($28.27/ton sediment and $19.82/lb. P) and N reduction and soil C sequestration having the lowest costs per unit ($3.65/lb. N and $1.05/lb. soil C). (See the first row of table 3.)

The dual targeting approach (i.e., the geographic priorities + benefit-cost targeting) was the most successful at achieving the greatest benefits per dollar spent. Under the N optimization scenario, the dual targeting approach achieved N reductions at a rate that is **12 times more cost effective** than BAU ($0.30/ lb. N compared to $3.65/lb. N for BAU). For P, sediment, and soil C sequestration, the dual targeting approach was about **eight times more cost effective** than BAU under the respective optimization scenarios (i.e., $2.46/lb. P compared to $19.82/lb. P under BAU, $3.63/ton sediment versus $28.27/ton sediment under BAU, and $0.14/lb. soil C compared to $1.05/lb. soil C under BAU). Because the dual targeting approach optimizes funding allocations across entire landscapes and also on individual acres, it is able to achieve greater environmental benefits per dollar spent.

The benefit-cost targeting approach, which maintained BAU regional funding allocations but optimized allocations to the most cost-effective acres within these existing regional funding constraints, was also able to achieve significant environmental gains per dollar spent. For example, the benefit-cost approach achieved N reductions at an average cost effectiveness of $0.41 lb./N under the N optimization scenario compared to $3.65 lb./N under BAU. This

* In Table 3, dollars per pound or ton of environmental benefit is derived by dividing the total budget constraint of $335 million by the total pounds or tons of environmental benefits achieved under each scenario. Cells with numbers highlighted in blue represent the results of the targeted benefit in each of the respective scenarios. Non-highlighted cells in the same row show the co-benefits for the non-targeted benefits. For example, in the N optimization scenario, the cell showing the N reduction benefits is highlighted, while the associated benefits for P, sediment, and soil C that were generated alongside the targeted N reductions are shown in the same row but are not highlighted.

Table 3 | **Cost effectiveness and environmental benefits achieved under BAU, the targeting approaches, and optimization scenarios**

TARGETING APPROACH	OPTIMIZATION SCENARIOS	$/LB. NITROGEN REDUCED (1,000 LBS. N REDUCED)	$/LB. PHOSPHORUS REDUCED (1,000 LBS. P REDUCED)	$/TON SEDIMENT REDUCED (1,000 TONS SEDIMENT REDUCED)	$/LB. SOIL CARBON SEQUESTERED (1,000 LBS. C SEQUESTERED)
BAU	N/A	**$3.65** (91,843)	**$19.82** (16,891)	**$28.27** (11,845)	**$1.05** (317,565)
Geographic + Benefit-Cost	N Reduction	**$0.30** (1,124,304)	**$5.15** (65,100)	**$11.82** (28,353)	**$1.71** (196,350)
	P Reduction	**$0.68** (492,979)	**$2.46** (136,395)	**$6.45** (51,909)	**$0.39** (855,065)
	Sediment Reduction	**$1.32** (254,597)	**$4.87** (68,759)	**$3.63** (92,354)	**$0.32** (1,033,443)
	Soil C Sequestration	**$0.98** (343,226)	**$5.47** (61,210)	**$9.84** (34,034)	**$0.14** (2,377,003)
	Multiple Benefits (100P+10N+1C)	**$0.36** (934,517)	**$2.82** (118,993)	**$7.02** (47,709)	**$0.38** (881,588)
Benefit-Cost Only	N Reduction	**$0.41** (819,261)	**$6.24** (53,707)	**$16.86** (19,869)	**$0.62** (542,451)
	P Reduction	**$0.83** (404,103)	**$3.46** (96,863)	**$10.54** (31,771)	**$0.39** (854,530)
	Sediment Reduction	**$1.47** (227,359)	**$6.46** (51,818)	**$6.34** (52,815)	**$0.40** (837,604)
	Soil C Sequestration	**$1.17** (286,211)	**$6.86** (48,802)	**$13.67** (24,512)	**$0.18** (1,859,155)
	Multiple Benefits (100P+10N+1C)	**$0.48** (692,694)	**$3.84** (87,289)	**$10.94** (30,622)	**$0.32** (1,048,015)
Geographic Only	N Reduction	**$4.41** (76,011)	**$19.12** (17,522)	**$25.33** (13,224)	**$1.34** (250,474)
	P Reduction	**$4.42** (75,804)	**$17.06** (19,641)	**$22.18** (15,106)	**$1.33** (252,323)
	Sediment Reduction	**$4.88** (68,692)	**$15.81** (21,191)	**$19.44** (17,230)	**$1.55** (216,065)
	Soil C Sequestration	**$3.76** (89,068)	**$15.76** (21,250)	**$26.76** (12,520)	**$1.07** (311,652)
	Multiple Benefits (100P+10N+1C)	**$4.26** (78,656)	**$17.56** (19,073)	**$24.01** (13,950)	**$1.28** (261,284)

means that, by allocating existing conservation funding using a benefit-cost approach, the model finds **nine times as many N benefits** than under the current BAU approach. When optimizing for P and soil C, the benefit-cost targeting approach was able to achieve nearly **six times the amount of P and soil C benefits** per dollar spent as compared to BAU. When optimizing for sediment, the benefit-cost approach achieves about **four and a half times the sediment benefits** as compared to BAU.

The geographic priorities-only targeting approach proved to be the least cost-effective targeting approach and achieved results on par with BAU. In fact, the geographic targeting approach slightly underperformed BAU for N and soil C optimization scenarios and performed only slightly better than BAU for the P and sediment optimization scenarios.

One possible reason for the geographic targeting approach's failure to achieve significant environmental gains may be the scale at which our analysis was run. We were restricted to using the 4-digit HUC scale, which is a scale that is generally larger than the scale at which geographic priorities would be set. When funds are targeted at a smaller scale, where environmental concerns are concentrated (e.g., a 12-digit watershed), we might expect to find greater cost effectiveness of conservation dollars as compared to BAU than was estimated in our analysis.

Table 4a | **Benefit ratios of environmental outcomes achieved in the dual targeting approach versus the business-as-usual approach and ranking of scenarios based on average percentage difference from the optimal**

ENVIRONMENTAL BENEFITS	NITROGEN REDUCTION OPTIMIZATION	PHOSPHORUS REDUCTION OPTIMIZATION	SEDIMENT REDUCTION OPTIMIZATION	SOIL CARBON SEQUESTRATION OPTIMIZATION	MULTIPLE BENEFITS OPTIMIZATION
N Reductions	**12.2**	5.4	2.8	3.7	10.2
P Reductions	3.9	**8.1**	4.1	3.6	7.0
Sediment Reductions	2.4	4.4	**7.8**	2.9	4.0
Soil C Sequestered	0.6	2.7	3.3	**7.5**	2.8
Average Percentage Difference from the 'Optimal' (Blue) Scenario	-53%	-41%	-46%	-47%	-35%
Rank (1=the best)	5	2	3	4	1

Note: The values in this table represent the "ratio of benefits" under **dual targeting** compared to the benefits under BAU. Thus, the dual targeting approach under the N optimization scenario achieves 12.2 times more pounds of N reductions than BAU (as shown in the cell in the first column and row). The values in the second-to-last row reflect the average percentage difference in benefit ratios from each optimal scenario, reflecting how well each scenario does at achieving co-benefits. This is found by subtracting the benefit ratios in each column from the corresponding benefit ratio achieved in the optimal scenario for the same resource concern (shown in blue) and calculating the average (e.g., ((12.2-12.2)/12.2)+((3.9-8.1)/8.1)+((2.4-7.8)/7.8)+((0.6-7.5)/7.5)*100/4= -53%). The five optimizations were then ranked from 1 to 5 with 1 being the best scenario. The multiple benefits optimization scenario is the best because it provides 65 percent of the benefits that would be achieved if each benefit had been optimized individually. Alternatively, the multiple benefits optimization provides 35 percent fewer benefits than can be realized when each benefit is optimized individually.

Nevertheless, we might infer that the environmental gains from geographic targeting are likely to be less than optimal unless paired with a benefit-cost approach that can help maximize the most cost-effective acres to treat within a given priority area.

Environmental Benefits

Benefit ratios

In this section, we derive "benefit ratios" as a means of comparing the relative gains in environmental benefits under the five optimization scenarios (see table 3) to the benefits achieved under BAU. We display the benefit ratios for both the dual targeting scenario and the benefit-cost targeting scenario in tables 4a and 4b, respectively. The benefit ratios highlighted in blue font in tables 4a and 4b show the 12.2 benefit ratio of the targeted parameter. For example, in table 4a, the benefit ratio for N reductions under the N optimization scenario is highlighted and indicates that there are 12.2 times the N reductions achieved under the dual targeting approach (1.12 billion lbs. displayed in table 3) than those achieved under BAU (91.8 million lbs.).

Note also that this blue highlighted benefit ratio reflects the greatest amount of N reductions over BAU that can be achieved across all five optimization scenarios. For example, when the "multiple benefits" optimization was run to simultaneously optimize N, P, and soil C benefits, we see that 10.2 times the number of N reductions is generated (934.5 million) compared to BAU. Benefit ratios for N reductions

Table 4b | **Benefit ratios of environmental outcomes achieved in the benefit-cost targeting approach versus the business-as-usual approach and ranking of scenarios based on average percentage difference from the optimal**

ENVIRONMENTAL BENEFITS	NITROGEN REDUCTION OPTIMIZATION	PHOSPHORUS REDUCTION OPTIMIZATION	SEDIMENT REDUCTION OPTIMIZATION	SOIL CARBON SEQUESTRATION OPTIMIZATION	MULTIPLE BENEFITS OPTIMIZATION
N Reductions	**8.9**	4.4	2.5	3.1	7.5
P Reductions	3.2	**5.7**	3.1	2.9	5.2
Sediment Reductions	1.7	2.7	**4.5**	2.1	2.6
Soil C Sequestered	1.7	2.7	2.6	**5.9**	3.3
Average Percentage Difference from the 'Optimal' (Blue) Scenario	-44%	-36%	-43%	-42%	-28%
Rank (1=the best)	5	2	4	3	1

Note: The values in this table represent the "ratio of benefits" (i.e., the amount of times there are more benefits) under benefit-cost targeting compared to the benefits under BAU. For example, there are 8.9 times the pounds of N reductions under the N optimization scenario when the benefit-cost targeting approach is employed than the number of N reductions under BAU. The average percentage difference from the optimal scenario is found by subtracting the "ratio of benefits" achieved under the scenario for each resource concern from the "ratio of benefits" achieved from the optimal scenario for the same resource concern (in blue) and calculating the average (e.g., ((8.9-8.9)/8.9)+((3.2-5.7)/5.7)+((1.7-4.5)/4.5)+((1.7-5.9)/5.9)*100/4= -44%). The five optimizations were then ranked from 1 to 5 with 1 being the best scenario.

under the dual targeting approach range from 2.8 to 12.2 depending on the optimization scenario (table 4a) and range from 2.5 to 8.9 in the benefit-cost targeting approach (table 4b).

The non-highlighted benefit ratios in each *column* in tables 4a and 4b represent the benefit ratios of the non-targeted environmental parameter for each optimization scenario. Thus, the remainder of the benefit ratios in the first column in the dual targeting approach are not highlighted because they represent the relative gains in P, sediment, and soil C that were generated as *co-benefits* in the N optimization scenario. For example, when optimizing N reductions, there are 3.9 more P reductions (65.1 million lbs. P) generated as co-benefits than the P reductions achieved under the BAU approach (16.9 million lbs. P). In contrast, when the P optimization scenario aims to maximize P reductions, 8.1 times the P reductions (136.4 million lbs. P) occurs than under BAU (16.9 million lbs. P).

In both the dual and the benefit-cost targeting results, environmental benefits increased significantly over BAU for each of the four parameters under the respective optimization scenarios. Improvements were much greater in the dual targeting approach (table 4a), again highlighting the finding that when the optimization model is unconstrained by regional budget constrictions and allocates money based on benefit-cost ratios, it will achieve the greatest environmental outcomes.
The co-benefits of the non-optimized parameters increased as compared to BAU in all but one optimization scenario. The exception is the N optimization approach in the dual targeting approach where soil C benefits were only 60 percent (benefit ratio was 0.6) of the soil carbon benefits that are achieved under BAU (see table 4a). This result illustrates that, by targeting a single parameter, we risk incurring unintended or undesired trade-offs for other environmental benefits. In the case of the soil carbon sequestration trade-off under the N optimization scenario, it is possible that a policy that targets N reductions only, for example, would incentivize reduced nitrogen fertilizer applications, which may reduce biomass in the soil, resulting in less organic matter and, in turn, lead to less soil C being stored and reduced soil health.

In both the dual and benefit-cost targeting results, environmental benefits increased significantly over BAU for each of the four parameters under the respective optimization scenarios.

Ranking optimization scenarios

In addition to the potential for trade-offs, we notice that the magnitude of potential co-benefits for non-optimized environmental parameters varies widely among the optimization scenarios. To identify the optimization scenario under each targeting approach that offered the greatest overall benefits (for all environmental parameters), we ranked each scenario in terms of its ability to maximize benefits over the four targeted parameters (N, P, and sediment reduction and soil C sequestration).

To rank the optimization scenarios, we first determined the percentage difference from the optimal result for each environmental benefit in each scenario. For example, in the N optimization scenario under the dual targeting approach, the P co-benefit ratio is 3.9. In contrast, the fully optimized P benefit ratio is 8.1. This is the benefit ratio for P reductions under the P optimization scenario that is highlighted in blue in Table 4a. The P benefits achieved under the N optimization scenario represent 52 percent fewer P reductions than would have occurred if P reductions had been the targeted parameter. Similarly, under the N optimization scenario, sediment reductions are 69 percent less than would have occurred under the sediment optimization scenario, and soil carbon sequestration is 92 percent less than what would have occurred under the soil carbon optimization scenario.

To generate an average difference in total benefits achieved under the N optimization scenario compared to the optimal benefits, we simply averaged the percentage differences of each benefit for each scenario. So, for the N optimization scenario we averaged -52% (P), -69% (S), -92% (soil C), and 0% (N) for an overall average of -53 percent, which means that, on average, the N optimization scenario fell 53 percent short of the total benefits that could be achieved under each benefit's optimization scenario. This number is meant to be compared to the other optimization scenarios in order to better understand which scenarios have the most trade-offs (e.g., the largest decrease in outcomes from non-targeted co-benefits) and which scenarios have the least trade-offs.

