A Guide to Water Quality, Climate, Social, and Economic Outcomes Estimation Tools

QUANTIFYING OUTCOMES TO ACCELERATE FARM CONSERVATION PRACTICE ADOPTION

Michelle Perez, PhD | Emily J. Cole, PhD

DECEMBER 2020

ABOUT AMERICAN FARMLAND TRUST

American Farmland Trust (AFT) is the largest national organization dedicated to protecting farmland, promoting sound farming practices, and keeping farmers on the land. AFT unites farmers and environmentalists in developing practical solutions that protect farmland and the environment. We work from "kitchen tables to Congress," tailoring solutions that are effective for farmers and communities and can be magnified to have greater impact. Since our founding, AFT has helped to protect more than six and a half million acres of farmland and led the way for the adoption of conservation practices on millions more. AFT has a national office in Washington, D.C., and a network of offices across America where farmland is under threat.

For more information, visit us at www.farmland.org.

ABOUT THE AUTHORS

Michelle Perez, PhD is the Water Initiative Director at American Farmland Trust. She has over 16 years of experience working to improve farm conservation programs and policies so they result in better water quality. She conducts research evaluating voluntary, regulatory, and market-based approaches to reducing agricultural nonpoint source pollution and advises AFT's watershed conservation projects on measuring their outcomes. Recently, with a team of seven AFT staff and two consultants, she developed the Soil Health Economic and Environmental Case Study Tool Kit.

Contact: mperez@farmland.org

Emily J. Cole, PhD is the Climate and Agriculture Program Manager for New England at American Farmland Trust. She has 20 years of research and education experience, with the last 10 years focused on soil health in agroecosystems and carbon sequestration though the application of biochar and soil health management practices. As a university professor, extension educator, and now in her role at AFT, she works to improve and advocate for the integration of climate smart management practices into New England's productive farming communities.

Contact: ecole@farmland.org

ABOUT THIS GUIDE

This guide is a working paper, as it provides an initial assessment of the approaches, methods, and tools available to quantify environmental, social, and economic outcomes associated with farm conservation practices. The guide features 14 outcomes estimation tools and two methods, which can be used by farm conservation project managers without requiring professional computer modeling experience. We hope this will help conservationists take the next steps in their outcomes quantification journey. Doing so may help drive greater adoption of conservation practices. In addition, we hope this analysis stimulates efforts by government, academics, foundations, and the private sector to further refine existing tools and methods, provide additional guidance and support to project managers, and build a national dataset to continually calibrate and validate outcomes quantification models and tools. Note this publication provides hotlinks to enable online readers to easily jump to different sections within this guide and to also visit the tool websites.

Suggested citation:

Perez, Michelle and Emily J. Cole. 2020. A Guide to Water Quality, Climate, Social, and Economic Outcomes Estimation Tools: Quantifying Outcomes to Accelerate Farm Conservation Practice Adoption. Washington, DC: American Farmland Trust. farmlandinfo.org/publications/guide-to-outcomes-estimation-tools

MAIN COVER IMAGE: Natalie Lounsbury (then University of Maryland graduate student) in a field of forage radish cover crops. Also known as tillage radish, this cover crop provides multiple soil health benefits to cropland; it alleviates soil compaction, suppresses weeds, and reduces nitrogen leaching. Photo by Edwin Remsberg/USDA-SARE.

INSET IMAGES: iStockphoto.

A Guide to Water Quality, Climate, Social, and Economic Outcomes Estimation Tools

QUANTIFYING OUTCOMES TO ACCELERATE FARM CONSERVATION PRACTICE ADOPTION

Michelle Perez, PhD | **Emily J. Cole, PhD**

DECEMBER 2020

ACKNOWLEDGMENTS

This guide was made possible with grants from the Walton Family Foundation, the Mosaic Foundation, and the McKnight Foundation. The authors could not have completed this study without the collaboration of the many tool developers and researchers featured in this report.

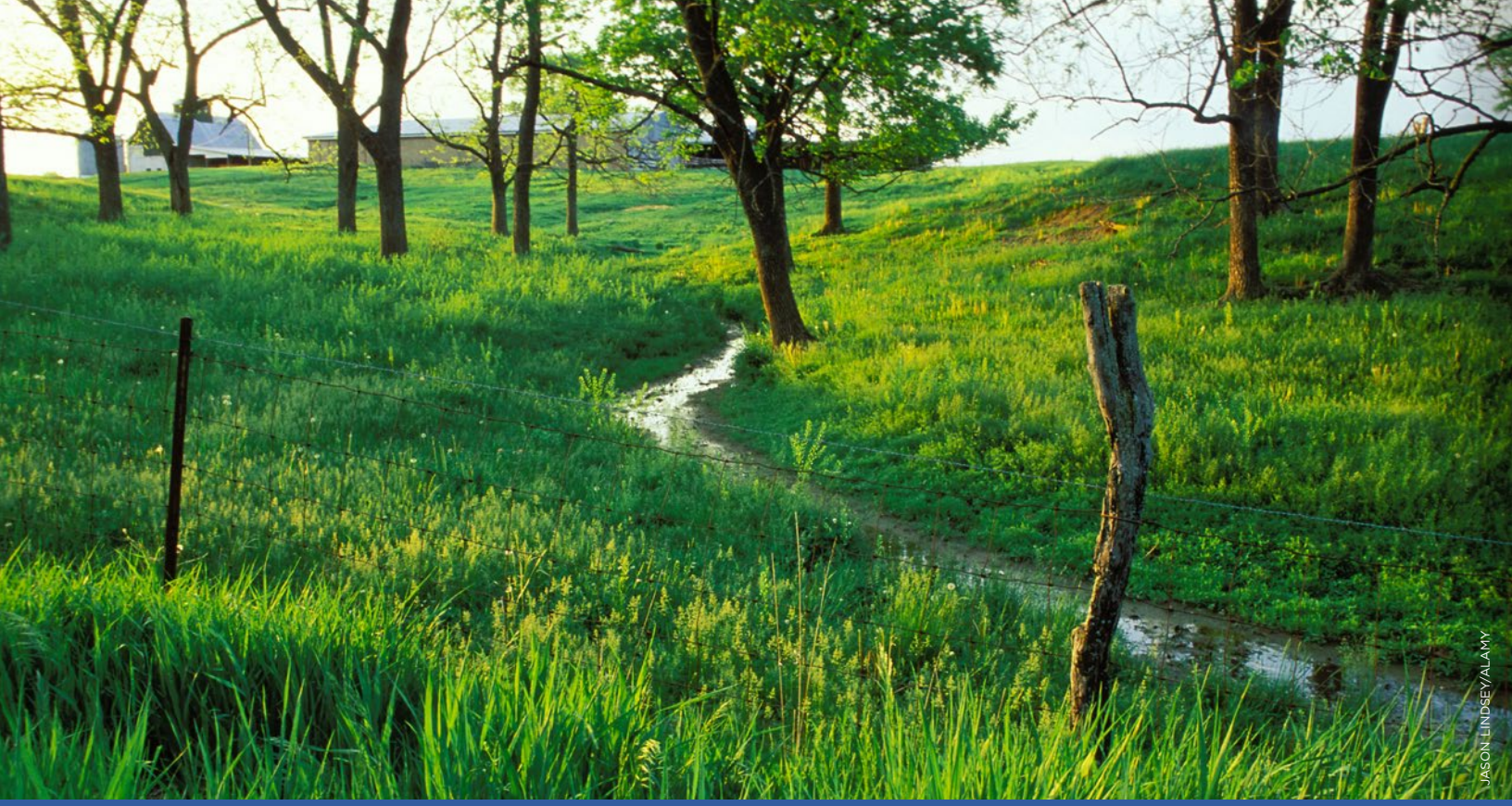
The authors would like to thank the reviewers who provided feedback and editing assistance which made this report stronger. Internal reviewers at AFT included Emily Bruner, Jimmy Daukus, Tim Fink, Mitch Hunter, John Larson, Jennifer Marie Moore, Gabrielle Roesch-McNally, and Kris Reynolds. External reviewers included Katie Cerretani, Seth Fieldler, Martin Lowenfish, and Elizabeth Marshall (NRCS), Katie Flahive (EPA), Linda Prokopy (Purdue University), and Peter Kyveryga and Todd Sutphin (ISA Research Center for Farming Innovation).

The tool developers provided reviews of our write-ups for their tools and reviewed the same draft that was reviewed by the external reviewers. We are grateful for the tool developers' responsiveness and helpfulness during our email and phone communications, as it improved our understanding of the tools. They include:

- STEPL: Colin Geisenhoffer (EPA)
- Region 5: Colin Geisenhoffer (EPA), Jill Reinhart (NRCS-IN), and Trevor Laurays (ISDA)
- NTT: Mindy Selman (USDA OEM) and Ali Saleh (Tarleton State University)
- ModelMW: David Arscott and Matt Ehrhart (Stroud) and Anthony Aufdenkampe (Limnotech)
- PTMApp: Matt Drewitz (MN BWSR) & Drew Kessler (Houston Engineering)
- CAST: Olivia Devereaux (Devereaux Consulting)
- FieldDoc: John Dawes & Erin Hoffman (The Commons)
- S.T.A.R.: Emily Bruner (AFT)
- COMET-Farm & COMET-Planner: Mark Easter, Haley Nagel, and Amy Swan (CSU)
- Fieldprint Platform: Allison Thomson (Field to Market)
- Cover Crops Economics Tool: Lauren Cartwright & Bryon Kirwan
- R-SHEC: Florence Swartz (AFT Consulting Economist)
- Cropping Systems Calculator: Robin Moore (LSP)
- SIPES/SIDMA: Linda Prokopy (Purdue), Gary O'Neil and Jeremiah Asher (IWI)

The authors are grateful to AFT's Samuel Madrigal for reference research and to Kirsten Ferguson and Ellen Yeatman for copy editing and proofreading, as well as to Sally Murray James of Cutting Edge Design, Inc., for design and layout.

All errors of fact or interpretation belong to the authors.


JASON LINDSEY/ALAMY

Executive Summary

Advancing the adoption of conservation practices and keeping farms viable is a fundamental goal of the farm conservation community. This community is large and includes producers and landowners, farm and environmental groups, agricultural retailers and crop consultants, government representatives at federal, state, and local levels, academics, supply chain sustainability leaders, environmental market developers, and many others.

Together, this diverse community supports farmers in reducing unintended environmental effects of agriculture through educational, financial, and technical assistance projects to adopt conservation practices. Practices such as no-till, cover crops, and nutrient management, just to name a few, can result in improved soil health, better water quality, reduced greenhouse gas emissions, a boost to the farmer's bottom line, and other benefits. While there are many challenges confronting agriculture, this paper is concerned primarily with the challenge of measuring the environmental, economic, and social outcomes associated with the adoption of the farm conservation practices.

The goal of quantifying outcomes has been part of the Regional Conservation Partnership Program (RCPP) since its establishment in the 2014 Farm Bill. The Natural Resource Conservation Service's (USDA NRCS) RCPP Announcement for Program Funding in 2014 stated RCPP prioritizes farmer financial and technical assistance awards to projects that "generate near-term results that are measurable from environmental, economic, and social perspectives." The 2018 Farm Bill's report language clarified the rationale behind quantifying outcomes by stating:

> The Managers emphasize the importance of a partner's duty to quantify the environmental outcomes of their RCPP projects, and partners are encouraged to assess and report on the economic and social outcomes of their projects, as partners may be able to encourage increased adoption of conservation practices.

In its 2019 report to Congress, NRCS stated:

> The ideal RCPP project proposes solutions to natural resource challenges in a watershed or region. Many existing RCPP projects include efforts to monitoring (sic) the outcomes of conservation activities using partner capabilities. This information will be critical to

improving our collective understanding of how to use conservation funding more efficiently and effectively in the future.

American Farmland Trust (AFT) concurs with the rationale from Congress and NRCS that RCPP project managers who are able to effectively quantify and communicate the outcomes associated with the conservation practices being adopted by farmers within the project area may be able to accelerate practice adoption by other farmers. Quantification of environmental, social, and economic outcomes by projects could become a powerful new addition to the "conservation toolbox" to help the local conservation community "sell" conservation better, faster, and across more acres. Lessons learned from these locally led projects could help inform other federal, state, and private sector conservation programs, making them more effective at achieving the desired landscape-level improvements in water quality, improved resilience to climate change, and more prosperous farms, among other benefits.

However, leaders of RCPP and other landscape-scale projects struggle to quantify their project outcomes due to a lack of knowledge about which direct monitoring or indirect modeling estimation methods, models, or tools they should use. This is in part because there are numerous options available and finding the right one can be daunting. Furthermore, actually conducting the monitoring, modeling, or using an outcomes estimation tool can be very hard. NRCS provides outcomes quantification support to RCPP project managers on a case by case basis.

This paper seeks to supplement the NRCS efforts by providing additional information and guidance that could be useful to RCPP project managers and those leading projects receiving funds from the NRCS Mississippi River Basin Healthy Watersheds Initiative (MRBI) and National Water Quality Initiative (NWQI); the U.S. Environmental Protection Agency (EPA) 319 Nonpoint Source Pollution Control Program; state and local programs; and corporate supply chain sustainability programs, among others.

There are many options for measuring outcomes. They can range from directly monitoring changes in a stream, in the soil, or in a wildlife population. But monitoring often requires technical data collection and statistical analyses skills that can be expensive. And it can take a long time for changes to be detectable (e.g., three to 10 or more years). Other options include quicker modeling approaches to estimating environmental outcomes. Those can range from sophisticated modeling analyses conducted by modeling experts to the use of outcomes estimation tools meant for use by generalists (defined as persons without modeling experience, such as the authors).

The quantification of outcomes through estimation techniques seems like it should be a straightforward exercise. We quickly experienced for ourselves in our own RCPP project just how difficult it can be. We also observed our fellow conservationists experiencing significant confusion over methodologies, tools, and approaches, as well. In our limited search while preparing for this paper, we identified nearly 50 different models, tools, and methods, each designed for different purposes, based on different datasets and methodologies, and with differing assumptions. As non-modelers, we undertook this effort to identify, describe, and compare readily available outcomes quantification tools and methods with the end goal of educating ourselves and our fellow conservationists and empowering project managers to select one or more tools or methods to meet their project outcomes quantification goals.

While many valid methodological approaches exist with which RCPP and other farm conservation project managers can evaluate their outcomes, for this inventory we focused on outcomes estimation tools that meet the following criteria:

1. Provide quantitative estimates of water quality, climate, social, or economic outcomes associated with farm conservation practice adoption;
2. Are available to the general public, either for free or for a fee;
3. Are intended for direct use by conservationists or farmers; and
4. Do not require users to be a modeling professional.

For expediency's sake, we added a fifth criteria for tools we would feature in this report—"Are available to users in more than one state and for more than one commodity"—to maintain the focus on tools that are more broadly available.

Many tools and models did not satisfy some of these five criteria, and we describe 35 of them in the Appendices. We also found two methods that we thought were important to discuss, though we did not feature them to the same extent as the tools because they do not require in-depth technical explanation. (Note we are defining methods here as a systematic

procedure for accomplishing the task of estimating outcomes. This is in contrast to a tool, which we define as a technical device intended to make the task of estimating outcomes easier.)

This guide provides insights and analysis on the 14 outcomes quantification estimation tools and two methods that satisfied our five criteria: seven water quality tools and one water quality method, three greenhouse gas tools, one social indicators analysis method and one social indicators tool, and three economic tools. Primarily, we hope this guide and the tools and methods featured will be useful to the RCPP and many other project managers trying to measure their conservation practice and project outcomes.

Secondarily, because neither author is a modeler, we regard this guide as a working paper that reflects our earnest and first-ever study of the challenges that project managers face in trying to find a tool or a method to quantify their outcomes. Thus, it reflects preliminary research, analysis, findings, and recommendations. AFT is circulating this working paper to encourage discussion amongst the many members of the farm conservation community, and in particular to engage the tool developers, tool users, NRCS, EPA, other federal agencies, Congress, state agencies, the academic community, the research and charitable foundation communities, and supply chain sustainability leaders. The goal of this desired discussion is to further refine existing outcomes quantification tools, project evaluation methods, and guidance to better support project managers who are trying to quantify outcomes of farm conservation practices and projects.

To further this goal, we offer 14 recommendations for various outcomes quantification stakeholder groups and institutions, a few of which we summarize here:

- Tool developers—provide more easy-to-understand information and make training readily available to project managers;
- Project managers—consider which tool or method is right for your effort and then pursue a partnership with the tool developers to develop an outcomes quantification plan;
- NRCS—provide a guidebook on the available options for outcomes quantification for project managers and facilitate regular trainings on methods and tools;
- Congress, federal agencies, states, research and charitable foundations, academics, and the supply chain sustainability leaders—support efforts to improve the outcomes quantification methods, tools, and models for use by project managers and support development of a national calibration dataset to continually improve the accuracy of the tools.

USDA/LANCE CHEUNG

ABBREVIATIONS

AOI	Area of Interest
APEX	Agricultural Policy/ Environmental eXtender model
ARS	Agricultural Research Service
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CAST	Chesapeake Assessment Scenario Tool
CEAP	Conservation Effects Assessment Program
CCS	Conservation Cropping Systems
CLD	Crop Land Data Layer
CSP	Conservation Stewardship Program
DEM	digital elevation model
DRP	dissolved reactive phosphorous
ERS	Economic Research Service
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
GHG	Greenhouse Gas
GIS	Geospatial Information Systems
GRTS	Grants Reporting and Tracking System
GLRI	Great Lakes Restoration Initiative
HTF	Hypoxia Task Force
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
ModelMW	Model My Watershed
MRBI	Mississippi River Basin Healthy Watersheds Initiative
NASS	National Agricultural Statistics Service
NIFA-CEAP	National Institute for Food and Agriculture-Conservation Effects Assessment Project
NRCS	Natural Resources Conservation Service
NPS	Nonpoint source
NTT	Nutrient Tracking Tool
NTT-RE	Nutrient Tracking Tool Research and Education
NWQI	National Water Quality Initiative
PBA	Partial Budget Analysis
PES	Payments for Ecosystem Services
PTMApp	Prioritize, Target, & Measure Application
R-SHEC	Retrospective-Soil Health Economic Calculator
RCPP	Regional Conservation Partnership Program
RUSLE2	Revised Universal Soil Loss Equation 2
SIDMA	Social Indicators Data Management and Analysis
SIPES	Social Indicator Planning and Evaluation System
SSURGO	Soil Survey Geographic Database
STEPL	Spreadsheet Tool for Estimating Pollutant Load
SWAMM	Spatial Watershed Assessment and Management Model
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS HUC	United States Geological Survey Hydrologic Unit Code
USLE	Universal Soil Loss Equation
WIP	Watershed Implementation Plan

CONTENTS

5 Executive Summary

11 Introduction
11 The Challenge of Quantifying Project-Scale Outcomes
12 Why Quantify Project Outcomes
16 What to Quantify and the Hurdles that Hinder

17 Methods
17 How Tools Were Identified
19 Summary of Tools Included and Excluded
22 Limitations of this Study

24 Choosing Outcomes Quantification Tools
24 Clarify Project Objectives
24 Reflect on Project Goals, Scale, and Capacity
25 Comparing the Tool Capabilities and User Experiences

29 Water Quality Outcomes Quantification Tools

48 Greenhouse Gas Outcomes Quantification Tools

57 Methods and Tools for Estimating Social Outcomes

61 Economic Outcomes Quantification Tools

71 Conclusion
71 Reflections on What Tools Are Best Suited for Which Projects
72 Reflections on the Trade-offs Required When Choosing and Using a Tool
75 Reflections on the Rationale for Outcomes Quantification

76 Recommendations
76 Recommendations for Tool Developers
77 Recommendations for Project Managers
79 Recommendations for USDA NRCS
79 Recommendations for Congress, USDA, EPA, the States, Academics, Foundations, and Supply Chain Sustainability Leaders

82 References

87 Appendices
88 Appendix A. Resources and Reviews of Agricultural-Environmental Models and Tools
89 Appendix B. List of Environmental Monitoring Methods and Resources
92 Appendix C. Summaries of Excluded Tools
96 Appendix D. Summaries of Excluded Models

List of Figures

12 Figure 1. Excerpt from the RCPP Section of the 2018 Farm Bill
13 Figure 2. How Many Projects Are There?
14 Figure 3. Why Quantify Project Level Outcomes?
15 Figure 4. Envisioning a Self-Strengthening Cycle of Outcomes Quantification & Farm Conservation
15 Figure 5. Outcomes Quantification: A New Tool in the Toolbox
18 Figure 6. Why AFT Is Interested in Outcomes Quantification
19 Figure 7. Definitions of Key Terms
20 Figure 8. Criteria for Outcomes Quantification Tools
22 Figure 9. How Tools Were Evaluated
25 Figure 10. Some Uses of Outcomes Quantification Tools
27 Figure 11. What Purpose did the Tool Developers Initially Build the Tool to Satisfy?
47 Figure 12. The S.T.A.R. Method
57 Figure 13. SIPES Method Handbook Sections
60 Figure 14. Alternative Survey Software

List of Tables

20 Table 1. Featured Outcomes Quantification Tools and Methods
21 Table 2. Tools and Models that Were Excluded
28 Table 3. Getting into the Tool, Getting Started, and Getting to the Finish Line
29 Table 4. Water Quality Outcomes Quantification Tools
48 Table 5. Greenhouse Gas Outcomes Quantification Tools
61 Table 6. Economic Outcomes Quantification Tools
92 Table 7. Why Tools Were Excluded
96 Table 8. Why Models Were Excluded

KEVIN KEENAN

Introduction

The Challenge of Quantifying Project-Scale Outcomes

Agricultural production can result in the unintended effects of impairing water quality in surface and ground waters and producing harmful climate changing gases. In fact, agriculture remains "the leading source of water quality impacts on surveyed rivers and lakes" (EPA, 2016) and as a sector, "agriculture emits an estimated 9.9 percent of total U.S. greenhouse gases" (EPA, 2020). Addressing these unintended environmental impacts, increasing resilience to climate change, and keeping farms viable are among the paramount challenges that agriculture faces today.

A large and diverse farm conservation community is addressing these challenges including farmers and landowners, farm and environmental groups, agricultural retailers, equipment dealers, and crop consultants, representatives from all levels of government, academics, supply chain sustainability leaders, environmental market developers, and many others. This community supports farmers through educational, financial, and technical assistance projects to adopt conservation practices that can result in improved water quality, reduced greenhouse gas emissions, increased soil health and carbon sequestration, a boost to the farmer's bottom line, and many other benefits.

Over the decades, USDA NRCS together with associated agency efforts (e.g., NIFA-CEAP) have increased their capacity for evaluating federal conservation programs by expanding from primarily an on-farm focus to include an emphasis on achieving and measuring environmental outcomes at the landscape scale (NRCS, 2003–2006; Osmond et al., 2012; Perez, 2017; Moriasi et al., 2020).

The 2014 Farm Bill established the Regional Conservation Partnership Program (RCPP) so that project partners could, in partnership with NRCS staff and others, promote adoption of farm conservation practices and conduct assessments of the outcomes of those practices. The 2018 Farm Bill updated the RCPP section (See Figure 1 for an excerpt).

Photo above: Steve Gould, HaR-Go Farms, New York— Gould is standing in a field of triticale cover crop. He is featured in AFT's Soil Health Economic and Environmental Case Studies (AFT, December 2020).

FIGURE 1.
EXCERPT FROM THE RCPP SECTION OF THE 2018 FARM BILL

Section 1271B(c) [emphasis in bold by the authors]:

(c) DUTIES OF PARTNERS.—

(1) IN GENERAL.—Under a partnership agreement, the eligible partner shall—

(A) define the scope of a project, including—

(i) 1 or more conservation benefits that the project shall achieve;

(ii) the eligible activities on eligible land to be conducted under the project to achieve conservation benefits;

(iii) the implementation timeline for carrying out the project, including any interim milestones;

(iv) the local, State, multistate, or other geographic area covered; and

(v) the planning, outreach, implementation, and assessment to be conducted;

(B) conduct outreach and education to producers for potential participation in the project;

(C) at the request of a producer, act on behalf of a producer participating in the project in applying for assistance under section 1271C;

(D) leverage financial or technical assistance provided by the Secretary with additional contributions to help achieve the project objectives;

(E) conduct an assessment of—

(i) the progress made by the project in achieving each conservation benefit defined in the partnership agreement, including in a quantified form to the extent practicable; and

(ii) as appropriate, other outcomes of the project; and

(F) at the conclusion of the project, report to the Secretary on its results and funds leveraged.

NRCS's 2014 RCPP Announcement for Program Funding emphasized that RCPP would prioritize farmer financial and technical assistance awards to projects that "generate near-term results that are measurable from environmental, economic, and social perspectives" (USDA NRCS, 2014). The NRCS "RCPP Expectations" document (2020) defined outcomes this way:

> Outcomes are the measurable environmental, economic and social impacts of RCPP project activities. Examples of outcomes are pounds of nitrogen runoff avoided, tons of carbon sequestered, cost savings to producers, number of neighboring producers adopting a practice, decision factors leading to producer adoption of a soil health management system, etc.

This paper focuses on the challenges of quantifying outcomes at the **project level** by RCPP and other project managers and provides additional information and guidance to help enable more widespread quantification by local projects. It is important to point out that outcomes quantification of farm conservation practices has been underway at a variety of other scales by various government and academic scientific communities:

- **Regional-scale** modeling simulations of the nutrient and sediment reductions of farm conservation practices (e.g., the 2003 to 2006 NRCS CEAP River Basin Cropland Modeling Study Reports);
- **Program-scale** modeling analysis of the nutrient and sediment reductions associated with current MRBI and NWQI practice data through 2023 in the 2019 MRBI and NWQI Progress Reports (NRCS, 2019b&c);
- **Long-term NIFA-CEAP watershed projects** (2003 to ongoing) that conduct in-stream and in-field monitoring as well as modeling estimates of the effects of practice adoption (e.g., Moriasi et al., 2020).

Ideally, the quantification efforts of **RCPP and other project managers** will be able to build on the knowledge and experience of the government and academic groups and complement their efforts.

Why Quantify Project Outcomes

The importance of outcomes measurement at the **program-scale** was noted in 2004 by USDA's Mausbach and Dedrick in their aptly titled article, "The Length We Go: Measuring Environmental Benefits of Conservation Practices":

> Tracking the progress of conservation programs in terms of the outcomes achieved will allow policymakers and program managers to improve the effectiveness of existing programs and design new programs to increase the conservation of our nation's natural resources.

More recently, USDA Under Secretary Bill Northey (2020) said this about the **conservation programs**:

> One of the requests of the 2018 Farm Bill was to refocus USDA's efforts to document outcomes of conservation programs on private lands. We agree. It's imperative that we show that USDA conservation programs work and that farmers and ranchers using voluntary conservation efforts are making a difference. In fact, USDA has a long history of working toward this goal.

The report language for the 2018 Farm Bill's RCPP section stated the rationale for quantifying outcomes specifically at the **project-scale** this way:

> The Managers emphasize the importance of a partner's duty to quantify the environmental outcomes of their RCPP projects, and partners are encouraged to assess and report on the economic and social outcomes of their projects, as partners may be able to encourage increased adoption of conservation practices.

In NRCS' 2019 report to Congress, it stated this about **RCPP projects**:

> The ideal RCPP project proposes solutions to natural resource challenges in a watershed or region. Many existing RCPP projects include efforts to monitoring (sic) the outcomes of conservation activities using partner capabilities. This information will be critical to improving our collective understanding of how to use conservation funding more efficiently and effectively in the future.

We agree with the many reasons for quantifying outcomes of farm conservation practices, projects, and programs laid out by Congress, USDA, and NRCS, and we believe that doing so may aid in accelerating practice adoption. This is likely true not just for RCPP projects but also for every other project operating under federal programs (e.g., NRCS's Mississippi River Basin Healthy Watersheds Initiative or MRBI, NRCS's National Water Quality Initiative or NWQI, the EPA 319 Nonpoint Source Pollution Control Program, etc.), state programs, corporate supply chain sustainability programs, and environmental markets.

The social science literature also supports the oft-repeated adage, "If you can't measure it, you can't improve it." Prokopy et al. (2019) conclude:

> A related key takeaway is that both awareness of and positive attitudes toward the actual program or practice to be adopted are found to be positive predictors of adoption. This is consistent with Fishbein and Ajzen's (2010) reasoned action approach, which argues that object-specific attitudes are more important than general attitudes. Thus, helping farmers form specific attitudes about specific programs and practices is critical to adoption.

Per this insight, one way to develop **awareness** and **positive farmer attitudes for farm conservation practices** that reduce water quality and greenhouse gas (GHG) emissions is to quantify the environmental, social, and economic outcomes attributable to **specific** practices. The RCPP and other landscape-scale project managers have thousands of projects currently interfacing with tens of thousands of farmers over millions of acres, giving them a major opportunity to quantify outcomes and develop positive farmer attitudes (See Figure 2).

FIGURE 2. HOW MANY PROJECTS ARE THERE?

We believe there are easily over one thousand federally supported farm conservation projects operating right now that are collaborating with tens of thousands of farmers on millions of acres. Further still are hundreds of state- or county-sponsored projects and dozens of supply chain sustainability projects that are likely out there as well as.

To estimate a least a few groups of federal conservation projects, we reached out to USDA NRCS and EPA.

Based on data in the Clean Water Act Section 319 Grants Reporting and Tracking System (GRTS), EPA estimates that approximately 40% (thus, about **600**) of the 1,500 EPA 319 projects underway, in any given year, are focused on agricultural conservation practices (A. Pontious, personal communication, 10/26/20).

RCPP Director Kari Cohen reports that 375 RCPP projects were initiated under the 2014 Farm Bill. In FY21, under the 2018 Farm Bill, 65 projects are scheduled to start while several initial projects are expiring. Cohen estimates there are now around **400** active projects (Personal communication, 9/3/2020).

Landscape Conservation Initiatives Director Martin Lowensfish reports that MRBI started in FY10 under the CCPI** framework with 127 projects. In FY21, MRBI has **47** projects covering 204 HUC-12 watersheds in their implementation phase and another **19** projects covering 72 watersheds in their planning phase.

As for NWQI, which does not report by project but by watershed, Lowenfish says that since FY2012, NRCS has delivered NWQI in 736 HUC-12 watersheds. In FY21, they will have 173 HUC-12 watersheds in the implementation phase and 211 in the planning phase (Personal communication, 10/2/2020).

---

* HUC-12 refers to a system for categorizing watersheds and the acronym stands for "hydrologic unit code." A HUC12 watershed is a small watershed that can measure, on average, about 40 square miles.

** CCPI stands for Cooperative Conservation Partnership Initiative.

From a pragmatic perspective, there are many reasons for project managers to quantify outcomes at the **project level** that may make efforts to increase conservation practice adoption even more effective:

1. **Generate new evidence-based outreach and education materials.** Emerging tools offer project managers the opportunity to assess environmental and economic outcomes already experienced by local farmers who have adopted soil health management systems (SHMS) to provide evidence to other farmers that practices "can work." This may help farmers who have not yet adopted practices gain the confidence they need to overcome the risks associated with making major management changes (AFT, 2019, 2020; Monast et al., 2018; Datu Research, 2017).

2. **Develop new farmer engagement activities**. Many outcomes quantification tools can be used like decision-support tools (Ranjan et al., 2020) to engage local farmers on the fence about practices by running "what if" conservation planning scenarios. Decision-support tools (DST) that also offer quantitative estimates of potential environmental or economic outcomes may improve the likelihood of getting farmers to say "yes" to conservation, or get them to say yes sooner, than DSTs without outcomes quantification capabilities.

3. **Report on collective success**. Project managers can also use outcomes quantification tools to aggregate individual farmer practice adoption in order to report on cumulative results of practice adoption and evaluate a project's progress at the local level, be it within a watershed or a county, or to aggregate collective progress up to the state level (S.T.A.R., 2020; Perez, 2017; ICP, 2015).

Thus, we envision a **"self-strengthening cycle"** where quantification opportunities result in more farm conservation adoption, which then offers more quantification opportunities inspiring even more adoption (See Figure 5). The idea is that if local project managers are able to quantify outcomes of practice adoption by some farmers in these projects, it will help raise awareness, increase positive attitudes, and make them more successful at persuading other farmers within and outside of the project area to adopt the desired conservation practices. That is, outcomes quantification may help local project leaders to dialogue more persuasively with local farmers and develop more effective outreach and educational events to help "sell" conservation better, faster, and across more acres. **In effect, we think that practice- and project-scale outcomes quantification by local project managers can become another "tool" in the "conservation toolbox" alongside educational, financial, and technical assistance efforts to accelerate practice adoption (See Figure 5).**

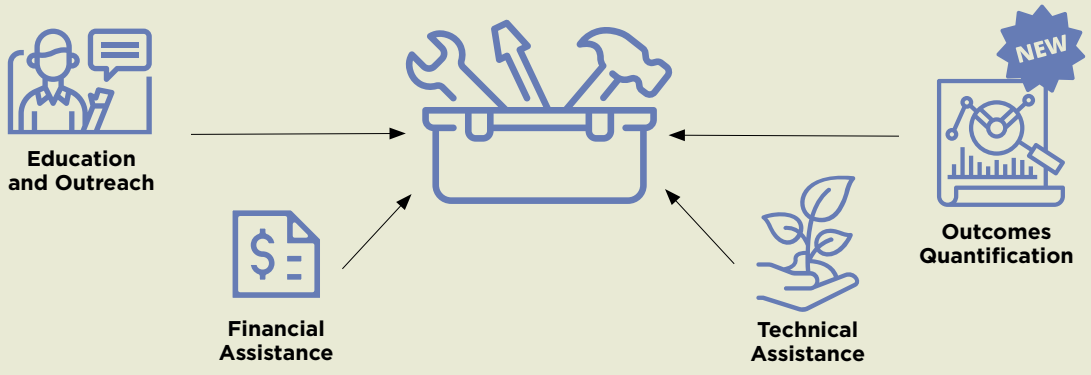
FIGURE 3. WHY QUANTIFY PROJECT LEVEL OUTCOMES?

Incorporating the lessons learned from these locally led projects into other federal, state, and private sector conservation programs could lead to the desired landscape-level improvements in water quality, improved resilience to climate change, and more prosperous farms, among other benefits.

Project managers for the EPA 319 projects report annually on the modeled estimates of their water quality outcomes through the EPA's Grants Reporting and Tracking System (GRTS) and can use any tool that works for them; many use two of the tools developed by the agency and its contractors, STEPL and Region 5 tools (both are featured in this guide). EPA has published 834 success stories documenting monitored water quality improvements in streams or lakes within the project, which can be attributed to the project's nonpoint source pollution control or restoration efforts

FIGURE 4. ENVISIONING A SELF-STRENGTHENING CYCLE OF OUTCOMES QUANTIFICATION & FARM CONSERVATION

FIGURE 5. OUTCOMES QUANTIFICATION: A NEW TOOL IN THE TOOLBOX



(see EPA Section 319 Success Stories website: epa.gov/nps/success-stories-about-restoring-water-bodies-impaired-nonpoint-source-pollution).

What to Quantify and the Hurdles that Hinder

Many conservationists do not know which outcomes to quantify, how to quantify them, which approaches are available to them, and which methods or tools are right for their project (LMW, 2018). Many are intimidated by the prospect and process of quantifying project outcomes and want more guidance (LMW, 2018). This study discovered nearly 50 models and tools that might be appropriate for use by an RCPP project manager. Many tools abound that are only available to participants in a corporate supply chain project. Other tools like e.g., RUSLE-2 are available to the general public but have largely remained in the purview of government or academic users due to the significant training required to run the tool.