A rank from 1 to 5, with 1 being the best, was assigned to each optimization scenario based on the average percentage difference from the optimal scenario. Our results show that the multiple benefits optimization scenario is ranked first in both the dual and benefit-cost targeting approaches as it results in the smallest percentage change from the optimal (-35 percent under dual targeting and -28 percent under benefit-cost targeting). The multiple benefits optimization scenario provides a greater number of environmental benefits across all parameters as compared to the other optimization scenarios. This is perhaps not surprising since it targets N, P, and sediment simultaneously.

When only one benefit is optimized, the P optimization scenario has the smallest average percentage difference from each parameter's optimal scenario (-41 % in the dual targeting approach and -36% in the benefit-cost targeting approach) and thus ranks best among the individual benefits scenarios. The P optimization scenario has more equally distributed benefits across N, sediment, and soil C as compared to the other single-benefit optimization scenarios.

In both the dual and benefit-cost targeting approaches, the N optimization scenario is ranked last with the highest average percentage difference from optimal. We might infer that targeting N reductions only may result in the least number of co-benefits as compared to other single-benefit optimization scenarios.

It is important to note that this analysis assumes that society (e.g., the agricultural and environmental stakeholders involved in farm conservation funding decisions) values each benefit equally. In reality, depending on location and the impairments causing eutrophication in priority water bodies, the stakeholders will likely have preferences for different environmental benefits. Those preferences would better inform the discussion about which environmental benefit or benefits are the most important to maximize cost effectively and thus which optimization scenario is the best. Barring that information at this time, we employed an "average percentage difference" calculation to facilitate this co-benefits comparison.

In addition to agriculture's water quality impacts, there are also climate change impacts. Currently, APEX is able to estimate the soil carbon sequestration that accompanies the six modeled conservation treatments that address nutrient and soil erosion resource concerns. As expected, when the model aims to optimize the soil C sequestration benefits, the greatest gains in soil C sequestration over the BAU approach occurs. More modest soil C sequestration gains over BAU also occur as co-benefits when the model aims to optimize for N, P, or sediment reduction (see the Soil C Sequestration Optimization column and Soil C Sequestration row in tables 4a and 4b).

In addition to carbon emissions, nitrous oxide (N_2O) is one of the most potent greenhouse gases with a warming potential 298 times that of carbon dioxide. The N_2O emissions are released through volatilization during the application of chemical or manure fertilizers to cropland. Box 2 provides an estimate of the potential for avoided N_2O emissions (and carbon dioxide equivalent emissions) from the nitrogen fertilizer savings that occurred in each optimization scenario.

BOX 2 | IMPACT OF TARGETING APPROACHES ON AVOIDED NITROUS OXIDE EMISSIONS

As part of our analysis, we estimated the potential avoided nitrous oxide (N_2O) emissions from the various targeting approaches based on reported nitrogen fertilizer savings (in pounds) that occurred in each optimization scenario when the erosion control and nutrient management (ENM) treatment was selected. Since APEX does not provide N_2O emissions analysis, we relied on data and conversion factors from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. See Appendix A.7 for more details.

Table 5 provides the estimated avoided N fertilizer applications, avoided N_2O emissions, and CO_2 equivalent avoided emissions under the dual and benefit-cost targeting approaches.

In the dual targeting approach, between 37 million and 1.2 billion pounds of nitrogen fertilizer could be avoided nationwide, depending on which optimization scenario is run. This results in between 266 and 8,200 metric tons of avoided N_2O emissions and between 82,000 and 2.5 million metric tons of avoided CO_2 equivalent emissions. Similar informaton is provided for the benefit-cost targeting approach. As is expected, the N reduction optimization scenario offers the greatest N fertilizer savings followed by the multiple benefits optimization scenario.

The avoided N_2O emissions estimated below make up only about 0.5 to 1 percent of U.S. agricultural N_2O or agricultural greenhouse gas emissions, respectively. However, it is important to note that fertilizer savings were only estimated for about 13 million acres of cropland—less than 5 percent of all U.S. cropland. Total avoided N_2O emissions would likely be significantly higher were we able to include additional acres in our analysis.

Table 5 | Nitrous oxide and carbon dioxide-equivalent benefits from avoided nitrogen fertilizer

	OPTIMIZATION SCENARIO				
	NITROGEN REDUCTION	PHOSPHORUS REDUCTION	SEDIMENT REDUCTION	SOIL CARBON SEQUESTRATION	MULTIPLE BENEFITS (100P+10N+1C)
DUAL TARGETING (GEOGRAPHIC + BENEFIT-COST) APPROACH					
Avoided N Fertilizer (lbs. x 1,000)	1,153,293	433,803	37,311	49,696	889,971
Direct N_2O Avoided (metric tons)	8,221	3,092	266	354	6,344
CO_2 Equivalent (metric tons)	2,548,365	958,550	82,444	109,811	1,966,515
BENEFIT-COST ONLY TARGETING APPROACH					
Avoided N Fertilizer (lbs. x 1,000)	773,450	336,810	43,472	62,940	609,778
Direct N_2O Avoided (metric tons)	5,513	2,401	310	449	4,346
CO_2 Equivalent (metric tons)	1,709,046	744,229	96,058	139,076	1,347,391

Acres Treated

Figure 2 illustrates the relative change in acres treated under the three targeting approaches compared to BAU for the five respective optimization scenarios (N, P, sediment, soil C, and multiple benefits). Approximately 8.7 million cropland acres were being treated annually under BAU. But if dual targeting and benefit-cost targeting approaches were implemented, the number of acres that could receive conservation practices could increase to between 12.8 and 16.8 million acres with existing funding levels—a potential increase of 50 percent. The geographic targeting approach tended to treat a similar number of acres as the BAU scenario. For the N, P, sediment, and multiple benefit optimization scenarios, the geographic targeting scenario treated slightly fewer acres, while for the soil C sequestration scenario it treated slightly more.

Figure 2 | **Number of treated acres compared to BAU for the three targeting approaches**

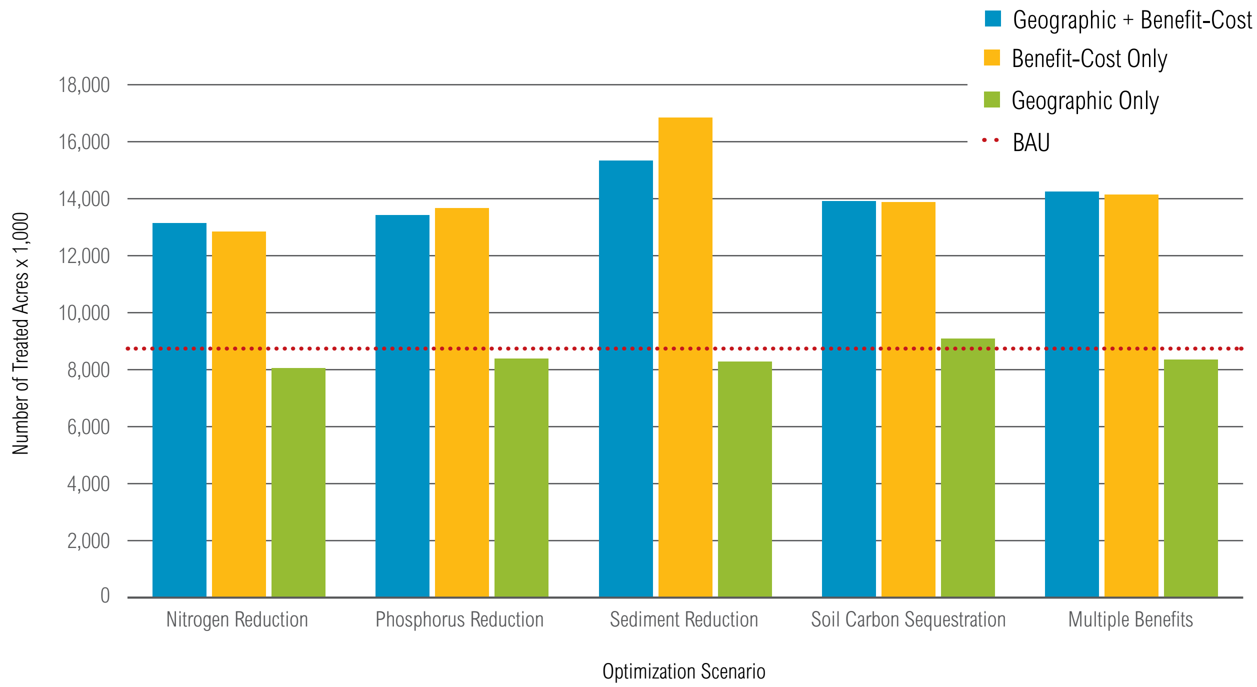
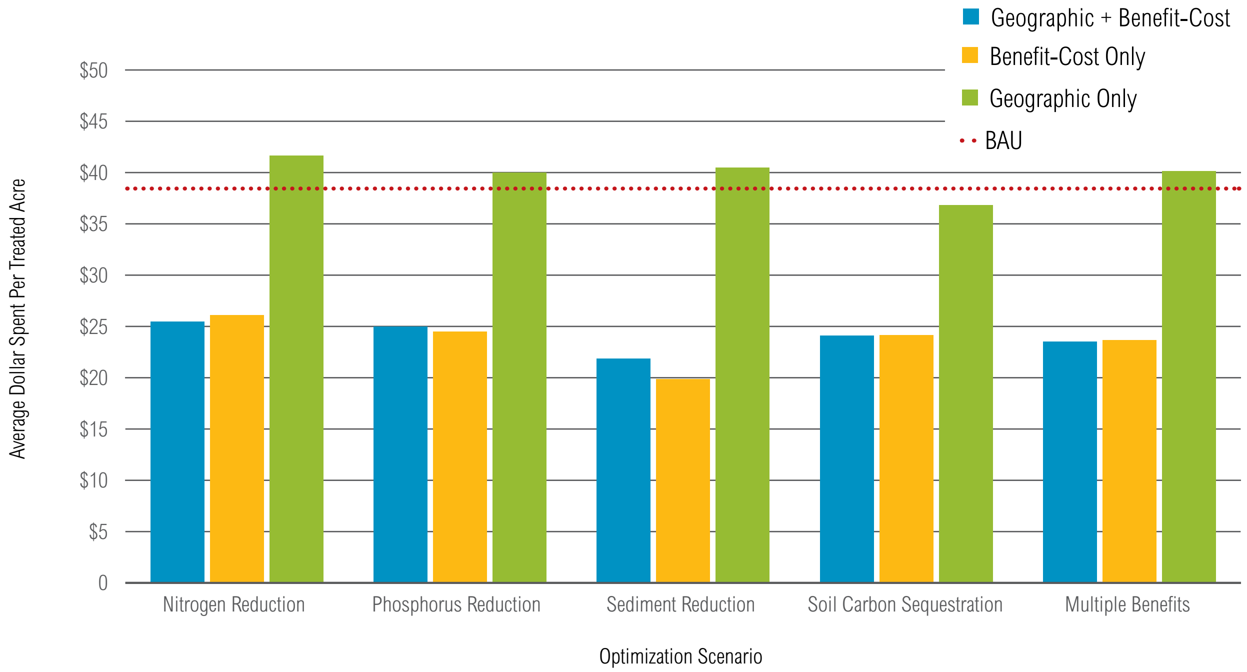


Figure 3 | **Average dollar amount spent per treated acre for the three targeting approaches**



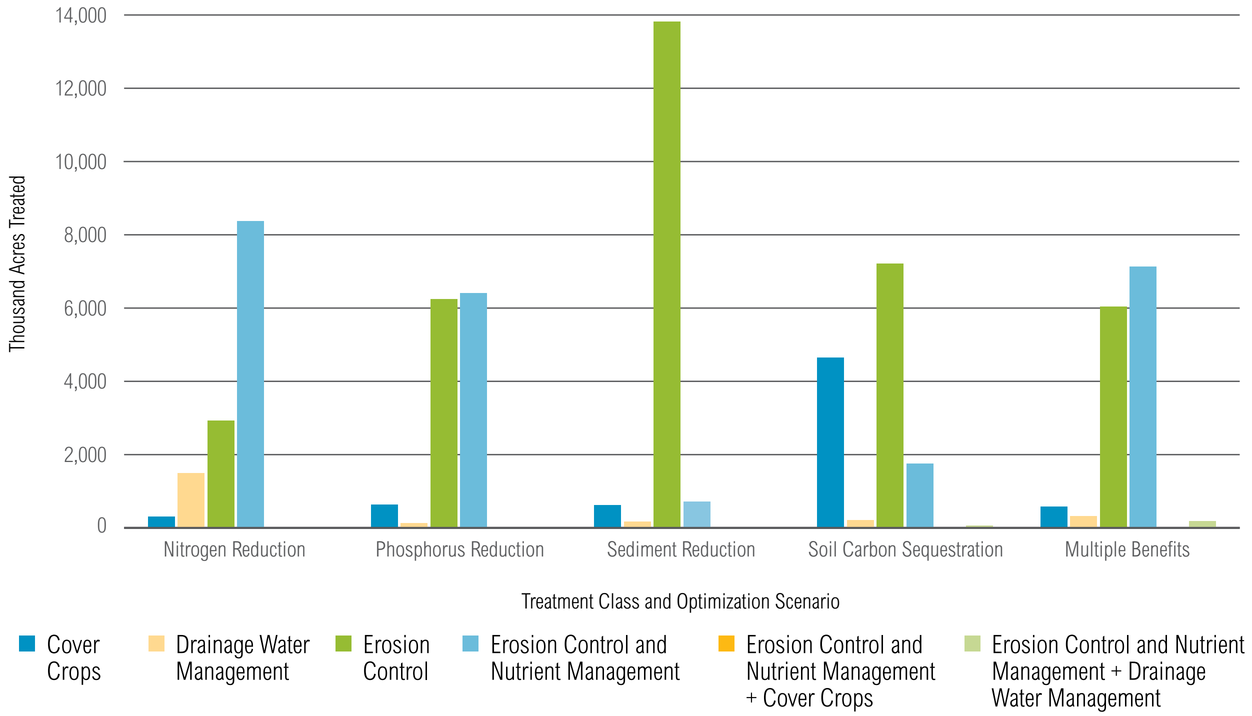
By corollary, because our budget (for analysis purposes) is fixed, under the dual and benefit-cost targeting approaches where the number of acres treated increased, the dollars spent per acre decreased ($20–$25/acre versus $39/acre under BAU). (See figure 3.) Thus we can infer that, if conservation dollars were to be allocated using a benefit-cost targeting approach, programs might spend less per acre because they would begin treating the most cost-effective acres first. By spending less per acre, these programs would then be able to treat a greater number of acres. Under the geographic targeting approach, dollars spent per acre were similar to BAU costs. (See figure 3.)