The 2014 Announcement for Program Funding for RCPP stated that "Both partners and NRCS staff will be involved with documenting the outcomes of these conservation investments through collecting environmental resource data designed to measure the results of projects." In the 2018 Farm Bill, Congress requires USDA to provide definitions of outcomes and guidance to project managers on how to quantify them and report on a bi-annual basis on the progress being made on quantifying outcomes.

NRCS posted a five-page "RCPP Expectations" document on its website (in 2019 and re-released it in August 2020), which offers some definitions and examples of outcomes. Given the enormous number of competing tools, models, and methodologies, however, project managers would benefit from additional guidance. NRCS is currently providing enhanced support to RCPP project managers on a case by case basis (Personal communication, M. Lowenfish, 10/2/20).

In 2019, NRCS provided the required bi-annual report to Congress on the RCPP program (NRCS 2019a) stating: "The first iteration of RCPP did not emphasize outcomes to the extent that the 2018 Farm Bill program does, so developing outcomes-related reporting for the 2014-2018 projects is not feasible." Reporting emphasized accomplishments associated with covered program awards, as data provided by partners on contributions was not readily summarized (Personal communication, S. Fiedler, 10/2/20).

While there are other published reviews that assemble and discuss a collection of water quality and climate models or tools, many of these focus on the technical aspects of the models and share limited practical and user experience details. Fewer still include economic and social outcomes quantification tools in their review. Hence, project managers of RCPP and other landscape scale projects continue to struggle on the outcome's quantification front (LMW, 2020). AFT is producing this guide for fellow conservationists to help meet this need.

As a working paper, this guide presents initial research and findings about tools and methods that may be helpful to RCPP and other project managers for quantifying outcomes associated with conservation practice adoption. This paper also includes recommendations to advance the access to and use of these tools.

AFT hopes this paper will foster discussion among the many members of the conservation community, particularly the tool developers, tool users, USDA, EPA, other federal and state agencies, the academic community, the research and charitable foundation communities, and supply chain sustainability leaders. The goal is for these key stakeholders to take the steps necessary to further improve existing outcomes quantification tools and project evaluation methods to better support the RCPP and other project managers as they endeavor to quantify outcomes of farm conservation practices and projects.

WUNDERVISUALS/ISTOCKPHOTO

Methods

How Tools Were Identified

This guide developed out of AFT's own desire to find out what effects our watershed project efforts were having and to fulfill the outcomes quantifications expectation of the RCPP for our own 2017 RCPP project in Illinois' Upper Macoupin Creek watershed (**See Figure 6**). Because our RCPP project focuses on water quality, and we know that agriculture can help reduce its climate emissions, we focused our search on methods and tools that quantify water quality and GHG changes in response to farm conservation practice adoption.

Recognizing that dozens of project managers regularly attend the annual Leadership for Midwestern Watersheds (LMW) group (e.g., RCPP, MRBI, NWQI, Extension, 319, and state- and county-funded projects, etc.) and need user-friendly tools to quantify their outcomes, we cast the net wider than our first investigation into water quality, climate, social, and economic tools for our own RCPP project.

Even as we undertook this study, new demands for quantification arose. Since Illinois became one of 25 members of the U.S. Climate Alliance in 2019, there is a new need to quantify the GHG impacts of the farm conservation practices being adopted in the state as part of the Illinois Nutrient Loss Reduction Strategy. The Economics/Social Indicator Workgroup of the Hypoxia Task Force for the Mississippi River Basin-Gulf of Mexico is identifying potential metrics to illuminate ecosystem changes due to implementation of nutrient reduction strategies, including social indicators, such as farmer attitudes towards the adoption of conservation practices.

To narrow down the number of tools to review, we focused on tools that were intended to be used directly by conservationists. We intentionally avoided models that would require modeling expertise, and we avoided direct monitoring techniques that would take many years and resources to conduct, but we feature those important outcomes quantification techniques in the Appendices.

FIGURE 6. WHY AFT IS INTERESTED IN OUTCOMES QUANTIFICATION

This guide is, in part, a result of AFT's own investigations into which outcomes quantification tools would be right to quantify environmental, economic, and social outcomes for our own project. AFT's RCPP project in Illinois' Upper Macoupin Creek (UMC) was developed to address the challenge of phosphorus losses, because the larger Macoupin (HUC8) watershed was identified by the Illinois Science Assessment as one of the top three phosphorus-losing watersheds in the state (David et al., 2014).

AFT developed a Measurement and Evaluation Plan (MEP) for our UMC RCPP, which includes in-stream monitoring led by the Illinois-US Geological Survey, IL-EPA, and several other partners to detect whether the conservation practices adopted by farmers in the watershed are helping to achieve the project's goal of a 25% nitrate-nitrogen (N) reduction and a 15% phosphorus (P) reduction mirroring the Illinois Nutrient Loss Reduction Strategy.

However, because in-stream monitoring takes a long time to show results, we investigated which tools might work for our project to estimate our N, P, and sediment reductions to track our progress. Furthermore, we wanted to find a tool that would do this at both the field-scale and the watershed-scale and have an engaging web interface and calculator for use in our outreach and education activities with farmers, both one-on-one and in group settings. We hypothesize that by helping farmers quantify outcomes, our project managers will be more effective in persuading farmers to adopt the project's priority conservation practices.

We looked for tools to do the following:

- WORK AT THE FIELD-SCALE. Tools that help farmers, one-on-one and in group settings (e.g., farmer workshops), better understand their current nutrient, sediment, or GHG losses and to conduct iterative "what if" planning scenarios estimating how their on-farm losses might be reduced by adopting certain conservation practices. The purpose of these tools is to provide **field- or farm-scale estimates of outcomes**. These tools often offer a **field-specific** and **site-specific analysis** because they reflect farmer-specific production data and/or site-specific environmental data (e.g., soil, slope, weather, etc.).
- WORK AT THE PROJECT-SCALE. Tools that help project managers estimate the cumulative outcomes of practice adoption by multiple participants in the project. A project may be delineated by county, watershed, state, or other boundaries. These tools help managers estimate environmental progress associated with the collective action of multiple farmers towards the project's environmental goals. A watershed-focused project needs tools to estimate progress towards goals established for a specific waterbody within the project watershed. Project-scale tools typically provide **generalized estimates of outcomes** but can reflect known environmental and land use data within the watershed or the county.

We provide the following definitions of key terms we developed for ourselves in this guide in Figure 7.

To find these tools, we pursued several approaches:

- Conducted a cursory literature review in several academic databases including Academic Search Premier, Agricola, Directory of Open Access Journals, ScienceDirect, and JSTOR. Additional focused searches in JSWCS and JEQ were also completed;
- Reviewed several comprehensive papers describing and comparing outcomes quantification models and tools, geographic targeting tools, and decision-support tools (See Appendix A);
- Asked the 90 respondents of a Leadership for Midwestern Watersheds June 2020 survey which methods and tools they are using to quantify outcomes;
- Reviewed a list compiled and provided by NRCS of outcomes quantification methods and tools identified by MRBI project managers in their proposals (Personal communication, Dee Carlson, 5/15/20).

We also found two methods that were worth presenting. Note we are defining methods here as a systematic procedure for accomplishing the task of estimating outcomes. This is in contrast to a tool, which we define as a technical device intended to make the task of estimating outcomes easier. One method we fondly refer to as a **"back-of-the-envelope" method**, because project managers would perform the calculation outside of a tool and could choose to do so on an actual envelope; however, they will likely want to do the math in a spreadsheet. The back-of-the-envelope method we feature in this guide was developed by AFT's Midwest Science Director using best available data to provide our RCPP project with

FIGURE 7. DEFINITIONS OF KEY TERMS

Defining Scale of Outcomes Quantification Analysis

FIELD-SCALE

Working with individual farmers; running "what if" planning scenarios to estimate how their on-farm water quality or GHG losses might be reduced by adopting conservation practices

PROJECT-SCALE

Tracking multiple farmers adopting conservation practices, working towards project-scale environmental goals that may occur across one or more counties or watersheds

WATERSHED-SCALE

Working towards goals established for a specific waterbody, within a watershed, or a group of watersheds

Primary versus Secondary Tool Capabilities

PRIMARY

Original purpose and scale of the tool

SECONDARY

While not the original purpose, additional capability at another scale is possible

Specificity of Data and Outcomes Estimates

FIELD-SPECIFIC

Farmer production and management data inputs; outcomes only applicable to field of interest

SITE-SPECIFIC

Location-based environmental data inputs (e.g. soil type); outcomes are only applicable to that location

GENERALIZED

Watershed-scale or county-scale data inputs; outcomes are broadly applicable within watershed or county of interest

water quality outcomes estimates, and it is featured in Figure 12. The other methodological approach we highlight is a guidebook called the "Social Indicator Planning and Evaluation System (SIPES) for Nonpoint Source Management: A Handbook for Watershed Projects." We feature that in the Social Section of this guide.

Summary of Tools Included and Excluded

In sum, we identified and feature 14 tools and two methods (see Table 1) that have satisfied our criteria for outcomes quantification tools (see Figure 8). See Figure 9 for the questions that we tried to answer when investigating each tool.

See Table 2 for the list of tools and models we reviewed but did not feature because they did not fully satisfy our criteria (see Appendices C and D for more details). These models and tools were excluded for reasons including they:

- Do not provide quantitative estimates of conservation outcomes or are index tools;
- Are not focused on agriculture;
- Are only available to members of a group (e.g., private collaborative or the government) rather than the public;
- Require a consultant or staff with specialized modeling skills or require continuous interface with

TABLE 1. FEATURED OUTCOMES QUANTIFICATION TOOLS AND METHODS	
Seven Water Quality Tools and One Method	
EPA's STEPL—Spreadsheet Tool for Estimating Pollutant Load	MN BWSR's PTMApp-Web—Prioritize, Target, & Measure Application Tool (MN & ND)
EPA's Region 5 Tool	EPA & CBP CAST—Chesapeake Assessment Scenario Tool (Chesapeake Bay Watershed)
USDA's NTT—Nutrient Tracking Tool	The Common's FieldDoc (Chesapeake Bay & Delaware River Watersheds)
Stroud Center's ModelMW—Model My Watershed	S.T.A.R.—Saving Tomorrow's Agricultural Resources Method
Three Climate Tools	
USDA's COMET-Farm	USDA's COMET-Planner
Field to Market's Fieldprint Platform	
One Social Tool and One Method	
SIDMA—Social Indicators Data Management and Analysis Tool	SIPES—"Social Indicator Planning and Evaluation System (SIPES) for Nonpoint Source Management: A Handbook for Watershed Projects" Method
Three Economic Tools	
NRCS's Cover Crops Economics Tool	LSP's Cropping Systems Calculator (MN & IL)
AFT's R-SHEC—Retrospective Soil Health Economic Calculator	

FIGURE 8. CRITERIA FOR OUTCOMES QUANTIFICATION TOOLS

TABLE 2. TOOLS AND MODELS THAT WERE EXCLUDED	
Tools that Were Excluded (See Appendix C)	
1-State: IA-only: Nitrogen Load Estimate Calculator	MapShed (underlies Model My Watershed)—Uses Generalized Watershed Loading Function—Enhanced
1-State: NC-only: NC Agricultural Nutrient Assessment Tool (NCANAT)	Nitrogen and Phosphorus Index
1-State: WI-only: SNAP-Plus-Soil Nutrient Application Planner	Precision Conservation Management
ACPF—A Conservation Planning Framework	RSET—Resources Stewardship Evaluation Tool
APLE—Annual Phosphorus Loss Estimator	RUSLE2—Revised Universal Soil Loss Equation
CaRPE—Carbon Potential Reduction Evaluation Tool	SCI—Soil Conditioning Index
Climate FieldView	TruTerra Insights Engine
FARM Environmental Stewardship Tool	WASP—Water Quality Analysis Simulation Program
HAWQS—Hydrologic and Water Quality System	WQIag—Water Quality Index for Agriculture
Models that were Excluded (See Appendix D)	
AnnAGNPs—Annualized Agricultural Non-Point Source	MIKE-SHE—Système Hydrologique Europée
APEX—Agricultural Policy/Environmental eXtender	P8—Program for Predicting Pollution Particle Passage through Pits, Puddles, and Ponds
ArcSLAMM/WinSLAMM—Source Load and Management Model	RZWQM2—Root Zone Water Quality Model 2
Bathtub	SPARROW—Spatially Referenced Regression on Watershed Attributes
Daycent	SWAMM—Spatial Watershed Assessment & Management Model
DNDC—Denitrification-Decomposition	SWAT/SWAT+—Soil and Water Assessment Tool
HSPF—Hydrological Simulation Program-FORTRAN	WARMF—Watershed Analysis Risk Management Framework
L-THIA—Long-Term Hydrologic Impact Assessment	WEPP—Watershed Erosion Prediction Project
WEPS—Wind Erosion Prediction System	

the modeler, rather than a model or tool meant for direct use by conservationists or farmers; and

- Are only available for use in one state.

Readers who do not see an outcomes quantification tool listed in the body of this paper or in Appendix C or D can conclude that AFT is not aware of their tool or method, and they are invited to contact us for inclusion in potential future iterations of this guide.

A NOTE ABOUT REVIEWS

AFT pursued several reviews of this paper. First, it underwent internal review by six AFT staff, then external review by 14 sets of tool developers and the authors of the two methods. The write-ups of each of the featured tools were reviewed twice by the developers for accuracy, and AFT engaged in email and phone correspondence with several tool developers to gain greater clarity. We also asked the developers to share specific examples, if possible, of projects using their tool for estimating outcomes of conservation practice adoption. Also, during external review, we asked several staff at NRCS and EPA, a private sector conservation group, and a university professor to provide us with a review of the whole paper. All the tool developers received the whole paper as well. Any time we attained information from a reviewer that would not be readily available in a public document or website, we used the "personal communication" citation and we offered those persons the opportunity to review the citation.

Limitations of this Study

The scope of this guide was limited to tools and methods focused only on water quality and GHG resource concerns rather than other important resource concerns such as water quantity, air quality, or wildlife. The scope of the paper was also limited because we did not pursue interviews with users of the tools featured in the paper. Doing so would provide more real-world user experiences and details about the pros and cons of using each tool.

As non-modelers ourselves, we strived to provide readers with useful descriptions and minor comparisons of the tools (see Figure 11 and Table 3), but we stopped short of conducting a full-fledged evaluation of the tools. We also conducted our analyses over a short time frame, so we admit there could be

FIGURE 9. HOW TOOLS WERE EVALUATED

When investigating each tool, we tried to answer the following questions and supplied the information in the following six categorical sections in our write-up of each tool:

a. About the Tool

- Who developed the tool, for what purpose, and at what scale does it operate (e.g., field, farm, county, watershed, project, state, etc.)?
- Does this tool directly or indirectly estimate project scale outcomes? If indirectly, what process should the user follow to estimate project scale outcomes?
- Who are the intended users—conservation project members, farmers, and farm advisors or persons with a modeling background?
- How is this tool made available? Is it free or is there a fee to use it?
- Where geographically can this tool be used? And for what land-use types?
- Is the tool meant to run "what if" scenarios with a farmer to explore potential, future outcomes of conservation practices that the farmer has been considering?

b. Site-specific Inputs & BMP Analysis Options

- What underlying model is this tool built upon? What types of data and datasets does it use? How does it work?
- Does this tool require significant data input by users? Is the required information readily available to all users?
- Which conservation practices can the tool estimate the environmental, social, or economic outcomes for?

c. Which Outcomes Are Quantified?

- What water quality and climate change resource concerns can the tool estimate? In what units of measurement?
- Is the quantification focused on estimating the field- or farm-scale outcomes of conservation practices adopted by an individual farmer or landowner? Or is the quantification focused on estimating the cumulative outcomes of practice adoption by multiple participants in the project, which may be delineated by watershed, county, state, or other boundaries?
- Does this tool quantify outcomes with a high degree of specificity or as a generalized estimate? A highly specific estimate of outcomes might reflect field-specific data such as farmer production and conservation data inputted into the tool, as well as site-specific data, such as soil type, weather, and slope. A generalized estimate of outcomes might reflect watershed-scale or county-scale data recognized by the tool.
- Does the tool provide confidence intervals reflecting the possible range of values that most likely contains the true value?
- How are results presented to the user–in a table or are graphs also provided?

d. Tool Strengths and Limitations

- What are the pros and cons of the tool?
- Does it have GIS (i.e., mapping) features?
- Can data and results be downloaded for further analysis or to generate report graphs and tables?
- Has the tool been verified in a peer-reviewed journal or undergone some other form of thorough review?

e. Who's Using This Tool?

- Which project leaders have used or are using this tool?
- What outcomes have been quantified for which practices adopted by how many farmers?
- Is there evidence that the tool has helped project managers increase conservation practice adoption?

f. Supporting Information

- What background or training materials are provided to aid use of the tool?
- Do users need to create an account?
- Is there a point of contact for the tool for users to interact with for trouble-shooting questions?
- When was the latest version of this tool released?

JOYRIDE/ISTOCKPHOTO

errors. And because the world moves quickly, several statements about access to tools or features about the tools may have changed over the course of our analyses, which may render statements we have made incorrect.

The guide also omits discussion of geographic targeting, which is a critical component of any project attempting to improve water quality. Geographic targeting identifies areas with disproportionate nutrient or sediment losses that could be prioritized and treated to optimize use of financial, technical, and evaluation resources (Gale et al., 1993; Osmond et al., 2012; Perez, 2017). Methods, tools, and models that aid geographic targeting but do not also estimate quantitative outcomes are discussed in Appendix C and D. And monitoring methods were also omitted from this guide, but Appendix B provides highlights of useful guidance documents and insightful case studies. This guide also only mentions decision-support tools in passing but provides a reference to an important paper (Ranjan et al., 2020) urging the improvement of DST for conservation planning by conservation agency staff (see Appendix A).

Despite these shortcomings, we hope this working paper is a reasonable first iteration of a guide for RCPP and other project managers to support their investigation, selection, and possible use of one or more of these tools or methods to estimate their practice and project outcomes.

USDA

Choosing Outcomes Quantification Tools

Clarify Project Objectives

As a project manager, choosing a method or a tool to measure potential outcomes for your project may not be a priority and may be overwhelming during the project development process, but it is an essential one. There are dozens of water quality models alone, and the process of narrowing down the options and identifying the model or tool that meets project needs can be daunting. When evaluating options, conservationists should consider what objectives they are trying to achieve through outcomes quantification for their existing or future projects (see Figure 9).

Taking a step back and reflecting on the project objectives prior to finalizing specific quantification plans can provide project managers an opportunity to identify the specific tools that will best support project objectives and measure desired outcomes. Planning ahead is important to establishing a baseline of information at the beginning of the project in order to compare how that data changes, and hopefully improves at the middle and end to know whether the project interventions are working. This is particularly important for projects endeavoring to conduct direct water quality or GHG monitoring but also important for projects wanting to track changes in social or economic indicators. Tacking on data collection and analytical methods after the start of the project is possible, although not ideal or easy (unless the project is intentionally conducting a retrospective economic analysis).

Reflect on Project Goals, Scale, and Capacity

There are key differentiating features that can be used to eliminate tools that do not meet project quantification needs, making the evaluation and decision process easier. To determine which tool is right for each project, conservationists need to consider their project focus and goals, scale, and capacity. Answering the following questions may assist project managers in determining the correct model or tool to meet project needs.

FIGURE 10. SOME USES OF OUTCOMES QUANTIFICATION TOOLS

1

Educate farmers about the outcomes they are already achieving from current practice use.

2

Offer more interesting education and outreach activities that feature such outcomes quantification results.

3

Improve farmer conservation decision-making and help farmers "get to yes" by running "what if" conservation scenarios that generate estimated outcomes.

4

Evaluate results of farmer participation in government-funded conservation projects.

5

Evaluate farmer credits for participation in water quality or climate markets.

6

Evaluate results of farmer participation in corporate supply chain sustainability programs.

PROJECT FOCUS AND GOALS

- Are water quality or GHG outcomes quantification (or both) needed? What type of outcomes quantification is required by project funding institutions?
- Does this project expect to quantify economic or social outcomes?
- Does your project focus on implementation of a specific set of conservation practices (e.g., management or structural)?

PROJECT SCALE

- Is the quantification effort focused on estimating the outcomes of an individual's conservation practices or adoption of many practices by many people?
- Does quantification need to be at the field, whole farm, watershed scale, or project scale?
- Does this project require field-specific outcomes estimates or will a generalized estimate (not site-specific) suffice?

PROJECT CAPACITY

- How experienced are project staff at using models and tools and in interpreting input and results data?
- If site-specific and detailed analysis of farm conservation practice outcomes is important, do participating farmers maintain detailed farm records going back many years, and do project staff and farmers have the necessary time to gather and process that data?
- Have funds been budgeted for project staff or other partners to obtain farmer data, input the data into the tool, conduct outcomes estimation analyses, and interpret and write-up the results?
- Have funds been budgeted for a quantification tool or method, or is a free tool or back-of-the-envelope method ideal?

Knowing the answers to the above questions will help the project manager in the process of choosing an appropriate tool for their project needs and developing an outcomes quantification plan.

Comparing the Tool Capabilities and User Experiences

To further assist RCPP and other project managers in identifying whether any of the 14 tools and two methods featured in this guide might satisfy their

outcomes quantification needs, we developed several schematics to aid in this deliberation (see Figure 11 and Table 3). Should project managers already know which type of outcome is the first priority to quantify for their project—water quality, climate, economic, social—those readers should proceed directly to the section of this guide that provides descriptions of tools and methods pertaining to that outcomes category.

To aid in the selection of tools within an outcome category, recognizing that some project managers have ambition to quantify more than one type of outcome, we developed Figure 11 to help. **Figure 11 indicates the initial purpose that the tool developer originally built the tool to satisfy, and thus identifies the primary scale at which the tool was designed to quantify outcomes (e.g. field-scale versus project-scale).** A solid arrow indicates applicability of the tool at additional secondary scales, whereas a dotted arrow represents the *potential* additional scales that a project manager might be able to apply the tool.

On the left side of Figure 11, readers will see tools that were built to provide **field-scale outcomes estimation**. These tools may require interviews with individual farmers to obtain field-specific information, i.e., what crops are being produced and which conservation practices might be added, to run "before versus after" conservation analyses (as in the case of NTT and COMET-Farm). Farmers who want to know what is happening on their fields and are willing to provide production-specific and conservation-specific details to an interviewer (or input the information directly into the tools themselves) will be interested in these field-focused outcomes estimation tools. Other tools (such as Region 5) provide generalized field-scale estimations, but without requiring field- or site-specific data. This may be preferred to limit farmer time requirements or in cases where site-specific practice data is not available.

All three economic tools were built to provide field-focused economic outcomes analysis. Thus, they were designed to engage farmers directly to obtain field or crop rotation-specific details to run "before versus after" economic analyses.

Tools that were built to provide **project-scale outcomes estimation** are positioned on the right side of Figure 11. Overall, these tools provide a generalized estimate of water quality or climate outcomes, and thus they do not require interviews with individual farmers. Rather they require counts of the numbers of each type of practice being adopted (e.g., acres or other units) within the project. Some project-scale tools offer increased specificity due to the scale of the datasets in the underlying models, such as slope at a 30 meter resolution (e.g., NTT). The CAST tool in the Chesapeake Bay offers analysis at the land-river segment (which is typically large though some can be as small as a HUC12 watershed). ModelMW offers watershed analysis as small as HUC12 and county scale, while COMET-Planner offers county-level climate analysis.

Many of these project-scale outcomes estimation tools were originally developed for planning purposes to explore what numbers and combinations of practices could lead to attainment of nutrient and sediment reduction goals (e.g., CAST and STEPL) or GHG reduction goals (e.g. COMET-Planner).

Four tools were built to offer both field- and project-focused outcomes estimation analysis: STEPL operates nationwide, FieldDoc is available in the Chesapeake Bay and Delaware River Watersheds, PTMApp-Web is available in Minnesota and North Dakota, ,and Fieldprint Platform is nationwide. In addition, PTMApp-Web offers geographic targeting analysis to identify the best locations for siting conservation practices to gain the greatest environmental benefits.

Once project managers have identified tools or methods that they think might work, they should take the next step and gain access to the tool and start exploring its functions and features. **In Table 3, we developed a visual aid to describe the experience of selecting the tool, starting the process, and getting to the finish line for quantifying outcomes of cover crop adoption.**

The "**Getting In**" column describes the steps project managers have to take to gain access to the tool. Some tools offer an immediate start online while most other tools and methods require users to start by completing simple steps like creating free accounts or downloading the methodology. Some tools require users to fill out a form asking for basic contact information, while other tools require users to create a free account and wait for a tool manager to provide account approval.

Once project managers have gained access to the tools, in the "**Getting Started**" column, we describe the steps required to begin the outcomes quantification process. As one would expect, tools that offer generalized outcomes estimation services require a few simple steps to get started. Tools that estimate outcomes specific to field management require users to gather farmer-specific data to get underway.

Finally, in the "**Getting to the Finish Line**" column, we offer a rough representation of our experience playing around with the tools to estimate outcomes associated with cover crop adoption. We employed a Likert scale with a "1" representing very few steps needed to complete the outcomes estimation process and a "5" to represent very many steps to get to the finish line.

FIGURE 11. WHAT PURPOSE DID THE TOOL DEVELOPERS INITIALLY BUILD THE TOOL TO SATISFY?

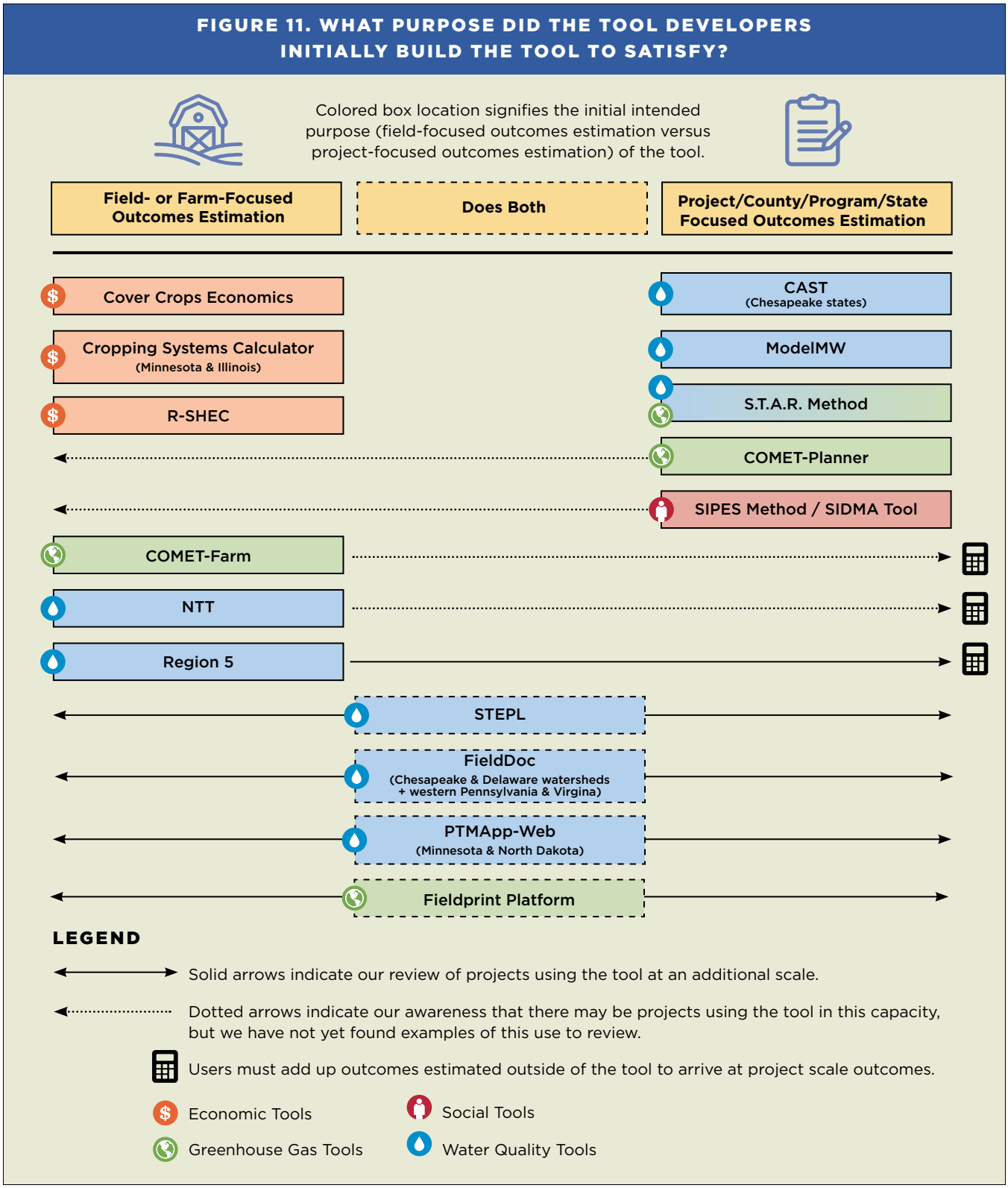


TABLE 3. GETTING INTO THE TOOL, GETTING STARTED, AND GETTING TO THE FINISH LINE

	TOOL	GETTING IN (Gaining Access)	GETTING STARTED (Setting Up)	GETTING TO THE FINISH LINE (Steps Involved)
WATER QUALITY	**STEPL** (Pages 30–32)	Download the Excel tool	Collect non-ag & ag sources of pollutant loads & land uses from the tool's Data Input Server (or identify your own data inputs)	1 2 **3** 4 5
	Region 5 (Pages 32–34)	Download the Excel tool	Select state & county from dropdown boxes	1 **2** 3 4 5
	NTT (Pages 34–37)	Create a free account	Secure interview with farmer for field-specific production & conservation practice data to build "before" & "after" conservation scenarios	1 2 3 4 **5**
	ModelMW (Pages 38–39)	Create a free account	Zoom into the map & select watershed or outline the field	1 **2** 3 4 5
	PTMApp-Web (MN & ND) (Pages 40–42)	Create a free account, then wait for account approval		1 2 **3** 4 5
	CAST (Chesapeake Bay) (Pages 42–45)	Create a free account	Create scenario: Enter scenario name, geographic scale, location, BMP & cost profile from drop down menus	1 **2** 3 4 5
	FieldDoc (Chesapeake Bay & Delaware River Basins) (Pages 45–47)	Create a free account, then wait for account approval	Select your funder (If not a grantee, select "NFWF" or "CACBTF" & turn on privacy settings)	1 2 **3** 4 5
	S.T.A.R. Method (Page 47)	Download S.T.A.R. report & read the methodology	Collect baseline water quality data for your watershed(s) or county(ies) & practice reduction efficiency values	1 2 3 **4** 5
GREENHOUSE GAS	**COMET-Farm** (Pages 49–51)	Create a free account	Secure interview with farmer for the past 20 years of field-specific production & conservation practice data to build "before" and "after" conservation scenarios	1 2 3 4 **5**
	COMET-Planner (Pages 51–52)	Immediate, online start	Select state & county from dropdown boxes	**1** 2 3 4 5
	Fieldprint Platform (Page 53–56)	Create a free account	Secure interview with farmer for field-specific production & conservation practice data for the current crop year	1 2 3 **4** 5
SOCIAL	**SIPES Method** (Page 57–58)	Download and read the report	Proceed through the tool to develop and mail a survey for project farmers by accepting pre-developed survey questions, modifying them, or adding questions	**1** 2 3 4 5
	SIDMA (Page 58–60)	Create a free account, then wait for account approval		1 2 **3** 4 5
ECONOMIC	**Cover Crops Economics Tool** (Page 63–64)	Download the Excel tool	Secure interview with farmer for field- or rotation-specific production & conservation practice data to build "before" & "after" conservation scenarios	1 2 3 **4** 5
	R-SHEC (Page 65–67)	Complete form to immediately gain download access		1 2 3 4 **5**
	CSC (MN & IL) (Page 68–70)	Complete form to immediately gain download access		1 2 3 **4** 5

LEGEND: A conceptual Likert scale representing the relative number of steps involved in achieving an estimate of outcomes associated with cover crop adoption

1 2 3 4 5

Very few steps | **Very many steps**

DAVEALAN/ISTOCKPHOTO

Water Quality Outcomes Quantification Tools

TABLE 4. WATER QUALITY OUTCOMES QUANTIFICATION TOOLS

	Tool	Developer	Format	Scale Options for Analysis	Quantified Outcomes (Degree of Specificity)
NATIONALLY AVAILABLE	**STEPL**	EPA	Excel	**Primary**: Project & Watershed **Secondary:** Field	Sediment loss, N, P, & BOD (Generalized estimates)
	Region 5 Model	EPA	Excel	**Primary:** Field **Secondary:** Project	Sediment loss, associated N & P (Generalized estimates)
	Nutrient Tracking Tool	USDA & Tarleton State University	Web	**Primary:** Field **Secondary:** Project & Watershed	Sediment loss, TN, TP, & crop yield differences (Field-specific estimates)
	Model My Watershed	Stroud Water Research Center	Web	**Primary:** Project & Watershed	Run-off, infiltration, sediment, TN, & TP (Generalized estimates)
REGIONALLY SPECIFIC	**PTMApp** (MN & ND)	MN Board of Water & Soil Resources	Web	**Primary:** Field, Project & Watershed	Run-off, sediment, TN, TP, & cost (Generalized estimates)
	CAST (Chesapeake Bay)	Devereux Consulting	Web	**Primary:** Project & Watershed	TSS, TN, TP, & BMP costs (Generalized estimates)
	FieldDoc (Chesapeake Bay & Delaware River Basins)	The Commons	Web	**Primary:** Field & Project **Secondary:** Watershed	TSS, TN, & TP (Generalized estimates)

Acronyms: BOD = biological oxygen demand, N = nitrogen, P = phosphorous, TN = total nitrogen, TP = total phosphorus, TSS = total suspended solids

1. Spreadsheet Tool for Estimating Pollutant Load (STEPL)

A. ABOUT THE TOOL

The Spreadsheet Tool for Estimating Pollutant Load (STEPL) is a project-scale spreadsheet tool that estimates average annual phosphorus (P), nitrogen (N), the 5-day biological oxygen demand (BOD), and sediment load reductions associated with adoption of farm conservation practices. STEPL was originally developed by the USEPA to replace the Region 5 spreadsheet tool (which is described in the next write-up) and to serve as a more robust planning and reporting tool to help 319 project managers. STEPL can be used at the beginning of a project to gain a rough sense of the types and numbers of practices that, in combination, could achieve a project's pollution load reduction goals. The tool can also be used to report on the pollutant load reductions associated with practices that are being adopted during the course of the project. STEPL has four main tabs and an additional 11 hidden tabs that may be accessed as the user proceeds through the tool. STEPL is also linked to an online Input Data Server and to a best management practices (BMP) calculator to aid data entry and analysis.

STEPL operates by estimating baseline pollutant loading in a watershed from various agricultural and non-agricultural sources and then by providing loading reduction estimates based on a single conservation scenario or a suite of BMPs applied to a watershed. The tool uses county-level soils and weather data and static equations to estimate reductions in sediment and nutrient loads associated with implementation of practices. Practice adoption occurring within up to 10 different watersheds can be modeled simultaneously. The tool is publicly available and has an online user guide. STEPL can be used by any project, not just 319 projects, in all 50 states and counties, to estimate pollutant reduction from practices applied to the following five land uses: cropland, pastureland, feedlots, urban land, and forests. It can also be used at the field scale to generate "what-if" BMP conservation scenarios for engaging with farmers one-on-one or in a group setting.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

Users begin by populating the STEPL Input tab with watershed data by clicking on the state, county, and appropriate local weather station. Doing so automatically pulls in the required datasets, such as historic precipitation averages and the Universal Soil Loss Equation (USLE) factors. The remaining necessary data to set up the STEPL tool can be easily compiled using STEPL's online input data server, which is available to all users. This online database provides, among other items, the sources of pollutant loads in the watershed. The input data server walks the user through a series of dropdown menus with state, county, and subwatershed (HUC12) options to identify the user's project area. The information generated by the input data server can be exported and compiled in an external spreadsheet, which can be a useful interim step when there are multiple watersheds within the project. Users then input the data retrieved from the input data server into the STEPL input tab. Instructions for accessing and using the input data server can be found in Appendix D of the STEPL user guide.

Up to 10 different locations can be analyzed simultaneously by the tool, which can be defined by the user to mean 10 watersheds, 10 subwatersheds, or even 10 individual farm fields. This feature of the tool provides flexibility in estimating outcomes at varying scales, while also providing project-level outcome quantification. Should the user need more than 10 locations, they can use the tool again and add results together, outside of the tool.

The BMP tab is where the user inputs information about the types of practices and numbers of acres being adopted in the project area by each location. The BMP tab offers the Run Solver button that allows users to explore what combinations of practices can be found to maximize load reductions and minimize the needed acres. Though this feature does not account for cost, it can give users a sense of the scale of the needed practice solutions to attain the project's pollutant reduction goals.

The BMPs that can be evaluated in STEPL include those that apply to the following types of farmland:

- **Cropland**: bioreactor, buffer-forest (100 feet wide), buffer-grass (35 feet wide), conservation tillage, contour farming, controlled drainage, cover crop, land retirement, nutrient management, streambank stabilization and fencing, terrace, and two-stage ditch.
- **Pastureland**: 30 meter buffer with optimal grazing, alternative water supply, critical area planting,

forest buffer (minimum 35 feet wide), grass buffer (minimum 35 feet wide), grazing land management (rotational grazing with fenced areas), heavy use area protection, litter storage and management, livestock exclusion fencing, multiple practices for pasture and hayland planting (also called forage planting), prescribed grazing, streambank protection without fencing, streambank stabilization and fencing, use exclusion, and winter feeding facility.

Default pollution reduction efficiencies for these BMPs are sourced from the literature by EPA and its contractors and are embedded in the STEPL spreadsheet. However, users can input their own efficiency values, if available. More than one BMP can be evaluated at a time using the tool's BMP Calculator feature, which can be downloaded from the same EPA site as the STEPL. See the next section for more details.

C. WHICH OUTCOMES ARE QUANTIFIED?

The STEPL tool quantifies annual N, P, and BOD load in pounds per year and estimates sediment load in tons per year. STEPL estimates annual nutrient loading for the baseline scenario and each entered BMP scenario. In the Total Load tab, STEPL provides all of the results in tabular form. It also presents amount of pollutant load reduction and associated percent reductions for each land use such as cropland, pasture, etc. The Graphs tab generates easy-to-interpret bar and pie charts of the results.

Users who wish to evaluate multiple types of BMPs can do so in the BMP Calculator. The calculator aids evaluation of BMPs adopted in parallel (e.g. cover crop acres on Field A and conservation tillage on Field B), in series (grassed buffers *and* conservation tillage used on the same field), and in combination (reflecting both parallel and series BMP scenarios). The calculator adjusts the BMP efficiencies to reflect the scenarios defined by the user.

D. TOOL STRENGTHS AND LIMITATIONS

One strength is that STEPL was developed for project-scale planning and reporting by 319 watershed projects, but it can be used by any project to plan and report on field scale practice adoptions as well. STEPL includes all functionality also available in the Region 5 Tool, its precursor, but does so with greater accuracy given the many underlying datasets that account for the different sources of pollutant loads in a project area, updated and enhanced equations, and additional features, such as the BMP Calculator. STEPL does not require significant training, and with the more recent release and updates, the tool has been expanded to include additional land uses and additional BMPs. STEPL has been peer-reviewed, and "can be used to evaluate relative contribution of different land uses to overall pollution load" (Nejadhashemi et al., 2011).

One limitation is that users must gather significant data prior to using the STEPL tool. If projects have locations within multiple watersheds, and many different land uses, data collection may be onerous. During a recent training, Tetra Tech consultants copied and pasted data into the tool from another spreadsheet that they had assembled prior to the webinar, highlighting how users might prepare their input data for easy copying and pasting themselves (See those training materials on the main STEPL home page here: epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl).

E. WHO'S USING THIS TOOL?

The STEPL Manager, Colin Geisenhoffer (National Project Lead for STEPL), said that STEPL has been used in all but 12 states and territories (including Puerto Rico and D.C.) by state agencies, EPA staff, local watershed groups, academia, and other stakeholders to report on the outcomes associated with practice adoption occurring in EPA 319 projects (Personal communication, C. Geinsenhoffer, 10/2/20). These 319 project reports can be viewed at this site, although many do not mention what technique they used to estimate their project outcomes, let alone specify STEPL: epa.gov/nps/319-grant-reports-and-project-summaries.

In the state of Wisconsin, STEPL was used to model loading from agriculture in the Lower Fox River Mainstem (City of Green Bay–Fox River and Garners Creek-Fox River) as part the Nonpoint Source Watershed Implementation Plan (WIP) (Outagamie County Land Conservation Department, 2019) developed by conservation departments in Outagamie, Calumet, and Brown County.

According to the Lower Fox River Mainstem WIP:

> The Lower Fox River Mainstem watershed contributes an estimated:
>
> - 127,130 lbs of phosphorus and 6,128 tons of sediment to the Bay of Green Bay per year.
> - Agriculture and regulated urban (MS4) contribute

- Agriculture and regulated urban (MS4) contribute the majority (64%) of the sediment load in the watersheds.
- Streambank erosion is estimated to contribute 12% of the sediment load in the watershed.
- The STEPL model estimated 169 lbs. of phosphorus/year, and 79 tons of sediment per year can be attributed to the pasture/hay land use category. Encouraging farms to convert cropland or land used for hay to managed grazing land could result in significant pollutant reductions.

Using STEPL, the project managers estimated that implementing a combination of conservation practices across the 2,600 acres of cropland within this watershed will reduce TP by 2,288 lbs./yr. (59.5% reduction) and reduce TSS by 724 tons/yr. (42.8% reduction). The practices to be applied to cropland include cover crops, conservation tillage/residue management, nutrient management, low disturbance manure injection, and prescribed grazing.

F. SUPPORTING INFORMATION

The most recent version of the tool, STEPL 4.4, was updated in 2020. To download STEPL and view user guides visit epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl. The online STEPL Input Data Server with a map-based interface that works with ArcGIS can also be accessed from that site. Currently the input data server requires flash player, but it is slated to be migrated to another website hosted by EPA in the near future. Training videos and helpdesk information can be found at epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl. A transition to a web-based version of STEPL is underway. RCPP and other project managers interested in using STEPL to estimate their project's outcomes can contact Colin Geisenhoffer, the EPA point of contact, or the Tetra Tech contractors, Aileen Molloy and Mustafa Faizullabhoy, for support, all of whom monitor the email stepl@tetratech.com.

2. Region 5 Model for Estimating Pollutant Load Reductions

A. ABOUT THE TOOL

The Region 5 model was developed by EPA Region 5 in the early 2000s, and the Michigan Department of Environmental Quality (now the Michigan Department of Environment, Great Lakes, and Energy or EGLE), to measure water quality impacts at the conservation practice level. The tool was first developed to help leaders of EPA 319 projects model estimates of phosphorus, nitrogen, and sediment reduction on individual fields associated with adoption of one or more conservation practice(s). This eight-tab spreadsheet tool is a simple, straightforward, free, and publicly available spreadsheet calculator that allows the user to estimate reductions for individual BMPs for a single field.

Initially intended for use by Region 5 states only, the tool can be used by project staff and conservationists in all 50 states and counties on cropland and grazing land. However, EPA considers the Region 5 tool to be a legacy tool and has shifted support to STEPL instead. Several states continue to support their own state-modified version of the Region 5 tool, and thus AFT wanted to feature the tool in case project managers want to encourage their state to further develop and support their own version of this simplified tool.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

The Region 5 tool is a similar but simplified version of the STEPL model. The Region 5 spreadsheet tool has dropdown boxes that lets users select the field's watershed location, soil texture, nutrient content of the soil, gully erosion dimensions, and it will auto-populate the default Universal Soil Loss Equation (USLE) parameters based on state and county location. Users must then input the USLE factors for that field after BMP implementation in the grey cells labeled "After Treatment."

The Region 5 tool can analyze one streambank stabilization practice (streambank protection) and 20 farm field practices: contour buffer strips, contour farming, contour strip-cropping, cover and green manure, cover crops, critical area planting, crop rotation, diversions, filter strips, grade stabilization structure, grassed waterway, pasture and hayland planting, prescribed grazing, residue management mulch till, residue management no-till, residue management ridge till, terraces with underground outlet, terraces with vegetative outlet, and water and sediment control basins.

The spreadsheet has a total of eight tabs; the first is for tool instructions, and then there are tabs for specific practice categories and land uses including:

- Gully Stabilization;
- Bank Stabilization;
- Agricultural Fields and Filter Strips;
- Feedlots;
- Two tabs for estimating Urban Run-Off Loads and Urban Run-Off Event Mean Concentrations (EMC); and
- Conservation Easements.

Users navigate to the appropriate tab based upon the practice implementation. The Agricultural Fields and Filter Strips tab are where conservationists and farmers can estimate sediment load reduction from management practices, while the Urban Runoff tab is used to analyze urban stormwater practice implementation. Once on the Ag Fields and Filter Strips tab, users choose their state and county from the dropdown boxes and baseline USLE parameter values automatically populate the "Before Treatment" cells. Users must select Agricultural Field Practice and/or Filter Strip at the top of the tab for the appropriate estimations to compute. Then users must enter the local C and P values (cover management and support practice factor, respectively; both of which are available from the local NRCS office) into the appropriate "After Treatment" cells. Other data is required to be entered in by the end user in labeled data cells, including implementation area in acres and gross soil texture (sand, silt, clay, or peat). Once that data is entered, estimated load reductions will auto populate at the bottom of the tab.

C. WHICH OUTCOMES ARE QUANTIFIED?

The Region 5 tool is a deterministic (equation-based) model that quantifies a single outcome—sediment loss and reduction (in tons/year)—due to implementation of a single BMP at a single field location. This tool will estimate nitrogen and phosphorus load reduction (lbs./yr.) based upon the estimated sediment load reduction.

There is the option to estimate additional sediment loss reduction due to the implementation of a filter strip on the same field where the BMP is being implemented. At the top of the Ag Fields and Filter Strips tab, users can select the Filter Strips box and a second load reduction calculation will be completed with the results presented in a table below the results of the BMP calculation. This calculation uses a default Filter Strip efficiency that can be modified by the user.

The Region 5 tool will then combine both the BMP and Filter Strip load reduction calculations for a total estimated load reduction of sediment, N and P.

D. TOOL STRENGTHS AND LIMITATIONS

One strength of this tool is that it does not require specialized training and allows for easy data entry. This can result in a lower margin of user error than more complicated tools with complicated data requirements.

The Region 5 tool has a few limitations. Reductions in dissolved nutrients, such as dissolved reactive phosphorus (DRP) and nitrate (NO_3^-), are not accounted for by the Region 5. Any N and P reductions are calculated based upon sediment load reduction. That can result in significant under reporting where there are high concentrations of dissolved nutrients present. This tool also does not allow users to include nutrient management plans to recognize the reductions in nutrient application rates that can be associated with that conservation practice.

This model should only be used to estimate load reductions for individual BMPs. An overestimate may occur when more than one BMP is used on a field and each of the BMPs is assessed individually in the tool. Since it is spreadsheet-based, the tool does not offer GIS visualizations of the field. Also, users cannot specify and/or update the BMPs in the model. Lastly, the Region 5 Tool capabilities are all available within the previously described STEPL tool, and the STEPL tool produces more accurate results (Personal communication, C. Geisenhoffer, 10/2/20).

E. WHO'S USING THIS TOOL?

Currently, Indiana maintains its own version of the Region 5 tool to estimate nutrient and sediment reductions associated with the practices being adopted in their state to achieve their state nutrient reduction strategies. For a three-page description of their methods using the Region 5 tool, see: in.gov/isda/files/Methodology_USEPS_Region_5_Load_Reduction_Modeling_of_Completed_Conservation_Practices.pdf. For more about Indiana's State Nutrient Reduction Strategy and their 2019 Accomplishments Report, see in.gov/isda/2991.htm.

In the statewide 2019 Accomplishments Report, the Indiana Conservation Partnership (ICP, 2020), "comprised of eight Indiana agencies and organizations

who share a common goal of promoting conservation," reports that landowners supported by the ICP installed over 26,000 new conservation practices in 2019: 15,910 of which were modeled (with the Region 5 tool) to quantify the following reductions (each of which were accompanied by engaging infographics):

> 1,050,318 tons of sediment were saved from entering Indiana's waterways, which is equivalent to a football field covered to a depth of 456 feet, which is 26 feet taller than the Great Pyramid of Giza.
>
> 2,220,615 lbs. of Nitrogen were kept out of Indiana's waterways, enough to fill 11 fifty-foot freight cars. One would need 26 billion gallons of water to dilute this amount of nitrogen to meet drinking water standards.
>
> 1,110,453 lbs. of Phosphorus were saved from entering Indiana's waterways, enough to fill 5.5 fifty-foot freight cars. This reduction is enough to prevent over 550,000,000 pounds of surface algae from growing.

Furthermore:

> And 311,000 cover crop acres planted with ICP assistance in 2019 sequestered 162,563 tons of carbon, which is equal to the emissions of 31,875 cars.

[See these engaging infographics: storymaps.arcgis.com/stories/afec6e0bfc814279997d9cdd2352d656]

Also, Indiana's Middle Eel MRBI Watershed Project used the Region 5 model to quantify the field-scale sediment, nitrogen, and phosphorus outcomes of the 670 soil health practices (e.g., cover crops, residue and tillage management, no-till, and conservation cover) that have been adopted through 2014 and used compelling infographics to tell their success story (ICP, 2015):

- 92,428,400 lbs. of sediment (enough to fill five 50'x100' silos)
- 59,135 lbs. of phosphorus (enough to fill one backyard 15'x4' swimming pool)
- 118,987 lbs. of nitrogen (enough to fill about two backyard swimming pools).

F. SUPPORTING INFORMATION

The Region 5 tool can be downloaded from www.epa.gov/nps/region-5-model-estimating-pollutant-load-reductions, and the latest available version of the tool (from 2018) will open up in a zipped excel file. Once open, select the Instructions and the Ag Fields and Filter Strip Tab for use. A Training Manual from 2015 is also provided on this site along with a training webinar from 2015. The EPA has discontinued updates for the Region 5 Tool due to the capability of STEPL to compute the same estimates with better accuracy.

However, states such as Indiana continue to support their modified version of the Region 5 tool. Project leaders and states interested in learning more about Indiana's Region 5 tool are encouraged to contact Trevor Laureys, who is the ICP Data Lead and the Director of GIS and Data Analysis for Indiana State Department of Agriculture (tlaureys@isda.in.gov).

3. Nutrient Tracking Tool (NTT)

A. ABOUT THE TOOL

Nutrient Tracking Tool is a web-based tool with a GIS mapping interface that provides site-specific load reduction estimates at the field and small watershed level. NTT was developed by USDA and Tarleton State University's Texas Institute for Applied Environmental Research (TIAER) for farmers, conservationists, and the general public to run "what if" conservation practice scenarios on crop or pasture fields to compare baseline water quality losses (nitrogen, phosphorus, and sediment) to reductions associated with adoption of conservation practices. NTT offers a user-friendly way to run the Agricultural Policy Environmental eXtender (APEX) model, the most commonly used field-focused cropping systems models in the United States.

NTT requires users to input field management practices into the tool. The user can create several field management scenarios in order to compare alternative management practices, crop rotations, and structural practices. Users can compare the outcomes of each management scenario to determine which conservation practice(s) offers the best reduction opportunities. NTT also estimates yield impacts of each scenario, allowing users to weigh potential trade-offs between environmental performance and yield. There is a researcher-focused version of NTT, NTT-Research and Education (NTT-RE), that allows users greater access to modify elements of the underlying APEX model (e.g. simulation period). NTT-RE is intended for research and education but provides a similar user-interface to APEX as the NTT tool.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

The APEX model that underlies NTT is used nationwide for conducting water quality analysis at the field and small watershed scale (see Appendix C for more information on APEX). NTT is designed to evaluate the impacts of existing and proposed conservation practices on both water quality (nitrogen, phosphorus, and sediment) and quantity (flow) at the edge-of-field or at the outlet of the watershed (if run at a watershed scale). NTT allows users to define an area of interest (AOI), e.g., a single field, multiple fields, or a small watershed, by manually drawing the area boundary using drawing tools that are provided or by uploading a GIS shapefile of the field(s). Based on the geographic location of each field, NTT defines the slope using 30-meter Digital Elevation Model data, soils using the USDA-NRCS soil survey (SSURGO) database, and historic climate data (at 4-km^2 resolution) from the Oregon State University PRISM model.

Once the user has finished defining fields through the NTT mapping system, they may click on each selected field name to begin defining one or more management scenario for the field. Users provide current and future cropping management systems, including crop rotation, planting, harvesting, tillage, grazing, irrigation, nutrient management, and single or multiple structural practices for the field. Each management scenario can include several combinations of practices. NTT simulates each scenario created by the user and returns results in a series of reports.

The major practices that can be simulated and evaluated by NTT include bioreactors, brush management, conservation crop rotation, contour buffers, cover crops, critical area planting, drainage water management, field borders, filter strips, grade stabilization structure, grassed waterways, irrigation management, land-leveling, livestock exclusion/ fencing, nutrient management (e.g., user can vary rate, timing, placement and source inputs), pasture planting, prescribed grazing, range planting, riparian forest buffer, terraces, tile drains, tillage management (e.g., no-till, reduced till, mulch till), water and sediment control basins, and wetlands.

C. WHICH OUTCOMES ARE QUANTIFIED?

NTT can estimate the impacts of each user-defined management scenario (which may include a wide variety of management and structural practices) on total flow (inches), sediment losses (ton/ac), nitrogen losses, phosphorus losses, and crop yield at both the field and the full farm scale. Nitrogen losses can be further categorized as organic N, runoff N, subsurface N, and tile drain N-losses. Similarly, P losses are broken out into organic P, PO_4-P, and tile drain P losses. Losses can be viewed as pounds per acre or as total pounds.

NTT offers users options for viewing nutrient and sediment loss estimates to suit their interests: average annual losses (based on up to 35 years of weather simulation), average monthly losses (based on up to 35 years of weather simulation), and annual losses (for individual years selected by the user). NTT results can be presented in tabular form or graphically as bar charts, which can both be downloaded. Confidence intervals are available as an option to be displayed in the results tables.

NTT provides site-specific loss estimates for each field, based on the field-specific management data provided by the farmer and environmental conditions (e.g. soil, slope and climate). NTT has been validated for all major soils and weather across the United States using generally available data including NASS and other state-level data (this is used by another version of NTT that is designed to run NTT at the regional scale). The developers also continue to refine the NTT model parameters and routines using field-scale studies (where these are available) and the latest science. USDA continues to invest in refinement of these parameters and routines moving forward to ensure the validity of the NTT results.

D. TOOL STRENGTHS AND LIMITATIONS

One strength of NTT is that its interface is user-friendly and requires no software download. NTT GIS visualization uses Google Maps and allows users to draw the outline of each field assessed by the tool or to upload a shape file. The GIS interface allows for automated inputs of slope, soil, and weather data for each field. Another strength is that NTT can provide farmers with site-specific analysis about their fields or farms because it sources national soils and weather datasets and runs the powerful APEX field production model.

Another strength is that users can conduct analysis at the field scale but also analyze multiple fields at once or even conduct analysis at the small watershed-scale to conduct project-scale evaluation. Users can choose to evaluate multiple fields at once, either by drawing the multiple fields using the AOI drawing function or

DOUGBERRY/ISTOCKPHOTO

by uploading a shape file representing the multiple fields. Doing so allows many fields to be identified and linked together by NTT to estimate the flow of nutrients and sediments through each field. The user would then describe generalized "before versus after" scenarios reflecting homogenous production and conservation practices on the multiple fields.

Similarly, users could conduct a project-scale evaluation reflecting practice adoption by multiple producers within one or more watershed by uploading an appropriate shape file and then describing generalized "before versus after" scenarios to reflect the aggregated change in production systems and conservation practices by multiple farmers.

NTT results can be downloaded for future viewing. NTT provides the technical validation for the tool in 37 states; see the "Validation" link on the tool home page. NTT has been verified in a number of peer-reviewed journal articles (e.g. Nelson et al., 2019; Guo et al., 2020).

One limitation is that NTT can be data intensive and require significant interview time with the farmer to obtain the production and management data. The tool does provide several default values and copy features to help minimize data entry. Some of the AFT staff who used the tool for our nine case studies experienced the tool freezing up, which is similar to their experience with the COMET-Farm tool as well and may reflect poor rural internet connection rather than a problem with either tool. However, the NTT development team has recently improved the functionality and speed of this program. Thus, project managers may consider conducting data entry in locations with good internet connection and not while interfacing with the farmer.

E. WHO'S USING THIS TOOL?

There is no information about project use of NTT on the tool's website. Through personal communication, the tool developer, Mindy Selman reported use of NTT in several projects, including the Freshwater Trust (highlighted below), the Conservation Kick project in the Great Lakes, Heidelberg University in Ohio, Iowa Department of Natural Resources, Upstream Tech, and Sustainable Environmental Solutions. Note that Virginia, Maryland, and Pennsylvania worked with World Resources Institute to develop a version of NTT for the Chesapeake Bay states called CBNTT. The Department of Agriculture in Maryland is using CBNTT as an outreach and education tool with farmers at workshops to run "what if" conservation scenarios in Maryland (cbntt.org) (Personal communication, M. Selman, 9/3/2020).

The Freshwater Trust has used NTT in their conservation work in the Pacific Northwest. One project highlighted on their site mentions using NTT to quantify the positive environmental impacts of

planting native buffer vegetation, including sapling cottonwood trees, along Cedar Creek in Oregon in 2015 (i.e., 10lbs./year reduction in P, 116 lbs./year reduction in N, and 23,000 lbs./year reduction in sediment) (thefreshwatertrust.org/case-study/nutrient-tracking-tool-cedar-creek).

AFT used NTT in 2019 and 2020 to estimate the N, P, and sediment reductions associated with six soil-health-successful row crop farmers we featured in two-page case studies. AFT used NTT to conduct a retrospective analysis (rather than a predictive, "what if" analysis that NTT was originally developed to do). Thus, the "before" scenario for the farmers was how they grew their crops before adopting the soil health practices, which they are currently implementing (reflecting the "after" scenario). AFT developed a farmer interview questionnaire combining NTT data collection questions with COMET-Farm data collection in order to conduct only one environmental interview with the farmers. AFT staff conducted the NTT interview and analysis on just one representative field for each featured farmer where all the soil health practices being adopted were in place.

Highlights of just two of the case studies include:

- **Jay Swede, New York diversified crop farmer.** AFT author Aaron Ristow used NTT to evaluate the water quality outcomes associated with Swede's use of strip-till, cover crops, and nutrient management on a 25-acre field within a rotation of sweet corn, corn for silage or for grain, and alfalfa. NTT estimates that Swede's use of all three soil health practices reduced the N, P, and sediment losses by 40, 92, and 96%, respectively.
- **Larry Thorndyke, Illinois corn-soybean farmer.** AFT author Emily Bruner used NTT to evaluate the water quality outcomes associated with Thorndyke's use of strip-till and no-till, nutrient management, and cover crops on a 70-acre field. NTT estimates that the three soil health practices reduced the N, P, and sediment losses by 45, 89, and 76%, respectively.

Overall, on the selected fields for six row crop farms plus one almond grower, NTT estimates the soil health practices already being implemented by the producers (no-till, cover crops, nutrient management, and for almonds mulching and composting) are resulting in:

- Average reduction in N losses of 43% (range was 23 to 98%)
- Average reduction in P losses of 74% (range was 33 to 92%)
- Average reduction in sediment losses of 81% (range was 37 to 99%)

Note that AFT decided to publish only the percent change figures rather than the baseline, reduction, or change in nutrient and sediment losses in pounds and tons given the sensitivity surrounding individual farmer field estimates of water quality losses. To read the case studies and the paragraphs that feature the NTT findings, see: farmlandinfo.org/publications/soil-health-case-studies.

AFT also plans to use NTT in our Ohio Payments for Ecosystem Services (PES) Project. The project is implementing an innovative approach to conservation financial and technical assistance in that it seeks to pay farmers for their water quality services rather than the practices adopted. During the PES application phase, the project will ask farmers and/or their conservation or crop advisors to use NTT to complete a "what if" conservation planning scenario for the practices the farmer proposes to implement and then input the estimated nutrient and sediment reductions data into their PES Application Form. This step will establish the initial estimate of the PES payment. Then, after the practices have been adopted, the project managers will ask for a second NTT analysis to reflect activities actually implemented to set the actual PES payment (B. Brandt, personal communication, 10/19/20).

F. SUPPORTING INFORMATION

A variety of resources, including several "about" videos, a user manual, and an FAQ page are available at ntt.tiaer.tarleton.edu/welcomes/new?locale=en. Also, on each page of the simulation process within the tool there is a "Page Instructions" link that provides the user with step-by-step directions. Project managers interested in using NTT should contact Mindy Selman of OEM (mindy.selman@usda.gov) or Dr. Ali Saleh (saleh@tarleton.edu) for user support or questions about the capabilities of the tool. Users can gain immediate entry into the tool by creating a free account by selecting "New User" at the login page. The most recent update to this tool was version 20-2, released in February 2020.

The next update for NTT is scheduled for late 2020 and will include an economic module. The Farm Economic Model (FEM) will be linked to the NTT tool and provide estimates of costs and revenues for each NTT scenario simulated by the user. This will allow users to evaluate scenarios based not only on economic and yield outcomes, but also on estimated profitability.

4. Model My Watershed

A. ABOUT THE TOOL

Model My Watershed® (ModelMW) is a watershed-modeling web application that enables conservationists, citizens, educators, and others to analyze real land use and soil data in their neighborhoods and watersheds to model storm water runoff and water-quality impacts at the subwatershed level. ModelMW is part of the WikiWatershed® toolkit developed by Stroud Water Research Center in Pennsylvania (with multiple partners across the U.S.). Users can also explore "what-if" scenarios and compare how changes in land cover/use (across all categories), or implementation of best management practices for agricultural and urban land uses, or changes to the climate (temperature and precipitation), could affect runoff, infiltration, and water quality. ModelMW is available to the public for free and can be used across the coterminous United States.

The ModelMW application allows the user to select from three different modeling approaches: the "Site Storm Model," the "Watershed Multi-Year Model," and the "Watershed Multi-Year Model Worksheet." For the purpose of this guide, only the Watershed Multi-Year Model is featured because, at this time, the Site Storm Model only has a limited number of agricultural BMPs, and the Worksheet is designed specifically for use in Pennsylvania (although it can be used for the entire contiguous United States).

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

ModelMW simulates nutrient and sediment fluxes using the Generalized Watershed Loading Function-Enhanced (GWLF-E) model that was previously used within the MapShed desktop modeling application (a customized GIS interface; see Appendix C for more information). After the user outlines an Area of Interest (AOI) using the integrated drawing tools, users select the Multi-Year Model to run the model and then build their scenario(s). By selecting "Add changes to this area" users then choose to add conservation practices, change land cover or weather, or can alter the default settings for a variety of model assumptions within the AOI. The user can also download the legacy MapShed datafile (*.gms) and use the legacy GWLF-E Model desktop application (see Appendix C).

The model can then run watershed-level "what-if" scenarios to simulate load reductions based on the implementation of any one of 10 agricultural management and structural practices: conservation tillage, cover crops, livestock and poultry waste management, no-till agriculture, nutrient management, reduced till, steambank fencing, streambank stabilization, and vegetative buffer strips. Users can adjust livestock density and grazing assumptions within the watershed and can change land cover demographics. There are also urban conservation practices, including urban vegetative strips, streambank stabilization, surface water retention, and infiltration/bioretention.

ModelMW uses USLE, daily weather from the EPA's National Climate data (1960-1990), land cover data from the 2011 NLCD, soils data from SSURGO, 30-meter elevation data for slope, and USDA animal population estimates (county-level census). Users also have access to many other settings and assumptions of the initial model run, such as conservation practice efficiencies, point source discharge, septic system assumptions, and other model data (sediment delivery ratio, tile drain and groundwater nutrient concentration assumptions, and wetland water filtration and retention assumptions). Users can adjust these to AOI interest data accuracy.

C. WHICH OUTCOMES ARE QUANTIFIED?

ModelMW provides both baseline and what-if scenario results for hydrology, sediment, TN, and TP by source (i.e., each land use category, livestock sources, and streambank erosion, among others) within the AOI. Baseline and scenario results are provided in tabular form, along with a 12-month line graph representation of the hydrological outcomes. Data are all downloadable. ModelMW produces generalized estimates of outcomes associated with watershed-scale implementation of conservation practices due to resolution of the source data (e.g., 30 m land cover resolution) and a geospatially limited model calibration (described in the technical documentation). Outcomes quantified include the change in total loads (kg), loading rates (kg/ha), mean annual concentrations (mg/L), and mean low-flow concentration (mg/L). The user can also choose to report "units" in either metric or U.S. customary units. ModelMW does not provide confidence intervals for estimates at this time.

D. TOOL STRENGTHS AND LIMITATIONS

ModelMW integrates land use data with a user-friendly map interface for modeling hydrology, sediment, N, and P loading. ModelMW also helps users discover and layer into their analysis water monitoring data from several data portals (including the Water Quality Portal maintained by the USGS and the EPA). Users can define their project area or area of interest with multiple tools, including a free drawing tool, a "delineate watershed" function, or by uploading their own boundary file (in .shp or .geojson formats). Project areas can be defined by the United States Geological Survey Hydrologic Unit Code (USGS HUC) watershed boundaries or by counties, congressional districts, and even school districts.

Users can create "what if" scenarios by adding conservation practices, changing land cover classifications (e.g., changing from cropland to wooded, or open land to low-density development), or changing weather data (e.g., using one of the provided future weather scenarios). There is a "compare" function that provides graphical and tabular tables that quickly shows differences in modeled scenario results within the area of interest. However, with the use of 2011 NLCD data and watershed (not site-specific) nutrient concentration estimates, accuracy is more limited, providing generalized estimations of sediment and nutrient load reduction. ModelMW has been reviewed and used in multiple peer-reviewed publications (e.g. Haag & Shokoufandeh, 2019). Data is downloadable for further use outside of the ModelMW web-app.

E. WHO'S USING THIS TOOL?

There is no information about projects using the ModelMW tool on the tool's website. However, the tool developers shared results from a survey of 391 registered ModelMW users that was conducted in 2017-18 (note, the survey had a 21.8% response rate out of 1,797 users contacted) (Stroud Center, unpublished data). Survey results indicated the most commonly reported use of ModelMW was for analyzing an area of interest to obtain watershed statistics (e.g., stream lengths, land cover, soil types, etc.). However, approximately 22% of users used ModelMW for forest conservation and restoration planning. Users of the Watershed Multi-Year Model reported nearly equal use of all conservation practices for building modeling scenarios, which indicates that collectively, users value the ability to implement both agricultural and urban best management practices.

As reported by the tool developer, Dave Arscott (Executive Director and Research Scientist, Stroud Water Research Center), ModelMW is used regularly by many conservation practitioners in the Mid-Atlantic region as a planning tool for conservation programs supported by several funding entities (e.g., National Fish and Wildlife Foundation, William Penn Foundation, and Pennsylvania Department of Environmental Protection). Developers of the tool are also aware of a growing demand for the tool by other state and local conservation practitioners (D. Arscott, personal communication, 9/20/20).

F. SUPPORTING INFORMATION

Users may create a free account that enables them to save and share their projects, but an account is not required prior to accessing ModelMW at modelmywatershed.org. Resources for ModelMW include user guides, an FAQ page, technical documentation, as well as middle and high school curricula, which are available at (wikiwatershed.org/help/model-help). Several in-depth, hour-long video tutorials are available for a range of ModelMW users (e.g., the beginner user to specific watershed project partners). The most recent version is Release 1.31.0 updated in August 2020 with details available here: github.com/WikiWatershed/model-my-watershedreleases. For troubleshooting support, users should contact Dave Arscott (Executive Director, Stroud Water Research Center), via the contact link here: wikiwatershed.org/contact.

5. PTMApp-Web

A. ABOUT THE TOOL

The online version of Prioritize, Target, & Measure Application (PTMApp-Web) is a tool developed through collaboration between the Minnesota Board of Water and Soil Resources (BWSR), the International Water Institute (IWI), the Red River Watershed Management Board (RRWM), and Houston Engineering (HE), with support from the Minnesota Clean Water Fund. Currently, this web-based tool is maintained by the BWSR with a contract to HE. PTMApp-Web access is limited to those entities that are involved in documenting water management efforts, such as soil and water conservation districts, local planners, and state agency staff in parts of Minnesota and North Dakota. However, members of the public and watershed project managers from those states can easily request access to PTMApp-Web online by registering for a free account here: ptmapp.bwsr.state.mn.us/Account/Register.

PTMApp-Web offers many features for project managers, including:

- Conducting geographic targeting analysis to help users identify "hotspots" with disproportionately large pollutant losses, or other priority sites within the watershed to prioritize BMPs implementation;
- Conducting watershed planning and plan preparation;
- Running "what if" conservation scenarios with individual or groups of farmers to quantify pollutant load and potential reductions at both the field and watershed scale;
- Conducting field-scale or watershed project outcomes evaluation.

Most users of PTMApp-Web will access the tool for both planning and estimating project outcomes. The tool has been recently upgraded to the beta version and does not require GIS experience.

Users outside of Minnesota and North Dakota with intermediate to advanced GIS experience may download PTMApp-Desktop (an ArcGIS Toolbar), which is available free anywhere to conduct the same analyses as the web-based tool without the easy-to-use online interface.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

PTMApp-Web relies on many data sources and sub-models including the stream power index (SPI), RUSLE, land use with Light Detection and Ranging (LiDAR) data, the NASS Crop Land Datalayer (CDL), the National Land Cover Database (NLCD), event mean concentrations (EMCs), and monitoring data to tailor each watershed baseline scenario. The PTMApp model can also be aligned with the HSPF (Hydrological Simulation Program—Fortran) model, and outputs from the Agricultural Conservation Planning Framework (ACPF) model can be run through PTMApp to estimate load reductions for ACPF practices.

BMPs are divided into the following categories: storage, filtration, bio-filtration, infiltration, protection, source reduction, or user defined categories. Each category allows practice combinations to develop and run "what if" scenarios. Specific agricultural BMPs include 2-stage ditch, alternative tile intakes, cover crops, critical planting areas, conservation cover easements, denitrifying bioreactor, depression storage, drainage water management/controlled drainage, embankment pond, filter/buffer strip, grade stabilization, grassed waterway, nutrient management, ponds for water use, saturated buffer, streambank and shoreline protection, perennial crops, and tillage management (e.g. no-till or reduced till), water and sediment control basin (WASCOB), and wetland restoration/creation. The tool developer, Drew Kessler, states that the next release of PTMApp, due out in Fall 2020, will map these BMPs into 23 different NRCS codes (D. Kessler, personal communication, 9/21/20).