Distribution of Practice Treatments

The distribution of practice treatments applied under each optimization scenario varied. Table 1 in the methods section previously displayed the 16 cropland conservation practices that can be modeled by APEX through the use of the six conservation treatments.[22] Figure 4 displays the number of acres treated by each treatment system under each optimization scenario using the dual targeting approach. The mix of treatments was nearly identical for the benefit-cost targeting approach.

As would be expected, erosion control treatments were applied most often when sediment was targeted, whereas the erosion control plus nutrient management treatment was applied more frequently when optimizing for N or P reductions. The cover crop treatment, in addition to erosion control, was applied on the largest number of acres to achieve soil C sequestration. Figure 4 suggests that the dual targeting approach for all five optimization scenarios would achieve the greatest environmental benefits per dollar spent using practices within the erosion control and the erosion control plus nutrient management treatments.

Figure 4 | **Number of treated acres per treatment class and optimization scenario for the dual targeting approach**



Regional Allocation of Funding

Until this point, the analyses have focused on the national level. We now examine two different patterns for allocating funds regionally:

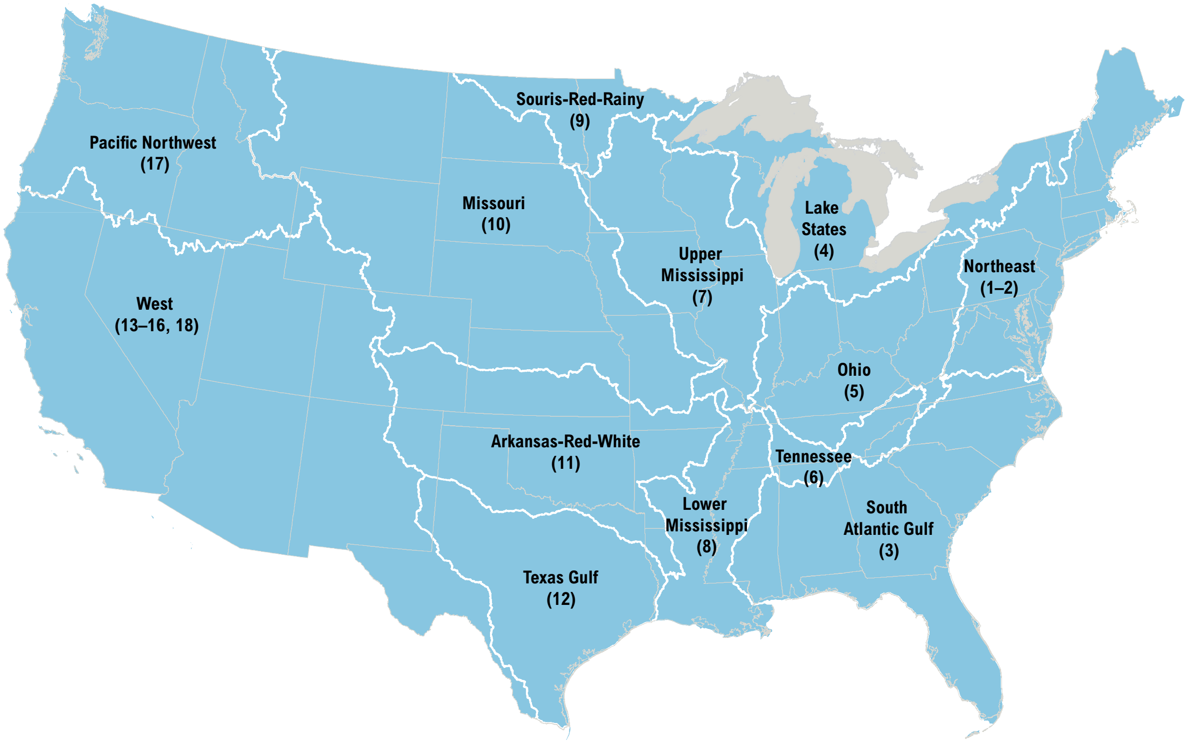
1. The benefit-cost targeting approach assumed that funding would be allocated at the regional level in a manner that is identical to BAU (i.e., state funding allocations were kept constant and were based on average annual allocations between 2006 and 2011).
2. The dual and geographic targeting approaches assumed that funding would be reallocated to watershed regions based on cost effectiveness (i.e., dollars were allocated to those watersheds where the most benefits could be realized per dollar spent).

To more easily compare relative changes in funding allocation under the geographic and dual targeting approaches compared to the BAU funding allocations, we analyzed the data at a larger regional scale, using the 18 2-digit HUC watersheds.[23] Note that NRCS combined watersheds 1 and 2 into a region called the Northeast and watersheds 13 through 16 plus watershed 18 into a region called the West, reflecting some data limitations that are discussed in the Appendix. (See figure 5.)

In the dual and geographic targeting approaches, the regional distribution of conservation funds depends on which optimization scenario is chosen. Table 6 below displays the change in funding that each region would experience in comparison to its BAU funding level under each of the optimization scenarios.

A targeting approach that regionally reallocated the same pot of funding to prioritize areas with the greatest opportunities to increase the cost effectiveness of federal taxpayer dollars would result in some regions receiving more funds and other regions receiving less funds than under BAU. For instance, the Missouri and Arkansas Red-White regions showed significant funding decreases under each of the optimization scenarios while the Texas Gulf region showed varying levels of decreased funding, depending on the scenario, due to the model determining that other regions had more cost-effective

Figure 5 | **Map of the 13 project regions and associated 18 2-digit HUC watersheds (established by NRCS)**



Note: There are 18 2-digit HUC watersheds in the contiguous United States. Due to some data limitations discussed in the Appendix, NRCS combined some watersheds to arrive at 13 project regions.

opportunities. Funding in the Northeast and the Upper Mississippi regions generally stayed the same, with only slight decreases under each optimization scenario.

Meanwhile, the Pacific Northwest and the Lower Mississippi regions show increased funding under every scenario as compared to BAU because marginal returns per conservation dollar spent in these areas are greater. Based on this analysis, the Lower Mississippi experiences significant increases in funding relative to BAU ranging from 452 percent under the multiple benefit optimization scenario to 684 percent under the sediment optimization scenario. For other regions, funding either increased or decreased depending on the optimization scenario used to determine the optimal geographic allocation of funding.

It is important to remember that our targeting analysis looks at N, P, sediment, and soil C. We ignore other potential environmental concerns like habitat, pesticide losses, and greenhouse gas emissions. Furthermore, our analysis was necessarily limited to cropland. Thus while our analysis shows that targeting for parameters like N, P, sediment, and soil C on cropland would mean decreasing the share of the federal funding going to the Texas Gulf and Arkansas Red-White regions, our study might have shown an increase in funding to those same regions if we were instead using lesser prairie chicken habitat (for example) as our targeting parameter or including rangeland in our analysis.

We also include figures 6–11 to show how funding is allocated under BAU, as well as how funding is reallocated under the dual and geographic targeting approaches at the 4-digit watershed scale for

Table 6 | Percentage of current budget that is allocated to each region compared to BAU per optimization scenario under the dual and geographic targeting approaches

REGION	OPTIMIZATION SCENARIO				
	NITROGEN REDUCTION	PHOSPHORUS REDUCTION	SEDIMENT REDUCTION	SOIL CARBON SEQUESTRATION	MULTIPLE BENEFITS (N-P-C)
Northeast (1–2)	91%	74%	83%	86%	99%
South Atlantic Gulf (3)	**217%**	82%	70%	**114%**	**138%**
Lake States (4)	**142%**	86%	38%	**157%**	**121%**
Ohio (5)	82%	**207%**	**246%**	65%	**125%**
Tennessee (6)	52%	**184%**	**143%**	**164%**	**140%**
Upper Misssissippi (7)	93%	82%	76%	50%	77%
Lower Mississippi (8)	**325%**	**527%**	**684%**	**583%**	**452%**
Souris-Red-Rainy (9)	21%	28%	0%	**214%**	28%
Missouri (10)	24%	37%	32%	54%	39%
Arkansas-Red-White (11)	43%	29%	1%	41%	35%
Texas Gulf (12)	27%	74%	7%	67%	55%
Pacific Northwest (17)	**272%**	**270%**	**454%**	**121%**	**244%**
West (13–16,18)	**258%**	60%	25%	31%	**168%**

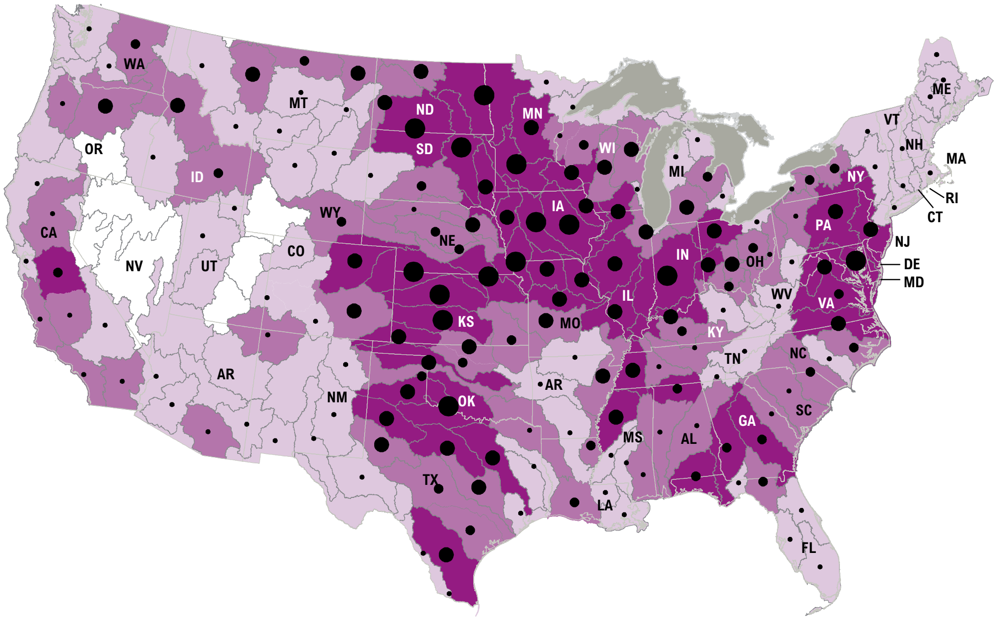
Note: Percentages below 100 percent are shown in a regular weight font and indicate that the region would receive that amount of its current allocation of funding under the specific optimization scenario. Percentages above 100 percent, shown in bold, indicate the percentage increase the region would receive as compared to its current allocation of funding.

each of the single optimization scenarios and for the multiple benefits scenario. The funding allocations in the figures are summarized in categories of high, medium, and low (based on standard deviation from the mean) to facilitate comparing the relative allocation of funding across watersheds nationally. In addition, these figures indicate the relative number of cropland acres treated in each of the watersheds by the $335 million project budget. See Appendix A.6 for more information on the methods to generate these mapping analyses.

Note that watersheds categorized as "non-priority" in BAU did not receive any of the $335 million in funding for nutrient and erosion control practices between 2006 and 2011. The "non-priority watershed" category under the five optimization scenarios may occur if the analysis determined that the watershed was not as cost-effective as others or if any of the following criteria occur: (1) the watershed does not have a significant amount of cropland; (2) there were no sample points from the CEAP subset of the NRI survey in the watershed; (3) the alternative conservation treatments were not defined; (4) costs for treatments could not be attributed; or (5) the alternative conservation treatments did not reduce the pollutant losses.

The funding allocation mapping analysis at the 4-digit watershed level (figures 6–11) suggests that the selection of which environmental benefit to optimize can make a significant difference in where the model finds the most cost-effective benefits. In addition, visualizing the shifts in budgets and treated acres from the BAU allocations to the dual targeting schemes at the 4-digit watershed level illustrates that many 4-digit watersheds continue to receive significant funding even when their overall region is categorized as losing funds (table 6). For example, the Upper Mississippi region experiences a minor decrease in funds for each of the optimization scenarios while the majority of its 4-digit watersheds continue to be rated as high- and medium-priority watersheds for cost-effective spending in all the scenarios.