This tool was originally developed by the state of Minnesota to allow local governments to document the water quality benefits (i.e., sediment, phosphorus, and nitrogen reductions) of conservation practices on or at the edge-of-fields of agricultural lands. PTMApp can be used by local soil and water conservation district (SWCD) staff to highlight practices that are most cost effective and present options to farmers they are working with.

PTMApp-Desktop (i.e., without the user-friendly, web interface) can be used nationwide, outside of Minnesota and North Dakota. This option is available to any organization outside of the two initial states

who are interested in quantifying the water quality benefits of conservation practices for downstream water resources. However, this free ArcGIS toolbar plug-in does require moderate to advanced GIS skills.

These skills are not required to use the toolbar itself, but rather prepare the numerous GIS data inputs needed to set up and run the tool, including obtaining LIDAR data and conducting the hydroconditioning of the digital elevation model (DEM) for each HUC12 watershed in the new state (or portions of the new state).

See here for a an explanation of the hydroconditioning process: ptmapp.bwsr.state.mn.us/files/DEM-Hydrologic-conditioning-Steps-FINAL.pdf. This is a time-intensive process, as it takes up to an hour per square mile, and is challenging because both a high-quality LIDAR dataset and a valid common land unit dataset must be sourced. BWSR has a full suite of learn-at-your-own-pace training materials for potential Desktop users: ptmapp.bwsr.state.mn.us/User/Documentation.

C. WHICH OUTCOMES ARE QUANTIFIED?

PTMApp-Web quantifies the following outcomes associated with farm conservation practices:

- Run-off (ft^3);
- Sediment (tons/acre per year);
- And TP and TN (lbs./acre per year).

Upon simulation of the baseline scenario, PTMApp-Web generates a source assessment map with the flexibility to target priority sites with high nutrient load, identify conservation practices with high load reduction potential, identify and target the most cost-effective BMPs, and simulate reduction in nutrient and sediment loads due to the implementation of BMPs at both the field and watershed scale.

Users can also overlay the original scenario map layer with selected BMPs to identify areas where the selected BMP is technically feasible. Combined practice impacts can be compared to the baseline scenario to generate reduction estimates and compare those to project goals. Results are presented in tabular form with supporting watershed maps.

D. TOOL STRENGTHS AND LIMITATIONS

PTMApp-Web is designed to reduce the need for expert modelers or consultants in the development of watershed implementation plans. PTMApp-Web has a very interactive GIS interface, which allows users to easily change, add, or manipulate detailed map layers and save and print the created maps for inclusion in project reporting. PTMApp-Web's functionality provides users with an easy interface they can use to prioritize resource concerns, target location, and then plan and measure BMP impacts. Users can map source loads, analyze BMP implementation feasibility, and generate estimated water quality benefits throughout the watershed.

Field-scale mapping provides a way to engage individual landowners using detailed views of concentrated flow paths, along with phosphorous and sediment delivery to locate on-field opportunities for BMP implementation. Regarding peer review, the tool developers report that a journal article from the University of Minnesota is forthcoming that reviews the tool, and the tool undergoes continuous technical and peer review by University of Minnesota Biosystem Engineering faculty (D. Kessler, personal communication, 9/16/20).

Users of the PTMApp-Desktop retain all results in the form of ArcGIS databases. In contrast, PTMApp-Web users are able to download both tabular and GIS data from the scenarios they develop. In addition, users are able to create .pdf reports that contain data tables and maps generated on PTMApp-Web. An ArcPro version is forthcoming in the next PTMApp-Desktop release.

E. WHO'S USING THIS TOOL?

PTMApp-Web is supported by the Minnesota Board of Soil and Water Resources and used by Soil and Water Conservation District (SWCD) and other water quality professionals to implement the state's "One Watershed, One Plan" projects across the agricultural regions of Minnesota.

PTMApp-Web has been used in the development of multiple local watershed management plans through Minnesota's One Watershed, One Plan Program (bwsr.state.mn.us/one-watershed-one-plan). Within these plans, it is used as a tool to support local conservation professionals in targeting areas for future conservation efforts and estimating the water quality benefits of the targeted practices. PTMApp-Web has also been used as part of local conservation plans to improve lake and stream water quality, to satisfy components of watershed planning requirements for VESPA 319 Grants, and to target upland water

quality improvements under NRCS PL-566 watershed planning efforts.

Through email correspondence, the tool developers mention that Watershed Districts and Conservation Districts in Minnesota have quantified annual load reductions of sediment, total phosphorus, and nitrogen at the field edge, and for downstream resources (lakes, rivers, streams). The tool developers also shared that there are anecdotal reports that PTMApp has aided efforts to increase conservation practice adoption. In at least two watersheds in the last year, watershed groups have used PTMApp to target areas of concern, developed a list of high priority practices, and developed a mailer to landowners based on those priority areas to help market conservation for their planning effort (M. Drewitz, personal communication, 10/18/20). The developers said that PTMApp-Web is currently being used in a sustainability project involving Minnesota, North Dakota, Iowa, Wisconsin, and Manitoba, Canada (D. Kessler, personal communication, 9/16/20).

F. SUPPORTING INFORMATION

The PTMApp-Web tool for Minnesota, and a variety of resources, including the new account registration page (such as a user guide ptmapp.bwsr.state.mn.us/files/PTMApp_Web_User_Guide.pdf), version release notes, step-by-step scenario instructions called "workshops," and training webinars for PTMApp-Web, are available here: ptmapp.bwsr.state.mn.us. The North Dakota PTMApp-Web is available here: nd.ptmapp.iwinst.org. The PTMApp-Web user guide was updated last in September 2019. Requests for technical support can be emailed to ptmapp@state.mn.us. Matt Drewitz (Measures and Outcomes Coordinator) is the point of contact for PTMApp-Web at the Minnesota Board of Water and Soil Resources, a state agency. Representatives of other state agricultural conservation agencies that are interested in developing the PTMApp-Web for their state should contact Drewitz to explore data requirements, partnership options, and license sharing.

6. CAST

A. ABOUT THE TOOL

Originally developed by Devereux Consulting with funding from the Maryland Department of the Environment, the Chesapeake Assessment Scenario Tool (CAST) is now funded solely by the EPA Chesapeake Bay Program. CAST can be used to develop Chesapeake Bay Watershed Implementation Plans (WIPs) and enable watershed project managers to conduct farm conservation scenario simulations at the sub-watershed scale and also at the full Chesapeake Bay basin scale. The finest scale of spatial segmentation in CAST is the land-river segment, which corresponds to the intersection of a land segment and a river segment. Land segments primarily represent counties, and river segments represent watersheds associated with river reaches. Depending on the size of the land-river segment, scenarios can be run at as small as the HUC-12 scale, or aggregations of several HUC-12s or other subwatershed scales. CAST is intended for use by state and local planners to support their development of WIPs and for TMDLs. Users can request a free account and quickly gain access to the tool here: cast.chesapeakebay.net. The CAST site provides detailed instructions that walk users through the process of planning watershed nutrient and sediment reduction goals and then comparing how well various conservation scenarios achieve the desired targets. Anyone is eligible to use CAST. It is free and open to the public.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

CAST is a web-based assessment tool that integrates the Chesapeake Bay Program's Phase 6 Watershed Model (P6 WSM) with user inputs, including BMPs, as either a percent of available site or in acres. The P6 WSM is based on a modified Hydrological Simulation Program-FORTRAN (HSPF) model and now integrates aspects of other models including RUSLE, SWAT, and updated biogeochemical processes in the most recent update. The datasets incorporated into CAST are numerous and include:

- Chesapeake Bay Program approved BMPs;
- Census Bureau human population data;
- High resolution land cover and land use data;
- USDA-NASS animal populations, crop acres, and annual poultry production data;
- American Plant Food Control Officials (AAPFCO) fertilizer sales for farms and non-farms;

- Manure nutrient concentrations;
- Manure/litter production per animal;
- Soil phosphorus data by crop and county;
- Zoning;
- Sewer service area boundaries; and
- Septic system growth data.

In total, there are 283 detailed BMPs, 176 of which are agricultural BMPs ranging from biofilters, conservation cover, cover crops, grazing and forage management, nutrient management, pasture, and structural water control practices. An updated and detailed description of some of the more commonly used BMPs can be found here: chesapeakebay.net/documents/BMP-Guide_Full.pdf. A table of all of the BMPs modeled may be downloaded with the source data here: cast.chesapeakebay.net/Home/SourceData. In addition, to aid development of a WIP, a user can include an assessment of project cost by using the default BMP costs, which can also be adjusted by the user. Knowing the BMPs that are most effective and lowest cost makes it possible to develop the most cost-effective plan.

CAST only requires the user to input the BMP they want to assess by first selecting a general location (choices in a dropdown menu range from the full Chesapeake Bay watershed to minor basins and the county level and more) for the analysis. No other inputs are required. CAST already has a record of all BMPs implemented that were tracked by federal and state programs, by location, as reported by the states. Users can edit and add to those data or begin with no BMPs. CAST uses data from 1985 through 2025, and the model is updated every two years to include land use changes, animal populations, crop data, updated BMP efficiencies, and to also include new practices.

C. WHICH OUTCOMES ARE QUANTIFIED?

CAST provides TN, TP, and TSS baseline loads and reductions in pounds per year associated with BMPs inputted by the user. In addition, CAST can provide the user with estimated costs and the potential environmental co-benefits (improved habitat, tree canopy, and climate resiliency, are among the qualitatively ranked co-benefits, for example) of many BMPs. These baseline nutrient and sediment loads estimated for each watershed are the same as the loads estimated by Chesapeake Bay Program's Phase 6 Watershed Model.

Users have many options for viewing results reports. Users can report out the base scenario conditions, historical yearly reports, or the potential BMP implementation results. This allows an easy comparison of different conservation scenarios. CAST can also provide co-benefit and cost estimations if included in the initial planning process. "What-if" scenarios can be individually built in the CAST interface and then compared for load reduction estimates. Additionally, CAST offers a Compare Map that allows users to choose two different publicly available outcomes scenarios and compare N, P, and sediment loads in a side-by-side comparison at the full Bay watershed and at various land-river segment scales. For more detailed comparison data, visit gis.chesapeakebay.net/mpa/comparescenarios.

Trends from 1985 to the present can be viewed for BMPs, wastewater, loads, and other parameters at: cast.chesapeakebay.net/Home/TMDLTracking#trendsOverTimeSection. Users can also compare scenarios to the Chesapeake Bay TMDL planning targets, or other scenarios.

D. TOOL STRENGTHS AND LIMITATIONS

One strength of CAST is that through the CAST home page is the Chesapeake Bay Watershed Data Dashboard, an online visualization tool that can help planners develop scenarios based upon different BMP implementation across the project area. Project managers can also review loading and BMP implementation trends, find previously developed scenarios that may meet their planning needs, and help with targeting efforts and choosing BMPs. The site is divided into guided modules that prompt the planner to answer specific questions to guide and develop the planning process (gis.chesapeakebay.net/wip/dashboard).

CAST also has a GIS interface called Map Viewer. This provides visualization of a selection of public reports based upon Load Scenarios as well as several available data-layers that are most applicable and commonly requested: gis.chesapeakebay.net/mpa/scenarioviewer. The same model that powers CAST is used to determine the Bay's TMDL. This alignment is helpful with planning BMP implementation projects and reporting consistency. The P6 WSM underwent a rigorous review process and continues to be reviewed and updated by the Chesapeake Bay Scientific and Technical Advisory Committee: chesapeake.org/stac.

BLEND IMAGES/ALAMY

E. WHO'S USING THIS TOOL?

CAST is used in the development of the Phase 3 Watershed Implementation Plans (WIPs) required as part of the Chesapeake Bay TMDL. The website epa.gov/chesapeake-bay-tmdl/phase-iii-wips links to all states' WIPs. The narratives for the WIP reports are written by state and local agency representatives who used CAST to quantitatively assess which practice combinations would enable each state and locality to reach their planning targets.

The Bay Partnership's water quality data, and information about the effect of BMPs has indicated increased conservation practice adoption (cast.chesapeakebay.net/Home/TMDLTracking#trendsOverTimeSection), as well as a movement from less effective BMPs to more effective BMP implementation over time. According to the tool developer, Lancaster, Pennsylvania, indicated that they have moved away from implementing more grass buffers and shifted to forest buffers, after using CAST and learning that forest buffers were so much more effective (Olivia Devereux, personal communication, 10/20/20).

CAST offers a list of BMPs that have the highest load reduction and a list of BMPs with the "most bang for your buck" (lowest cost for greatest load decrease) here: cast.chesapeakebay.net/Documentation/CostProfiles.

In Pennsylvania, CAST is being used to estimate the impacts that different programs have on the progress being made in pollutant loading that reaches the Chesapeake Bay (referred to as Edgo-of-Tide (EOT) load). According to the PA Phase 3 WIP Report (PA DEP, 2019), in the 20 years it has been administered, the Pennsylvania DEP Agriculture Inspection Program, which handles manure management plans among other BMP implementation, has resulted in:

- An estimated reduction of 487,000 lbs N;
- A reduction of 13,400 lbs P; and
- A reduction of almost 32,000,000 lbs. of sediment reaching the Chesapeake Bay.

F. SUPPORTING INFORMATION

Users register for a CAST account by clicking the Register button on the CAST Home page (cast.chesapeakebay.net). There are myriad documents available for guidance, history, technical, and model information, as well as training videos under the "Learning" tab on the CAST homepage as well. The underlying model of CAST, the P6 WSM, underwent a significant update, and as a result CAST was also updated to CAST-19 from CAST-17d in July 2020. All publicly available scenarios were also updated using the new model, and CAST-19 was re-released. Update documentation can be found here: cast.chesapeakebay.net/Documentation/ModelDocumentation. The point of contact for the tool for users to interact with for trouble-shooting questions is Olivia Devereux: olivia@devereuxconsulting.com or CASTteam@chesapeakebay.net.

7. FieldDoc

A. ABOUT THE TOOL

FieldDoc is a web-based tool with a user-friendly interface that provides "ballpark" estimates of field-level load reductions at the project scale in the Chesapeake Bay and Delaware River watersheds for user-specified BMP implementation. It was developed by The Commons (a nonprofit organization) in partnership with the National Fish and Wildlife Foundation (NFWF), the Chesapeake Bay Stewardship Fund, and the Maryland Department of Natural Resources (DNR). Continued development and feature releases of the tool have been supported by additional funding partners.

FieldDoc is currently used by conservationists who apply to receive or are currently receiving funding from several regional organizations, including the Delaware Restoration Watershed Initiative, National Fish and Wildlife Foundation (NFWF), Chesapeake Bay Program, Open Space Institute, Virginia Environmental Endowment, Richard King Mellon Foundation, William Penn Foundation, and Maryland DNR. These funding organizations also use FieldDoc to evaluate project proposals and measure program impact. Anyone can create a FieldDoc account and creating a project then allows users to gain access to the modeling the platform supports. When creating a project, users must assign a FieldDoc associated funding program to their project in order to access a list of practice types and generate the respective calculations for their work. This allows projects funded by those programs to track and report project outcomes.

However, other users (who are not existing grantees of the associated programs) can still use FieldDoc to quantify project outcomes. These users must still assign a funding program to their project, but if the project status is set to private, this prevents the project from connecting and reporting to the funding program while still using FieldDoc for estimating outcomes. Because FieldDoc allows projects to report to several different funding programs, the models and datasets used vary to align with those programs; this tool also has the capacity to integrate additional models so that the platform can be used anywhere in the United States where there is an interest.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

Individual users who use FieldDoc to track their implementation impact create projects first by selecting the funding program. Once a project is assigned to a funding program, FieldDoc automatically loads the associated list of practices and metrics for that program. Users who are not funded by any of the associated programs may choose either the Chesapeake & Atlantic Coastal Bays Trust Fund (CACBTF) or the NFWF Chesapeake Bay Small Watershed program when setting up their project, as the models and metrics behind those two programs have broad applicability in the region. FieldDoc uses the various models "behind-the-scenes" and then generates "ballpark" estimates to assist project managers in developing N, P, and sediment load reduction plans. Users can set goals and input target load reduction metrics within the project's area of implementation using over 200 BMPs and associated default efficiency values and track progress.

FieldDoc uses datasets provided from the CAST model, as well as additional sources, depending on the BMP selected including:

- Adapted Nutrient and Sediment Load Reduction Model (developed by The Commons for FieldDoc) based on a simple algorithm to include BMP efficiency and practice area;

- Shoreline management BMP efficiencies (created by an expert panel for the CBP P6 model);
- In-stream load reduction estimates (created by Chesapeake Stormwater Network BMP Expert Panels).

For over 75% of all practices in the system, the user selects a practice type from the available list, identifies the location of the practice (map-based site boundaries), and confirms the area of the practice footprint in order for the system to calculate the estimated reductions. For the remaining 25% percent of all practices, FieldDoc requires users to input additional information (such as BMP efficiencies) before the system can calculate the reductions.

In order to accommodate a diversity of access to GIS software, FieldDoc provides GIS tools within FieldDoc to draw the practice area or users can upload existing shapefiles representing a field or multiple fields. Users can also copy practices to quickly add multiple practices on a single site.

C. WHICH OUTCOMES ARE QUANTIFIED?

FieldDoc provides TSS, TN, and TP reduction estimates in pounds per year associated with individual BMP implementation. FieldDoc generates load estimates for the given practice and according to the model summary (help.fielddoc.org/en/articles/2816539-model-summary) it "is not meant to replace or align with Bay Program scenario tools or TMDL reduction targets, it is useful in understanding a rough estimate of reductions if a practice were to be implemented based on size, type, and location." FieldDoc provides practice-level metrics that roll up to show the impact of all implementation within one project. This tool was designed so users can easily report progress towards grant-funded project targets. FieldDoc will provide ballpark estimates of site-specific outcomes and can also group project sites to track overall project progress. Results are presented in a simple table.

D. TOOL STRENGTHS AND LIMITATIONS

FieldDoc's straightforward interface and integrated ability to manage planning, tracking, and reporting of project implementation and outcomes are strengths. The alignment with grant reporting makes this tool streamlined and easy to use. Another exceptional feature is a "privacy" button that allows project managers to take advantage of the modeling without publicly identifying the location of the farms where they are implementing BMPs.

At the time of this report, the FieldDoc development team is working to provide users with the ability to export their data. FieldDoc developers report they anticipate releasing a fully tested version of export function by the end of the 2020 calendar year. While FieldDoc has not been verified in a peer-reviewed journal, it has been built with coordinated input and feedback from the CAST modeling team, which has reviewed and approved the accuracy of the calculations for practices that use that model.

E. WHO'S USING THIS TOOL?

NFWF, one of the largest agricultural conservation funding organizations in the Chesapeake Bay and the Delaware River Watershed, is using FieldDoc for their Small Watershed Grants program as well as their Innovative Nutrient and Sediment Reduction Grant Program. In 2019, FieldDoc, with support from NFWF, was expanded to support watershed planning in the Delaware River Watershed too. Additional users include Pennsylvania DEP, which will soon use FieldDoc to track their Clean Water County Wide Action Plans; Richard K. Mellon Foundation, which is using FieldDoc to track implementation investments in Western Pennsylvania; and the Virginia Environmental Endowment.

Furthermore, FieldDoc has developed a feature to showcase project and program level implementation through an interactive map and target dashboard. The feature, named Dashboard, can be embedded into third party websites in order to share impact with targeted stakeholders who may not have access to individual projects within FieldDoc.

Below is just one project found on the dashboard (hdashboard.fielddoc.org/141?pi=3994) highlighting a farmer who has used FieldDoc to track the impacts of implementing intensive rotation grazing, creating animal exclusion areas, and planting forest buffers on sediment, N, and P loss on his fields:

> Meadow View is a forty-acre farm that has Middle River flowing through it along with two intermittent streams. It has six acres of riparian buffers and thirty-four acres of perennial pasture. The pasture is divided up into four grazing units. Livestock are rotated in and out of these grazing units to consume the forage. When the forage is high, we move the livestock in and when they graze it down to no shorter than four inches, we move the livestock out to allow the forage to regrow.

Using the Adapted Chesapeake Nutrient and Sediment Load Reduction Model, FieldDoc estimates the annual load reduction from the three practices implemented by Meadowview Farm to be:

- 415,511.06 pounds per year of total suspended solids reduced
- 2,045.33 pounds per year of total nitrogen reduced
- 644.20 pounds per year of total phosphorus reduced

Project managers have shared with the developer that they use FieldDoc both as a requisite tool to meet funding requirements and also as a calculator for planning and strategic implementation purposes. The developer heard from the funders that FieldDoc has allowed them to track, for the first time, the location of their investments and the impact the investments have had to date on reducing TN, TP, and TSS (E. Hofmann, personal communication, 9/24/20).

F. SUPPORTING INFORMATION

Anyone can sign up for an account; however, unless your organization is already associated with FieldDoc, you will have to email support@fielddoc.org to register your organization before you can access the tool. Furthermore, all projects must be assigned to a grant program in order for the system to load practices and models. An interested organization could potentially fund the set up and support of a program for anyone to use FieldDoc as a basic calculator and practice tracking tool.

First released in 2016, FieldDoc underwent a significant update in 2019, including updating the user interface, improving data input and reporting workflows, and adding additional modeled practices. Support materials, including step-by-step instructions, downloaded pdfs, and video tutorials, can be found at help.fielddoc.org. For technical questions, users can quickly access support from FieldDoc Team members via an online chat box or support@fielddoc.org. For programmatic questions, such as what practice to select, each funding opportunity has listed a program officer to contact. Organizations interested in using FieldDoc for their program can reach out to R. John Dawes (executive director of The Commons) via support@fielddoc.org.

FIGURE 12. THE S.T.A.R. METHOD

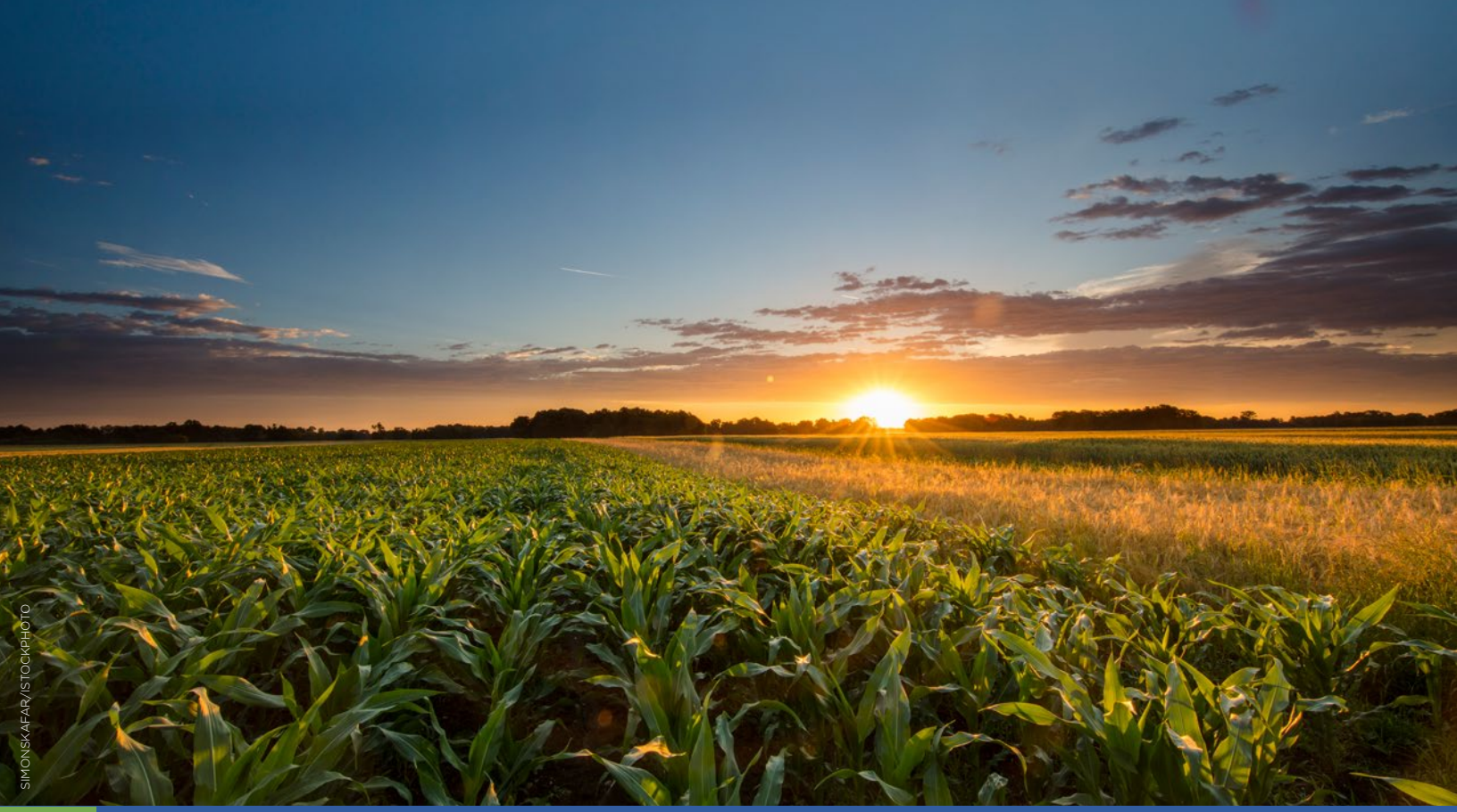
In addition to the quantification tools we have featured, there is a back-of-the-envelope method developed by AFT as an option for a coarse yet reasonable approach to quantifying project-scale water quality and climate outcomes, which may be modifiable for application to projects. Originally developed to quantify our Illinois Upper Macoupin Creek RCPP project outcomes, our Midwest Science Director Dr. Emily Bruner further developed this methodology to quantify the outcomes associated with practice adoption tracked by the statewide Illinois Saving Tomorrow's Agriculture Resources (S.T.A.R.) Initiative.

This method can easily be applied at the project scale (defined by either county or watershed boundaries) to estimate outcomes and "provide an estimate of practice level performance" (S.T.A.R., 2020). The S.T.A.R method uses total acres enrolled in the program; GHG reductions using COMET-Planner; BMP efficiencies from the Illinois Nutrient Loss Reduction Strategy; Illinois HUC8 nonpoint source (NPS) nutrient loading data; HUC8 and county boundaries using geospatial data; 2017 Census of Agriculture information; and the average annual sediment load per county to calculate nutrient and sediment load reductions.

While this method may be less sophisticated than site-specific, online dynamic modeling tools, it does incorporate recent regionally specific and watershed and county-level NPS data. Thus, it may provide a realistic picture of what is going on across the landscape. It should be pointed out that before project leaders can use this method, they must first ascertain whether the county or watershed level baseline nutrient and sediment loss information and reduction efficiencies for conservation practices are available.

The S.T.A.R. Method is published in the report listed below (on pages 13–15):

S.T.A.R. (2020). *S.T.A.R. Annual Report. Crop Year 2019. Improving Conservation One Field At A Time.* Saving Tomorrow's Agriculture Resources. img1.wsimg.com/blobby/go/45c3f789-47fb-40df-9bb7-3dc4d7bf6c2f/downloads/Star%20report%20FINAL%202020.pdf?ver=1597671964705



SIMONSKAFAR/ISTOCKPHOTO

Greenhouse Gas Outcomes Quantification Tools

TABLE 5. GREENHOUSE GAS OUTCOMES QUANTIFICATION TOOLS

Tool	Developer	Format	Scale Options for Analysis	Quantified Outcomes (Degree of Specificity)
COMET-Farm	NRCS & Colorado State University	Web	**Primary:** Field **Secondary:** Project	Soil organic carbon, biomass carbon, CO, CO_2, N_2O, and CH_4, all presented in metric tons of CO_2 equivalents per field (or parcel) annually (Field-specific estimates)
COMET-Planner	NRCS & Colorado State University	Web	**Primary:** County & State-level	CO_2, N_2O, CH_4, and total CO_2 reduction estimates are all presented in metric tons of CO_2 equivalents annually (Generalized estimates)
Fieldprint Platform	Field to Market	Web	**Primary:** Field **Secondary:** Project	CO_2, N_2O, and CH_4 emissions presented in lbs. of CO_2 equivalent per acre annually (Field-specific estimates)

Acronyms: CO = carbon monoxide, CO_2 = carbon dioxide, N_2O = nitrous oxide, and CH_4 = methane

8. COMET-Farm

A. ABOUT THE TOOL

COMET-Farm is an online tool that integrates spatially explicit soil and climate data with individual field production data to forecast GHG emissions and carbon sequestration potential under current management practices and with additional conservation practices under potential "what-if" scenarios. This tool was developed by Colorado State University (CSU) with USDA NRCS and USDA Climate Change Program Office (CCPO) collaboration, and with additional support from state agencies, NGOs, and private foundations and individuals.

COMET-Farm is free and available for not-for-profit use nationally to evaluate and estimate GHG emission changes on cropland, pasture, rangeland, orchards, vineyards, agroforestry, forestry, and animal agriculture. This tool is intended for use by farmers and agricultural service providers working directly with farmers. COMET-Farm also allow users to assess the impacts of management changes to potentially participate in carbon markets. Users have the option of registering for a free account (no credentials needed) or using the tool without registering.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

COMET-Farm is a modeling platform that implements more than 40 different models described in the USDA "Methods Document" (Eve at al. 2014). The principal model used for soil organic carbon and soil nitrous oxide emissions is the DayCent dynamic model, which integrates well-tested published research with biogeochemical processes (plant and soil organic matter decomposition, nitrogen gas fluxes, methane oxidation) with Intergovernmental Panel on Climate Change (IPCC) methods of carbon and GHG accounting. DayCent is a daily time-step model that takes into account the daily plant growth, organic matter decomposition, and nutrient and water uptake based on the weather at the site for each individual day of the year. In comparison, the CENTURY model uses average weather on a monthly basis. DayCent is also used for the National GHG Inventory prepared by the EPA (see Appendix D for more information on the DayCent model). Field specific soils information using the NRCS SSURGO database and local climate data from the Oregon State University PRISM weather model are automatically integrated by identifying the field boundaries using the GIS mapping interface.

The field-specific inputs that must be obtained from a farmer through interviews or review of farm records are numerous and include historic crop or pasture management practices (for the previous 20 years) including cropping sequence and approximate planting and harvest date; grazing system, type of tillage; rate, timing, fertilizer and manure application; irrigation; and residue management. For animal systems, inputs include herd size, herd composition, manure management information, and feed characteristics.

C. WHICH OUTCOMES ARE QUANTIFIED?

The specific outcomes quantified by COMET-Farm include soil organic carbon, biomass carbon, as well as the trace gases, CO, CO_2, N_2O, and CH_4 from IPCC-recognized greenhouse gas emissions sources and sub-sources (e.g., mineral-C stocks vs organic C stocks). All are presented in metric tons of CO_2 equivalents per field annually. Both baseline and "what if" scenarios are calculated as well as the change between the two scenarios and percent change.

Results are presented in a simple tabular form, and the more detailed calculations can be displayed by choosing "Click to Show Detailed Emission Reductions." This provides greater detail in regard to the source or sink of C and N_2O by providing the emission reduction coefficients (a value of GHG reduction on a per acre basis) of the chosen practice (or practices) on soil carbon, biomass carbon, fossil CO_2, biomass burning CO_2, biomass burning CH_4, liming, and soil N_2O, in tonnes CO_2 equivalent per acre per year. The maximum and minimum total emissions reduction estimates are also provided. Negative values indicate a reduction in GHG emissions or an increase in C sequestration. The tool provides confidence intervals using Monte Carlo simulation methods for all emissions sources except for soil organic carbon and biomass carbon. A model for soil organic carbon confidence intervals consistent with the USDA methods document and the U.S. National GHG Inventory has been developed and is currently under review by CSU staff as well as the NRCS and USDA.

D. STRENGTHS AND LIMITATIONS

The interface of COMET-Farm is user-friendly, and the online program walks the user through the full data entry process in a step-by step manner. The mapping feature is straight forward, and users can easily navigate to their specific field and draw field boundaries. This tool has been developed to be customizable, and it can generate highly detailed and site-specific scenarios.

However, the process of gathering and then entering historical management data for a single field for the past 20 years is very time consuming, and it can be difficult to determine what information to enter when project farmers do not maintain such long records or did not manage the field the entire time. Once that hurdle is crossed, users who create an account can save the field(s) and the historic management data for future seasons.

And, although the tool offers farmers and their advisors the option of running multiple (up to 10) "what if" scenarios to explore what conservation options will work best for the producer, doing so can take a long time to complete and will take even further if each scenario includes multiple farm fields.

AFT staff who used COMET-Farm tool for our nine case studies experienced the tool freezing up, which is similar to their experience with the NTT tool as well (and may reflect poor internet connection rather than a problem with either tool). Users can choose to collect data from the farmer ahead of completing data entry in the COMET-Farm tool to minimize having these technical glitches interfere with time spent with the farmer.

In response to user feedback, CSU has developed a recent feature to allow the user to copy one year's management information to subsequent years, saving quite a bit of time during the input process. A method to speed the data entry process by auto-populating land use and management histories from satellite imagery and survey information has been developed and is expected to be deployed before the end of March 2021.

GHG reduction estimates are presented in tabular and graphical formats (e.g., bar graphs compare GHG emissions in baseline to implemented or potential scenarios), both of which are downloadable. COMET-Farm has been peer-reviewed, is used in multiple peer-reviewed publications (Capalbo et al., 2018; Paustian et al., 2018; Ziegler et al., 2016), and is being adopted for use in carbon-market trading.

E. WHO'S USING THIS TOOL?

There is no information about projects using the COMET-Farm Tool on the tool's website. The tool developers said they are aware that many projects use the tool, but they do not keep track of them. However, since the 2015 release of COMET-Farm, 3,313 users have used the tool and over 10,052 sessions have been completed (H. Nagle, personal communication, 10/2/20). They encouraged us to look into the Nori company, which uses COMET-Farm in their carbon market efforts. According to Nori's website (accessed November 19, 2020), more than 26,756 tonnes of CO_2 have been removed from the atmosphere due to the adoption of conservation practices by farmers in the NORI network. Of those, 19,464 tonnes have been purchased by buyers on their marketplace. Among the practices included were cover crops, tillage reduction, and use of organic matter additions (e.g., compost, manure) in place of synthetic fertilizers.

AFT also used the COMET-Farm tool to provide estimates of the climate outcomes associated with the successful adoption of soil health practices by eight farmers featured in our AFT-NRCS case studies (2019 and 2020). AFT also transformed the total GHG reductions (tonnes CO_2-eq/year) into number of cars using the EPA's Greenhouse Gas Equivalencies Calculator provided on the COMET-Farm results page (epa.gov/energy/greenhouse-gas-equivalencies-calculator). Each producer's individual GHG reduction percentage estimate and equivalent number of cars can be read in each of the two-page case studies (farmlandinfo.org/publications/soil-health-case-studies).

Here are highlights of just two examples:

- **Jim Ifft, Illinois corn-soybean farmer.** AFT Author Emily Bruner used COMET-Farm tool to evaluate the climate outcomes associated with Ifft's use of nutrient management and cover crops on one of Ifft's 80-acre fields that was representative of the rest of his 1,650 acres implementing the practices. COMET-Farm tool estimates that Ifft's use of these two soil health practices have resulted in a 35% reduction in greenhouse gas emissions from the one field, offsetting the emissions from eight cars.
- **Eric Niemeyer, Ohio corn-soybean farmer.** AFT Author Brian Brandt used COMET-Farm tool to evaluate the climate outcomes associated with Niemeyer's use of no-till, cover crops, and variable rate applications on one of Niemeyer's 110-acre fields that is representative of the 1,250 acres he

is using the three practices on. COMET-Farm tool estimates that Niemeyer's use of the three soil health practices have resulted in a 494% reduction in total GHG emissions corresponding to taking 17 cars off the road.

AFT conducted a summary analysis of all the featured farmers and found total greenhouse gas emission reductions for five of the six crop farms averaged 217% and was 28% for the two almond growers, which corresponds to taking between ¾ of a car to 17 cars off the road each year. AFT decided to publish the percent change figures rather than the baseline, reduction, or change in emissions in tonnes of CO_2-equivalent figures given the sensitivity surrounding individual farmer field estimates of GHG emissions.

F. SUPPORTING INFORMATION

Video tutorials are available at comet-farm.com/HelpPage and range from introductory presentations to in-depth instructions for assessing outcomes for differing types of agriculture. The most recent video was posted in 2020. There are many pdf tutorials, demonstration projects, an extensive FAQ page, and online support desk at cometfarm.freshdesk.com/support/home. Users can email questions or feedback to: appnrel@colostate.edu or directly through the helpdesk widget in the bottom right corner of the COMET-Farm page.

COMET-Farm was updated to version 2.43 in September, 2020, to include an updated soil N_2O method, improved model throughput and faster tool response, addition of the state of Hawaii, more available options for fertilizers and organic matter additions, and an improved animal agriculture module allowing modeling of multiple livestock herds over multiple years on a flexible baseline.

9. COMET-Planner

A. ABOUT THE TOOL

COMET-Planner is a quick and easy online planning tool that estimates GHG changes, at the county and state level, as associated with NRCS conservation practices applied to annual and woody perennial cropland and grazing lands. Launched in 2015, this tool is not intended for field-specific simulation (like COMET-Farm) but for broader planning purposes during project development to produce generalized estimates of project outcomes. It was developed by Colorado State University and NRCS with additional support from NGOs, private donors, and state agencies. This is a free tool available for use nationally. Further, the full dataset underlying the tool can now be downloaded as an Excel spreadsheet from the website.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

There are only four data entries made by the user in COMET-Planner. Users choose the state, county, and area (in acres) of their planned project and then choose a single practice or a combination of practices (also broken down by acres) to simulate implementation and estimate GHG emission reductions. The included conservation practices are those that have been identified to mitigate GHG emissions. In total, there are 35 NRCS conservation practices that fall under the five broader categories of:

- Cropland management;
- Grazing lands;
- Cropland to herbaceous cover;
- Woody plantings; and
- Restoration of disturbed lands.

In the most recent update of COMET-Planner, developers improved the practice combination flexibility, allowing users to choose from a variety of common combinations.

The site-specific modeling used to generate regional average estimates of GHG changes in COMET-Planner used several datasets to capture soil properties, weather, cropping systems, and typical agricultural management. Details on the specific datasets and how they were used can be found in the COMET-Planner Report (planner-prod-dot-comet-201514.appspot.com/static/media/COMET-Planner_Report_Final.3de20776.pdf), linked from the Help page on the tool website. The only data entered by users are the state, county, and area to which they would apply the conservation practice(s).

C. WHICH OUTCOMES ARE QUANTIFIED?

COMET-Planner presents GHG emissions as compared to the baseline scenario using an estimated range (minimum and maximum) for GHG changes and relies on the COMET-Farm modeling platform (i.e., the DayCent model and a suite of empirical models). The GHG outcomes estimated include CO_2, N_2O, CH_4, and total CO_2. Equivalent reduction estimates are all presented in metric tons of CO_2 equivalents annually. Negative estimates indicate that the "what if" scenario results in greater emission of CO_2 while positive estimates indicate a reduction of emissions. It is noted on the COMET-Planner site and in the accompanying report that "carbon dioxide reductions reported should be viewed as average values over a 20-year duration."

Results are presented in a simple tabular form, and the more detailed calculations can be displayed by choosing "Click to Show Detailed Emission Reductions." This provides greater detail in regard to the source or sink of C and N_2O, by providing the emission reduction coefficients of the chosen practice (or practices) on soil carbon, biomass carbon, fossil CO_2, biomass burning CO_2, biomass burning CH_4, liming, and soil N_2O, in tonnes CO_2 equivalent per acre per year. The maximum and minimum total emissions reduction estimates are also provided. Standard errors, representing modeled variability, are included in the downloadable Excel spreadsheet of results.

D. TOOL STRENGTHS AND LIMITATIONS

One of COMET-Planner's greatest strengths is also its limitation: with just a few clicks, the tool provides a very easy user experience to produce generalized GHG outcome estimates of conservation practices. However, for projects or farmers who want a site-specific estimate of GHG emissions and "what if" scenarios that capture their soils, management, and cropping history, the COMET-Farm will satisfy their need. Despite the easy user experience, CSU staff provide examples during their training videos of outcomes estimates generated by COMET-Farm and by COMET-Planner for the same baseline and "what if" scenarios that reveal similar results. See here for the training video: cometfarm.freshdesk.com/support/home.

A recent update to COMET-Planner improved the underlying models' spatial resolution of the CO_2 equivalents estimate. COMET-Planner is suitable for project planning and could also be used to provide project managers with quick and easy, generalized estimates of their project's GHG outcomes. Results and COMET-Planner datasets are both downloadable.

E. WHO'S USING THIS TOOL?

There is no information about projects that have used COMET-Planner on the tool's website, although the developers report that COMET-Planner is used within NRCS, state agencies, and resource conservation districts for conservation planning purposes to dialogue with farmers about the benefits of certain practices and to run "what if" scenarios. The developers also report that NGOs are using COMET-Planner to do broadscale analyses, and states are using it to design and administer soil health programs. For example, COMET-Planner was adapted to support the California Healthy Soils Program, providing estimates of GHG reductions of practices supported by program payments. All applicants to the program must complete an analysis in COMET-Planner and include their results in their application.

For example, in the 2020 California Healthy Soils Program solicitation by the California Department of Food and Agriculture, 578 applicants used the COMET-Planner Healthy Soils tool.

F. SUPPORTING INFORMATION

COMET-Planner was last updated in August 2020. There is a six-minute introductory video at the top of the home page that briefly gives an overview of the tool and walks users through its four steps. A 141-page companion report is accessible via the "help" link. The original version of the tool has been retired, but users may still access the original report, which contains all coefficients (based on meta-analyses and simple empirical models), from the Help page. Users with questions or feedback are encouraged to contact Amy.Swan@colostate.edu.

10. Fieldprint Platform

A. ABOUT THE TOOL

The Fieldprint® Platform is an online tool developed in 2009 by Field to Market: The Alliance for Sustainable Agriculture, a multi-stakeholder non-profit organization. The tool is intended for farmers to assess their sustainability performance, understand how practice changes can improve sustainability scores, and track progress towards improvements. The Fieldprint Platform consists of a free and publicly available online Calculator that collects field-level information directly from farmers about their operations to estimate five quantitative metrics–greenhouse gas emissions, soil conservation, land use, energy use, and irrigation water use–and three qualitative index metrics: water quality, biodiversity, and soil carbon. It is available for 11 crops (alfalfa, barley, cotton, corn, peanuts, potatoes, rice, sorghum, soybean, sugar beets, and wheat) across the continental United States.

The tool is designed to be used by farmers in collaboration with their advisors to identify practices appropriate to their specific operations that will improve one or more of the sustainability outcomes. Users can run the platform multiple times for the same field as "what if" scenarios to explore how alternative practices would impact their environmental impacts. The Fieldprint Platform also includes project management features allowing individual farmers to associate their fields with a project. Their data will then be available to a designated project administrator who can access and download a database of all inputs and outputs for all fields enrolled in that project, while upholding farmer data privacy requirements.

The Platform also includes an Application Programming Interface (API) connection. The API enables licensed data partners to share data inputs with the calculator from their farm production management and other software programs used by farmers. The API partners then incorporate the calculated Fieldprint sustainability metrics into the software programs.

B. SITE-SPECIFIC INPUTS & BMP ANALYSIS OPTIONS

This guide focuses on two of the five quantitative metrics estimated by the Fieldprint Platform: soil conservation and greenhouse gas emissions. The soil conservation metric (tons of soil lost to wind and water erosion per acre per year) uses the USDA NRCS soil erosion models: WEPP and WEPS (see Appendix D for more information). Soil properties and weather data pertinent to a farmer's fields are obtained by the platform from direct connections to USDA data servers to access the SSURGO and PRISM databases, respectively. The greenhouse gas metric (carbon dioxide emissions equivalent in lbs. per acre and per unit of production) is comprised of four components: (1) emissions associated with on-farm energy use, (2) nitrous oxide emissions from soils using the DayCent and DNDC models (see Appendix D) based upon crop, land, soil, and fertilizer input data, (3) methane emissions from rice production, and (4) emissions from crop residue burning.

Users begin by delineating the boundary of each field using a built-in GIS based mapping function, designating a crop, and providing a list of operations for that field in one crop year. For each field, users provide management information including tillage operations, residue management, cover cropping, irrigation system and water volume, fertilizer and chemical applications, crop drying, transportation, and conservation practices. Seventeen conservation practices can be evaluated in the tool, including conservation cover, contour buffer strip, contour strip cropping, field borders, field strip cropping, filter strip, grass waterway, integrated pest management, nutrient management plan, riparian forest buffer, riparian herbaceous cover, sediment basins, stream habitat improvement and management, tailwater recovery system, vegetative barrier, water and sediment control basin, and wind barriers.

Data entry for the calculator occurs through a web-based interface that provides a rotation builder feature. The rotation builder allows access to the NRCS Land Management Operations Database library of field rotations that can be used directly or edited by a user with additional details relevant to their field. Data entry may also occur through the API connection so that farmers who already have information stored in other software platforms do not have to re-enter similar information into the Fieldprint Platform.

C. WHICH OUTCOMES ARE QUANTIFIED?

Five outcomes are quantified through the Fieldprint Platform: greenhouse gas emissions (carbon dioxide emissions equivalent in lbs. per acre and per unit of production), soil conservation (soil lost to wind and

LINDSAY MORRIS

water erosion in tons per acre per year), land use (acres per unit of production), irrigation water use (water volume in acre-inch per unit of production or per incremental increase in yield achieved), and energy use (energy volume in btu per acre and per unit of production). The platform also includes three qualitative index metrics: the USDA Water Quality Index (WQIag), the USDA Soil Conditioning Index (SCI), and a Habitat Potential Index tool to estimate biodiversity developed by Field to Market.

Results are presented multiple ways to a farmer in a Fieldprint Analysis Summary report. A spidergram reflects relative indices on a scale of 1-100 to represent each metric score. And the available quantitative estimates of outcomes are presented in tabular form. The report also includes descriptions of each metric and how to interpret each score. Results for the quantitative greenhouse gas emissions, soil conservation, and energy use metrics, plus the qualitative water quality metric, include a breakdown of the contribution of different conservation practices to the final metric score. Companion fact sheets for each metric include guidance on the most important BMPs relevant to each environmental outcome.

The outcomes estimate for greenhouse gas emissions is comprised of four individual components, presented in tabular form as CO_2-eq per acre (or per unit of production) values, including:

1. The emissions associated with energy use on the farm, defined as all operations from pre-planting to the first point of sale, and including emissions embedded in the production of fertilizers, chemicals, and seeds used on the field, also accounting for use of both renewable forms of energy and energy from the electric grid.
2. An estimate of N_2O emissions based on the International Panel on Climate Change (IPCC) Tier 2 methodology, which calculates emissions based on crop, land resource region (to account for climate zones), soil texture, and nitrogen application rate, and uses emissions factors from DayCent and DNDC models (see Appendix D).

3. An estimate of CH_4 emissions from flooded rice production (following an IPCC Tier 2 methodology) that was developed based on a meta-analysis of literature on CH4 measurements from rice production fields in the United States (Linquist et al., 2018).
4. A national emissions factor applied to calculate crop residue burning emissions that reflects the volume of residue based on the previous year's crop yield and estimates the non-CO_2 GHG emissions associated with combustion on-field.

These four components have been developed by Field to Market in collaboration with expert advisory groups; full documentation and publications are available at fieldtomarket.org/our-programs/sustainability-metrics. The Fieldprint Platform does not provide confidence intervals.

D. TOOL STRENGTHS AND LIMITATIONS

The Fieldprint Platform and all associated metrics, tools, and educational materials have been developed in collaboration with farmers and farm organizations, as well as environmental organizations, university researchers, and agricultural value chain companies. As a result, data entry is user-friendly.

The tool also provides outcomes quantification estimates at both the field scale and the project scale. Site-specific environmental data (i.e., soils and weather) informs the estimates of field-specific outcomes. The tool also facilitates aggregation of information about multiple farmers to the project scale. A web-based data quality analysis tool is available to assist project administrators in visualizing results, evaluating their databases, and calculating aggregate results from across the project.

Another strength is that the platform can also be used to report sustainability data frequently requested by grain buyers and food companies. There are over 60 active projects where companies are working with groups of farmers to assess sustainability outcomes using the platform. Field to Market has also established equivalency with other sustainability organizations such as Sustainable Agriculture Initiative (SAI) Platform and The Sustainability Consortium, providing farmers and their buyers with the ability to report data into commonly used value chain sustainability assessments.

One limitation of the platform is that it calculates all eight metrics simultaneously, so it cannot be used to calculate one indicator independent of the others. This means there may be additional data entries required, compared to other tools that calculate only water quality or greenhouse gas outcomes, which are the focus of this guide.

To use this tool to create "what if" scenarios, users must go through a few steps. Users would enter data about their field reflecting current crop and conservation management to generate baseline information, save those results, and export or print them as a PDF. Next, users would reopen that field's saved file, make adjustments to reflect potential conservation practices to generate new potential outcomes, save as a new file, and export or print as a PDF. Then, the user would compare the two output files to see the effect of adding conservation practices. The platform allows users to create a management template library to make this process easier.

Also, if more than one crop is grown on a field—although Field to Market encourages users to enter multi-year rotation data for as many years as possible—the platform provides results for just one year at a time. Thus, the same field can be run multiple times to reflect data from different years and the exported pdf results can be compared to observe the changes in performance over time.

Although the tool is free and publicly available for use by any individual, another limitation is that in order to gain access to the full suite of project data management features, projects using the tool need to include one partner who is a member of the Alliance, register the project with Field to Market, and report on activities each year. This requirement is relatively easy to achieve since USDA NRCS and the National Association of Conservation Districts (NACD) are members of the Alliance, in addition to several land-grant universities and other institutions, which make up the 140+ members. This project registration step ensures Field to Market can track the use of the tool, as well as make sure the projects are receiving updates and support.

Finally, while results can freely be used to communicate with farmers, project partners, and sponsors—and also in academic and research settings such as peer-reviewed journal articles—there are specific rules for communications about quantitative environmental impacts if reported in a public-facing promotional document such as a press release or a corporate sustainability report. These rules are designed to ensure farmer data privacy and provide

independent verification and assurance of results. Project managers are encouraged to contact Field to Market at the beginning of a project to discuss goals and ensure the project design will enable them to communicate their results as desired (fieldtomarket.org/get-in-touch).

E. WHO'S USING THIS TOOL?

Over the past decade over 90 projects have used the Fieldprint Platform for a range of sustainability and conservation practice adoption goals. The tool is also used by university extension advisors in their work with growers, and in academic research projects that include on-farm research. A list of 65 active projects using the platform to assess sustainability is available on a project directory at members.fieldtomarket.org/members/projects. These projects involve growers operating 3.7 million acres of farmland (fieldtomarket.org/media/2020/06/FTM_2019_Annual-Report_HiR-2.pdf).

There are over 140 members of Field to Market, currently, including NRCS, NACD, and many land-grant universities, non-profit organizations, and companies. The full list, and additional details on membership, can be accessed here: fieldtomarket.org/our-members. There are also currently six organizations that have integrated the metrics into their software; a list is available here: fieldtomarket.org/our-programs/fieldprint-platform/scaling-farmer-access.

Typical users are enrolled in a project where multiple organizations are working in partnership to advance a particular sustainability goal in a particular region. For example, USA Rice and Ducks Unlimited have used the Fieldprint Platform in a Rice Stewardship RCPP project to support and enhance wildlife habitat.

It is also used in corporate sustainable sourcing projects where brands that source the crops establish partnerships and programs to work with growers in their supply region to assess and improve environmental outcomes. For example, PepsiCo has partnered with Illinois Corn to use the platform in another RCPP project to assess sustainability of key commodities that they source for food products, and to support adoption of practices to improve soil health and water quality. These companies may further use the aggregated results in their corporate sustainability reporting and in reporting progress towards science-based targets or other objectives.

Examples of the GHG outcomes quantified by the Fieldprint Platform come from several research projects. Working with a university extension advisor, a Tennessee cotton farmer used the Fieldprint Platform to evaluate the potential benefits of variable rate fertilizer applications and was able to reduce nutrient use on 500 acres, resulting in a GHG reduction of 425,000 lbs. CO_2e (Duncan et al., 2014). The University of Arkansas has used the Fieldprint Platform with rice growers to demonstrate greenhouse gas emissions reductions from 300-500 kg CO_2e per ton associated with various alternative water management practices that reduce methane emissions (Moreno-Garcia, 2018). Cotton farmers participating in the Discovery Farms on-farm research program in Arkansas have also demonstrated the greenhouse gas emissions reductions associated with changing tillage practices and adopting cover crops (Robertson, 2017).

F. SUPPORTING INFORMATION

The Fieldprint Platform can be accessed for free online at calculator.fieldtomarket.org, where several demonstration fields are available, and step-by-step guidance is provided for new users. Field to Market also offers an annual training program, called the Continuous Improvement Academy, which requires a registration fee. The program provides training on all aspects of the platform and guidance on how to run projects to successfully meet goals. Full documentation of sustainability metrics and supporting publications can be found at fieldtomarket.org/our-programs/sustainability-metrics.

User support is provided through a contact link (support@fieldtomarket.org), which will then direct questions and issues to a team of diversified experts who will troubleshoot reported problems. All sustainability metrics are governed by a review and revision process designed to allow modifications that take advantage of scientific advances and tool developments. The last major revision of the platform, version 3.0, was released in November 2018, but there have been minor updates each year related to improvements in the metrics, infrastructure, or databases, and the version as of December 2020 is 3.1.1.

PIXDELUXE/ISTOCKPHOTO

Methods and Tools for Estimating Social Outcomes

One fundamental challenge to quantifying social outcomes associated with the adoption of farm conservation practices is simply defining social outcomes. The RCPP "Expectations" document (NRCS, 2020) states that:

> Reporting of social outcomes can inform strategies to increase adoption of conservation practices and systems in pursuit of lasting change beyond the duration of an RCPP project. Social outcomes analyses consider the factors that go into a producer's decision to undertake conservation activities, how that producer's decision influences other producers, and any broader impacts on communities.

The RCPP Expectations document recommends project managers consider use of the Social Indicators Data Management and Analysis (SIDMA) tool. The parent guidance document of the SIDMA tool is the 2011 "Social Indicator Planning and Evaluation System (SIPES) for Nonpoint Source Management: A Handbook for Watershed Projects." It is a thorough, easy-to-read manual for project managers wanting to establish, evaluate, and use social indicators for their farm conservation projects to help ensure achievement of their projects' desired social outcomes and eventually the water quality goals.

FIGURE 13. SIPES METHOD HANDBOOK SECTIONS

A. Steps for Using the SIPES
   1. Review Project Plan
   2. Collect & Enter Pre-Project Survey Data
   3. Review Data & Refine Social Outcomes
   4. Monitor Social Data Throughout Project
   5. Collect & Enter Post-Project Survey Data
   6. Collect & Enter Additional Post-Project Data
   7. Review Data & Use Results

B. NPS Project Planning: Setting the Stage for Working with Target Audiences

C. Getting Started with SIDMA—the Online Social Indicators Data Management & Analysis Tool

D. Choosing a Survey Method & Sample Size

E. Developing Your Social Indicators Questionnaire

F. Administering the Social Indicators Questionnaire

G. Features of SIDMA

H. Using Survey Results to Develop Education and Outreach

I. Evaluating Outreach Activities During Project Implementation

J. Collecting & Analyzing Data at the End

The SIPES methods document provides the following definition of social outcomes (page 55):

> Social outcomes are broadly defined as the social changes needed to bring about and sustain the environmental conditions you are trying to achieve in your project area. These outcomes will address the changes in awareness, attitudes, capacity, constraints, and behaviors that will help achieve your project's environmental goals and management objectives. These social changes are outcomes that project activities are expected to achieve.

The SIPES Handbook provides the following examples of social outcomes (also on page 55) (emphasis by authors):

- Increased **awareness** of relevant technical issues and/or recommended practices in critical areas;
- Changed **attitudes** to facilitate desired behavior change in critical areas;
- Reduced **constraints** to behavior change;
- Increased **capacity** to leverage resources in critical areas;
- Increased **capacity** to support appropriate practices in critical areas; and
- Increased **adoption** of practices to maintain or improve water quality in critical areas.

SIPES broadly defines social indicators on page 1 as "measures that describe the capacity, skills, awareness, knowledge, values, beliefs, and behaviors of individuals, households, organizations, and communities.... By measuring these indicators over time, water quality managers can target their project activities and assess whether their projects are accomplishing changes expected to improve and protect water quality."

The handbook walks readers through seven steps for using the Social Indicator Planning and Evaluation System (see Figure 3) and includes 11 sections and four appendices (e.g., sample surveys and other helpful documents). The handbook dedicates several sections to instructions on how to use the corresponding SIDMA tool.

11. Social Indicators Data Management and Analysis (SIDMA) Tool

A. ABOUT THE TOOL

The SIDMA tool was developed by several social scientists at Purdue University, Michigan State University, and EPA Region 5 to provide water quality project managers with a systematic approach to creating a social indicators questionnaire as well as administering and analyzing results of the survey. The tool is publicly available and free to use nationwide in projects addressing nonpoint source water quality concerns. The tool has stock questions that apply to farmers, landowners, and homeowners, indicating it applies to cropland and suburban land. The tool addresses survey question needs for several project types including the following categories: Watershed Planning, TMDL Implementation, Implementation, Outreach, and Training.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

Project managers must create an account and receive a return email to be accepted as a user of the SIDMA tool by the tool managers. Four preliminary questions are asked of the user to communicate basic information about the use of the survey (i.e., what are the priority resource concerns, who is the target audience, what actions are desired of the target audience to address the NPS problems). The tool then walks users through at least 11 categories of pre-developed social indicator questions—many of which are required to be asked in every survey generated by SIDMA. Most questions are in the Likert format (variants of strongly disagree, disagree, neutral, agree, strongly agree), but there are other question formats as well.

The 11 categories of questions are Rating of Water Quality, Your Water Resources, Your Opinions, Water Impairments, Sources of Water Pollution, Consequences of Poor Water Quality, Practices to Improve Water Quality, Making Decisions for My Property, About Your Farm Operation, About You, and Information Sources. In addition to the required sections and required questions, extra questions can be developed by the user and additional response options can be added to existing questions as well.

There are 185 conservation practices to choose from in the "Practices to Improve Water Quality" sections to address agricultural and other sources of water quality pollution (G. O'Neil, personal communication, 9/24/20). Once a user downloads the survey, they can

modify the practices to select only those that apply to their project (L. Prokopy, personal communication, 10/2/20). Three training videos found on an associate Purdue University website indicate soil health practices (e.g., no-till, cover crops, nutrient management, pesticide management) and structural practices (e.g., riparian buffers) are available.

C. WHICH OUTCOMES ARE QUANTIFIED?

The SIDMA tool aids quantification of social outcomes via social indicator measures by facilitating creation of a social indicators survey. The tool will help project managers select survey questions and responses that are relevant to their projects among the numerous questions and responses listed in the many question categories. When survey creation is completed, it can be printed in Word for mail distribution or a link can be generated for an electronic version. The tool also allows users to export the survey and results into excel (and other tab-delimited formats).

One advantage of the SIDMA tool over other free survey software (e.g., Google Form or Microsoft Form) is that it automatically codes the question responses to facilitate analysis. In addition, SIDMA allows users to change the codes and the code names if questions or responses are added. SIDMA also provides several analytical features, such as automatically generating pie charts and bar graphs to view the results, and it allows for sub-analysis of respondents by their responses.

D. TOOL STRENGTHS AND LIMITATIONS

The highlights of the SIDMA tool are that it provides a straightforward mechanism to develop a social indicator survey for a variety of water quality projects based on questions that have been vetted by university researchers. The SIDMA tool was initially developed by the Great Lakes Regional Social Indicators Team in collaboration with Region 5 EPA staff, state water quality agencies, and others in the six states that comprise EPA Region 5 (IL, IN, MI, MN, OH, and WI), but it has been used in other projects throughout the United States.

Another benefit is that the tool can help project managers track progress at the beginning, middle, and end of their project by developing and using surveys to gauge change in social indicators associated with the project's desired social and environmental outcomes. When used in conjunction with the SIPES Handbook, the SIDMA tool can be used to analyze many relationships, including the relationship between social outcomes and types of outreach activities (see SIPES page 56, Table H.3), which project managers can do to continuously evaluate the effectiveness of project activities.

One limitation of the SIDMA tool is that the map function is not functioning. The tool developers informed us through email correspondence that the map function originally contained an interactive map with watershed-scale demographic data. But the platform that it was built upon (ArcIMS) is no longer supported by Esri, so the developers had to take it down. If future funding for SIDMA development becomes available, the developers will explore rebuilding the map option on a more current web-GIS platform (G. O'Neil, personal communication, 9/16/20).

Another limitation of the tool appears to be the requirement that *all* categories of questions must be asked each time a survey is generated. Project managers may consider using the tool to inform their question options but then resort to using the free Microsoft Forms or Google Forms software (see Figure 14) instead to generate short, one-page surveys with just a few (e.g., three to five) questions aimed at evaluating the effectiveness of the project interventions. Short surveys may be tolerable to farmers and conservation service providers as exit-surveys after an educational event (such as a field day or a workshop). In contrast, the many sections of the SIDMA tool and the many required questions result in a very long survey length, which is best suited for a mailed survey instrument as SIDMA intended (L. Prokopy, personal communication, 10/2/20).

E. WHO'S USING THIS TOOL?

There is no information about project use on the tool website. However, once users gain access to the tool, they can conduct a keyword search for questionnaires that have been developed for use with, say, "farmers" and for "implementation" efforts. A recent search with those key words returned over 30 links to questionnaires, although several links appeared to be drafts of the same survey by the same project manager. Access to all the questions in the surveys was not allowed, although some questions could be viewed. Summary information about survey use or survey results is reserved to a particular survey's author and not publicly available.

The tool developers reported they are aware that many projects are using the SIDMA tool, but they do not

FIGURE 14.
ALTERNATIVE SURVEY SOFTWARE

In addition to the SIDMA tool, AFT staff have begun using Microsoft Forms (forms.office.com) survey software and Google Forms (google.com/forms/about) software to develop, administer, and analyze social indicator survey results for a variety of our soil health conservation projects. Both programs offer data management in Excel and offer results analysis using pie charts and bar charts.

The downside to this survey software is that it offers no guide rails for developing sound social indicator questions, which is available in the SIDMA tool. The advantage of using this survey software is that it can be used to generate only a few of the most important project evaluation questions needed for deployment as entry-or exit-surveys at farmer events.

maintain information on those projects (L. Prokopy, personal communication, 10/2/20). During email correspondence, the SIDMA tool developers told us the EPA 319 Nonpoint Source Agency in Michigan requires all 319 projects to use SIDMA and suggested we reach out to learn more (J. Asher, personal communication, 9/17/20). We did, and although the Michigan program representatives were able to share several examples of SIDMA use in final 319 project reports, they were not for agricultural projects, but for projects addressing septic tank and urban storm water issues.

AFT did use the SIDMA tool in the early days of our Illinois Upper Macoupin Creek watershed project when it was still an MRBI project and had not yet received RCPP funding. AFT staff used SIDMA to generate questions and administered those surveys via mail to lists of farmers located both inside and outside of our project area to establish baseline social data. We now track just a handful of social indicator questions via one-page exit surveys administered at the annual UMC farmer winter meetings and through an annual Macoupin County Farm Service Agency (FSA) office spring survey.

F. SUPPORTING INFORMATION

The SIDMA tool is available here: iwr.msu.edu/sidma/Info/About.aspx. A 10-part video tutorial series on SIDMA is available to walk users through the tool. Users can fast forward through the single video to get to the tutorial section of interest. In addition, three short SIDMA training videos are available here: engineering.purdue.edu/watersheds/webinars/SocialIndicators. Additional information about SIDMA and insights on how to select questions and analyze the results are available in several sections of the SIPES Handbook: iwr.msu.edu/sidma/Info/pdfs/SI_Handbook_v4_02012012.pdf. Contact information for the SIDMA tool is provided for Glenn O'Neil (oneilg@msu.edu) and Jeremiah Asher (asherjer@msu.edu), both at the Institute of Water Research at Michigan State University.

AVALON STUDIO/ISTOCKPHOTO

Economic Outcomes Quantification Tools

TABLE 6. ECONOMIC OUTCOMES QUANTIFICATION TOOLS

Tool	Developer	Format	Conservation Practices	Quantified Outcomes
Cover Crops Economics Tool	NRCS	Excel	Cover crops	Total costs, total benefits, and net benefit for short-term and long-term analysis ($/ac) of cover crop use
Retrospective—Soil Health Economic Assessment Calculator	American Farmland Trust	Excel	No-till, reduced till, cover crops, conservation cover, nutrient management, mulching, and compost application	Partial budget analysis table showing benefits, costs, impact on net income, and return on investment of already adopted soil health practices
Cropping Systems Calculator	Land Stewardship Program	Excel	Conservation crop rotation, cover crops, and grazing options	Average yearly costs and returns on a per acre and total basis to compare the original crop rotation to the alternative crop rotation

The guidance from the NRCS's RCPP Expectations document (2020) states that:

> Economic indicators can quantify the financial impacts of conservation practices on a farm, ranch or forestland. Economic indicators that may be used to report outcomes include (but are not limited to):
>
> - Conservation cost effectiveness—the cost to the producer of practice implementation vs. conservation benefits.
> - Economic/financial benefits—the impact of conservation implementation on net profit, the value of farmland/farm assets, etc.
> - Valuation of ecosystem benefits—benefits to downstream beneficiaries, local economies, etc.

The document also includes two examples of RCPP project-based economic analyses produced by the Precision Conservation Management team (Schnitkey and Gentry, 2019a,b).

This section of the working paper features three tools that calculate the economic estimates of the effects of various farm conservation practices. The first two tools, the NRCS Cover Crops Economics Tool and the AFT R-SHEC Tool, conduct partial budget analyses (PBA) for cover crops and for soil health practices, respectively. The third tool, the Land Stewardship Project's Cropping System Calculator, conducts a costs-returns analysis, which is similar to a full enterprise budget (B. Kirwan, personal communication, 9/21/20).

According to NRCS (Gordon, 2013):

> Partial budgeting is a method that systematically displays the benefits and costs of an alternative where only changes from the baseline (or current) condition are considered. This technique simplifies data collection. For example, only the costs and beneficial impacts of installing a conservation practice are considered in the analysis, rather than gathering information about the whole farm enterprise where the practice is installed.

A USDA NRCS effort is currently underway to provide PBA and other economic trainings to 5,000 NRCS conservation planners so they may be able to offer economic analysis services to their farmer clients (H. Gordon, personal communication, 1/11/2018; L. Knight, personal communication, 7/25/19). NRCS Economist Hal Gordon summarizes the steps to conducting a PBA in the 2013 publication quoted above and, specifically, to produce what is referred to as "Level III T-Charts" to display the results.

There are a number of case studies that use the PBA technique. Because farmers regularly ask what it will cost them to adopt the conservation practices that are being promoted by the conservation community, using these case studies to discuss the already quantified costs and benefits experienced by other farmers should be helpful in prognosticating the potential costs and benefits of farmers on the fence about adopting the same practices.

There are many examples of NRCS economic case studies, though not all are quantitative. See reference (NRCS, 2001, 2017) for a link to 57 of them. Two NRCS case studies that are among the best (because they are quantitative, easy-to-read, two-pages only, and have engaging photos) are by the NRCS New York State Economist Florence Swartz (NRCS-NY, 2016a,b). Other examples of PBA include:

- Four 16-page case studies by Datu Research and NACD featuring two farmers in Illinois, one in Iowa, and one in Missouri (Datu Research, 2017).
- Nine case studies featuring two California farmers, two Illinois farmers, two Ohio farmers, and two New York farmers that Florence Swartz led as the Consulting Economist (AFT, 2019, 2020).

There are case studies that use other economic analytical approaches and could also become new outreach and education materials for the conservation community. Three case studies by EDF and K-Coe ISOM use a farm enterprise analysis and are four pages each featuring an Iowa, Kansas, and Ohio farmer (Monast et al., 2018). The Illinois Corn Grower's Precision Conservation Management (PCM) Booklet released a summary of their whole farm enterprise analysis of 325 farmers operating 300,000 acres from 2015 to 2019 (Illinois Corn Growers, 2020).

This next section of the paper features details about three economics tools that can be used to provide quantitative costs and benefits associated with various conservation practices:

- Cover Crops Economics Tool by USDA NRCS
- Retrospective Soil Health Economic Calculator Tool by AFT
- Cropping Systems Calculator Tool by Land Stewardship Project.

12. NRCS's Cover Crops Calculator Tool

A. ABOUT THE TOOL

The Cover Crop Economics Tool was developed by the state economists for NRCS-Missouri (Lauren Cartwright) and NRCS-Illinois (Bryon Kirwan) to estimate the expected economic returns in the short-run and long-run for farmers who are deciding to add cover crops. The tool conducts a partial budget analysis in a five-tab Excel spreadsheet, which is publicly available and free. The tool applies to row crop production nationwide and has been used for small grain and cotton production as well (B. Kirwan, personal communication, 9/21/20). The tool may be modified for vegetable production by users who are experienced with those rotations (L. Cartwright, personal communication, 9/22/20). The tool offers default cover crop scenarios pertaining to corn-soybean rotations and corn-wheat/double crop soybean rotations among other variations.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

The Excel-based tool includes five tabs: (1) References & Citations, (2) Instructions, (3 and 4) Cover Crop Economics—Short Term Analysis (which toggles back and forth with the Long-Term Analysis tab), and (5) Farm Machinery Cost Estimator. Data sources for the farm machinery costs are from 2013 from the University of Minnesota Extension Service.

Version 3.1 of the tool (released on January 16, 2018) allows users to select mixes with up to 10 cover crop species. Five default scenarios are provided:

1. Cover crops added to a corn-soybean rotation, no grazing of cover crop;
2. Cover crops added to a corn-soybean rotation with grazing of cover crop;
3. Cover crops in a corn-corn-wheat/double crop soybean rotation plus no-till adoption;
4. Cover crops in a corn-soybean rotation with avoided terracing;
5. Rotation change from corn-soybean-wheat/double crop soybean to corn-soybean-wheat/red clover rotation.

Users can choose to use the default scenarios as is, modify them, or create up to five new default scenarios of their own to evaluate.