Figure 6 | **Funding allocation for the business-as-usual scenario**



■ High Priority Watershed ($2.9M–$15.8M), n = 48

■ Medium Priority Watershed ($578K–$2.8M), n = 63

■ Low Priority Watershed ($1K–$577K), n = 83

□ Non-priority Watershed ($0), n = 7

Acres Treated

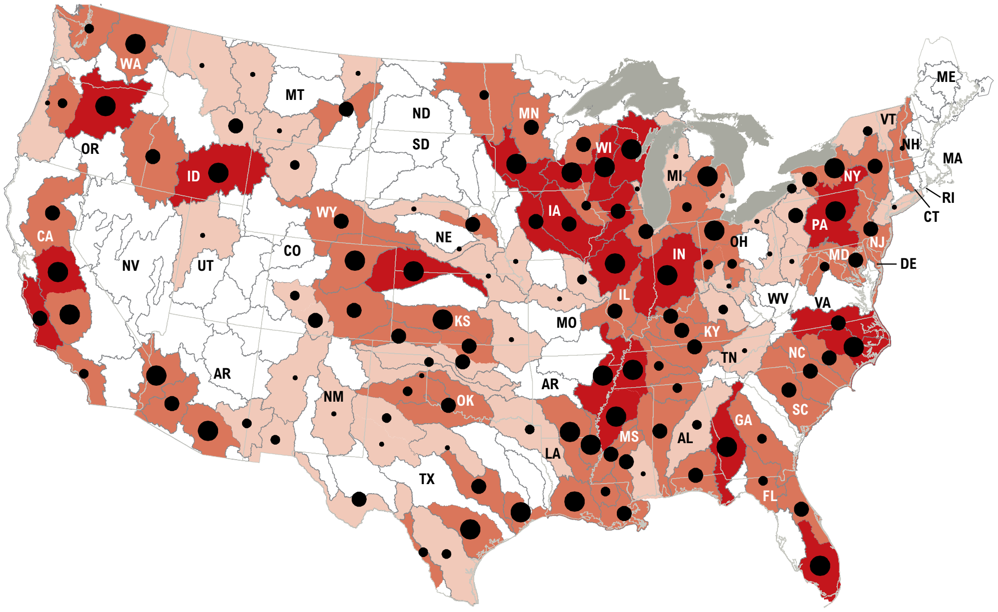
● 126,000–514,000

● 51,000–125,000

• 26,000–50,000

· 1,000–25,000

Figure 7 | **Funding allocation for nitrogen reduction optimization**



■ High Priority Watershed ($4.4M–$24.2M), n = 22

■ Medium Priority Watershed ($838K–$4.3M), n = 62

■ Low Priority Watershed ($21K–$837K), n = 45

□ Non-priority Watershed ($0), n = 72

Acres Treated

● 126,000–691,000

● 51,000–125,000

• 26,000–50,000

· 1,000–25,000

Figure 8 | **Funding allocation for phosphorus reduction optimization**

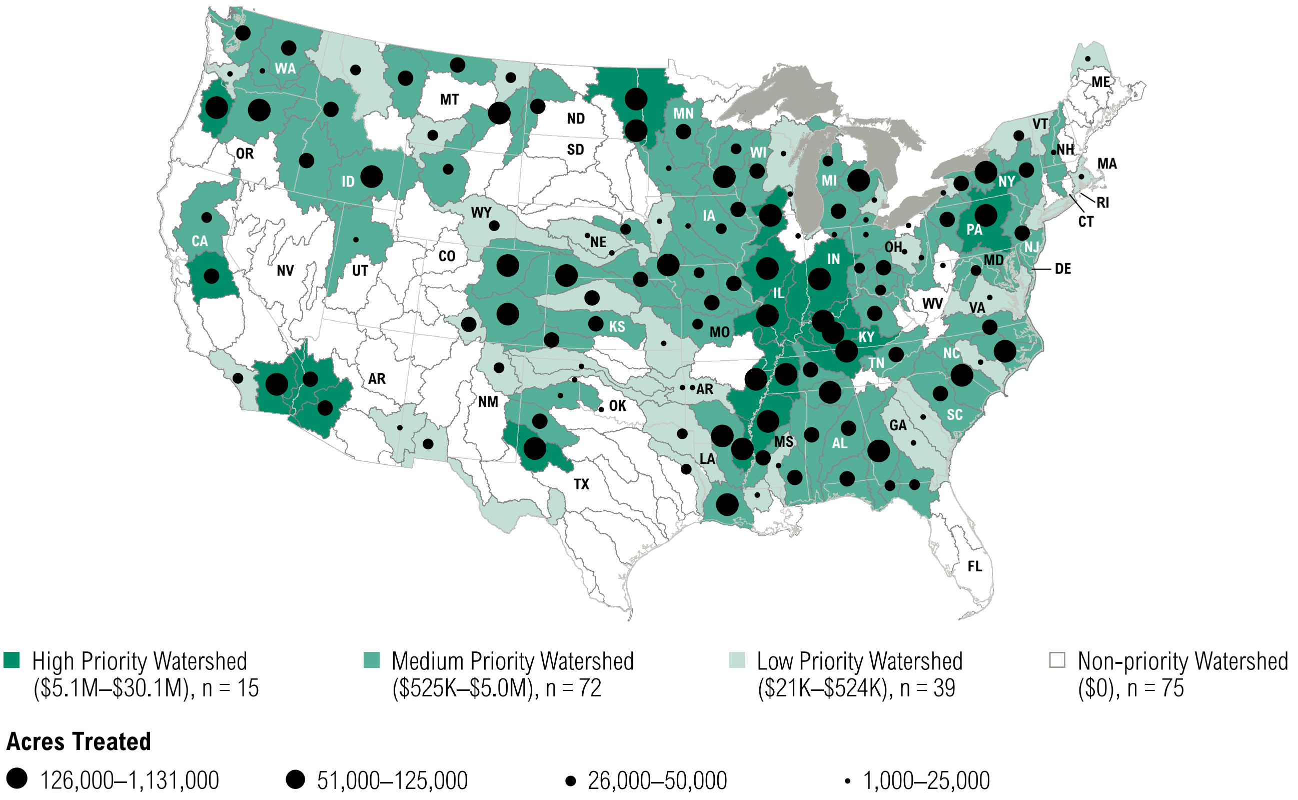


Figure 9 | **Funding allocation for sediment reduction optimization**

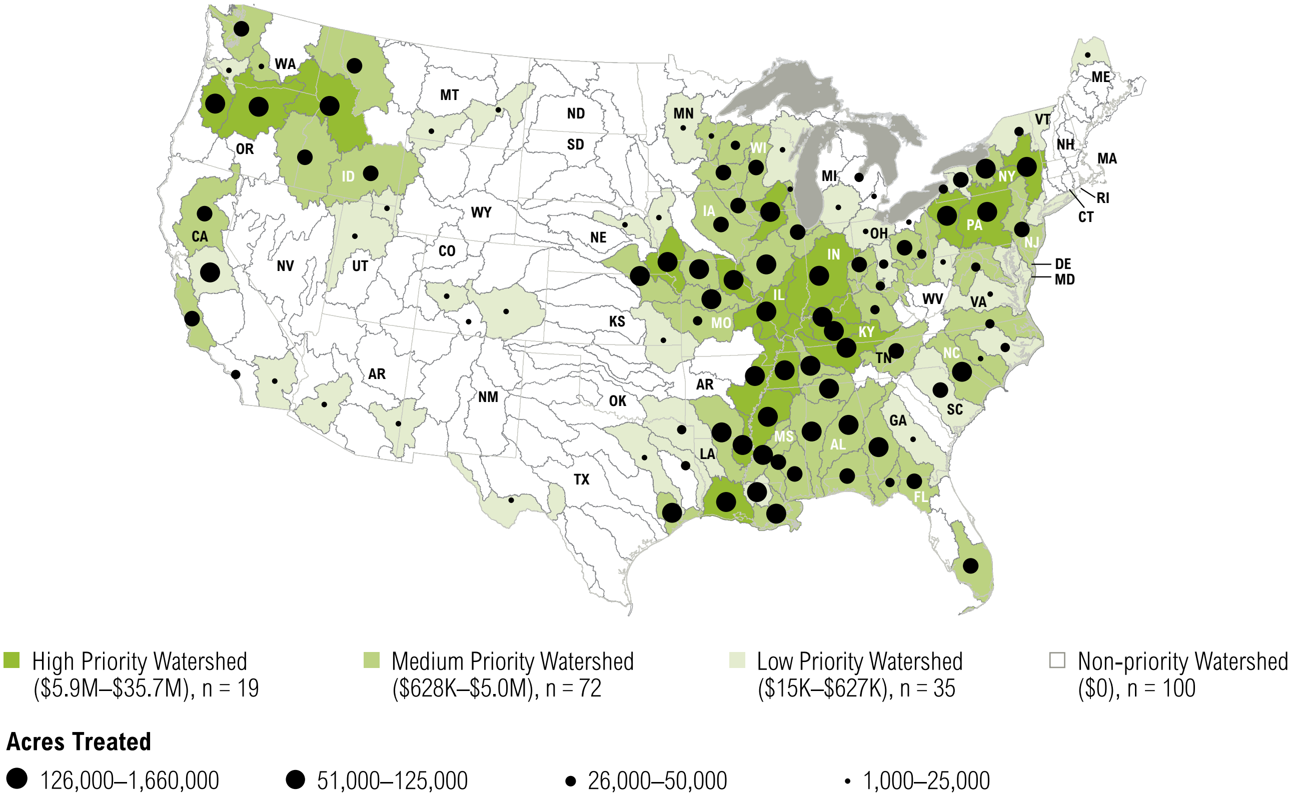


Figure 10 | **Funding allocation for soil carbon sequestration optimization**

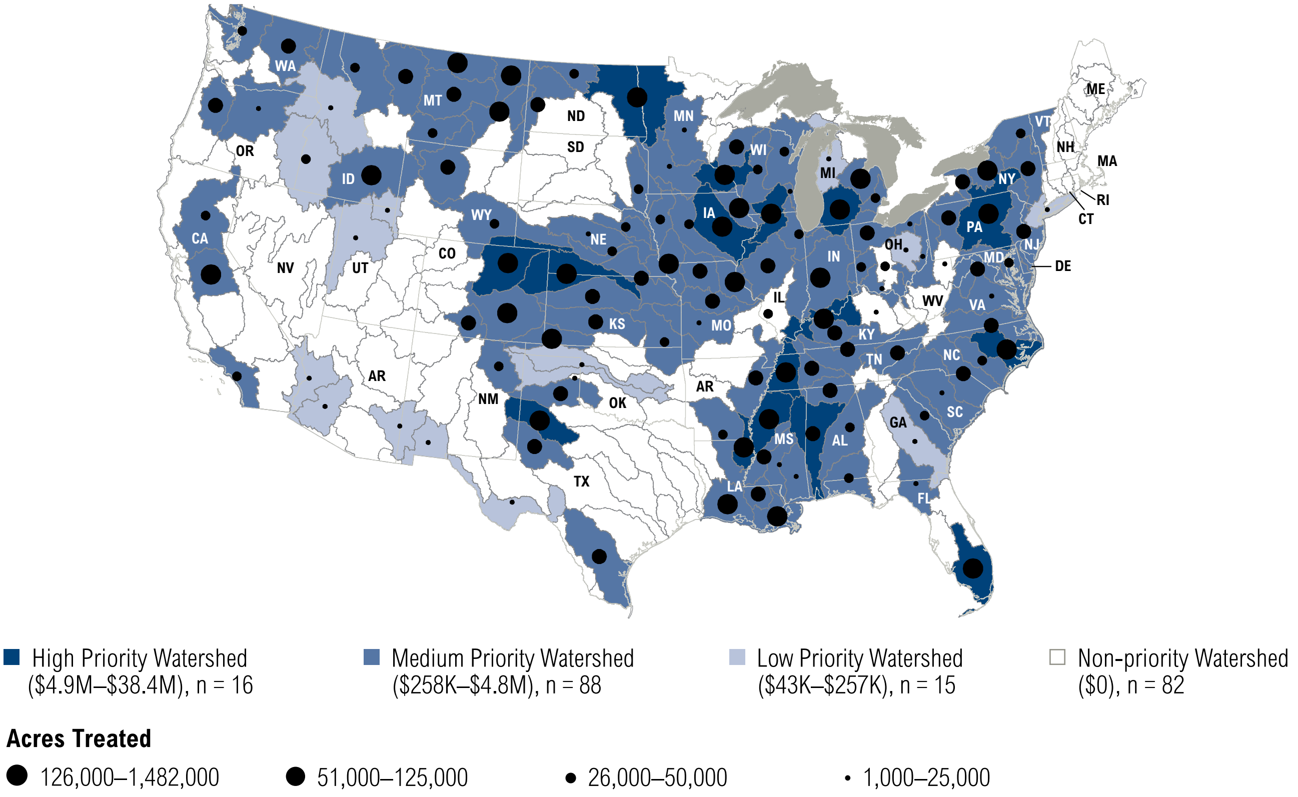
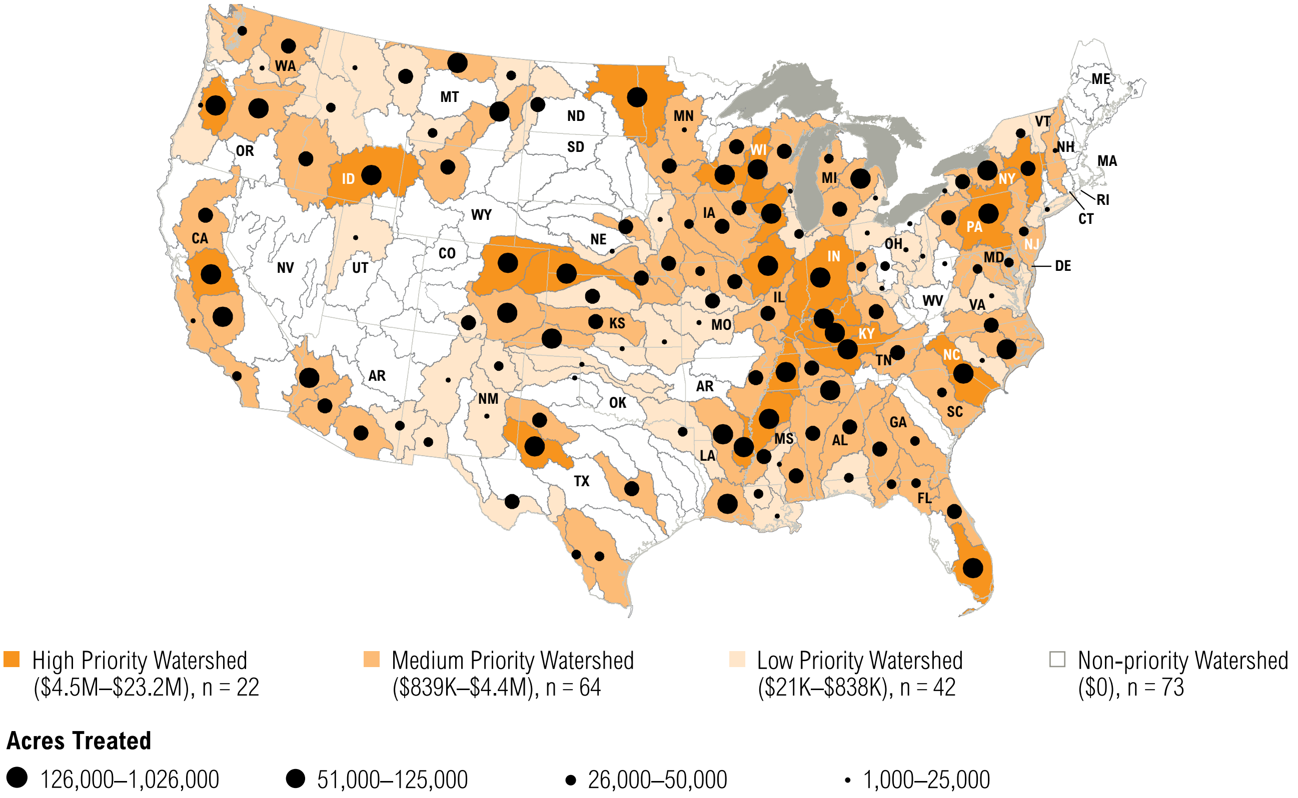


Figure 11 | **Funding allocation for the multiple benefits optimization (100P+10N+1C)**



Section III

CONCLUSION

The modeling results of this study are illustrative of the upper bounds of increased cost effectiveness that targeting could provide to water quality-related federal conservation programs.