C. WHICH OUTCOMES ARE QUANTIFIED?

The short-term analysis results in an estimate of the total costs, total economic benefits, and net benefit on a per acre basis of incorporating cover crops into a rotation. The short-term analysis includes economic estimates of the (a) direct nutrient credit to each cash crop the year the cover crop is planted, (b) chemical input reduction due to the cover crop, (c) expected yield increases due to cover crops resolving the yield-limited factors (e.g., compaction, moisture, nitrogen availability), (d) erosion reductions both for avoided lost fertility and value of off-site water quality benefits, (e) additional benefits such as reduced tillage costs, and (f) grazing, baling, or seed production benefits for cover crop utilization.

The long-term analysis incorporates literature-based economic estimates for the (a) overall soil fertility benefit from the potential increase in plant-available nitrogen, phosphorus, and potassium and (b) water storage benefits for farms with irrigation represented as the avoided cost of irrigation or avoided crop yield reduction due to drought stress on farms without irrigation. The long-term results are presented as an economic and a financial analysis, which answers the following questions, respectively: "Is the management change profitable over the lifespan of the analysis?" and "Is the management change affordable."

Although the tool does not have a GIS function, it does offer a graphing feature for the long-term analysis that shows the overall soil fertility and water storage benefits over time in one graph and the financial analysis net benefits over time in a second graph. The tool also offers a print summary function to easily view summaries of the inputs and the results in a printer-friendly format, as well as a save function to allow the user to save the model for viewing later.

D. TOOL STRENGTHS AND LIMITATIONS

The strengths of the NRCS Cover Crops Economics Tool are that it is a simple, straightforward but nevertheless sophisticated tool for estimating the economic costs and benefits of cover crops. It also provides economic insights into utilization of cover crops, e.g., grazing of cover crops by livestock, baling of cover crops for additional feed source for livestock, and cover crop seed production. The tool offers the opportunity to discuss both the on-farm and off-farm economic benefits of reducing soil erosion with cover

crops as it uses $2.10/ton for the value of avoided lost fertility and $4.93/ton for the value of off-site water quality benefits (both of which are values from the peer-reviewed literature). The long-term analysis and graphical displays offer useful analyses and techniques to communicate the benefits of consistent use of cover crops in a rotation helping to answer critical questions (i.e., Will cover crops be profitable and affordable?).

Although the tool was last updated in 2018, because there are no datasets that the tool is referencing and it relies on user inputs, users are able to update prices and yield information themselves and the default scenarios can be edited.

The tool has not been published in a peer-reviewed journal, but it was reviewed and tested by over 20 individuals within and outside USDA (including the Agricultural Research Service and the Economic Research Service), including both academic reviewers and practitioners (B. Kirwan, personal communication, 9/21/20).

E. WHO'S USING THIS TOOL?

There is no information about projects using the NRCS Cover Crops tool on the tool's websites, and the tool developers said they have not kept track of which projects have used their tool. The tool developers do report helping many NRCS and Soil and Water Conservation District (SWCD) employees use the tool over the years, and they provide regularly scheduled as well as adhoc presentations on the tool. They have consulted with university researchers and non-profits about the tool's ability to estimate cover crop benefits and costs (L. Cartwright and B. Kirwan, personal communication, 9/2/20).

Cartwright has used the Cover Crops Tool to produce five one-page economic case studies of Missouri farmers, which are found on the following Missouri NRCS Soil Health webpage: nrcs.usda.gov/wps/portal/nrcs/mo/soils/health/nrcseprd352825. The case studies feature farmers who had begun adopting cover crops at least within five years of Cartwright's interviews with them, and thus the short-term economic analysis is retrospective while the long-term analysis is predictive.

Highlights of the first two of those case studies include:

- **Case Study 1**. A corn-soybean farmer in Missouri added winter cover crops to his rotation to reduce erosion and improve soil health. Using the Cover Crops Economics Tool, Cartwright found that although the total costs for adding a cereal rye cover crop before soybeans and before corn was $27.50/acre each time, the short-term rotation net benefit of $4.13/ac was realized thanks to a 25% reduction in herbicide cost, soybean yield increases, and reduced erosion. The projected long-term benefits of continued cover crop use was $23.50/acre, reflecting potential improvements to soil fertility and water storage benefits. When the short- and long-term results were combined, a net benefit for the rotation was $51.23/acre for years 21 to 30. See the 2018 case study for more details: nrcs.usda.gov/wps/portal/nrcs/mo/soils/health/nrcseprd352825.
- **Case Study 2**. Another corn-soybean farmer added a cover crop mix to portions of his corn land to help with erosion and provide an additional forage source for his beef cows. Using the Cover Crops Economics Tool, Cartwright found that although the cover crop mix cost $49/acre in total costs, and the producer had to invest in about $120/acre in fencing and watering facilities to be able to graze the cover crops, the operation net income increased by $109.76/acre starting in year 2. The long-term analysis projects that with increased soil fertility (20 lbs/acre of plant available N) and water storage ($8/ac avoided yield reduction due to drought), there is a $19/ac/yr. total long-term benefit potential. And when the short-term and long-term results are combined, Cartwright estimates a $164.76/acre rotation net benefit in years 21 to 30. See the 2015 case study for the bar graph displaying the long-term net benefits each year over 30 years (nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd410233.pdf).

F. SUPPORTING INFORMATION

To download the Excel-based tool, users can scroll down to the Crops/Hay section on the main NRCS Economic Tools website to find the Cover Crops Tool listed third: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/econ/tools. Users can more easily access the tool on both the Missouri NRCS Soil Health websites (nrcs.usda.gov/wps/portal/nrcs/mo/soils/health) and the Illinois NRCS Soil Health websites (nrcs.usda.gov/wps/portal/nrcs/il/soils/health). On these two state NRCS websites, users can access two training videos (20 minute and one hour) and a one-page factsheet describing the tool. Contact information is provided for the two tool developers: Lauren Cartwright, State Economist, USDA/NRCS-Missouri (lauren.cartwright@mo.usda.gov) and Bryon Kirwan, State Economist USDA/NRCS-Illinois (bryon.kirwan@il.usda.gov).

13. Retrospective-Soil Health Economic Calculator (R-SHEC) Tool

A. ABOUT THE TOOL

The R-SHEC tool was designed by AFT for a 2018 USDA Conservation Innovation Grant project. AFT's Project Economist, Florence Swartz (former NRCS New York State Economist), and AFT's Water Initiative Director Michelle Perez developed the 12-tab Excel spreadsheet tool and corresponding 20-page Word-based questionnaire to conduct retrospective partial budget analyses of the economic effects associated with soil health practices already adopted by farmers.

When developing the R-SHEC tool, AFT benefited from discussion and guidance from the developers of the NRCS Cover Crops Economics Tool and accompanying questionnaire, and largely based the R-SHEC tool and questionnaire on those resources. The tool is free and available for use by farmers and conservationists for evaluating row crop farms, farms with diversified row crop rotations, and for almond orchards. The tool can be used to assess the economic costs and benefits of soil health practices adopted on one field, a defined study area comprising a crop rotation occurring across multiple fields where the practices were adopted, or a whole farm operation (that adopted practices across all acres).

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

For row crop and diversified production systems, the R-SHEC tool offers analysis of the following soil health practices: no-till or reduced till, cover crops, nutrient management, and conservation crop rotation. For almond production, the tool analyzes the following soil health practices: conservation cover (or planted cover crops), nutrient management, mulching, and compost application.

The R-SHEC tool is comprised of 12 tabs:

1. Read Me (instructions and data sources);
2. Farm Info (to enter in crop rotation and estimate learning costs);
3. Tillage (where tillage machinery changes are entered and the effects from the tillage change on machinery cost, yield, nutrients, pesticide use, decreased erosion, and other benefits and costs are analyzed);
4. Cover Crops (where cover crop costs are analyzed along with effects from the cover crops on yield, nutrients, pesticides, erosion, etc.);
5. Nutrient Management (similar analytical approach to tillage);
6. Conservation Crop Rotation (where changes to income and other effects due to modifying the rotation are analyzed);
7. Combined Practice Effects (this tab is used when benefits or costs cannot be attributed to a single soil health practice);
8. Partial Budget Analysis (PBA) (pulls information from each practice tab and calculates net returns per acre and for the entire study area);
9. Editable PBA (to prepare a presentation-ready table with accurate footnotes);
10. Prices (e.g., 2019 national average crop prices from NASS from February 2020, fertilizer prices from Iowa State 2020, etc.);
11. Machinery Costs (machinery costs from the 2019 Farmdoc list from University of Illinois); and
12. Lists (for the tool's dropdown menus).

The R-SHEC Questionnaire can be used to interview the farmer in advance of data entry into the tool, although interviewing can be done directly using the tool, as well.

C. WHICH OUTCOMES ARE QUANTIFIED?

The R-SHEC tool generates a partial budget analysis table displaying the economic benefits (comprising increases in income or decreases in cost) on the left hand side and the economic costs (either decreases in income or increases in cost) associated with adopting the soil health practices on the right hand side. The annual net change in income is displayed at the bottom of the table along with the estimated return on investment or ROI.

The tool also allows for valuing the avoided loss of nitrogen and phosphorus present in the soil, in 2019 dollars, due to reduced soil loss.

The types of economic outcomes estimated by the tool will depend on the experiences reported by the farmer who has adopted the soil health practices. Thus, the questionnaire and the tool aim to be as comprehensive

LANCE CHEUNG/USDA

as possible with both specific and open-end questions about what costs were incurred and what economic benefits materialized in response to use of the soil health practice(s).

The tool does not have a GIS mapping feature.

D. TOOL STRENGTHS AND LIMITATIONS

One strength is that the R-SHEC tool can analyze the economic effects of a single or multiple soil health practices used in combination by the farmer. The tool also enables production of a compelling and easy-to-interpret partial budget analysis table. The tool provides guidance on how to change the text in the PBA table to provide even more specific and quantitative information and on how to write accurate footnotes to accompany the PBA table. Another benefit is the option to include economic costs and benefits of grazing or haying cover crops in the partial budget analysis. In addition, the tool allows for organic and non-organic crop production options.

Although the tool does allow for the analysis of financial assistance the farmer may have received for adopting soil health practices, that information is excluded from the PBA analysis because cost-share payments are not an economic effect of the soil health practices.

The existing tool provides machinery cost and crop price data for 2019. All the datasets can be updated or changed by the user by unlocking the Prices and Machinery Costs tabs in the workbook.

One limitation of the tool is the volume of data needed from the farmer, which may involve a one to 1.5-hour interview for completion of the 20-page questionnaire in advance of the conservationist entering data into the tool. Conservationists may opt to conduct the interview using the tool directly, although that approach has not been tested.

Although the R-SHEC tool has not yet been featured in a peer-reviewed journal article, the tool and the questionnaire have been reviewed by the developers of the NRCS Cover Crops Economics Tool, six economists and five soil health specialists at USDA and three economists at land grant universities (Cornell, Ohio State University, and University of Illinois) during the external review of the eight soil health case studies (discussed below).

E. WHO'S USING THIS TOOL?

AFT has used the tool to produce eight partial budget analyses of the economic effects of soil health practices adopted by farmers in four states (California almonds, Illinois and Ohio corn-soybeans, and New York diversified systems), which are available here: farmlandinfo.org/publications/soil-health-case-studies.

Highlights of one of the almond case studies and one of the row crop case studies include:

- **Tom Rogers, California almonds.** AFT case study author Paul Lum used the R-SHEC tool and questionnaire to interview Tom Rogers about the adoption of nutrient management, conservation cover, mulching, and compost application in his orchard to improve tree and soil health. Lum found that the soil health practices cost Rogers $31,337 each year or about $179/acre on this 175-acre orchard. However, the various benefits attributed to the practices (including increased almond yield) come to $204,862 or about $1,170/acre. Thus, the annual change in total net income was $173,345 or about $991/acre, providing a 553% return on investment in the soil health practices. See the Rogers case study for more details.
- **Dane Lane, Ohio corn-soybeans**. AFT case study author Brian Brandt used the R-SHEC tool and questionnaire to interview Dane Lane about his adoption of strip-till, nutrient management, and cover crops into his corn-soybean 1,830-acre operation. Lane reported a 40 bu/acre increase in corn yield due to his soil health practices and machinery cost savings from strip-till. These benefits more than offset his increased fertilizer costs, cover crop costs, and soil health learning costs. AFT estimates that Lane experiences an annual change in total net income of $102,366 or $56/acre and a 142% return on investment. See the Lane case study for more details.

In addition to the individual farmer economic outcomes in each case study, AFT's project website (farmland.org/soil-health-case-studies-findings) provides overarching, summary findings. For example:

- **Net income benefits:** The six field crop farms had an average increase of $41 per acre per year in net income while the two almond growers had an increase of $824 per acre in annual net income attributable to adoption of soil health practices.
- **Return on investment:** The ROI for the eight farmers ranged from 35% to 553%. The average ROI was 207%, which means that on average, the study participants received over three dollars back for every dollar they invested in soil health.

Additional available summary findings include changes in fertilizer costs, machinery/fuel/labor costs, pesticide usage, and learning costs.

The Oklahoma Conservation Commission has launched a project that will use the R-SHEC tool to develop four soil health economic and environmental case studies featuring successful farmers in four agro-ecoregions of their state.

At this time, AFT does not know if the R-SHEC tool has helped project managers increase adoption of soil health practices.

F. SUPPORTING INFORMATION

The R-SHEC tool and questionnaire for analyzing the economic effects of soil health practices already adopted by row crop farmers is available to the general public via the AFT project website (farmland.org/project/quantifying-economic-and-environmental-benefits-of-soil-health) along with recorded training videos on (a) how to use the R-SHEC tool, (b) how to use USDA's NTT and COMET-Farm Tools to quantify the water quality and climate benefits of already adopted soil health practices, and (c) how to produce two-page economic and environmental case studies. Project managers interested in using the R-SHEC tool to estimate the economic effects of already soil health successful farmers in their project area can gain immediate access to the tool upon completion of a short form asking for basic contact information. For more information, contact: Michelle Perez (mperez@farmland.org).

Note that AFT has developed a new tool, called the "Prospective Soil Health Economic Calculator (P-SHEC) Tool, to serve as a "what if" soil health conservation planning scenario tool for conservationists to use with farmers who have not yet adopted soil health practices. The P-SHEC tool shares the same 12 tabs as the R-SHEC tool for the short-term analysis but adds one additional analytical tab and six additional data tabs to conduct a long-term economic analysis. The P-SHEC tool is being tested by AFT staff with farmers in four states and will be released in 2021. In addition, both spreadsheet tools will transition to web-based tools in 2021.

14. The Cropping Systems Calculator

A. ABOUT THE TOOL

The Land Stewardship Project developed the Cropping Systems Calculator to encourage crop and livestock farmers located within the Chippewa 10% Project (Chippewa River Watershed, Minnesota) to evaluate the costs and benefits of planting and grazing continuous living cover as a way to lower water pollution levels. The tool helps answer farmer questions such as, "How much will diversifying my farm's rotation cost?" The tool is an Excel-based spreadsheet that has two-tabs to begin with and an additional two tabs that pop-up once users proceed through the tool. The tool was initially developed for crop and livestock farmers in 10 counties that comprise the Chippewa's watershed in west-central Minnesota, but it can now be used in an additional nine counties in southeastern Minnesota as well as northeastern, southern, and central Illinois counties. The tool is publicly available, and free to use.

B. SITE-SPECIFIC INPUTS AND BMP ANALYSIS OPTIONS

Users are given the opportunity to download a Minnesota- or an Illinois-specific version of the Cropping Systems Calculator, as well as a version for Apple computers. The Minnesota and Illinois version of the tool has two tabs, Tool Introduction and Rotation Summary. But when the Soil Erosion Calculator button is clicked within the Rotation Summary, a third tab will appear.

The tool allows users to compare their existing crop rotation, e.g., corn-soybeans, to a new cropping plan comprised of one or more rotations of perennial crops. Users begin by identifying their location. Farmers and conservationists in Minnesota have three choices: Chippewa, Southeastern MN, and Organic-Southeastern MN, while users in Illinois also have three choices: Southern, Central, Northern.

Regarding conservation practices, the tool primarily evaluates diversification of crop rotation, changes from row crop to perennial crops, adding cover crops, and adding grazing. One example demonstrated an analysis comparing a two-year corn-soybeans crop rotation to a six-year rotation that includes Y1–corn and late season cover crop, Y2–soybeans, Y3–spring wheat and alfalfa, Y4–alfalfa, Y5–alfalfa, and Y6–alfalfa and grazing.

Additional grazing details become available for analysis and customization on additional tabs when grazing is selected in the crop rotation section of the Rotation Summary tab. Grazing options include continuous grazing, basic rotational, managed intensive, and mob grazing.

The tool also can be further manipulated by the user to reflect changes experienced, such as during the switch to no-till planting, reduced labor costs for rock-picking and maintenance and fuel costs associated with the equipment needed for a tillage system (R. Moore, personal communication, 10/12/20).

Default values for crop-specific costs as well as overhead costs of the farm operation are provided by the FINBIN database (finbin.umn.edu) from the University of Minnesota for the regions specified. There are also organic and non-organic versions available.

C. WHICH OUTCOMES ARE QUANTIFIED?

The Cropping Systems Calculator tool provides tabular results for the average yearly costs and returns on a per-acre and total basis to compare the original crop rotation to the alternative crop rotation. In addition, a year-by- year financial analysis on a per acre basis is provided for all six years comparing the original crop plan to the new crop plan. Finally, annual tables comparing the costs and returns is provided for each of the six years of analysis.

The Soil Erosion Calculator component of the Cropping Systems Tool offers a soil erosion by water analysis based on RUSLE. Users input the original crop, new crop plans, and corresponding tillage methods into the Soil Erosion tab. Next, farm location and county, plus Slope Length (ft) and Slope Percent are needed to estimate the Length/Slope Factor. The K Factor is identified using a provided map. The P Factor is estimated from three Planting Directions (up and down slope, cross slope, and contour). The average yearly soil erosion on a per acre and total basis for the original and the new crop is provided along with a percent difference. The number of truckloads is also provided. Another table provides the year-by-year soil erosion estimate (also in tons/acre) and truckloads. Finally, the amount of nutrients lost through soil erosion by water in pounds is provided for carbon, nitrogen, phosphorus, and sulfur.

D. TOOL STRENGTHS AND LIMITATIONS

The strength of the Cropping System Calculator tool is that it provides default values from the FINBIN database options while also allowing for customization, thus enabling users who are unfamiliar with the costs associated with alternative cropping systems to conduct these assessments. Furthermore, it provides a sample 10-page results document showing a six-year analysis of multiple cropping, cover crop, and grazing rotation in comparison to a two-year corn soybean rotation, which helps to demonstrate to potential users of the tool its analytical abilities.

The limitation is that the tool is only available for use in portions of Minnesota and Illinois. The data supporting the tool is in hidden worksheets, which make it difficult to fully understand how the tool works. The tool is on version three and was last updated in May 2018 for both Minnesota and Illinois. Thus, analysis using the tool conducted after 2018 will reflect 2017 and earlier datasets. Users who want to input more recent datasets can contact LSP to request the password to open and edit the hidden data sheets.

Although the tool has not appeared in a peer-reviewed journal, it has been reviewed by several partners. Rebecca Wasserman-Olin developed this tool in collaboration with George Boody of the Land Stewardship Project (LSP) and Dr. John Westra (currently at Iowa State University). LSP shared the tool with Dr. William Lazarus, University of Minnesota, who compared the soil erosion estimates favorably to his use of RUSLE2 in southeast Minnesota. And Marcia DeLonge of Union of Concerned Scientists has collaborated with LSP to use the tool to generate economic evaluations for a report on the beef industry.

E. WHO'S USING THIS TOOL?

Robin Moore, one of the tool developers, uses the tool in personal interactions with farmers and landowners to help them assess how a change in cropping system practices may affect them financially. LSP's Farm Beginnings department has also offered the tool during their Beginning Farmer Training.

Moore recounted three stories of how her use of the Cropping Systems Calculator tool with farmers did help them adopt farm conservation practices (personal communication, 10/12/20). In collaboration with Moore to input data into the tool together, one farmer

DIEGO CERVO/STOCKPHOTO

determined that it was profitable to reduce his annual corn soybean acres and increase his perennial alfalfa acres from 10% to 20% annually. Using the tool enabled him to realize how to take advantage of the labor redundancy occurring on his farm in order to be able to plant more hay.

Another farmer used the tool with Moore and realized how much money he was losing on a poorly performing soybean field. The tool helped him pencil out the transition costs for putting up a fence to begin planting and grazing a more profitable perennial grass instead of continuing to plant annual soybeans.

Moore recalls several other farmers, who were on the cusp of grazing more acres, using the tool to review their finances with Moore. Doing so reassured them that they were making the right decision. The changes these farmers made ranged from incorporating cover crops into existing annual rotations or putting fences around croplands to graze corn stalks and cover crops that had been inter-seeded or sown after a small grain crop.

Moore explained that the first two examples were surprise outcomes to the farmers. The third story was an example of individuals using the tool to validate an option they were considering, which gave them confidence to make the change.

Moore is unaware if others outside of LSP have used it, although the tool has been downloaded many times. Because LSP requires users to provide contact information, Moore was able to conduct follow-up phone calls with the tool users and offer support. Moore reports that the majority of persons who have downloaded the tool have primarily been farmers and landowners who have used it themselves to answer financial questions they have about their own farms.

F. SUPPORTING INFORMATION

The Cropping Systems Calculator can be downloaded immediately after providing basic user information (name, organization, location, and a few questions for farmers):landstewardshipproject.org/stewardshipfood/chippewa10croppingsystemscalculator?cms_preview=true. A two-page factsheet describing the tool and recent findings is available (landstewardshipproject.org/repository/1/2529/cropping_calculator_fact_sheet_no_28_april_2018.pdf). In addition, a four-page Introduction document and a four-page documentation summary are available on the tool download page. Contact information is provided for the developer: LSP's Robin Moore at rmoore@landstewardshipproject.org. Project managers that wish to develop their own customized version of the Cropping Systems Calculator for their area should contact LSP to discuss data sources and partnership options.

SHAWN LINEHAN

Conclusion

Reflections on What Tools Are Best Suited for Which Projects

Beyond finding a tool that quantifies the outcomes desired for each project, managers must also choose a tool that is available for their location; fits the desired scale of outcomes estimation and level of specificity needed for their project; aligns with the capabilities of their staff; and meets project budgetary constraints. We hope the questions in Figure 9 and on pages 24–25 help project managers clarify their objectives, goals, scale, and capacity. Additionally, we hope Figure 11 and Table 3 assist project managers in their search for a tool that satisfies their outcome quantification needs.

Field-scale projects that want to provide **field- or farm-specific outcomes** estimates for individual farmers that have staff, and participating farmers who can spend the time collecting and inputting farmer-specific production and conservation information, should consider the Nutrient Tracking Tool for water quality or COMET-Farm or Fieldprint Platform for greenhouse gas outcomes quantification. If projects lack access to farmers to interview—or minimizing staff and farmer time is important and generalized estimates at larger than the field scale will suffice—then using COMET-Planner, STEPL (with its locations set to reflect fields), PTMApp-Web (currently limited to Minnesota and North Dakota), and FieldDoc (currently limited to the Chesapeake Bay, Delaware River Valley, and Western Pennsylvania and Virginia) will better suit your project needs.

Projects that are interested in conducting **watershed-specific analysis** of their project's water quality outcomes need tools that reflect both agricultural and non-farm sources of pollution loads. Model My Watershed and STEPL are both free and available nationally, and neither require significant staff time or farmer involvement. CAST also fits these parameters, and watersheds as small as a HUC12 or as large as a land-river segment can be used, but it is limited to Chesapeake Bay states. FieldDoc also integrates non-farm sources of pollution but is also regionally limited. Lastly, Model My Watershed also provides geographic targeting capabilities that can help increase project effectiveness by focusing resources towards areas of disproportionally high nutrient or sediment load.

Project managers who want to estimate **project-scale outcomes**, have limited time, capacity, and budget

but nevertheless want a reasonable, albeit generalized estimate can

- Use COMET-Planner for project-scale GHG outcomes;
- Use STEPL for water quality outcomes;
- Follow Indiana's example by supporting their own version of the Region 5 tool to aggregate water quality outcomes from projects to attain a state-level estimate of outcomes;
- Use STEPL, PTMApp-Web, FieldDoc, or Fieldprint Platform to provide both project-scale and field-scale analysis; or
- Follow the methods to evaluate water quality and climate outcomes in the S.T.A.R. report.

Managers of all projects can also peruse the SIPES Handbook to develop a social outcomes evaluation framework to discover how effective their project's interventions are at increasing awareness, improving attitudes, and persuading farmers to adopt the priority practices. Project managers can watch the SIDMA tool training videos to decide if they would like to use that tool or to use free survey software from Google Forms or Microsoft Forms to develop their survey instruments.

Projects wishing to evaluate individual farmer economic outcomes from practices already implemented can use the R-SHEC tool, while those wishing to run individual "what if" scenarios to estimate the potential future economic impacts of practices can run the Cover Crops Tool or the Cropping Systems Calculator. Unfortunately, none of those economic tools are currently set up to be project-level evaluation tools.

Reflections on the Trade-offs Required When Choosing and Using a Tool

This guide presents a wide array of tools available for project managers to choose from for outcomes quantification, and yet there are many trade-offs to be considered when making the decision. Choosing the tool that best meets project needs may result in missing out on attractive features offered by other tools. For instance, if farmer-specific outcomes estimation is valued by the project but the field-specific data necessary for NTT and COMET is unavailable, such as historical production and current management information, project leaders are limited to tools that provide generalized outcomes estimation at the field-scale, such as the Region 5 tool, or provide generalized estimates of climate outcomes at the county-scale, such as COMET-Planner. However, if field-specific data is available and project managers and the farmers being interviewed value field-specific outcomes analysis, they should plan for ample time to collect

USDA NRCS

data from their project farmers and input data into the chosen tool.

Additionally, there are other tool features and capability considerations that make choosing a tool a difficult process. Project-scale outcomes quantification is an inherent capability in some tools like FieldDoc (though regionally limited), while others will require external data collection, recording, and summary to prepare the tool before outcomes analysis can begin (e.g. STEPL). And by its very nature, the "back-of-the-envelope" S.T.A.R. method is not a tool and thus, to use it, project staff must be able identify the appropriate watershed or county datasets that their state may or may not provide for the baseline nutrient and sediment loss values in their project area, and then identify the conservation practice reduction efficiency values that are appropriate to their project before performing the calculations themselves. The advantage of the S.T.A.R. method is that it offers a defensible, straightforward estimate of outcomes pertinent to the project, if the datasets and efficiency values are available, and they represent the best-available data for the project area.

Then there are intrinsic tool characteristics, each with its own pros and cons, that are important to consider when choosing the best tool for each project. For example, web-based tools often offer engaging mapping features. For example, NTT, PTMApp-Web, FieldDoc, COMET-Farm, and Fieldprint Platform enable visualization of the field being analyzed. ModelMW and CAST offer visualization of the watersheds being analyzed. Spreadsheet tools (e.g., Region 5, Cover Crop Economics, R-SHEC, and CSC) lack the engaging mapping experience but can offer a simpler and more transparent user experience wherein users can control the datasets underlying the tool. Some tools, like COMET-Planner, offer immediate access and enable outcomes analysis right away, but a generalized, county-level estimation must be satisfactory to the project. Other tools involve more time to set up the numerous underlying datasets (e.g., STEPL) and enter the numerous user inputs required (e.g. NTT and COMET-Farm).

Project managers are faced with this dizzying array of competing tool characteristics making tool selection difficult. Managers must identify and prioritize their project outcomes estimation needs and choose the tool or method that best meets those needs, likely forcing them to forgo some desirable tool features and capabilities.

Reflections on the Status of This Paper's Originating Project

As mentioned at the beginning of this paper, AFT conducted reviews in 2016, 2017, and 2018 to find options for outcomes quantification that would work for our Illinois Upper Macoupin Creek RCPP/MRBI project in 2017. Our project began as an MRBI project in three HUC12 watersheds in 2016 and then expanded to three adjacent watersheds as an RCPP project in 2017. The MRBI and RCPP federal programs enable AFT as the project manager to collaborate with NRCS, SWCD, and ag retailer partners to encourage farmers in the six HUC12 project area to adopt practices with financial support from two funding sources: the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). We provide the following update on our experience to give readers a window into the real-world experiences of one RCPP/MRBI project that may prove helpful to others:

WHAT'S UNDERWAY:

- **In-stream monitoring.** We entered into contract with USGS-IL to establish an upstream-downstream monitoring program to directly monitor results in the stream attributable to practice adoption within our six HUC12 watershed project area. For a description of an upstream-downstream monitoring program, also referred to as the "above-and-below" or "above/below" sampling design, see page 64 in NRCS (2003) and page 92 in EPA (2016a).
- **Geographic targeting.** We entered into contract with Northwater Consulting to develop the Spatial Watershed Assessment Measurement Model (SWAMM) (see Appendix D) to identify fields with disproportionately high nutrient and sediment losses in order to help us prioritize use of EQIP and CSP funds in the project area. The SWAMM model enabled us to develop a nine-element watershed-based plan (that EPA has approved), which was a prerequisite to submitting an EPA 319-watershed implementation proposal.
- **Social indicators evaluation.** We used the SIDMA tool (see page 58) to generate questions and administered those surveys via mail to lists of farmers located both inside and outside of our project area to establish baseline social data. We now track just a handful of social indicator questions via paper-based, one-page exit surveys at the annual UMC farmer winter meetings and

through an annual Macoupin County Farm Service Agency (FSA) spring office visit survey.

- **Back-of-the envelope project-scale outcomes estimation.** AFT currently estimates our RCPP/MRBI's project-level N, P, and sediment outcomes with the back-of-the-envelope approach developed by our Midwest Science Director and detailed in the S.T.A.R. Annual Report's methodology section (see page 47). We first developed this method in 2018 to provide a water quality outcomes estimate of the project because at that time, we were unaware that STEPL could be used to do this for us and we felt that ModelMW was not yet ready for project-scale use in our area. This guide will be shared with the AFT Illinois UMC RCPP/MRBI project managers and together we will explore next steps in our outcomes quantification journey.

WE'RE LOOKING FORWARD TO:

- **Sophisticated field- and project-scale outcomes estimation.** AFT and our partners submitted an EPA 319 grant application in July 2018, to among other things, fund development of a public-facing online interface of the SWAMM model. This interface will transform the model into a user-friendly tool to help us and our conservation partners estimate field- and project-level N, P, and sediment outcomes of conservation practices. And although the approval and funding processes have taken over two years to complete (grant was awarded in November 2019 and funds were released in October 2020), we are eager to move this project forward.
- **Running "what if" scenarios.** Once the SWAMM model becomes a tool, we will use the SWAMM Online Interface with farmers one-on-one or in a group setting to run "what if" conservation planning scenarios with quantitative estimates of nutrient and sediment outcomes, which we hope will inspire farmers and give them the confidence they need to adopt soil health and structural conservation practices.

LESSONS FOR OTHER PROJECTS

- **Early in the project, reach out to NRCS to access practice and farmer contact information.** To use project-scale tools to produce generalized estimates of outcomes associated with certain practices, project managers have to know which practices are being adopted in their projects. To use the field-scale tools to provide site-specific estimates of outcomes associated with practices being adopted by farmers, project managers need contact information for the farmers to request interviews with them to obtain information needed to run the tools, including the location of the NRCS-supported practices.

  In the 2014 and 2018 Farm Bills, Congress laid out expectations that RCPP project managers produce outcomes assessments. In response, the agency developed NRCS RCPP Agreements to uphold the 1619 Confidentiality Provisions of previous Farm Bills, while also allowing RCPP project managers access to the same EQIP and CSP contract information as NRCS staff.

  However, privacy concerns can make sharing producer/landowner information challenging. It can take time to acquire this information, and there remain limits to what information can be easily accessed. Upon becoming a new RCPP project manager in 2017, AFT signed an RCPP Agreement and an additional 1619 Confidentiality Agreement with the agency to gain access to EQIP and CSP contract details within our RCPP/MRBI project. In 2020, we received the farmer contact for each EQIP and CSP contract but had to assemble a good amount of the practice data and location information by reviewing paper copies of case files. As a result, we have not been able to use field-specific tools to estimate our RCPP/MRBI project's water quality (NTT) or climate (COMET-Farm) outcomes, nor have we used the economic tools in this guide because they also rely on an interview with the farmer to obtain field-specific information. And our back-of the-envelope estimates of water quality outcomes so far have been underestimates reflecting only practices supported by EQIP due to lack of practice data for the CSP contracts.

  Other RCPP project leaders should reach out to the RCPP Coordinators that NRCS established in 2019 and 2020 in each state to determine what kind of turn-around they can expect for their requests to obtain farmer contact, practice, and practice location information in order to plan their selection of outcomes quantification tools accordingly.
- **Potential users should contact tool developers to ensure the tool is available.** Tools are not always applicable for use in all project locations. AFT was initially interested in using the EPA Region 5 spreadsheet tool to produce project-scale generalized estimates of outcomes. We discovered

REBECCA DROBIS

Illinois had stopped supporting their version of the tool. We did not discover until 2020 that EPA is promoting the STEPL tool as an improved version of the Region 5 tool.

Other RCPP project managers should be sure to contact the developers of any tool they are interested in using to be sure that the tool is applicable and operating for their project location, and if not to ask what options, if any, may exist.

Reflections on the Rationale for Outcomes Quantification

The vision that outcomes quantification will not only result in conservation practice adoption but will also accelerate it remains largely unproven, due primarily to the limited methodological approach of this paper. In this paper, we focused our attention on the tools and tool developers rather than on projects and the project managers. Most of the tool developers have not been tracking use of their tool by project managers, nor have they been tracking outcomes quantified by their tool or whether use of the tool has resulted in practice adoption. Thus, we remain hopeful that the vision of a self-strengthening cycle where outcomes quantification leads to more farm conservation practice adoption is nevertheless manifesting itself across the landscape.

Only one tool developer said they know that use of their tool resulted in farmers adopting conservation practices: Robin Moore of Land Stewardship Project (LSP) in Minnesota and the Cropping Systems Calculator (CSC) Tool. In this case, Moore is not only a tool developer, but she also uses her tool to explore "what if" conservation economic scenarios with her farmer and landowner clients. Moore recounted three stories in which farmers (a) switched from annual to perennial crops, (b) adopted cover crops, and (c) installed fences around croplands to graze corn stalks and inter-seeded cover crops (see the CSC write-up for more details). According to Moore, "Tools don't work in a vacuum. They work when paired with a relationship with a farmer or landowner, amplifying the power of both" (R. Moore, personal communication, 10/12/20).

USDA

Recommendations

Based on our assessment of the tools and numerous discussions with tool developers and fellow conservationists, we conclude there are 14 key areas that need to be addressed to improve the quantification of outcomes from farm conservation practices and projects. To continue developing and improving outcomes quantification tools and to provide better guidance and training to project managers on how to quantify outcomes, we offer the following recommendations for (1) tool developers, (2) project managers, (3) USDA NRCS, and (4) other federal agencies, the academic community, research and charitable foundations, and supply chain sustainability managers.

Recommendations for Tool Developers

1. **Develop more helpful guidance for project managers so they can easily assess whether the tool is right for their needs**

Tool developers need to make it easier for potential users to understand their tools—what they are designed to do, how they work, what datasets they use, and what data inputs are required of the user, etc. For the tools to be used widely they first must be understood and trusted by non-technical people. The tool developers should take the opportunity to review their websites and their training resources to fine tune and tailor information about their tools specifically for the managers of the thousands of RCPP and other projects, most of whom are not modeling professionals.

The tool developers should make it easy to understand which kind of outcomes quantification services each tool can and cannot provide, at what scale, and what level of specificity, requiring what kind of time and data of both farmers and conservationists. Tool developers should consider providing tool preparation guides so conservationists know what information they will need to collect ahead of time, either from farmers or about the watershed they are working in. Doing so would help project managers be able to develop a realistic budget for outcomes quantification during design of an RCPP or another project. Presenting answers to the questions used in this study in Figure 9 would be a good start.

2. **Develop instructions on how to use existing tools to evaluate project-scale outcomes or develop new tools to do that**

Given the recognition that possibly thousands of RCPP, MRBI, NWQI, and 319, state, local, and corporate project managers want to evaluate their project-scale outcomes, tool developers should develop instructions, with that audience in mind, on how to use their tool for that purpose. This may involve instructions on setting up a methodological framework around the tool like Indiana did to use the Region 5 tool as a state-scale evaluation system. And if the tool is currently not developed to be a project-scale outcomes estimation tool, but with some effort it could become one, the tool developers should pursue creation of that function.

3. **Include a list of projects that have used your tool to quantify outcomes to encourage other projects managers to use your tool**

Most of the websites for the 14 tools we featured in this guide did not provide examples of the projects that used their tools. At a minimum, we suggest all the tool developers intentionally collaborate with a handful of project managers to feature projects using their tool on the tool websites. Tool developers should strive to provide the following information per project, as available: the outcomes that were quantified (e.g., numbers of pounds of nutrients, tons of sediment, and tons of GHGs reduced) attributable to how many of which kinds of practices adopted by how many farmers covering how many acres, over what period of time. They should also strive to track and report on whether using the tool to quantify outcomes resulted in increased adoption of conservation practices. Furthermore, we suggest the tool developers provide links to the projects that have websites. Making a consistent effort to keep this list updated would do a lot to strengthen credibility of the tool, boost the confidence of other project managers, and inspire those managers to say, "We can do that too."

4. **Continue updating and expanding the geographic accessibility of the tools**

Most of the tools had been updated within the last two years, although a few have not been updated for quite some time. Tool developers should strive to continuously update their tool, provide regular trainings, record training videos and provide user guides, and be responsive to requests for support and/or trouble-shooting to entice the hundreds of RCPP and other project managers to use their tool for various outcomes quantification purposes at various scales.

Tool developers should recognize the opportunity to expand their tool into additional locations to make their outcomes quantification services (and, in some cases, also project planning and geographic targeting services) more accessible to more projects.

5. **Signal to NRCS, EPA, states, the foundation, and the sustainability supply chain communities that you are ready to implement some or all these recommendations to gain the support you need**

Most of the recommendations in this paper will take time and energy by the tool developers, which requires resources. Developers of outcomes quantification tools, models, and methods should signal to all possible sources of financial support in the federal, state, charitable, and private sectors that they are at the ready to tackle these opportunities to make outcomes quantification easier, more efficient, and more accessible for the thousands of RCPP and other project managers.

Recommendations for Project Managers

1. **To set up for success, connect with the tool developer to make sure the tool will work for you, seek training, and request a coaching partnership**

a. Connect with the tool developer

When deciding which tool to use to quantify project outcomes, project managers may be well-served to reach out to the tool developer to ascertain whether the tool is appropriate for their project needs. For example, the managers can confirm whether:

- The tool is appropriate for use in the project's location. For tools that are GIS-based (i.e., offer mapping features), the managers should confirm whether the tool has been sufficiently calibrated for use in their state, county, or project watershed. If not, managers should ask when the tool might be ready for use, and if the project manager may be able to assist in calibration activities with the developer.
- The tool is appropriate for use the way the project manager wants to use the tool. For example, many tools are designed to run "what if" scenarios that predict possible future outcome estimates. But, with the right guidance (and possibly additional materials and training) from the tool developers, a tool might be able to conduct a retrospective outcomes analysis too.

b. Seek training on use of the tool to set up for success

To improve the likelihood that the tool will be used correctly, project managers should seek out all available training from the tool developers. Many tools have excellent recorded videos (that range from a couple of minutes to more than an hour) as well as user manuals and Frequently Asked Questions (FAQ) documents that should be reviewed before beginning. In addition, some tool developers provide regularly scheduled training webinars (e.g., COMET-Farm) while others are very responsive to requests for a training webinar (e.g., NTT).

c. Request a coaching partnership with the tool developer

To increase the likelihood of accurate data entry and results interpretation, project managers should seek a coaching-styled partnership with the tool developers. Many project managers may benefit from one-on-one, back-and-forth conversations with the tool developers about their project needs. This coaching-styled partnership can provide some project managers with the "hand-holding" they may want for support at the beginning, middle, and end stages of the outcomes quantification effort. A coaching partnership could include:

- Training on use of the tool;
- Troubleshooting as the tools may freeze or return error messages;
- Providing reviews of the data entry (e.g., to ensure practice activities are recognized by the tool when they were actually conducted by the farmer);
- Providing reviews of the results interpretation to ensure that the conclusions the project managers draw are actually what the results tables and/or graphs are indicating.

2. If you cannot use existing tools, consider back-of-the envelope and other simple methods to estimate water quality and social outcomes

Some RCPP and other project managers may not have the staff capacity to use many of the tools described in this report or have insufficient access to farmer information to be able to do so. But all project managers want to be able to generate a defensible estimate of their project-level outcomes. At the moment, coarse but reasonable and transparent methods for estimating a project's water quality and climate outcomes are described in what we are referring to as "the S.T.A.R. Method." And simple, free survey software is available from Google Forms and Microsoft Forms for developing the key social indicator questions suggested by the SIPES Method to track progress towards a project's social outcomes. While more sophisticated tools can offer assistance and ease of use, sometimes "simple" meets project needs.

3. Signal to NRCS, EPA, states, the foundation, and the sustainability supply chain communities that you need more guidance and support to quantify outcomes and want access to tools that are not yet operating in your area

We hope that project managers that have wanted to quantify outcomes but have not had the wherewithal to do so find this guide useful to identify a tool or a method that will fit their needs. Project managers that want the recommendations in this paper to become a reality are encouraged to stand up and be counted in support of their priority recommendation(s) by reaching out to AFT (email us at OutcomesTools@farmland.org) so we can know what your needs are.

Project managers should tackle their priority next steps on outcomes quantification efforts by pursuing problem-solving conversations with an institution that best aligns with their needs, e.g., state RCPP Coordinator and/or RCPP headquarters, EPA 319 state office and/or EPA headquarters, state agricultural and environmental agencies, research and charitable foundations, and private sector leaders.

Project managers that are interested in using tools that are not yet operating in their area should let those tool developers know of their interest and plan next steps. PTMApp-Web and FieldDoc are two map-based tools that offer both field- and project-scale outcomes quantification but also offer project planning services. PTMApp-Web also enables geographic targeting. FieldDoc facilitates project reporting. Currently, they are confined to Minnesota and North Dakota (PTMApp-Web) and to the Chesapeake Bay and Delaware River Watersheds (FieldDoc). Project managers should dialogue with the tool developers to explore what it will take to expand such tools to their project location, over what time frame, and begin next steps.

Recommendations for USDA NRCS

1. Develop an outcomes quantification handbook for RCPP and other project managers to use to guide estimation of project outcomes

Akin to the 2003 NRCS Water Quality Monitoring Handbook (See Appendix B), NRCS should consider developing a handbook on methods and tools to estimate outcomes through modeling and estimation techniques. NRCS should not feel they have to do this alone but can reach out to the water quality, climate, social, and economic outcomes measurement and estimation leaders in the conservation community–in particular, the academic community, the modeling and consulting sectors, other federal and state agencies, and farm and environmental groups. In the interim, we encourage NRCS to consider disseminating this guide as a resource to RCPP, MRBI, NWQI, and other project managers.

2. Facilitate social outcomes training and coaching

The agency should consider making the SIPES methods and SIDMA tool training a normal offering during the proposal stages of RCPP and other USDA conservation programs (e.g., MRBI, NWQI, GLRI, Sage Grouse, etc.). Doing so will educate and empower the RCPP and other project managers to know the options and opportunities available to them to achieve their practice adoption and environmental outcome goals through establishment and tracking of social outcome goals and indicators. By providing this education opportunity during the project development and application stage, the project managers will be able to determine if they have the expertise "in house" or they will need to partner or contract with others to lead this effort.

NRCS should also consider hosting regular webinars with the developers of the SIPES methods and SIDMA tool to provide continuous education to project managers at various stages of their project. NRCS could go even further and support the social sciences academic community to provide continuous trouble shooting and coaching services to the RCPP and other project managers at any stage of their project. In so doing, project managers may be able to incorporate social outcomes goals and indicator tracking methods into their projects. This may enable the managers to continuously evaluate and adaptively manage their outreach and education activities. In turn, this may increase the likelihood of achieving project practice and environmental outcome goals.

3. Facilitate frequent and on-going training on existing outcomes estimation tools and offer coaching

Currently, there are thousands of conservation projects occurring in the United States involving tens of thousands of farmers, managing millions of acres.

Though difficult to tell, the majority of these projects are likely not quantifying their environmental outcomes let alone their social and economic outcomes. NRCS should take the opportunity each year to make the new crop of project managers aware of the outcomes quantification methods and tools available to them. In addition, existing project managers should be given the opportunity to take on these additional activities to strengthen their projects. By organizing regularly scheduled trainings for the RCPP and other project managers to hear presentations by the developers of the 14 tools and two methods featured in this guide (and by other tools and methods experts), NRCS could dramatically advance the quantification of outcomes achieved by agency-supported conservation projects.

On the other side of the coin, by increasing demand for trainings on options for quantifying environmental, social, and economic outcomes, NRCS will be stimulating the supply of these trainings and encouraging the developers of methods and tools to update and refine their offerings. For example, the SIPES report published in 2011 is the third edition and there may be added value in a fourth edition. The NRCS's "National Water Quality Handbook" that provides water quality monitoring guidance for farm conservation projects was published in 2003 and may similarly benefit from an update.

Recommendations for Congress, USDA, EPA, the States, Academics, Foundations, and Supply Chain Sustainability Leaders

1. Support the tool developers and tool users to implement the activities recommended in this paper

This paper offers many recommendations for tool developers to improve their tools and associated supporting materials. And for some developers, there are recommendations to expand their tools into additional geographies. There are many recommendations for project managers to take the next steps on their outcomes quantification journey, and recommendations for NRCS to further aid managers of RCPP and other projects on that journey.

EVGENIIAND/ISTOCKPHOTO

Making progress on all these fronts will take time and resources. Federal and state agricultural and environmental agencies, academic experts, research and charitable foundations, and the private sector leaders should do their part to tackle these recommendations and help the conservation community make progress on the outcomes quantification front. Many of these institutions could provide funding support for the many recommendations in this paper. And some of the institutions could foster multi-stakeholder discussions to, among other things, provide an avenue for tool users to share project needs and tool capability "wish lists" and for tool developers to collaborate with groups of "real-life" users of their tools. These discussions could lead to the development of new features or even new tools that better serve the outcomes quantification needs of project managers.

One multi-stakeholder discussion already underway is occurring within the Gulf of Mexico's Hypoxia Task Force (HTF). Led by USDA and EPA, in collaboration with states and tribes, the HTF is considering asking states to report on social and economic indicators as part of their efforts to track progress towards their state nutrient reduction strategies. Should this occur, and if the desired social and economic evaluations are to be conducted at the project-scale, then the government, academic, and foundation communities will need to provide the resources, tools, methods, and materials to the thousands of farm conservation project managers who may be asked to carry out this important and useful work.

2. Support additional research and assessments of tools and methods for measuring outcomes beyond this initial assessment

Given this guide offers a preliminary assessment of tools and methods that may be useful to project managers, it is based on limited research and conducted by non-modelers. Further research and assessments of tools and methods for quantifying outcomes of farm conservation efforts is needed and can build off this initial assessment.

During the internal and external review of this paper we received suggestions for future iterations of this

study or additional analyses (by AFT or others) including:

- Providing images of the outcomes quantification results table and/or graphs provided by the tools;
- Providing the workflow on a step-by-step basis for using each tool from start to finish;
- Providing more of an in-depth analysis and discussion of issues such as accuracy, field versus site-specificity, confidence intervals, and other challenging outcomes quantification topics;
- Conducting a mock field-scale and a mock project-scale analysis to compare results across the different water quality tools and method, across the three climate tools, and across the three economic tools (including discussions of why readers should or should not expect results to be similar);
- Conducting surveys and interviews with RCPP and other project managers to compile and feature the outcomes they have already estimated from the adoption of conservation practices in their projects so far; and
- Conducting interviews with RCPP and other project managers to learn what resources and materials they would like to support their outcomes quantification journey.

3. Establish a nationwide dataset for calibrating and validating outcomes quantification tools

Tools are only as good as the data they are based on. Tools that provide mapping features and/or site-specific outcomes estimates continually need calibration data to improve their accuracy for use in more crop production systems, agroecoregions, and states. The calibration data necessary for improving the location-specific datasets used by many of these tools is only as good as the field-scale research studies that are monitoring the effects of conservation practices on agricultural fields. Many sectors and institutions could be helpful here to provide technical direction and/or financial resources, including:

- Congress (e.g., the House and Senate Agriculture Committees);
- The research agencies, programs, and grant-making bodies of the USDA and EPA (e.g., ARS, ERS, CIG, CEAP, NIFA, SARE, etc.);
- State departments of agriculture and environment;
- The land grant university academic community;
- The agricultural foundations (e.g., Foundation for Food and Agricultural Research, the Nobel Research Institute, etc.);
- The charitable foundations (e.g., Walton Family Foundation and The Mosaic Company Foundation, etc.); and
- The supply chain sustainability leaders (e.g., Campbell Soup Company, Danone, General Mills, Kellogg's, PepsiCo, Unilever, etc).

These institutions could help develop and/or fund a comprehensive research program, in concert with the tool developers, to establish a nationwide set of data that can serve to continually calibrate and validate the outcomes quantification models and tools estimating the effects of conservation practices on the environment. Doing so would lend even greater credibility of the tools to conservationists, their farmer clients, and the public.

EDWIN REMSBERG AND USDA-SARE

References

American Farmland Trust. (2019). *Four Soil Health Case Studies; Okuye Farms, Rogers Farm, Thorndyke Farms, Ifft Yorkshires Farms*. American Farmland Trust and USDA NRCS. farmlandinfo.org/publications/soil-health-case-studies

American Farmland Trust. (2020). *Four Soil Health Case Studies; Swede Farm LLC, Macauley Farms, MadMax Farms, Homewood Farms*. American Farmland Trust and USDA NRCS. farmlandinfo.org/publications/soil-health-case-studies

Bosch, D., Theurer, F., Bingner, R., Felton, G., & Chaubey, I. (1998). *Evaluation of the AnnAGNPS water quality model.* ASAE Annual International Meeting. researchgate.net/publication/239278728_Evaluation_of_the_AnnAGNPS_water_quality_model

Brown County Land & Water Conservation Department, Outagamie County Land Conservation Department, & Calumet County Land & Water Conservation Department. (2019). *Lower Fox River Mainstem (City of Green Bay–Fox River & Garners Creek-Fox River) Nonpoint Source Watershed Implementation Plan.* outagamie.org/Home/ShowDocument?id=66370

Capalbo, S. M., Seavert, C., Antle, J. M., Way, J., & Houston, L. (2018). Understanding Tradeoffs in the Context of Farm-Scale Impacts: An Application of Decision-Support Tools for Assessing Climate Smart Agriculture. In L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw, & G. Branca (Eds.), *Climate Smart Agriculture: Building Resilience to Climate Change* (pp. 173–197). Springer International Publishing. doi.org/10.1007/978-3-319-61194-5_9

Cartwright, L., & Kirwan, B. (2014). *Cover Crop Economics Tool*. Cover Crop Economics. nrcs.usda.gov/wps/portal/nrcs/mo/soils/health

Chesapeake Bay Program. (2020). *Chesapeake Assessment and Scenario Tool (CAST) Version 2019*. Chesapeake Bay Program Office. cast.chesapeakebay.net/about

Cunningham, W. L., & Schalk, C. W. (2011). *Groundwater Technical Procedures of the U.S. Geological Survey. Techniques and Methods 1–A1*. U.S. Geological Survey. pubs.usgs.gov/tm/1a1/pdf/tm1-a1.pdf

Datu Research. (2017). *The Economics of Cover Crops and No-till, Overview of Four Economic Sudies*. Datu Research and National Association of Conservation Districts. daturesearch.com/upper-mississippi-river-basin

David, M. B., McIsaac, G. F., Schnitkey, G. D., Czapar, G. F., & Mitchell, C. A. (2014). *Science Assessment to Support an Illinois Nutrient Loss Reduction Strategy* (p. 68). University of Illinois at Urbana-Champaign. biogeochemistry.nres.illinois.edu/Biogeochem_lab/Science_documents/Illinois_Science_Assessment_Report_May_6.pdf

Devereux, O., & Rigelman, J. R. (2014). CAST: An Online Tool for Facilitating Local Involvement in Watershed Implementation Plans for the Chesapeake Bay Total Maximum Daily Load. *Journal of Water Management Modeling*. doi.org/10.14796/JWMM.C364

Devia, G. K., Ganasri, B. P., & Dwarakish, G. S. (2015). A Review on Hydrological Models. *Aquatic Procedia, 4*, 1001–1007. hdoi.org/10.1016/j.aqpro.2015.02.126

Dressing, S. A., Meals, D. W., Harcum, J. B., Spooner, J., Stribling, J. B., Richards, R. P., Millard, C. J., Lanberg, S. A., O'Donnell, J. G., North Carolina State University, Raleigh, NC, & Heidelberg University, Tiffin, OH. (2016). *Monitoring and Evaluating Nonpoint Source Watershed Projects, May 2016* (p. 522). United States Environmental Protection Agency Office of Water Nonpoint Source Control Branch Washington, DC 20460 EPA 841-R-16-010. epa.gov/sites/production/files/2016-06/documents/nps_monitoring_guide_may_2016-combined_plain.pdf

Duncan, L.A., Buschermohle, M.J., Velandia, M., & Reed, J. (2014). "Influence of Variable Rate Fertilization and Cover Crops on Cotton Sustainability Using the Field to Market Fieldprint Calculator." In Boyd, S., Huffman, M., & Robertson, B. (Eds.), *2014 Beltwide Cotton Conferences Proceedings,* New Orleans, LA, January 6–8, 2014 (pp. 413–419). Memphis, TN: National Cotton Council of America. Retrieved fromcotton.org/beltwide/proceedings/2005-2020/index.htm

Easton, Z., Scavia, D., Alexander, R., Band, L., Boomer, K., Kleinman, P., Martin, J., Miller, A., Pizzuto, J., Smith, D., & Welty, C. (2017). *Scientific and Technical Advisory Committee Chesapeake Bay Watershed Model Phase 6 Review STAC Review Report. STAC Publication Number 17-007*. chesapeake.org/pubs/379_Easton2017.pdf

Ecosystem Services Market Consortium. (2020). *Master Protocol Assessment Table: Supplement to An Assessment of Protocols, Methodologies, Tools and Approaches to Inform ESMC's Integrated, Tiered Ecosystem Services Market Protocol for Working Agricultural Lands*. ecosystemservicesmarket.org/wp-content/uploads/2020/01/ESMC-Integrated-Matrix-1.28.2020.pdf

Eve, M., Pape, D., Flugge, M., Steele, R., Man, D., Riley, M., & Biggar, S. (2014). *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* (p. 606). USDA. usda.gov/sites/default/files/documents/USDATB1939_07072014.pdf

Fu, B., Merritt, W., Croke, B. F. W., Weber, T., & Jakeman, A. (2019). A review of catchment-scale water quality and erosion models and a synthesis of future prospects. *Environ. Model. Softw., 114*, 75–97. doi.org/10.1016/j.envsoft.2018.12.008

Gale, J. A., Line, D. E., Osmond, D. L., Coffey, S. W., Spooner, J., Arnold, J. A., Hoban, T. J., & Wimberley, R. C. (1993). *Evaluation Of The Experimental Rural Clean Water Program Title*. NSCU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University. Raleigh, NC: U.S. Environmental Protection Agency: EPA-841-R-93-005. farmland.org/GaleEtAl1993

Genskow, K., & Prokopy, L. (2011). *The Social Indicator Planning & Evaluation System (SIPES) for Nonpoint Source Management: A Handbook for Watershed Projects* (3rd ed.). Great Lakes Regional Water Program. iwr.msu.edu/sidma/Info/pdfs/SI_Handbook_v4_02012012.pdf

Goodman, J., Bischoff, J., German, D., Kimball, C. G., United States Department of Agriculture, & United States Farm Service Agency. (1996). *Ground water monitoring: A guide to monitoring for agricultural nonpoint source pollution projects*. Huron, S.D.: U.S. Dept. of Agriculture, Farm Service Agency. archive.org/details/CAT10819301

Gordon, H., & WNTSC Economist. (2013). *Basic Economic Analysis Using T-Charts*. USDA NRCS. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1176611.pdf

Guo, T., Confesor, R., Saleh, A., & King, K. (2020). Crop growth, hydrology, and water quality dynamics in agricultural fields across the Western Lake Erie Basin: Multi-site verification of the Nutrient Tracking Tool (NTT). *Science of The Total Environment, 726*, 138485. doi.org/10.1016/j.scitotenv.2020.138485

Guzman, S., Cossman, R., Ingram, R., Genskow, K., & Davenport, M. (2017). *Social Indicators to Accelerate the Implementation of Nutrient Reduction Strategies Synthesis Report*. h2o.ssrc.msstate.edu/wp-content/uploads/2017/09/SI_Final_Report_9-21-17.pdf

Haag, S., & Shokoufandeh, A. (2019). Development of a data model to facilitate rapid watershed delineation. *Environmental Modelling & Software, 122*, 103973. doi.org/10.1016/j.envsoft.2017.06.009

Harrold, J., & Garner, L. (n.d.). *What is the Region 5 Model and how do you use it?* [Presentation]. Indiana State Department of Agriculture. engineering.purdue.edu/watersheds/webinars/Region5/Region%205%20webinar_final.pdf

Houston Engineering Inc. (2019). *Prioritize, Target, Measure Application (PTMApp) Web User's Guide*. ptmapp.bwsr.state.mn.us/files/PTMApp_Web_User_Guide.pdf

Illinois Corn Growers Association. (2020). *The Business Case for Conservation: Cost-Benefit Analysis of Conservation Practices (2015-2019 Data Summary)*. Precision Conservation Management & Illinois Corn Gowers Association; Personal Communication. .ilcorn.org/file/463/IL%20Corn%20PCM%20Booklet%20hires%20single%20pages_JUNE%2018.pdf

Indiana Conservation Partnership—ICP. (2015). *2014 Middle Eel Creek Nutrient and Sediment Load Reductions*. Indiana State Department of Agriculture. farmlandinfo.org/publications/2014-middle-eel-creek-nutrient-and-sediment-load-reductions

Indiana Conservation Partnership—ICP. (2020). *2019 Accomplishments*. ArcGIS StoryMaps. storymaps.arcgis.com/stories/afec6e0bfc814279997d9cdd2352d656

Institute of Water Research. (n.d.). *Social Indicators—Data Management and Analysis Tool* [Online Tool]. SIDMA. iwr.msu.edu/sidma/Home.aspx

International Labor Office. (2019). The business case for change. *Women in Business and Management*, 132. ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_700953.pdf

Knight, L. (2016). *Developing Conservation Case Studies for Decision-making* (Note No.: TN.200.ECN—4). USDA NRCS. nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1298424&ext=docx

Leadership for Midwestern Watersheds. (2018). *8th Annual Gathering Measuring Progress towards Environmental, Social and Economic Outcomes* [Proceedings]. sandcountyfoundation.org/uploads/LMW-18-Proceedings.pdf

Leadership for Midwestern Watersheds. (2020). *Survey of Watershed Project managers*. Upcoming Publication.

LimnoTech. (2017a). *Approaches for Modeling and Monitoring Water Quality Outcomes for Agricultural Fields*. fieldtomarket.org/ftm_whitepaper_final_august15_2017

Linquist, B.A., Marcos, M., Adviento-Borbe, A., Anders, M., Harrell, D., Linscombe, S., Reba, M.L., Runkle, B.R.K., Tarpley, L., & Thomson, A. (2018). "Greenhouse Gas Emissions and Management Practices that Impact Emissions in US Rice Systems." *Journal of Environmental Quality*, 47(3), 395–409. acsess.onlinelibrary.wiley.com/doi/abs/10.2134/jeq2017.11.0445

Liu, Y., Li, S., Wallace, C. W., Chaubey, I., Flanagan, D. C., Theller, L. O., & Engel, B. A. (2017). Comparison of Computer Models for Estimating Hydrology and Water Quality in an Agricultural Watershed. *Water Resources Management, 31*(11), 3641–3665. doi.org/10.1007/s11269-017-1691-9

Mausbach, M. J., & Dedrick, A. R. (2004). The length we go: Measuring Environmental Benefits of Conservation Practices. *The Journal of Soil and Water Conservation, 59*(5). nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013578.pdf

Meals, D. W., & Osmond, D. L. (2012). *Water Quality Monitoring for the Assessment of Watershed Projects/ NC State Extension Publications*. USDA NRCS. content.ces.ncsu.edu/water-quality-monitoring-for-the-assessment-of-watershed-projects

Monast, M., Sands, L., & Grafton, A. (2018). *Farm finance and conservation: How stewardship generates value for farmers, lenders, insurers and landowners*. Environmental Defense Fund/K-Coe Isom. edf.org/sites/default/files/documents/farm-finance-report.pdf

Moreno-Garcia, B., Suvočarev, K., Reavis, C., & Runkle, B. (2018). *User-friendly Greenhouse Gas calculators to assess water-saving practices in rice fields in Arkansas.* Poster presented at the 100th American Geophysical Union Fall Meeting, Washington, D.C., December 10-14, 2018. Retrieved from researchgate.net/publication/330567546_User-friendly_Greenhouse_Gas_calculators_to_assess_water-saving_practices_in_rice_fields_in_Arkansas

Moriasi, D. N., Duriancik, L. F., Sadler, E. J., Tsegaye, T., Steiner, J. L., Locke, M. A., Strickland, T. C., & Osmond, D. L. (2020). Quantifying the impacts of the Conservation Effects Assessment Project watershed assessments: The first fifteen years. *Journal of Soil and Water Conservation,* 75(3), 57A. doi.org/10.2489/jswc.75.3.57A

Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., Dangour, A. D., & Huybers, P. (2017). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health, 38*(1), 259–277. doi.org/10.1146/annurev-publhealth-031816-044356

Nejadhashemi, A., Woznicki, S., & Douglas-Mankin, K. (2011). Comparison of four models (STEPL, PLOAD, L-THIA, AND SWAT) in simulating sediment, nitrogen, and phosphorus loads and pollutant source areas. *Transactions of the ASABE, 54,* 875–890. doi.org/10.13031/2013.37113

Nelson, A., Moriasi, D., Talebizadeh, M., Tadesse, H., Steiner, J., Gowda, P., & Starks, P. (2019). Comparing the Effects of Inputs for NTT and ArcAPEX Interfaces on Model Outputs and Simulation Performance. *Journal of Water Resource and Protection, 11,* 554–580. doi.org/10.4236/jwarp.2019.115032

Nori LLC. (2020). *Croplands Methodology*. nori.com/resources/documents

Northey, B. (2020). Making conservation count: The importance of assessing resources and documenting outcomes to USDA. *Journal of Soil and Water Conservation,* 75(3) 49A; doi.org/10.2489/jswc.75.3.49A

Osmond, D. L., Meals, D. W., Hoag, D. LK., & Arabi, M. (2012). *How to build better agricultural conservation programs to protect water quality: The National Institute of Food and Agriculture, Conservation Effects Assessment Project experience*. Soil and Water Conservation Society. swcs.org/resources/publications/how-to-build-better-agricultural-conservation-programs-to-protect-water-quality

Park, Y. S., Engel, B., & Harbor, J. (2014). A Web-Based Model to Estimate the Impact of Best Management Practices. *Water*, *6*, 455–471. doi.org/10.3390/w6030455

Paustian, K., Easter, M., Brown, K., Chambers, A., Eve, M., Huber, A., Marx, E., Layer, M., Stermer, M., Sutton, B., Swan, A., Toureene, C., Verlayudhan, S., & Williams, S. (2018). *Field- and farm-scale assessment of soil greenhouse gas mitigation using COMET-Farm* (pp. 341–359). doi.org/10.2134/agronmonogr59.c16

Pennsylvania Department of Environmental Protection. (2019). *Pennsylvania Phase 3 Chesapeake Bay Watershed Implementation Plan*. files.dep.state.pa.us/Water/ChesapeakeBayOffice/WIPIII/FinalPlan/PA_Phase_3_WIP_Final.pdf

Perez, M. (2017). *Water Quality Targeting Success Stories: How to achieve measurably cleaner water through U.S. farm conservation watershed projects*. farmlandinfo.org/publications/water-quality-targeting-success-stories-how-to-achieve-measurably-cleaner-water-through-u-s-farm-conservation-watershed-projects

PRISM Climate Group, & Oregon State University. (n.d.). *PRISM Weather Model* [Web Tool]. PRISM Climate Data. Retrieved October 14, 2020, from prism.oregonstate.edu

Prokopy, L. (2012). *Indiana Watersheds Webinar Series: Social Indicators 101* [Presentation]. Indiana Watershed Leadership Program. engineering.purdue.edu/watersheds/webinars/SocialIndicators

Prokopy, L. S., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., Gramig, B. M., Ranjan, P., & Singh, A. S. (2019). Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation*, *74*(5), 520–534. doi.org/10.2489/jswc.74.5.520

Ranjan, P., Duriancik, L. F., Moriasi, D. N., Carlson, D., Anderson, K., & Prokopy, L. S. (2020). Understanding the use of decision support tools by conservation professionals and their education and training needs: An application of the Reasoned Action Approach. *Journal of Soil and Water Conservation*, *75*(3), 387–399. doi.org/10.2489/jswc.75.3.387

Robertson, B., Free, A., Flanders, A., Daniels, M., Henry, C.G., & Stevens, S. (2017). "Integrating Rye Cover Crop and Reduced Tillage to Improve Soil Health." In Boyd, S., Huffman, M., & Sarkissian, A. (Eds.), *2017 Beltwide Cotton Conferences Proceedings,* Dallas, TX, January 4-6, 2017 (pp.129-130). Memphis, TN: National Cotton Council of America. Retrieved from cotton.org/beltwide/proceedings/2005-2020/index.htm

Saleh, A., Gallego, O., Osei, E., Lal, H., Gross, C., McKinney, S., & Cover, H. (2011). Nutrient Tracking Tool—A user-friendly tool for calculating nutrient reductions for water quality trading. *Journal of Soil and Water Conservation*, *66*(6), 400–410. doi.org/10.2489/jswc.66.6.400

Saleh, Ali, Gallego, O., & Osei, E. (2015). Evaluating Nutrient Tracking Tool and simulated conservation practices. *Journal of Soil and Water Conservation*, *70*(5), 115A–120A. doi.org/10.2489/jswc.70.5.115A

Schnitkey, G., & Gentry, L. (2019a). The Economic Advisability of Lowering 2019 Nitrogen Application Rates on Corn. *Farmdoc Daily*, *9*(48). farmdocdaily.illinois.edu/2019/03/the-economic-advisability-of-lowering-2019-nitrogen-application-rates-on-corn.html

Schnitkey, G., & Gentry, L. (2019b). Tillage Passes and Returns on Corn-Soybean Farms in East-Central Illinois. *Farmdoc Daily*, *9*(53). farmdocdaily.illinois.edu/2019/03/tillage-passes-and-returns-on-corn-soybean-farms-in-east-central-illinois.html

S.T.A.R. (2020). *S.T.A.R. Annual Report. Crop Year 2019. Improving Conservation One Field at a Time.* Saving Tomorrow's Agriculture Resources. img1.wsimg.com/blobby/go/45c3f789-47fb-40df-9bb7-3dc4d7bf6c2f/downloads/Star%20report%20FINAL%202020.pdf?ver=1597671964705

Stroud Water Research Center. (n.d.). *Model My Watershed®*. WikiWatershed. wikiwatershed.org/model

USDA ARS & NRCS. (2008). *Revised Universal Soil Loss Equation Version 2: User's Reference Guide*. ars.usda.gov/ARSUserFiles/60600505/RUSLE/RUSLE2_User_Ref_Guide.pdf

USDA NRCS. (n.d.-a). *COMET-Farm Tool* [Web Tool]. COMET-Farm + Water Quality. comet-farm.com

USDA NRCS. (n.d.-b). *COMET-Planner* [Web Tool]. comet-planner.com

USDA NRCS. (n.d.-c). *Edge of Field Monitoring*. Water. nrcs.usda.gov/wps/portal/nrcs/detail/national/water/quality/tr/?cid=stelprdb1240285

USDA NRCS. (n.d.-d). *River Basin Cropland Modeling Study Reports 2003-2006*. Cropland National Assessment. nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144

USDA NRCS. (n.d.-e). *Synthesis Report: CEAP-NIFA Competitive Grant Watershed Studies|NRCS*. Retrieved September 18, 2020, from nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=stelprdb1047821

USDA NRCS. (2001, 2017). *57 NRCS economic case studies from 14 states and Puerto Rico*. nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/data/?cid=nrcseprd1298423

USDA NRCS. (2003). *National Water Quality Handbook: Water-Life's Most Essential Element*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044775.pdf

USDA NRCS. (2012a). *Edge-of-Field Water Quality Monitoring Data Collection and Evaluation Conservation Activity, Code 201*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097617.pdf

USDA NRCS. (2012b). *Edge-of-Field Water Quality Monitoring System Installation Conservation Activity, Code 202*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097618.pdf

USDA NRCS. (2015). *Soil Survey Geographic Database (SSURGO)* [Data set]. doi.org/10.15482/USDA.ADC/1242479

USDA NRCS. (2019a). *Administration and Status of the Regional Conservation Partnership Program: 2019 Report to Congress*. nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1595617&ext=pdf

USDA NRCS. (2019b). *Mississippi River Basin Healthy Watersheds 2019 Progress Report.* nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/initiatives/?cid=stelprdb1048200

USDA NRCS. (2019c). *National Water Quality Initiative 2019 Progress Report.* nrcs.usda.gov/wps/portal/nrcs/detail/national/water/?cid=stelprdb1047761

USDA NRCS. (2020). *Regional Conservation Partnership Program (RCPP)—Expectations of Partners for Project Outcomes Data and Reporting*. nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1628418&ext=pdf

USDA NRCS & ARS. (2001). *Soil Quality Test Kit Guide*. Soil Quality Institute. nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050956.pdf

USDA NRCS, & Commodity Credit Corporation. (2014). *Announcement for Program Funding for Regional Conservation Partnership Program. Announcement No. USDA-NRCS-NGQ-RCPP for Fiscal Years 2014/2015* (Announcement CFDA Number 10.930; p. 45). nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254644.pdf

USDA NRCS MRBI. (2017). *MRBI Middle Eel Project: Final Project Report*. farmlandinfo.org/publications/middle-eel-project-final-report

USDA NRCS New York. (2016a). *Economic Case Study—Farmer Profile, Dave Magos*. nrcs.usda.gov/wps/portal/nrcs/detail/ny/soils/health/?cid=nrcseprd1298872

USDA NRCS New York. (2016b). *Economic Case Study—Farmer Profile, John Kemmeren*. USDA. nrcs.usda.gov/wps/portal/nrcs/detail/ny/soils/health/?cid=nrcseprd1298853

USDA NRCS Soil Quality Institute. (2001). *Guidelines for Soil Quality Assessment in Conservation Planning*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051259.pdf

USDA Office of Environmental Markets. (n.d.). *The Nutrient Tracking Tool (NTT)* [Web Tool]. Home. oem.usda.gov/nutrient-tracking-tool-ntt

USEPA. (2015). *Success Stories about Restoring Water Bodies Impaired by Nonpoint Source Pollution.* Polluted Runoff: Nonpoint Source (NPS) Pollution. epa.gov/nps/success-stories-about-restoring-water-bodies-impaired-nonpoint-source-pollution

USEPA. (2018). *Nutrient and Sediment Estimation Tools for Watershed Protection. EPA 841-K-18-002*, 20. epa.gov/sites/production/files/2018-08/documents/loadreductionmodels2018.pdf

USEPA. (2020). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; Table ES-7* (p. ES-26:ES-27). EPA 430-R-20-002. epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

USEPA Office of Water. (2016a). *Monitoring and Evaluating Nonpoint Source Watershed Projects*. 522. epa.gov/sites/production/files/2016-06/documents/nps_monitoring_guide_may_2016-combined_plain.pdf

USEPA Office of Water. (2016b). *National Nonpoint Source Program—A catalyst for water quality improvements (A Report on Highlights of the Section 319 Program: The Nonpoint Source Program)* (p. 24). epa.gov/sites/production/files/2016-10/documents/nps_program_highlights_report-508.pdf

Ziegler, J., Easter, M., Swan, A., Brandle, J., Ballesteros, W., Domke, G., Chambers, A., Eve, M., & Paustian, K. (2016). A model for estimating windbreak carbon within COMET-FarmTM. *Agroforestry Systems. 90(5): 875-887.*, *90*(5), 875–887. doi.org/10.1007/s10457-016-9977-0

Appendices

FATCAMERA/ISTOCK

APPENDIX A

Resources and Reviews of Agricultural-Environmental Models and Tools

We reviewed several comprehensive papers describing and comparing outcomes quantification tools during our search for models and tools to include in this guide. Several of these resources provide additional details and summaries on tools that were not included in this paper. We encourage readers to also review these resources in their search for the best model or tool for their project.