WRI completed a national-level modeling analysis that estimated the current cost effectiveness of federal conservation programs based on $335 million associated with the financial and technical assistance from 2006 to 2011 for nutrient and soil erosion control cropland conservation practices nationwide. This served as the study's BAU approach. We focused on three environmental benefits pertaining to water quality, N, P, and sediment reduction in addition to soil C sequestration.

We next estimated how much more cost effective programs could be in comparison to BAU if the $335 million were allocated via a geographic targeting approach, a benefit-cost targeting approach, and a dual targeting approach that combined the two. Because conservation practices have differing effects on achieving N, P, sediment, and soil C benefits, we ran five optimization scenarios—four individually for each environmental benefit and one scenario that optimized N, P, and soil C benefits simultaneously.

This study observed several major findings:

Targeting Approaches

Finding 1. Combining geographic targeting with a benefit-cost targeting approach is most effective at increasing cost effectiveness. The dual targeting approach yielded 7 to 12 times more environmental benefits for the same conservation budget as compared to the BAU approach.

By reallocating funding to the regions where the largest opportunities exist for reducing the environmental losses simulated in this study and by targeting funding within those regions to the acres and practices that achieve the greatest environmental benefits per dollar expenditure, conservation programs can expect to gain the greatest overall benefits. While it is unlikely that this magnitude of gains would be achievable in a real-world scenario (given transaction costs and other barriers to targeting), these results illustrate the potential for targeting approaches to improve the overall cost-effectiveness of conservation payments compared to business as usual. (See tables 3, 4a, and 4b.)

Finding 2. Even adopting a benefit-cost approach without geographic targeting vastly improves the environmental outcomes that can be achieved for a given budget. Adopting a benefit-cost approach to funding allocation can result in public resources being spent four to nearly nine times more effectively than under BAU, if regional funding allocations cannot be optimized.

Given the political challenges associated with geographic targeting by members of Congress and producers who believe they do better under the status quo, geographic reallocation of funding to address national environmental priorities may face significant barriers. These results indicate that even under current regional funding allocations, conservation payments can achieve significant improvements in cost effectiveness if allocated using the benefit-cost approach. (See tables 3, 4a, and 4b.)

Finding 3. Geographic targeting alone achieves little improvement in environmental outcomes per dollar spent. At a large watershed scale, geographic targeting alone appears to be generally no more effective than BAU.

Our analysis found that geographic targeting alone yielded no marked improvements over BAU as it performed only slightly better than BAU for the P and sediment optimization scenarios and slightly underperformed BAU for the N and soil C optimization scenarios. This is surprising but may be a function of the assumptions and limitations in our analysis. Most notably, our analysis was restricted to the 4-digit HUC scale because of limitations in the sample point data (see the methods section and Appendix A.5 for more on the study's assumptions and limitations). In practice, geographic targeting of conservation dollars is likely to happen at a smaller watershed scale (e.g., a 12-digit HUC watershed) where environmental impacts may be more concentrated. Nevertheless, our analysis indicates that geographic targeting alone is not as effective as either the dual approach (geographic targeting coupled with a benefit-cost approach) or the benefit-cost approach alone. (See tables 3, 4a, and 4b.)

Optimization Scenarios

Finding 4. The multiple-benefit optimization approach yields the best overall results. Optimizing multiple environmental benefits simultaneously allows for the greatest number of co-benefits and the fewest trade-offs among the four environmental benefit categories (N, P, sediment, and C sequestration) than does optimizing each benefit independently.

Our results showed that the greatest overall benefits, across the four environmental outcomes we examined, were achieved through a multiple benefits scenario that optimized P, N, and soil C simultaneously. Under the multiple-benefit optimization, the cost-effectiveness estimates for individual benefits were between nearly two to nine times better than BAU, depending on environmental benefit. However, optimizing for multiple benefits is challenging because the approach is very complex to plan and implement. For example, only a few estimation tools are able to predict the many co-benefits associated with proposed conservation practices. (See tables 4a and 4b.)

Finding 5. Optimizing for phosphorus reductions provides more co-benefits than does optimizing any other environmental benefit individually.

Our analysis found that, if only one environmental benefit could be optimized, then a program designed to maximize P reductions is likely to yield the greatest overall environmental benefits in terms of P but also N reductions, sediment reductions, and soil C sequestration. Of the single-benefit optimization scenarios, the P optimization scenario resulted in the fewest trade-offs with other environmental benefits. (See tables 4a and 4b.)

Implications

Finding 6. Targeting may actually result in a greater number of acres receiving conservation practices, at less cost per acre.

Some concerns surrounding targeting have rested on the notion that targeting means more dollars going to fewer producers or to fewer acres. Our analysis, however, indicates that both dual and benefit-cost only targeting may result in more acres treated and at less cost as compared to BAU. The dual targeting and benefit-cost only targeting approach treats between 1.5 to 1.9 times more acres, depending on optimization scenario, than BAU (12.8 million to 16.8 million acres versus 8.7 million acres). Furthermore, dual targeting and benefit-cost only targeting made spending on a per-acre basis 36 to 49 percent more cost effective than BAU ($25/acre and $20/acre, respectively, versus $39/acre). (See figures 2 and 3.)

Finding 7. If conservation dollars were reallocated based on both geographic and benefit-cost targeting principles, spending would be optimized in fewer, more cost-effective watersheds than under BAU, and funding levels and acres treated would be higher in those watersheds.

With a fixed project budget of $335 million, our study determined that the most cost-effective watersheds in which to spend the funds depends on which environmental benefits scenario was optimized. Some of the 201 4-digit watersheds in the contiguous U.S. appear to be cost effective for achieving multiple benefits simultaneously (N, P, and soil C) while other watersheds appear to be cost effective for only one or two parameters. (See figures 6–11.)

It is important to recognize that the results of the study represent modeled estimates of the potential gains in environmental benefits and cost effectiveness. In practice, there are many barriers to realizing these optimum gains, including imperfect information, lack of readily available benefit assessment tools, participation challenges, etc. However, we can take from these results a sense of the relative gains that might be possible once the principles of targeting are better incorporated into conservation programs and policies.

Section IV

RECOMMENDATIONS

We hope that this report starts many positive and productive conversations between NRCS and conservation community stakeholders about how best to use limited taxpayer resources and how to realize gains in improved water quality and increased cost effectiveness.

WRI believes that USDA has an opportunity to gain substantial improvements in environmental benefits and achieve more cost-effective expenditure of limited public dollars. Using the targeting approaches outlined in this report, conservation program funding can be allocated to address the nation's environmental priorities more effectively.

Our analysis concludes that the optimal solution is to prioritize funding both geographically—to regions where there are more opportunities for environmental improvements—and by using benefit-cost targeting—that is, within geographic priority areas, to allocate dollars to acres where the greatest environmental outcomes can be achieved per dollar spent.

There are potentially significant technical, institutional, and sociopolitical barriers[24] to geographic targeting and benefit-cost approaches to conservation funding allocation that would need to be overcome if these approaches are to be adopted on a larger scale. Technically, both geographic and benefit-cost targeting require robust data and tools for assessing the environmental benefits and costs of conservation efforts on the ground. On an institutional level, the organizations carrying out targeting programs, such as soil and water conservation districts, would face changes in the way they traditionally operate to recruit the right producers that farm in priority areas and to measure progress in terms of environmental outcomes achieved, rather than solely the traditional metrics of acres treated and contracts signed.

Finally, politically, it will be challenging to decrease some states' conservation budgets in order to increase those of others. Political barriers to reallocation of funding among regions is likely to pose one of the largest hurdles to fully realizing the potential of targeting as members of Congress and producers may find a geographic targeting approach to be inequitable. However, this study found that, even if existing state funding formulas were maintained, instituting benefit-cost ranking criteria for how the funds are awarded to producers may offer significant opportunities for improved cost effectiveness and increase overall environmental outcomes.

NRCS has already shown its willingness to use discrete funding set-asides to target and potentially solve identified environmental problems. One example is the Mississippi River Basin Healthy Watersheds Initiative (MRBI), which targets small, high-priority watersheds in the Mississippi River Basin to achieve measurable improvements in water quality. However, these initiatives do not currently incorporate benefit-cost targeting approaches, which are essential to maximizing environmental outcomes. By taking the steps necessary to develop the tools and the programming changes needed to incorporate benefit-cost targeting principles, the MRBI and other targeting initiatives like the newly created Regional Conservation Partnerships Program (RCPP), will be even closer to realizing the dual goals of gaining environmental effectiveness (e.g., cleaning up impaired water) and cost effectiveness (maximizing benefits per dollar spent).

Given the many barriers to targeting, as well as the potential increase in transaction costs associated with targeting, we realize that it is unlikely that conservation programs would be able to achieve the same level of environmental benefits modeled in this report. However, the analysis illustrates that even small steps toward better targeting of conservation funds could yield meaningful improvements in environmental outcomes. Steps that NRCS might take to improve environmental outcomes and the cost effectiveness of its programs may include identifying the information gaps that exist between the modeling results and realizing the findings on the ground, developing the tools to quantitatively assess the environmental benefits of conservation practices, using benefits as well as costs as criteria for funding allocations, altering the program funding rules and ranking criteria, and adjusting conservation policies as needed.

WRI also believes that NRCS may benefit from the expertise of others at sister agencies, such as the Agricultural Research Service and the Economic Research Service, as well as experts in the university and nongovernment arenas to help develop solutions for surmounting these barriers. We hope that this report generates many positive and productive conversations among conservation community stakeholders about how best to use limited taxpayer resources and how to make such ideas a reality.

Based on the findings of this study and the potential to improve environmental outcomes per dollar spent, WRI recommends that USDA consider the following options for maximizing conservation program benefits.

1. **Begin tracking the water quality-related environmental benefits of federal conservation programs.**

   Current federal conservation programs related to water quality track administrative metrics, such as practices implemented, dollars spent, or conservation contracts signed. By also tracking environmental benefits, the agency will be taking a critical step toward being able to assess the cost effectiveness of these programs. In so doing, the agency will be able to improve program transparency and enhance its ability to track progress toward meeting stated water quality-related goals. Over time, this will ensure that government programs are gaining the most environmental improvement from limited taxpayer resources.

2. **Incorporate benefit-cost principles into existing farmer application ranking criteria used to allocate funding in the conservation programs.**

   To effectively incorporate and operationalize principles of benefit-cost targeting into current programs, NRCS must invest in tools and technologies to better estimate and quantify environmental benefits and costs from conservation at the farm scale. These tools should be used in lieu of or as supplements to existing conservation application ranking systems associated with nutrient and soil erosion control practices. Funding should then be allocated to farmers based on total expected environmental benefit(s) and project costs. Finally, when possible, NRCS should consider co-benefits and trade-offs when selecting the environmental benefits used in the ranking tool in order to ensure that the ranking tools and criteria reflect desired regional, state, or local environmental goals.

3. **Conduct pilot projects that combine geographic and benefit-cost targeting, and/or begin including benefit-cost criteria into existing geographic targeting initiatives like the Mississippi River Basin Healthy Watersheds Initiative (MRBI), the National Water Quality Initiative (NWQI), and the new Regional Conservation Partnership Program (RCPP).**

   To achieve measurable improvements in various water bodies (e.g., streams, rivers, and lakes) suffering from nutrient pollution, NRCS and its conservation partners should continue to increase the number of targeted watershed projects they undertake in small watersheds under the MRBI, NWQI, and RCPP initiatives. To ensure that the funds dedicated to these geographic targeting initiatives are used as cost effectively as possible, the agency should include benefit-cost criteria in the conservation planning process to aid farmer decision making and in the conservation contract selection process to select the most cost-effective contracts. The agency should also consider developing pilot projects that road test the new benefit-cost ranking criteria to identify problems that may materialize and develop solutions to overcome those problems.

4. **Improve federal funding allocation formulas for distributing conservation program funds to the states.**

   Should USDA invest the resources needed to pursue the three previous options, the agency will be laying the groundwork needed to improve federal conservation funding formulas. Efforts to improve the formulas should take advantage of the CEAP datasets and models but also take into account other sources of relevant data, such as on-the-ground best professional judgment, appropriate water quality data, and information generated from field-scale and watershed-scale tools, etc. In so doing, the formulas should result in better targeting of funds to watersheds, acres, and practices within states that can achieve the greatest environmental benefits per dollar spent.

APPENDIX: METHODS DISCUSSION

A.1. Overview of NRCS CEAP APEX Model and this Study's Optimization Model

The purpose of the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) Conservation Effects Assessment Project (CEAP) National Assessment for Cropland is to estimate the environmental benefits and effects of conservation practices applied to cultivated cropland. More specifically, the goals of the assessment are to:

1. estimate the effects of conservation practices currently present on the landscape;
2. estimate the need for conservation practices and the potential environmental benefits of these additional practices; and
3. simulate alternative options for implementing conservation programs on cropland in the future.[25]

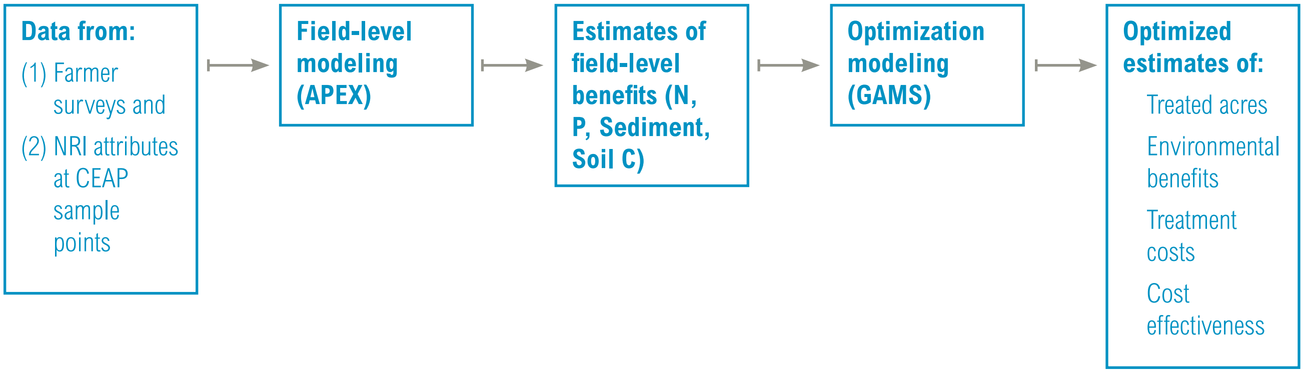
At present, CEAP has finished the modeling needed for the national assessment and has published eight regional cropland studies making up the national effort with several more reports underway.[26]

The approach to estimating the environmental benefits of conservation efforts as part of the CEAP cropland assessment involves using data from survey sample points, conducting statistical and analytical procedures, applying the Agricultural Policy Environmental Extender (APEX) process model, and then running further statistical analysis to aggregate and average output (see figure A-1). For this study, NRCS added an optimization model to select the most cost-effective sample points and treatments in order to analyze three targeting approaches and five optimization scenarios to achieve the greatest environmental benefits per dollar spent in comparison to business as usual (BAU).

The basic steps in developing the estimates of environmental benefits are as follows:

- A subset of sample points on cultivated or reserved cropland was selected from the 2003 National Resources Inventory (NRI)[28] to serve as "representative fields" that provide the statistical basis for the model and provide data on soils, topography, and weather.
- At these NRI sample points, the USDA National Agricultural Statistics Service (NASS) conducted CEAP cropland farmer surveys, a 40-page survey for three consecutive crop years[29] (between 2001 and 2006) that assesses the effects of conservation practices, which provides the foundation for field-level process modeling. These surveys also included interviews with farmers to obtain information on farming practices (e.g., crops and crop rotation, tillage practices, fertilizer application rate, timing, method, and form, irrigation, residue management, and conservation practices, etc.) over the same three-year period.[30]
- The physical process model APEX[31] was used to estimate field-level benefits from conservation practices, such as the effects of riparian buffers, nutrient management plans, and other practices. For the NRCS CEAP assessment, 16 practices within six conservation treatments were available for assignment by APEX to each sample point (see table 1). The APEX model first estimated the baseline N, P, sediment, and soil C losses at each sample point associated with the NRI-CEAP survey information. APEX analysts then compared those losses and the baseline conservation practices to conservation practice standards in order to classify each sample point as needing a low, moderate, or high level of additional conservation treatment with regard to nutrient input management, overland flow control, and edge-of-field flow control and trapping. The evaluation process

Figure A-1 | **Sampling and modeling approach to estimate benefits of conservation practices by CEAP**



Source: WRI's modification of NRCS CEAP schematic[27] then specified practice mix alternatives to provide the necessary treatment and generated estimates of the losses (and the loss reductions) for the six treatments applied at each sample point.

APEX is a daily time-step model, continuous in its simulation,[32] and it comprises hundreds of linear and nonlinear equations that are linked to one another to represent biophysical processes. The model generates output in terms of average annual environmental benefits that are expressed as reductions in sediment loss, nitrogen loss, phosphorus loss from fields, and soil carbon sequestered. These reductions and sequestrations are quantified against a baseline scenario representing what the losses of these resources would be if there were no conservation practices in place at all.

- For this WRI study, the NRCS CEAP team developed an economic optimization model to determine which sample points to treat first and what treatments to apply according to the specific targeting criteria outlined in this study. (See the section of this appendix titled "Modeling Targeting Approaches and Optimization Scenarios".) The optimization model reviewed the APEX results for each of the six treatments at each sample point, linked costs to each treatment, identified the most cost-effective treatment relative to baseline loss levels, and then ranked the sample points according to cost effectiveness for use of the available budget until the funds were consumed.
- The CEAP team worked with WRI to tailor its model process specifically to answer the policy and research questions of this study. Modifications included incorporating a conservation budget restriction and costs for conservation practices.

In short, the estimated environmental benefits (measured at the edge of the field) are the product of survey data that are extrapolated to areas of cropland with similar environmental characteristics within the contiguous United States. The outputs from this model, as featured in this report, include the estimated environmental benefits from conservation practices on croplands in terms of reductions in nitrogen (N), phosphorus (P), and sediment losses; increased soil carbon (C) sequestration; and the allocation of conservation funds to maximize these benefits. All outputs were reported at the 4-digit watershed hydrologic unit code (HUC4) level. The continental United States is made up of 201 HUC-4 watersheds, which range in size from about 1,400 to 48,000 square miles.

A.2. BAU Costs and Benefits Estimation

To estimate the net benefits of a conservation targeting approach in this study, the first step was to derive a BAU scenario via the APEX model, which serves as a baseline "current conservation condition" for comparing the optimized results. The BAU scenario estimates the cost effectiveness of current conservation funding based on the Program Contracts (ProTracts) database, which assembles information on fund allocations for conservation incentives and practices. ProTracts includes payments made from over a dozen different conservation programs, including the largest three: the Environmental Quality Incentives Program (EQIP), the Conservation Reserve Program (CRP), and the Conservation Stewardship Program (CSP).[33]

Expenditure data from the ProTracts database represent conservation payments from years 2006 to 2011 for 7.1 million practices (of which 5.2 million practices, or 73 percent, were crop-related)[34] with 43.2 million acres of cropland receiving one or more funded conservation practices during at least one of those years. Thus, this voluntary conservation program approach has been able to reach only about 14 percent of available cropland during these five years given that there are about 304 million acres of cultivated cropland nationwide. Using the BAU scenario and ProTracts data, NRCS derived the budget constraint for this study of $335 million per year, from an estimate of the amount of funds expended from 2006 to 2011 on cropland-related, nutrient and erosion control conservation practices.

The CEAP dataset indicates that, on average, about 8.7 million acres are treated annually with one or more practices under the BAU approach. Thus, for the last five years of data, NRCS has been treating just 3 percent of cropland nationwide on an annual basis via the working lands programs approach with the set of practices and payments identified in the ProTracts database. The total average annual costs under this BAU dataset were estimated at $335 million, which includes annual installation and maintenance costs of about $311 million and technical assistance costs of about $23.8 million every year. On average, working lands programs receive about $2 billion per year, and thus this study is able to estimate the environmental effects of about one-sixth of the total dollars available to working lands. The average per-acre costs reflected are $36 for installation and maintenance and $3 for technical assistance, for a total average per-acre cost of $39.

An important distinction between the BAU benefits and costs analysis and the CEAP optimization analysis is that the BAU analysis represents decisions made by local farmers and conservation planners, whereas the CEAP optimization analysis represents optimization decisions made by the CEAP model as to which types of treatments are best applied to cropland that is in need of further treatment.

NRCS generated an estimate of the current national level of conservation cost effectiveness for program spending on water quality-related practices to represent this study's BAU approach. To do so, NRCS used sample point data from the Conservation Effects Assessment Project-Natural Resources Inventory (CEAP-NRI) farm survey from 2003 to 2006, conservation program payment data from 2006 to 2011 identified in the NRCS ProTracts database for 40 cropland conservation practices nationwide associated with nutrient loss and soil erosion control, and the APEX model. A brief description of the sampling, baseline losses and benefits modeling, and costing methods is provided here while more details can be found in this appendix as well as in the regional CEAP cropland studies that have been published.[35]

Sampling. A subset of 18,691 NRI sample points for cultivated cropland was extracted from the total NRI sample set; and the associated soils, topography, and weather data were collected for each point, as well as the survey data reflecting baseline farmer production and conservation management practices. An NRI statistical weight was assigned to each sample point, reflecting how much acreage is represented at that point such that the environmental conditions and management attributes reflect the model's "statistically extended acres." With 18,691 sample points and about 304 million cropland acres in the contiguous United States, each point represents about 16,000 acres.

Baseline losses and alternative treatments. The APEX model was used to estimate the four environmental outcomes (N loss, P loss, sediment loss, and soil C loss) occurring at each sample point, given the baseline environmental and management survey data. The APEX analysts classified each sample point as needing a low, moderate, or high level of additional conservation treatment for the following environmental concerns: nutrient input management, overland flow control, and edge-of-field flow control and trapping of soil erosion. The CEAP team applied each of the six available alternative conservation treatments[36] to each sample point categorized as needing high or moderate treatment, based on the addition of 16 conservation practices,[37] and saved the results (losses and loss reductions) for each alternative treatment in an APEX dataset.

BAU benefits. To generate estimates of the benefits provided by the conservation practices funded as part of BAU, the study team conducted an APEX modeling exercise to remove subsets of the baseline conservation practices described in the previous paragraph. The goal of this modeling exercise is to estimate the partial benefits that can be attributed to BAU practices. For example, the difference between "baseline environmental losses" and "baseline losses with a riparian buffer practice removed" represents the partial benefits of the riparian buffer that was ascribed to the ProTracts BAU buffers. The CEAP team tallied the four environmental benefits achieved under BAU (N, P, sediment reductions, and soil C sequestration) measured at the field's edge and aggregated the results to the 4-digit HUC watershed level from these adopted practices. The number of acres that were treated by these BAU practices was also tallied and reported by each watershed.

BAU costs. To estimate the costs and cost effectiveness of the BAU conservation practices, the study team determined that the average annual spending on the 40 cropland practices identified in the ProTracts payments database was $335 million dollars, based on an implementation area of about 8.7 million acres averaged over five years. These costs included installation, maintenance, and technical assistance costs, as well as proxy estimates of forgone income for land converted to conservation use. Thus, the BAU cost-effectiveness estimates for each of the four environmental benefits within each watershed was generated by dividing the total cost ($335 million) by each benefit (e.g., pounds of N reduced), to derive a per-unit cost (e.g., $/lb. N reduced).

A.3. Conservation Practice Treatments and Cost Inclusion

One unique aspect of this study is that, for the first time, costs of the conservation practices and a budget restriction were incorporated and linked to the CEAP data. Estimated costs for conservation practices were broken out into two categories: installation and maintenance costs and technical assistance. Costs were estimated by state and by practice as follows:

1. Practice installation and maintenance costs (i.e., nontechnical assistance costs) were sourced primarily from the 2010 official USDA/NRCS payment schedule database, by state and practice. These are the official payment levels approved for cost sharing for the various conservation programs. These data were supplemented with cropland rental rate data as a proxy for forgone income for land converted to a conservation use. Note that the NRCS found that the variation in rental rates had no appreciable impact on optimal geographical allocation of funding (treatment) due to the reality that only a small fraction of fields are converted to filter strips or riparian buffers.

2. Technical assistance costs were represented by official reimbursement rate data, by state and practice, pulled from the technical service provider database.[38]

Of the 40 practices identified in the CEAP farm survey and related data to estimate the BAU budget constraint, only 16 practices could be simulated by APEX for this study (see table 1). NRCS believes that applying the 16 practices in the APEX simulations provides approximately the same benefits as would a richer set of 40 practices. These conservation practices were grouped into six categories of conservation treatments that the APEX system can model: (1) cover crops, (2) drainage water management (DWM), (3) erosion control, (4) erosion control and nutrient management (ENM), (5) ENM and cover crops, and (6) ENM and DWM. Furthermore, only 27 of the 40 practices could be linked to costs. Thus, both BAU benefits and costs are somewhat understated in this study. However, the dual and benefit-cost targeting approaches and five optimizations are far superior to BAU to the extent that a future improved and further refined BAU benefit and cost estimate would still not approximate the cost effectiveness from targeting.

The seven broad categories of environmental controls resulting from the conservation treatments that can be estimated by APEX include (1) overland flow control, (2) concentrated flow control, (3) trapping of runoff and sediment, (4) wind erosion control, (5) residue and tillage management, (6) nutrient management, and (7) cover crops.

A.4. Modeling Targeting Approaches and Optimization Scenarios

WRI developed three approaches to targeting federal conservation funds that could be modeled by NRCS through the addition of cost information and the use of the optimization modeling system: geographic targeting, benefit-cost targeting, and both geographic and benefit-cost targeting. NRCS conducted all three targeting scenarios and supplied estimates of the environmental benefits and cost effectiveness of the benefits achieved under each scenario at three different scales: the HUC-4 watershed, regional, and national level.

Within each of these targeting approaches, the model also seeks to select conservation treatments to mitigate certain resource concerns (i.e., N, P, sediment, or soil C losses) either individually or in combinations. Reduction of N losses will be used as an example to describe the three targeting approaches below. See Box A-1 for a conceptual illustration of the model process. Note that several different objective functions and equations were developed in the General Algebraic Mathematical Systems (GAMS) code to represent the various scenarios.

Table A-1 | **Percent of individual benefits achieved by the multiple benefits (100P+10N+1C) scenario and the dual targeting approach**

ENVIRONMENTAL BENEFIT	SINGLE BENEFIT OPTIMIZATION (A)	MULTIPLE BENEFITS (100P+ 10N+1C) OPTIMIZATION (B)	PERCENTAGE (B/A)
N Reductions (billion lbs.)	112.4	93.5	83%
P Reductions (million lbs.)	136.4	119.0	87%
Sediment Reductions (million tons)	92.4	47.7	52%
Soil C Sequestered (billion lbs.)	237.7	88.2	37%

1. **Geographic + Benefit-Cost Targeting.** The model optimizes budget allocations and treatments to achieve the greatest environmental benefits (e.g., N loss reductions) within the $335 million national budget without restrictions on funding ceilings or cost effectiveness for treatment practices in each watershed.
2. **Geographic Targeting.** Under this approach, the budget is set at the optimal level for each HUC-4 watershed for achieving the greatest environmental benefits, as dictated by the dual-targeting approach, while the BAU-level of cost effectiveness is maintained within each watershed.
3. **Benefit-Cost Targeting.** The model searches for and selects the most cost-effective treatment to achieve the greatest environmental benefits (e.g., nitrogen loss reductions) within the $335 million national budget while each HUC-4 watershed is restricted to the budget received under the BAU scenario.

We developed and analyzed five environmental benefit optimization scenarios:

1. Nitrogen (N) reduction
2. Phosphorus (P) reduction
3. Sediment reduction
4. Soil carbon (C) sequestration
5. Multiple benefits: 100P+10N+1C

In environmental benefit optimization scenarios 1 to 4 listed above, the model searches for acres that have high losses of N, P, sediment, or C (one per scenario) and chooses treatments to maximize environmental benefits (i.e., reductions and sequestrations) per dollar spent.

In addition, we ran a fifth optimization to maximize multiple benefits simultaneously, without favoring one benefit over another. Through trial and error and an understanding of the natural occurrence of these environmental elements, we determined that a weighting system of 100P+10N+1C achieved the closest number of benefits that the model could realize had it been optimizing for P, N, and soil C individually. These weights reflect nearly the inverse of losses that occur in nature, on average. Thus, this weighting system achieves the most “balanced” outcome of a “multiple benefits” scenario by putting P, N, and C losses on a nearly equivalent basis of importance in the model optimization. For this scenario, the optimization model chose acres and practice treatments to achieve the maximum sum of P, N, and C loss reductions at a ratio of 100 to 10 to 1, respectively.

To determine the degree to which the multiple-benefit optimization is achieving the optimized single benefit reduction potential, we determined the ratio of reductions achieved for the primary benefit for each of the four individual optimizations compared to the individual benefits achieved in the 100P+10N+1C optimization scenario **(see table A-1)**. We found that the trade-off for the multiple benefit optimization scenario ranges from just 17 percent of the N reduction potential to 63 percent of the soil C sequestration potential.

Each of the three targeting approaches was run with the goal of maximizing environmental benefits according to the five optimization scenarios. Box 1 in the report illustrates conceptually the modeling process for optimizing environmental benefits under each targeting approach. In essence, for a given watershed, the model maximizes the sum of environmental benefits in pounds per acre across all treated acres according to weights as dictated by the scenario. This process is constrained by the available acreage and budget.

BOX A-1 | SIMPLIFIED OVERVIEW OF THE OPTIMIZATION PROCESS

The optimization process is set up as a mathematical programming model using the Generalized Algebraic Modeling System (GAMS).

In narrative terms, for a given optimization criteria, for example, “maximize N loss reduction,” the model:

1. calculates the loss reduction and cost for each treatment for each sample point;
2. determines the best treatment for each sample point (largest loss reduction per dollar);
3. sorts the sample points according to largest loss reduction per dollar;
4. allocates funds to the best sample point, accounting for its acreage, and record the results, including remaining budget;
5. allocates funds to the second best sample point, record results, including remaining budget; and
6. continues until all funds are allocated.

Note that, at steps 4 through 6, the model can account for participation rates and any type of budget allocation restriction.

In terms of actual model process, the maximization criteria conceptualized in box A-2 is generated through a mathematical programming model using the GAMS, as illustrated in box A-1.

Note that the optimization model chooses a point to treat, a treatment for the point, and how much acreage associated with the point is to be treated. The NRI sample point reflects management data reported by the surveyed farmers about the farm field located at that point. The acreage of each farm field is not used in any of the CEAP analysis. Instead the CEAP model uses the statistically extended acres that reflect management and resource conditions similar to those in the acreage at each sample point. There are about 304 million cropland acres in the contiguous United States and 18,691 sample points. Thus, each point represents, on average, about 16,000 acres.

Box A-2 illustrates conceptually the modeling process for optimizing environmental benefits under each targeting approach. In essence, for a given watershed, the model maximizes the sum of environmental benefits in pounds per acre across all treated acres, according to weights as dictated by each scenario. This process is constrained by the acreage and budgets available in each watershed.

A.5. Modeling Assumptions and Limitations

At present, the NRCS APEX model and the NRI-CEAP dataset represent the best available means of estimating the environmental benefits from agricultural conservation practices in the United States. However, like all models and datasets, there are limitations to conclusions that can be drawn from them. In addition to those already mentioned in the report, a few more are discussed here.

An additional modeling scenario was run (but not reported) here using $550 million or 1.5 times this study’s project budget. One interesting observation from that analysis was the occurrence of the law of diminishing returns. As conservation funds were added, the considerable improvements in cost effectiveness of the targeting approaches started to get smaller, given that “the low-hanging fruit” in pollution reduction opportunities had already been identified and realized by the optimization model.

Currently, the APEX model is able to simulate only 16 cropland-related conservation practices. Although these practices are very common and well-regarded, there are dozens of other practices that could also be effective to treat nutrient, sediment, and soil carbon issues.

There are also a few spatial limitations in this study. The CEAP analysis relied on NRI sample points to derive a national-level data set. In some 8-digit HUCs there were not enough NRI sample points to create a statistically relevant finding. Thus, to ensure statistical validity, the results were aggregated to the HUC-4 watershed scale for reporting. The large scale of this analysis in particular hinders the geographic aspects of our targeting analysis as the study must rely on large basins as the geographic target area and thus cannot calculate the potential benefits of targeting at a smaller sub-watershed scale.

Given that the environmental benefits are calculated using APEX, which is a field-scale model, all of the estimates of losses and reductions are calculated at the edge of the field. Unlike the NRCS-CEAP national cropland study and eight regional reports that do use the watershed model, soil and water assessment tool (SWAT) in addition to APEX, this study did not make use of SWAT and thus does not account for delivery of nutrients beyond the edge of the field. Thus, this study does not account for the natural hydrological, biological, and chemical transformations affecting nutrients as they are transported from the edge of the field through a watershed and into the next watershed downstream. Hence, this study does not account for so-called hydrologic “network effects.”

BOX A-2 | CONCEPTUAL ILLUSTRATION OF THE OPTIMIZATION MODEL TO MAXIMIZE BENEFITS FROM CONSERVATION TREATMENT

We formulate the allocation problem as a linear program subject to budget and physical constraints. The different targeting strategies are implemented by varying the preference weights on different possible environmental benefits or by modifying the budget constraints. The optimization model chooses an NRI survey point to treat, selects a treatment for it (see table 1), and then determines how many of the statistically extended acres (which exhibit similar resource and management conditions as the sample point) to treat.

$$\text{Maximize } Z = \sum_{hijk} (WGT_h \times BEN_{hijk} \times Treat_{ijk})$$

Subject to the following constraints:

(1) For each NRI CEAP sample point, the sum of acres treated cannot exceed total acreage:

$$\sum_k (Treat_{ij}) <= Acres_{ij} \times PCN_{ij}$$

(2) Overall budget constraint, used for all scenarios:

$$\sum_{hijk} (Cost_{ijk} \times Treat_{ijk}) <= BUDGET$$

(3) Budget distributed proportionally to BAU conservation expenditure, by HUC-4, used only for the benefit-cost only targeting approach:

$$\sum_{jk} (Cost_{ijk} \times Treat_{ijk}) < = (BAUexpense_i / BAUexpenseT) \times Budget$$

where:

h = loss type (Nitrogen, Phosphorus, Sediment, Soil Carbon)
i = HUC_4 identifier
j = NRI sample point identification number
k = conservation treatments
WGT$_h$ = weight for hth loss type
Acres$_{ij}$ = available acreage (1,000s) by NRI sample point
BEN$_{hijk}$ = Benefit for hth loss type (lbs./acre) by sample point and treatment as estimated by the APEX model
BAUexpense$_i$ = the BAU expenditure level by HUC-4
BAUexpenseT = total national BAU expense
BUDGET = annual conservation budget ($1,000)
Cost$_{ijk}$ = annual conservation cost of treatment M at sample point (includes practice installation and maintenance costs, forgone income cost for land removed from production, as well as technical assistance costs)
PCN$_{ij}$ = CEAP treatment need indicator (1 if high or moderate, 0 if low)
Treat$_{ijk}$ = the “choice” variable or model, an acre of sample point with treatment k

Finally, an additional modeling scenario was run (but not reported) here using $550 million or 1.5 times this study’s project budget. One interesting observation from that analysis was the occurrence of the law of diminishing returns. As conservation funds were added, the considerable improvements in cost effectiveness of the targeting approaches started to get smaller, given that “the low-hanging fruit” in pollution reduction opportunities had already been identified and realized by the optimization model.

A.6. Mapping the National Budget Allocation

Figures 6–11 of this report show how funding is allocated under BAU, as well as how funding is reallocated under the dual and geographic targeting approaches at the 4-digit (HUC-4) watershed scale for each of the single optimization scenarios and for the multiple benefits scenario. In addition, these figures indicate the relative number of cropland acres treated in each of the watersheds by the $335 million project budget. The purpose of these figures is to provide a national picture of relative funding allocation by HUC-4 watershed and show how these allocations shift among the various optimization scenarios.

Table A-2 | **Categories used to organize and map funding allocation results**

CATEGORY	INTERPRETATION	DEFINITION
High	Watershed receives relatively high proportion of $335M national budget	More than 1/2 standard deviation above the mean
Medium	Watershed receives relatively moderate proportion of $335M national budget	Between 1/2 standard deviation below and 1/2 standard deviation above the mean
Low	Watershed receives relatively low proportion of $335M national budget	Less than 1/2 standard deviation below the mean
None	Watershed receives no funding	None

These maps were produced by linking the model results to their respective HUC-4 watersheds within a geographic information system (GIS). The HUC-4 watershed GIS data used in this exercise was sourced from the latest version of the U.S. Geological Survey and NRCS National Watershed Boundary Dataset (July 2012).

To facilitate mapping, visualization, and interpretation of model results on a comparative basis, results were grouped into categories of high, medium, and low, based on relative levels of budget allocation. A standard deviation classification scheme was used to divide results into these categories. This scheme was chosen because it is a relatively common and statistically straightforward approach that emphasizes grouping values based on their proximity to the mean.

Table A-2 shows the classification scheme used in organizing and mapping the budget allocation results. In short, the high category corresponds to the watersheds that received the highest proportion of funds; and, in turn, the low category corresponds to the watersheds that received the lowest proportion of funds. A “none” category applies to watersheds where the model did not allocate any portion of the budget. A “none” result may occur if the model determined the watershed was not as cost effective as others or if any of the following criteria occur: (1) the watershed does not have a significant amount of cropland; (2) there were no sample points from the NRI survey in the watershed; (3) the optimal conservation treatments could not be modeled; or (4) costs for treatments could not be attributed.

It is important to note that all results were summed at the HUC-4 level and cannot be disaggregated at a finer resolution, such as at the farm or field level. The number of CEAP acres treated is included on the maps to provide a sense of how many acres of cropland per watershed received conservation treatments relative to the funding allocated.

A.7. Estimating Nitrous Oxide (N_2O) Emissions

WRI’s estimates of the reductions in nitrous oxide emissions associated with the study’s nutrient management treatment are based on Equation 11.1 and the tier 1 default emission factor for managed soils as reported in Chapter 11, “N_2O Emissions from Managed Soils and CO_2 Emissions from Lime and Urea Application,” of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.[39] The default emission factor assumes that 1 percent of the N applied to soils from additions, such as fertilizers and crop residues, and mineralization of N in soil organic matter is released to the atmosphere.

ENDNOTES

1. Hall et al. (2012).
2. SWCS and EDF (2007).
3. GAO (2006).
4. In the 2012 farm bill, the first two components of the section on "Evaluation of Applications" require that the State Conservationist "shall prioritize applications (1) based on their overall level of cost effectiveness to ensure that the conservation practices and approaches are the most efficient means of achieving the anticipated conservation benefits of the project; (2) based on how effectively and comprehensively the project addresses the designated resource concern or resource concerns…." Source: Agricultural Act of 2014. H.R. 2642, 113th Congress, 2nd sess. (2014). http://www.gpo.gov/fdsys/pkg/BILLS-113hr2642enr/pdf/BILLS-113hr2642enr.pdf
5. The USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) Manual states that "(1) The State Conservationist …will rank all applications according to the following factors: (i) The degree of cost-effectiveness of the proposed conservation practices; (ii) The magnitude of the expected environmental benefits resulting from the conservation treatment and the priority of the resource concerns that have been identified at the local, State, and national levels;…" Source: Code of Federal Regulations, Agriculture, title 7, sec. 1466.20. Application for contracts and selecting applications. http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=0eacd96d60aaa06f18f4ac3c371e78c8&rgn=div5&view=text&node=7:10.1.2.2.29&idno=7
6. Perez and Walker (2012).
7. Perez and Cox (2009); Searchinger and Friedman (2003); SWCS and EDF (2007).
8. Perez and Walker (2014); Perez and Cox (2009); SWCS and EDF (2007); Wu et al. (2001).
9. Walter et al. (2007); Wu et al. (2001); Weinberg and Claassen (2006); Winsten et al. (2011); Winsten (2009); Perez and Cox (2009); Selman et al. (2008); Greenhalgh et al. (2006); SWCS and EDF (2007).
10. Walter et al. (2007).
11. USEPA (1993).
12. Claassen (2007).
13. Wu et al. (2001); Hansen and Hellerstein (2006); Zilberman and Segerson (2012); Greenhalgh et al. (2006).
14. Wu et al. (2001); Walter et al. (2007).
15. See CEAP's Cropland National Assessments; River Basin Cropland Modeling Reports Web site, the Farm Service Agency's CRP Monitoring, Assessment and Evaluation Project (MAE) Web site, the Economic Research Service's Environmental Quality Publications website, and the Farm Service Agency's FY 2011 CRP annual report.
16. Weinberg and Claassen (2006).
17. The ProTracts database used for this analysis included the following conservation programs: AWEP = Agricultural Water Enhancement Program, AMA = Agricultural Management Assistance; CBWI = Chesapeake Bay Watershed Initiative; CIG = Conservation Innovation Grants; CRBSCP = Colorado River Basin Salinity Control Program; CRP = Conservation Reserve Program; CSP = Conservation Security Program; CSP 2008 = Conservation Stewardship Program; CTA = Conservation Technical Assistance; ECP = Emergency Conservation Program; EWP = Emergency Watershed Protection; EQIP = Environmental Quality Incentives Program; FIP = Forest Incentives Program; FPE = Floodplain Easement Program; FRPP = Farm and Ranch Lands Protection Program; GLC = Grazing Lands Conservation; GLRI = Great Lakes Restoration Initiative; GRP = Grassland Reserve Program; RCD = Resource Conservation and Development; SWCA = Soil and Water Conservation Assistance; BNFTS ALL PGMS = HQ staff time; WF-08 or WF08 = Small Watershed Program and Flood Prevention Program; WFPO = Watershed and Flood Prevention Operations.
18. The following 40 cropland-related practices were identified in the ProTracts database: Alley Cropping; Residue and Tillage Management, No Till/Strip Till/Direct Seed; Contour Farming; Contour Orchard and Other Fruit Areas; Contour Buffer Strips; Cover Crop; Critical Area Planting; Residue Management, Seasonal; Residue and Tillage Management, Mulch Till; Residue and Tillage Management, Ridge Till; Sediment Basin Diversion; Multi-Story Cropping; Windbreak/Shelterbelt Establishment; Field Border; Riparian Herbaceous Cover; Riparian Forest Buffer; Filter Strip; Grade Stabilization Structure; Grassed Waterway; Hedgerow Planting; Hillside Ditch; Anionic Polyacrylamide (PAM) Erosion Control; Row Arrangement; Runoff Management System; Stripcropping; Cross Wind Ridges; Cross Wind Trap Strips; Nutrient Management; Terrace; Vegetative Barrier; Herbaceous Wind Barriers; Water and Sediment Control Basin; Windbreak/Shelterbelt Renovation.
19. The hydrologic unit code (HUC) is a hierarchical classification system for watersheds based on size. A 4-digit HUC watershed averages about 15,800 square miles. A 2-digit HUC watershed averages about 177,560 square miles.
20. For more information, see the box on page 12 of USDA, NRCS CEAP UMRB Report (2012).
21. An 8-digit HUC watershed averages about 700 square miles while a 12-digit HUC watershed averages about 40 square miles.
22. For each sample point, the CEAP-APEX analysts select the treatment and the associated practices that are most appropriate, given the targeted environmental outcome, by taking into account factors like site hydrology, the baseline farm and conservation management, and the baseline APEX estimate of environmental losses. The APEX model treats each sample point with each treatment deemed appropriate for the site in order to estimate the benefits, but the optimization model selects only the one single treatment for use of the project funds.
23. A 2-digit HUC watershed averages about 177,560 square miles.

24. Walker and Perez (2014).

25. USDA NRCS CEAP Cropland National Assessments. River Basin Cropland Modeling Reports. Web site.

26. USDA NRCS CEAP Cropland National Assessments. River Basin Cropland Modeling Reports. Web site.

27. USDA NRCS CEAP Cropland National Assessments. River Basin Cropland Modeling Reports. Web site.

28. The National Resources Inventory, conducted by NRCS with major data releases every five years since 1982, is a survey that provides data on the status, condition, and trends of land, soil, water, and other resources on non-federal lands in the United States and consists of hundreds of thousands of sample points.

29. Because the full national NRI-CEAP sample was so large, NRCS and NASS divided it randomly into four parts in order to spread the survey team workload over four years. The points sampled in 2003 included crop years 2001, 2002, 2003; the 2004 survey included crop years 2002, 2003, and 2004; while the 2006 survey included crop years 2004, 2005, and 2006. Each of the four sample subsets included points from all states.

30. See the USDA NRCS CEAP Cropland Farmer Surveys Web site: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/?ss=16&navtype=SUBNAVIGATION&cid=nrcs143_014163&navid=120160330000000&position=Not%20Yet%20Determined.Html&ttype=detail

31. The APEX model is most often characterized as a "process" model which means that it has hundreds of equations linked to one another to represent biophysical processes. Most of these equations are highly nonlinear, representing the S-curve convergence phenomena seen in most statistically estimated representations of natural phenomena. Some of the coefficients of the individual equations were developed with statistical methods, but many were not.

    A sensitivity analysis has been conducted for the APEX model while an estimate of the margin of error on acres was conducted for each of the nine CEAP regional reports. Additional information about model calibration and validation is available. See (a) "Sensitivity Analysis of APEX for National Assessment" at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013054.pdf; (b) the margin of error for selected acre estimates in Appendix A in the NRCS CEAP UMRB Report at http://www.nrcs.usda.gov/technical/nri/ceap; (c) "APEX Model Validation for CEAP" at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042102.pdf; (d) "I_APEX Calibration and Validation Using Research Plots in Tifton, Georgia" at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013180.pdf; and (e) "Historical Development and Applications of the EPIC and APEX Models" at http://www.card.iastate.edu/publications/synopsis.aspx?id=763

32. APEX is a "daily time step" model and continuous in its simulation so that all attributes at the end of one day become the beginning attributes for the next day. The same occurs for year to year of the simulation. On a daily basis, the equations interact with each other, and the hydrologic, nutrient, and soil structure components are rebalanced. Any of the hydrologic, nutrient, and soil attributes can be reported on a daily basis; but for these datasets with a large number of samples, that is impossible to do. From the model output, analysts can compute temporal trends. For the CEAP project, NRCS programs the APEX model to report out annual averages only, except for some month-by-year data elements that are passed to the SWAT model.

    For the CEAP simulations, NRCS uses actual daily weather datasets for the period 1961–2006 (47 years). NRCS is more interested in the impact of the variation of the weather than the temporal trend. Regarding temporal trends for smaller sample sets, some researchers have analyzed the sustainability of a particular resource and management situation, i.e., the change in crop yields and soil attributes over time.

    The entire analysis is based on the 2003 NRI data and on the NRI-CEAP farmer surveys covering three years of farm management data in the 2001–2006 period. NRCS looked at that data to determine what the rotation was and then used the appropriate reported years of data to set up a rotation for the APEX modeling. Then in APEX, the rotations are repeated over time for the full 47-year simulation. The annual practices might be used for some or all of the years of the rotation. Most structural practices are "permanent," used for all years of the rotation. But of these, something like a planted buffer strip would be established at the start of the 47-year simulation, and its effectiveness would increase over the years of the simulation as the trees matured. However, something like a terrace would be established the first year and be immediately effective for all years of the simulation.

33. See endnote 17 for all the conservation programs that are maintained in the ProTracts database.

34. Non-crop-related practices include those for livestock and poultry production, grazing lands, forest lands, etc.

35. USDA NRCS CEAP Cropland National Assessments. River Basin Cropland Modeling Reports.

36. See Table 1 for the six conservation treatments.

37. See Table 1 for the 16 practices that are used to simulate the six conservation treatments in APEX.

38. For both categories of costs, conversions from "units of practice" installed to "cost per protected acre" were accomplished by developing "units of practice installed per acre of land planning unit" from the National Conservation Practice database (a database of all conservation practices on file in district offices).

39. DeKlein et al. (2006).

REFERENCES

Claassen, R. 2007. “Buying Environmental Services: Effective Use of Economic Tools.” In *Managing Agricultural Landscapes for Environmental Quality*, 92—103. Ankeny, IA: Soil and Water Conservation Society. http://www.swcs.org/en/publications/managing_agricultural_landscapes/

De Klein, C., R. S. A. Novoa, S. Ogle, K. A. Smith, P. Rochette, T. C. Wirth, B. G. McConkey, A. Mosier, and K. Rypdal. 2006. “N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application.” Volume 4, Chapter 11. *IPCC Guidelines for National Greenhouse Gas Inventories*. Technical Report 4-88788-032-4, Intergovernmental Panel on Climate Change. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Government Accountability Office (GAO). 2006. “USDA Should Improve Its Process for Allocating Funds to States for the Environmental Quality Incentives Program.” GAO 06-969. http://www.gao.gov/assets/260/251620.pdf

Greenhalgh, S., M. Selman, and J. Guiling. 2006. “Paying for Environmental Performance: Investing in Farmers and the Environment.” *WRI Policy Note Environmental Markets No. 2.* Washington, DC: World Resources Institute. http://www.wri.org/sites/default/files/pdf/pep_reverseauction.pdf

Greenhalgh, S., J. Guiling, M. Selman, and J. St. John. 2007. *Paying for Environmental Performance: Using Reverse Auctions to Allocate Funding for Conservation*. Washington, DC: World Resources Institute. http://www.wri.org/sites/default/files/pdf/pep_reverseauction.pdf

Hall, L., T. Christensen, J. Bramblett, S. Hopkins, and J. Hubbert. 2012. “USDA’s National Water Quality Initiative: A Watershed Academy Webcast.” Presented on the U.S. Environmental Protection Agency’s Watershed Academy webcast, July 10, 2012. http://water.epa.gov/learn/training/wacademy/upload/2012_07_10-slides.pdf

Hansen, L., and D. Hellerstein. 2006. “Better Targeting, Better Outcomes. Conservation Program Design.” U.S. Department of Agriculture Economic Research Service. http://www.ers.usda.gov/publications/eb-economic-brief/eb2.aspx#.U3EY6_ldWCk

Osmond, D.L., D.W. Meals, D. LK. Hoag, and M. Arabi, eds. 2012. “How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture–Conservation Effects Assessment Project Experience.” Ankeny, IA: Soil and Water Conservation Society. http://www.swcs.org/en/publications/building_better_agricultural_conservation_programs/

Perez, M., and C. Cox. 2009. “Seizing a Watershed Moment: Making EQIP Work for Water Quality in 10 Mississippi River Border States.” Washington, DC: Environmental Working Group. http://static.ewg.org/reports/2009/seizing_a_watershed_moment/09EWG-EQIP-Summary-Report.pdf

Perez, M., and S. Walker. 2014. “Improving Water Quality: A Review of the Mississippi River Basin Healthy Watershed Initiative (MRBI) to Target U.S. Farm Conservation Funds.” Washington, DC: World Resources Institute. http://www.wri.org/publication/MRBI

Perez, M., and S. Walker. 2012. “Draft fact sheet on how NRCS evaluates the effects of conservation practices on resource concerns and uses a cost-efficiency factor in the ranking process for financial assistance.” Washington, DC: World Resources Institute.

Scarlett, L., 2011. “America’s Working Lands: Farm Bill Programs and Landscape-Scale Conservation.” Lincoln Institute of Land Policy. https://www.lincolninst.edu/pubs/dl/1958_1279_Scarlett%20final.pdf

Searchinger, T., and S. Friedman. 2003. “Getting More Bang for the Buck: Nine Suggestions for Improving State EQIP Ranking Criteria: A Discussion Paper.” Washington, DC: Environmental Defense Fund.

Selman, M., S. Greenhalgh, M. Taylor, and J. Guiling. 2008. “Paying for Environmental Performance: Potential Cost Savings Using a Reverse Auction in Program Sign-up.” *WRI Policy Note Environmental Markets No. 2*. Washington, DC: World Resources Institute. http://www.wri.org/sites/default/files/pdf/paying_for_environmental_performance_reverse_auctions_in_program_signup.pdf

Soil and Water Conservation Society (SWCS) and Environmental Defense Fund (EDF). 2007. “Environmental Quality Incentives Program: Program Assessment.” http://www.swcs.org/documents/filelibrary/EQIP_assessment.pdf

U.S. Department of Agriculture (USDA). 2013. Landscape Conservation Initiatives Web site. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/initiatives/

USDA. 2013. Mississippi River Basin Healthy Watersheds Initiative Web site. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/initiatives/?cid=stelprdb1048200

USDA, Economic Research Service (ERS). Environmental Quality Publications Web site. http://www.ers.usda.gov/topics/natural-resources-environment/environmental-quality.aspx#.U3EdHvldWCk

USDA, ERS. Conservation Programs Background Web site. http://www.ers.usda.gov/topics/natural-resources-environment/conservation-programs/background.aspx#.U3EdZfldWCk

USDA, Farm Service Agency (FSA). 2011. "Conservation Reserve Program's Annual Summary and Enrollment Statistics FY2011." See page 5 for the nitrogen, phosphorus, and sediment reduction estimates for CRP by the Food and Agricultural Policy Research Institute (FAPRI). http://www.fsa.usda.gov/Internet/FSA_File/annual-summary2011.pdf

USDA, FSA. 2013. CRP Monitoring, Assessment and Evaluation Project (MAE) Web site. http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ecpa&topic=nra

USDA, Natural Resources Conservation Service (NRCS), Conservation Effects Assessment Project (CEAP). 2009. Cropland National Assessments: River Basin Cropland Modeling Reports. Web site. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/na/?cid=nrcs143_014144

USDA NRCS, CEAP. 2012. Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042093.pdf

U.S. Environmental Protection Agency (USEPA), Office of Water. 1993. *Geographic Targeting: Selected State Examples.* Washington, DC: USEPA. http://bit.ly/k3tX7v

Walker, S., and M. Perez. 2014. "Improving Water Quality: Overcoming Barriers to Better Targeting of U.S. Farm Conservation Funds." *Issue Brief*. Washington, DC: World Resources Institute. wri.org/publication/targeting-barriers-us-farm-conservation-funds

Walter, T., M. Dosskey, M. Khanna, J. Miller, M. Tomer, and J. Wiens. 2007. "The Science of Targeting Within Landscapes and Watersheds to Improve Conservation Effectiveness." In *Managing Agricultural Landscapes for Environmental Quality*, 63—89. Ankey, IA: Soil and Water Conservation Society. http://www.swcs.org/en/publications/managing_agricultural_landscapes/

Weinberg M., and R. Claassen. 2006. "Rewarding Farm Practices versus Environmental Performance." *Economic Brief Number 5*. Washington, DC: USDA Economic Research Service. http://www.ers.usda.gov/publications/eb-economic-brief/eb5.aspx#.U3Efn_ldWCk

Winsten, J. 2009. "Improving the Cost Effectiveness of Agricultural Pollution Control: The Use of Performance-based Incentives. *Journal of Soil and Water Conservation* 64(3): 88A–93A, doi:10.2489/jswc.64.3.88A. http://www.jswconline.org/content/64/3/88A.full.pdf

Winsten J., C. Baffaut, J. Britt, T. Borisova, C. Ingels, and S. Brown. 2011. "Performance-based Incentives for Agricultural Pollution Control: Identifying and Assessing Performance Measures in the United States." *Water Policy* 13(5): 677-692. http://www.iwaponline.com/wp/01305/wp013050677.htm

World Resources Institute. Eutrophication and Hypoxia Map Web site. http://www.wri.org/our-work/project/eutrophication-and-hypoxia

Wu, J., D. Zilberman, and B. A. Babcock. 2001. "Environmental and Distributional Impacts of Conservation Targeting Strategies." *Journal of Environmental Economics and Management* 41 (3): 333–350. http://www.sciencedirect.com/science/article/pii/S009506960091146X

Zilberman, D. and K. Segerson. 2012. Top Ten Design Elements to Achieve More Efficient Conservation Programs. Council on Food, Agriculture, and Resource Economics. http://issuu.com/c-fare/docs/top10elementsconservationprograms/8

ABOUT WRI

WRI is a global research organization that works closely with leaders to turn big ideas into action to sustain a healthy environment—the foundation of economic opportunity and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

PHOTO CREDITS

Cover, pg. 9 Chesapeake Bay Program; table of contents, pg. 38 USDA/Bob Nichols; pg. 2 Wisconsin DNR; pg. 3 Chiot's Run; pg. 6 Carl Wycoff; pg. 15 Jack Dykinga; pg. 10, 40 NRCS/Lynn Betts; pg. 18 USDA/Tim McCabe; pg. 20 Darin; pg. 26 (l-r) Yukon White Light, NRCS South Dakota, Mike_tn; pg. 27 Mark Pouley; pg. 29 Ian Broyles; pg. 30 NRCS/Ron Nichols; pg. 32, 37 USDA; pg. 45, 49 NRCS/Jason Johnson; pg. 45 TC Davis; pg. 50 Jeff Zabinski; pg. 53 USDA/Ron Nichols; pg. 54 dbarronoss.

WORLD
RESOURCES
INSTITUTE

10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

ISBN 978-1-56973-826-9