Ecosystem Services Market Consortium. (2020). *Master Protocol Assessment Table: Supplement to An Assessment of Protocols, Methodologies, Tools and Approaches to Inform ESMC's Integrated, Tiered Ecosystem Services Market Protocol for Working Agricultural Lands*. ecosystemservicesmarket.org/wp-content/uploads/2020/01/ESMC-Integrated-Matrix-1.28.2020.pdf

Fu, B., Merritt, W., Croke, B., Weber, T., & Jakeman, A. J. (2019). A review of catchment-scale water quality and erosion models and a synthesis of future prospects. *Environmental Modelling & Software, 114*. doi.org/10.1016/j.envsoft.2018.12.008

LimnoTech. (2017). *Approaches for Modeling and Monitoring Water Quality Outcomes for Agricultural Fields*. fieldtomarket.org/ftm_whitepaper_final_august15_2017

Liu, Y., Li, S., Wallace, C. W., Chaubey, I., Flanagan, D. C., Theller, L. O., & Engel, B. A. (2017). Comparison of Computer Models for Estimating Hydrology and Water Quality in an Agricultural Watershed. *Water Resources Management, 31*(11), 3641–3665. doi.org/10.1007/s11269-017-1691-9

Ranjan, P., Duriancik, L. F., Moriasi, D. N., Carlson, D., Anderson, K., & Prokopy, L. S. (2020). Understanding the use of decision support tools by conservation professionals and their education and training needs: An application of the Reasoned Action Approach. *Journal of Soil and Water Conservation, 75*(3), 387–399. doi.org/10.2489/jswc.75.3.387

USEPA. (n.d.). *Nutrient and Sediment Estimation Tools for Watershed Protection. EPA 841-K-18-002*, 20. epa.gov/sites/production/files/2018-08/documents/loadreductionmodels2018.pdf

APPENDIX B

List of Environmental Monitoring Methods and Resources

To measure environmental outcomes directly, a variety of monitoring approaches exist to assess the ambient changes in response to adoption of farm conservation practices. Regardless of approach, direct monitoring of environmental outcomes is typically costly, requires significant skill, and is time intensive. Hence, many farm conservation projects do not invest the financial resources, expertise, and time needed to quantify outcomes through monitoring.

For project managers interested in exploring options to directly monitor their outcomes, this section provides brief descriptions of various monitoring approaches and links to additional resources for monitoring of streams or lakes, edge of field, groundwater, tile drain, and soil health. Project managers interested in pursuing direct monitoring would do well to develop a partnership with their state department of environment and/or state office of the U.S. Geologic Service (USGS), which have the expertise, may have their own monitoring program requirements, and in some cases may have financial assistance to support the monitoring program.

Instream Monitoring

Though water quality monitoring can evaluate the physical, chemical, and biological characteristics of a water body in relation to human health, ecological conditions, and designated water uses, it is "operational monitoring" that this report is concerned about: assessing the changes in water quality attributable to mitigation measures implemented by pollution reduction projects.

KEY RESOURCES

USDA NRCS. (2003). *National Water Quality Handbook: Water-Life's Most Essential Element*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044775.pdf

- The intended audience of this 368-page document, referred to as the NWQH, is "the NRCS field office, NRCS technical partners, and those providing technical services for NRCS... for basic orientation of NRCS water quality activities as well as advanced procedures for technical specialists." The NWQHI contrasts 10 different purposes for monitoring, walks readers through 12 steps for developing a monitoring study, provides engaging case studies to bring the methods to life, details eight statistical designs with pros and cons of each, and schematics to aid visualization of the design, etc.
- This handbook is available on an NRCS website called "Water Quality Guidance Documents," where it is described as "the definitive NRCS resource for water quality technical information, guidance, and procedures." However, the agency has not shared it with the RCPP or other Landscape Conservation Initiative project communities as a resource nor offered trainings.

USEPA Office of Water. (2016). *Monitoring and Evaluating Nonpoint Source Watershed Projects*. epa.gov/sites/production/files/2016-06/documents/nps_monitoring_guide_may_2016-combined_plain.pdf

- This 522-page guide provides an update to the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004). "This guide is written primarily for those who develop and implement monitoring plans for watershed management projects, but it can also be used by those who wish to evaluate the technical merits of monitoring proposals they might sponsor." The guide offers comprehensive and detailed information about designing, implementing, and evaluating water quality monitoring projects to evaluate the effectiveness of nonpoint source controls. In addition, there is a chapter on monitoring costs and an associated Excel spreadsheet to help project managers estimate and adequately plan and prepare a monitoring project.

USDA NRCS. (n.d.-b). *Synthesis Report: CEAP-NIFA Competitive Grant Watershed Studies | NRCS*. Natural Resource Conservation Services. Retrieved September 18, 2020, from www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=stelprdb1047821

- The NRCS website above compiles the many education resources produced to accompany the 387-page book, "How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture-Conservation Effects Assessment Project Experience." The 2012 book is edited Deanna L. Osmond, Donald W. Meals, Dana LK. Hoag, and Mazdak Arabi and is available for free at swcs.org/resources/publications/books/how-to-build-better-agricultural-conservation-programs-to-protect-water-quality. The book provides a comprehensive retrospective assessment of 13 watershed projects conducted between 2004 to 2011. In addition to the book, seven factsheets were produced to provide highlights of the lessons learned and can be found at the NRCS site above.

Meals, D. W., D. L. Osmond, J. Spooner, and D.E. Line. 2012. *Lessons Learned from the NIFA-CEAP: Water Quality Monitoring for the Assessment of Watershed Projects.* NC State University, Raleigh, NC. content.ces.ncsu.edu/water-quality-monitoring-for-the-assessment-of-watershed-projects

- This is an easy-to-read and engaging six-page summary document that provides highlights of the successes and shortcomings of water quality monitoring of the NIFA-CEAP watershed projects.

Perez, M. (2017). *Water Quality Targeting Success Stories: How to achieve measurably cleaner water through U.S. farm conservation watershed projects*. farmlandinfo.org/publications/water-quality-targeting-success-stories-how-to-achieve-measurably-cleaner-water-through-u-s-farm-conservation-watershed-projects

- See "Appendix C: Primer on Monitoring Objectives and Designs" for easy-to-read descriptions of the four monitoring approaches (Before/After; Trend; Above/Below; Paired Watershed) that EPA encourages project managers to pursue to answer two basic questions: Objective 1: Have water quality-related conservation practices resulted in the observed changes in the water body? Objective 2: Have water quality conditions significantly improved over time in the water body?
- See "Appendix E: Why it may take some targeted watershed projects longer than others to detect water quality success (or why they may never show success)" for seven such reasons.
- See pages 41, 52, 76, and 85 for project cost tables including the monitoring costs for the California, Oklahoma, and two Wisconsin projects.

Edge-of-Field Monitoring

In 2016, NRCS offered $2 million to project managers to conduct edge-of-field (EOF) monitoring in nine states: Alabama, Arkansas, Iowa, Michigan, Missouri, New York, Vermont, and Washington. The 206 watershed projects listed are comprised of Mississippi River Basin Healthy Watersheds Initiative (MRBI), National Water Quality Initiative (NWQI), and Lake Champlain. nrcs.usda.gov/wps/portal/nrcs/detail/national/water/quality/tr/?cid=stelprdb1240285

According to Karma Anderson, National Water Quality & Quantity Leader for NRCS (Personal communication, 10/25/20), in 2016, about 12 projects moved forward with the edge-of-field monitoring, and about two to five projects have been added every year. Anderson provided the following update:

> Voluntary edge-of-field water quality monitoring enables agricultural producers and scientists to quantify the benefits of conservation to water quality. Through edge-of-field monitoring, NRCS works with producers and conservation partners to measure the amount of nutrients and sediment in water runoff from a field and compare improvements under different conservation systems. During the first seven years of edge-of-field water quality monitoring, the agency provided about $6.5 million for over 40 monitoring projects collecting water quality data across the country.

KEY RESOURCES

USDA NRCS. (2012a). *Edge-of-Field Water Quality Monitoring Data Collection and Evaluation Conservation Activity, Code 201*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097617.pdf

USDA NRCS. (2012b). *Edge-of-Field Water Quality Monitoring System Installation Conservation Activity, Code 202*. nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097618.pdf

USDA NRCS. (n.d.). *Seven Conservation Webinars focused on edge-of-field monitoring*. The Webinar Portal. conservationwebinars.net/search?SearchableText=edge+of+field

Groundwater Monitoring

Discussions of groundwater and groundwater monitoring permeates both the 2003 NRCS NWQH and the 2016 EPA Monitoring Guide. The NWQH includes a standalone section for designing sampling locations for groundwater monitoring. The 2016 EPA Guide recommends the following additional guidance documents for groundwater monitoring:

KEY RESOURCES

Cunningham, W. L., & Schalk, C. W. (2011). *Groundwater Technical Procedures of the U.S. Geological Survey. Techniques and Methods 1–A1*. U.S. Geological Survey. pubs.usgs.gov/tm/1a1/pdf/tm1-a1.pdf

- This guidance document is comprised of "groundwater technical procedures documents," referred to as GWPDs that provide standardized technical procedures, including site and measuring-point establishment, measurement of water levels, and measurement of well discharge.

Goodman, J., Bischoff, J., German, D., Kimball, C. G., United States. Department of Agriculture, & United States. Farm Service Agency. (1996). *Ground water monitoring: A guide to monitoring for agricultural nonpoint source pollution projects*. Huron, S.D.: U.S. Dept. of Agriculture, Farm Service Agency. archive.org/details/CAT10819301

- This guide was developed from the experiences gained by the participants in the Rural Clean Water Program; it provides comprehensive instructions on a variety of groundwater monitoring objectives, including determining the effectiveness of BMPs.

Tile Drain Monitoring

Tile drain monitoring can be used to evaluate the chemical water quality of shallow groundwater and agricultural drainage water from tile lines to determine the effectiveness of conservation practices.

KEY RESOURCES

Options for Monitoring Tile Drain Flow. (n.d.). Transforming Drainage.Org. transformingdrainage.org/videos/monitoring-tile-drain-flow

- Transforming Drainage is a collaboration of nine universities in the Corn Belt and federal agencies to research and design new tools to more effectively manage drainage water storage practices to balance production and environmental sustainability goals. Among many resources on their website, there are six 10- to 15-minute webinars that provide instruction on various methods to monitor tile drain flow. transformingdrainage.org//videos/monitoring-tile-drain-flow

Soil Health Monitoring

Rebuilding soil health is the keystone of burgeoning agricultural climate resiliency and carbon farming efforts in the United States. Soil health is defined by NRCS as "the continued capacity of a soil to function as a vital living ecosystem that sustains plants, animals, and humans." The principal practices of healthy soils, carbon farming, and climate resiliency efforts overlap with conservation and water quality practices. Soil health cannot be measured directly or via any single property (e.g., crop yield, water quality, organic matter). Thus, a suite of indicators that identify soil processes and function are recommended covering biological, chemical, and physical soil properties assessed in the field and laboratory as well as visual or morphological features of plants.

KEY RESOURCES

Stott, D. E. (2019). *Soil Health Technical Note No. 450-03: Recommended Soil Health Indicators and Associated Laboratory Procedures* (p. 76). USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=44475.wba

- This 76-page technical note contains a minimum data set of recommended current best available standard laboratory methods for soil health indicators selected through a collaborative multi-organizational effort. USDA NRCS. (n.d.).

Cropland In-Field Soil Health Assessment Worksheet with Considerations and Indicator Details. www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1672815&ext=pdf

- This 11-page guide was developed as an in-field soil health diagnostic tool and provides detailed instructions on 11 field indicators to aid identification of key soil health resource concerns using simple, inexpensive tools.

APPENDIX C

Summaries of Excluded Tools

TABLE 7. WHY TOOLS WERE EXCLUDED

Tool Name	Produces quantitative estimates of the outcomes that are the focus of this paper	Available to general public for free or fee	Available to users in more than one state	Meant for direct use by conservationists or farmers	Does not require users to have a modeling background
1-State: IA-only: Nitrogen Load Estimate Calculator	✓	✓		✓	✓
1-State: NC-only: NC Agricultural Nutrient Assessment Tool (NCANAT)	✓	✓		✓	✓
1-State: WI-only: SNAP-Plus—Soil Nutrient Application Planner	✓	✓		✓	✓
ACPF—A Conservation Planning Framework		✓	✓	✓	
APLE—Annual Phosphorus Loss Estimator	✓	✓	✓	✓	
CaRPE—Carbon Reduction Potential Evaluation	✓	✓	✓		✓
Climate FieldView	✓		✓	✓	✓
FARM Environmental Stewardship Tool	✓			✓	✓
HAWQS—Hydrologic and Water Quality System	✓	✓	✓	✓	
MapShed	✓	✓	✓	✓	
Nitrogen Index/ Phosphorus Index		✓	✓	✓	✓
Precision Conservation Management	✓		✓	✓	✓
RSET—Resources Stewardship Evaluation Tool			✓	✓	✓
RUSLE2—Revised Universal Soil Loss Equation 2	✓	✓	✓	✓	
SCI—Soil Conditioning Index		✓	✓	✓	✓
TruTerra Insights Engine	✓		✓	✓	✓
WASP—Water Quality Analysis Simulation Program	✓	✓	✓		
WQIAg—Water Quality Index for Agriculture			✓	✓	✓

1-State: Iowa's Nitrogen Load Estimator Calculator

Iowa's Nitrogen Load Estimator Calculator was designed to support the state's Nutrient Reduction Strategy. The nitrate-N load estimate calculator uses the input of cropping systems, land use, and specific nitrate reduction practices to estimate reductions at both the field and watershed scale. This spreadsheet tool is straightforward and accessible to farmers and conservationists alike. The tool satisfies all the guide's criteria except that it is only available in one state, Iowa. It is free to download from naturalresources.extension.iastate.edu/waterquality/nitrogen-load-estimate-calculator.

1-State: North Carolina Agricultural Nutrient Assessment Tool (NCANAT)

North Carolina Agricultural Nutrient Assessment Tool (NCANAT) is a downloadable software tool that includes both the Phosphorus Loss Assessment Tool (PLAT) and the Nitrogen Loss Evaluation Tool (NLEW). These tools use cropping systems, BMPs, nutrient applications, and soil information for a specific field to estimate total pounds of nitrogen lost and a phosphorus-loss rating. These values can then be used to complete a nutrient management plan within the same software. The tool satisfies all the guide's criteria except that it is only available in one state, North Carolina. It is free to download from nutrientmanagement.wordpress.ncsu.edu/resources/software.

1-State: Wisconsin's SnapPlus

Wisconsin's Soil Nutrient Application Planner (SnapPlus) calculates a soil loss estimate based on RUSLE2 "that will allow producers to determine whether fields that receive fertilizer or manure applications meet tolerable soil loss (T) requirements." This downloadable software also calculates fertilizer recommendations and provides a Phosphorus Index value for each target field. Users can develop "what-if" scenarios and estimate soil loss reductions and cost impacts. The tool satisfies all of the guide's criteria except that it is only available in one state, Wisconsin. It is free to download from snapplus.wisc.edu/download-snapplus-20-beta.

ACPF

Agricultural Conservation Planning Framework (ACPF) is an ArcGIS based set of tools that allows conservationists to create maps detailing critical or priority locations where conservation practices would be most effective at reducing pollutant load. ACPF is a well-respected tool for geotargeting and is free and available for use in several states, including Illinois, Iowa, Minnesota, and Wisconsin. Portions of other Midwestern states can also use ACPF: Indiana, Kansas, Missouri, Nebraska, North Dakota, and South Dakota. However, it does not provide quantitative estimates and requires users to have modeling skills and to conduct a time-intensive digital hydro-conditioning process to set up the tool. For more information visit acpf4watersheds.org.

APLE

Annual Phosphorus Loss Estimator (APLE) is a downloadable spreadsheet tool that simulates P loss in surface runoff. The interface is straightforward but users must have site-specific data, including soil nutrient test results, soil property data, including depth of the top two soil layers, Mehlich-3 soil test P, soil clay content, and soil organic matter content, field area(ha), annual rain, runoff, and erosion amounts, total annual crop P uptake, the total number of animal days in the field, including beef cattle and calves, dairy lactating and dry cows, and dairy heifers and calves, the manure amount applied, manure % solids, manure total P_2O_5 content, % of manure total P that is water extractable P, the % of manure that is incorporated, and the depth of incorporation. This tool was excluded due to the need for extensive data entry. For more information on APLE please visit ars.usda.gov/midwest-area/madison-wi/us-dairy-forage-research-center/docs/aple-homepage.

CaRPE Tool™

The Carbon Reduction Potential Evaluation Tool (CaRPE Tool™) was developed by American Farmland Trust and the USDA Agricultral Research Service (ARS) to quantify and visualize county-level GHG emission reductions resulting from the implementation of cropland and grazing land management practices. The CaRPE Tool™ scales the emission reduction coefficients (ERC) extracted from the COMET-Planner tool to the county level by coupling COMET-Planner ERCs with county level cropland data from the 2017 Census of Agriculture (2017 AgCensus). The CaRPE Tool also allows users to assess practice payment costs for scenarios. Climate impacts quantified in this tool are estimated values and should be used for general planning purposes only. For more information, and to use the free tool, visit carpe.shinyapps.io/CarpeTool.

Climate FieldView

Climate FieldView, a product of The Climate Corporation, is a versatile, fee-based, farmer-focused suite of management tools. It has a robust suite of digital tools for analyzing farm data, including field and business management data. However, it does not quantify GHG or water quality outcomes. For more information, visit climate.com.

FARM Environmental Stewardship

The Farmers Assuming Responsible Management (FARM) Environmental Stewardship program is a free environmental assessment program used by the National Milk Producers Association that provides tools and resources for dairy farmers to track and improve their carbon footprint. The assessment includes a set of questions to assess a farm's carbon and energy footprint, and it generates a quantitative estimate of the GHG emissions and energy footprint of milk in lbs. CO_2-eq per lb. FPCM (fat and protein corrected milk).

However, the program is available only to dairy farmers, cooperatives, and processors, and it is not available to the public. For more information, visit nationaldairyfarm.com/dairy-farm-standards/environmental-stewardship.

HAWQS

HAWQS (Hydrologic and Water Quality System) is a web-based water quantity and quality tool that is built upon SWAT. "HAWQS substantially enhances the usability of SWAT to simulate the effects of management practices based on an extensive array of crops, soils, natural vegetation types, land uses, and other scenarios for hydrology and the following water quality parameters" (epa.gov/sites/production/files/2017-09/documents/hawqs_v1_flyer.pdf). The potential use of HAWQS for outcomes quantification in conservation projects is very promising. However, HAWQS is a more advanced tool and users must have modeling experience using SWAT, therefore it has been excluded from this guide. For more information, please visit epa.gov/waterdata/hawqs-hydrologic-and-water-quality-system.

MapSHED/GWLF-E

MapShed, developed by Pennsylvania State University, integrates the Generalized Watershed Loading Function—Enhanced (GWLF-E) with a GIS interface. It is a watershed scale tool and has since been integrated into Model My Watershed as the multi-year model. The GWLF is less complex than other watershed scale tools and deemed a "mid-level" model. It cannot distribute nutrient loading within the watershed scale, which reduces the overall accuracy but provides a modeling option when input data is limited. Implementation of BMPs scenarios can be generated to estimate load reductions by re-running the input data with modified BMP information. MapShed is not meant for farmers and conservationist without prior modeling experience. More information on the GWLF-E model and integration into Model My Watershed is available here: wikiwatershed.org/help.

Nitrogen (and Phosphorus) Index Tool

The Nitrogen Index Tool is a downloadable java-based software that is used to compare the effects of BMPs on nitrogen by ranking practices from "very high" and "high" risk of nitrogen loss to those with low risk. This tool also includes a nitrogen leaching index and a phosphorus index. The next release will include an N_2O index and the Phosphorus Index. This tool is meant to provide a quick estimate but is not quantitative. For more information or to download the software, please visit ars.usda.gov/research/software/download/?softwareid=275&modecode=30-12-30-15.

PCM

Precision Conservation Management (PCM) is a program of the Illinois Corn Growers Association. This is a farmer service program that supports the adoption of financially sensible conservation practices. PCM offers participating farmers their environmental analysis services using FieldPrint Calculator, among other supporting services, including an economic analysis of their farm through the Farmer Portal. Farmers can input their own specific costs and get an economic assessment of their operation. The PCM program was developed as a response to the Illinois Nutrient Loss Reduction Strategy. Within PCM, the Saving Tomorrow's Agricultural Resources (S.T.A.R) tool is available nationally and provides farmers an opportunity to be recognized for their increased conservation practice adoption. Farmers complete a simple data form, and the evaluation assigns points for a wide array of BMPs. Those points translate into a scale value—a STAR rating from 1–5. For more information about the S.T.A.R tool please, visit starfreetool.com/about. And for more information about PCM, visit www.precisionconservation.org.

RSET or RS

The Resource Stewardship Evaluation Tool (RSET or RS) is a web-based tool used by NRCS staff during conservation planning to evaluate soil, water, and air on site. However, it does not quantify outcomes. nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/?cid=nrcseprd429509

RUSLE2

The Revised Universal Soil Loss Equation (RUSLE2) is an algorithm-based software developed by USDA NRCS and ARS. RUSLE2 is commonly used in the conservation planning process by NRCS employees. While it does have a graphical interface, users must download regional datasets for climate and soils data. In addition, users must identify the specific soil type using a different source (such as the Web Soil Survey) and then input into RUSLE2. Users are also required to input a detailed initial scenario and then can generate "what-if" scenarios to estimate impacts of practice implementation. RUSLE2 can run whole-farm scenarios by identifying and inputting details for each field and combine parcels during analysis. The program is available for download but requires training to navigate the somewhat complicated pathway to quantify potential outcomes and also requires significant data input and upload of specific databases to support the program. Due to the necessary training, data input requirements, and lack of technical support if you are not an NRCS partner, it has been excluded from this guide. The program download file, necessary soils and climate datasets, user guides, and support materials are all available at fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

SCI

The Soil Conditioning Index (SCI) is a qualitative assessment tool that predicts future impacts of cropping systems and tillage on soil organic matter (SOM) content. Positive values indicate likely increases in SOM; negative values indicate that SOM is likely to decrease under the current management system. As an index tool, SCI does not provide quantitative estimates and is embedded in the RUSLE2 tool; therefore it was not featured in this guide. For more information on SCI, please visit nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcs142p2_008548.

TruTerra Insights Engine

TruTerra Insights Engine is a project of Land O'Lake SUSTAIN program. TruTerra Insights Engine "allows farmers, agriculture retailers, and food companies to measure their sustainability and track their progress over time all the way down to sub-sections of their fields." This tool is available to Land O'Lakes network farmers and associated companies looking to increase conservation practice adoption in their supply chain. Though this tool does provide quantitative estimates of outcomes (wind and water erosion, nitrogen use efficiency, and GHG emissions), it was excluded due to the restricted access. For more information, please visit truterrainsights.com or truterraag.com.

WASP

Water Quality Analysis Simulation Program (WASP) was developed by the EPA and is one of the most widely used water quality models (both within the U.S. and internationally). WASP has been used in the development of TMDLs and is also capable of linking to other watershed models. This tool is intended for a more experienced user-group, such as environmental engineers and regulatory agencies, and does not itself model farm conservation practice impacts on water quality; therefore it was excluded from this guide. For more information, please visit epa.gov/ceam/water-quality-analysis-simulation-program-wasp.

WQIag

The Water Quality Index—Agriculture (WQIag) was developed by researchers at the USDA Natural Resources Conservation Service to give farmers and ranchers a simple way to quantify the management and physical conditions of their fields relative to potential water quality impacts. WQIag is an index-based tool, combining multiple water quality parameters into a single value ranging from 1–10, therefore it was excluded from this guide. For more detailed information about WQIag, please visit wcc.nrcs.usda.gov/ftpref/wntsc/WQI/RunoffWaterQualityIndex.pdf.

APPENDIX D

Summaries of Excluded Models

TABLE 8. WHY MODELS WERE EXCLUDED

Tool Name	Produces quantitative estimates of the outcomes that are the focus of this paper	Available to general public for free or fee	Available to users in more than one state	Meant for direct use by conservationists or farmers	Does not require users to have a modeling background
AnnAGNPS—Annualized Agricultural Non-Point Source	✓	✓	✓		
APEX (underlies NTT)—Agricultural Policy/Environmental eXtender	✓	✓	✓		
ArcSLAMM/ WinSLAMM—Source Loading and Management Model	✓	✓	✓		
Bathtub	✓	✓	✓		
Daycent (underlies COMET-Farm & Planner)	✓	✓	✓	✓	
DNDC—Denitrification-Decomposition	✓	✓	✓	✓	
HSPF (underlies CAST & PTMApp) Hydrological Simulation Program—FORTRAN	✓	✓	✓		
L-THIA—Long-Term Hydrologic Impact Assessment	✓	✓	✓		✓
MIKE-SHE—Integrated Hydrological Model	✓	✓	✓		
P8—Program for Predicting Polluting Particle Passage Through Pits, Puddles, and Ponds	✓	✓	✓		
RZWQM2—Root Zone Water Quality Model 2	✓	✓	✓		
SPARROW—Spatially Referenced Regression on Watershed attributes	✓	✓	✓		
Spatial Watershed Assessment & Management Model	✓	✓	✓	✓	
SWAT/SWAT+ —Soil and Water Assessment Tool	✓	✓	✓	✓	
WARMF—Watershed Analysis Risk Management Framework	✓	✓	✓		
WEPP—Watershed Erosion Prediction Project	✓	✓	✓	✓	
WEPS—Wind Erosion Prediction System		✓	✓	✓	✓

AnnAGNPS

The Annualized Agricultural Non-Point Source (AnnAGNPS) model was developed by USDA ARS and NRCS as an improvement over AGNPS, which was a single event model. This model requires modeling experience and therefore was excluded from this guide. For more detailed information about AnnAGNPS, please see the EPA resource in Appendix A. The AnnAGNPS tool is available online here: go.usa.gov/KFO.

APEX (Underlies Nutrient Tracking Tool)

The Agricultural Policy/Environmental eXtender (APEX) model was developed by the Blackland Research Extension Center to extend the Environmental Policy Integrated Climate (EPIC) model from a crop/soil productivity model to include land management impacts, including erosion, soil quality, economics, weather, and pests. APEX is a downloadable software program that can be used to simulate impacts on water quality, climate (CO_2) at the field, farm, and small- to medium-watershed scale. This model requires modeling experience, and therefore was excluded from this guide. For more detailed information about APEX, please see the EPA resource in this paper's Appendix A and visit the APEX site: epicapex.tamu.edu.

ArcSLAMM/WinSLAMM

ArcGIS or Windows Source Loading and Management Model (ArcSLAMM or WinSLAMM) is an urban catchment model – meaning it models stormwater quantity and flow in urban watersheds. This model requires purchase from the developer, PV & Associates and is not applicable to agricultural scenarios, nor is it meant to be used directly by conservationists and farmers without modeling experience; therefore it was excluded from this paper. For more information please go to winslamm.com.

Bathtub

Bathtub is a water quality model developed by the US ACE for modeling lake water quality. It is publicly available and used quite often across the nation to quantify lake water quality and nutrient loads. It is excluded from this guide because it is not associated with farm conservation practices, nor is it meant for use by farmers or those without modeling experience. For more information please go to: wwwalker.net/bathtub/help/bathtubWebMain.html.

DayCent (Underlies COMET-Planner and COMET-Farm)

Developed by Colorado State University, DayCent is a daily-step version of the monthly based Century model, which simulates plant-soil nutrient interactions and can model carbon and nitrogen fluxes at both the field and watershed scales. Soil water content, mineralization, nitrogen cycling, methane production and oxidation, net primary production, and decomposition processes are key subcomponents in the model that can provide daily N-gas flux, CO_2 flux, soil organic C and N, net primary production, and water and nitrate leaching. This is not a novice or user-friendly model, and therefore was excluded from this guide, but it is powerful and is the underlying model for COMET-Planner and COMET-Farm. More information on the DayCent model can be found here: www2.nrel.colostate.edu/projects/daycent.

DNDC

Denitrification-Decomposition (DNDC) simulates carbon and nitrogen cycling in agriculture and has been used to quantify GHG emissions at both the field and watershed scales. Developed by the University of New Hampshire and written in the C++ programming language, DNDC is not a "ready-to-go" or user-friendly model. DNDC requires significant site-specific information to be inputted into the model in order to run a daily-time step simulation. DNDC provides an annual report of soil organic carbon content, CH_4, N_2O, NO, dinitrogen, ammonia, and nitrate leaching loss for each year in the simulation. This model requires experience and therefore was excluded from this guide. The DNDC model, user manual, and technical information are available at dndc.sr.unh.edu. For more detailed information about DNDC, please see the ESMC resource in Appendix A.

HSPF

The Hydrological Simulation Program-FORTRAN (HSPF) is a mechanistic and empirical model that uses historic precipitation, temperature, evaporation, land use, soils characteristics, and agricultural management practices to simulate water transport and water quality at multiple scales and time steps. This model can simulate sand, silt, and clay as well as N, P, and organic pollutants. Originally developed by AquaTerra, it is now supported by the EPA, who describes HSPF as "the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions." It requires a highly experienced user to both run and validate the model; therefore it was excluded from this guide. For more detailed information about HSPF, please see the resources in this paper's Appendix A. epa.gov/ceam/hydrological-simulation-program-fortran-hspf.

L-THIA

The Long-Term Hydrologic Impact Assessment (L-THIA), model integrates land use and soil data input by the user to estimate pollutant load changes, but due to changes in land use, not as a result of the implementation of agricultural BMPs. Due to the lack of agricultural BMP input, this model has been excluded. For more detailed information about L-THIA, please visit engineering.purdue.edu/~lthia/ or see the EPA resource in this paper's Appendix A.

MIKE-SHE

MIKE-SHE is an integrated hydrological modeling system used to simulate surface water flow and groundwater flow. MIKE SHE can simulate the entire land phase of the hydrologic cycle and allows components to be used independently and customized to local needs. However, this model is not free, and a license must be purchased for use. It is also not meant for direct use by conservationists or farmers and users must have modeling experience; therefore it was excluded from this guide. For more information, please go to mikepoweredbydhi.com/products.

P8

Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds—Urban Catchment Model (P8) estimates stormwater quantity and flow in urban watersheds. There is no agricultural watershed simulation, nor is there soil erosion simulation, therefore it was excluded from this guide. For more information on P8, please go to wwwalker.net/p8/.

RZWQM2

Root Zone Water Quality Model 2 (RZWQM2) models the vertical movement of water, nutrients, and other organics within the soil profile. While RZWQM2 has a significant capacity for BMP scenario building, this model requires significant data collection and input by an experienced model user and therefore was excluded from this guide. For more detailed information about RZWQM2, please go to ars.usda.gov/research/software/ or see the EPA resource in this paper's Appendix A.

SPARROW

SPAtially Referenced Regression on Watershed attributes (SPARROW) coarsely describes the spatial distribution of pollutants throughout a watershed. SPARROW does not allow users to create BMP scenarios and requires modeling experience, hence it was not included in this guide. For more detailed information about SPARROW, please visit water.usgs.gov/nawqa/sparrow or see the EPA resource in Appendix A of this paper.

SWAMM Model

The Spatial Watershed Assessment and Management Model (SWAMM™) is a web-based model developed and available through Northwater Consulting, a firm in Illinois. The model is customized and calibrated to meet the nonpoint source pollution monitoring and quantification needs of specific projects. For those clients with in-house GIS specialists, the raw data-layers can be shared to integrate with internal mapping activities. The SWAMM model is built on both the Universal Soil Loss Equation (USLE) and event mean concentrations (EMC), integrating a comprehensive watershed inventory (windshield survey) with soils, land use, water flow and quality, and climate data to model pollutant loads and identify target areas for BMP implementation within the target watershed. Information on SWAMM can be found on northwaterconsulting.com/swamm.

SWAT/SWAT+

The Soil and Water Assessment Tool (SWAT) is a mechanistic model developed by USDA ARS and Texas A&M University (TAMU) that is widely used to estimate soil erosion, N, P, and pesticides at both the field and small watershed scale. A wide range of both crops and practices are available to build scenarios in SWAT. It is also widely used to identify priority areas for practice implementation. SWAT requires extensive input and requires an experienced user to both run and validate the model based upon site monitoring data. This model must also be calibrated using local hydrology and water quality data by an experienced modeler, and therefore was excluded from this guide. For more detailed information about SWAT, please go to swat.tamu.edu or see the resources in Appendix A of this paper.

WARMF

Watershed Analysis Risk Management Framework (WARMF) is a comprehensive watershed model that can simulate chemical, biological, and physical processes within a watershed. However, WARMF does not support BMP implementation and therefore was excluded from this guide: hero.epa.gov/hero/index.cfm/reference/details/reference_id/2517633. For more detailed information about WARMF, please see the resources in Appendix A of this paper.

WEPP

The Watershed Erosion Prediction Project (WEPP) is a continuous simulation, process-based model that can be used in a number of land-type simulation scenarios including cropland and rangeland. WEPP needs significant calibration prior to use and requires an experienced user. For more detailed information about WEPP, please visit ars.usda.gov/midwest-area/west-lafayette-in/national-soil-erosion-research/docs/wepp or see the EPA resource in Appendix A.

WEPS

The Wind Erosion Prediction System (WEPS) is a process-based daily time step model used to simulate wind erosion on agricultural lands and to assess plant damage, suspension loss, and PM-10 emissions. It requires field-specific data. WEPS estimates soil loss; it does not address nutrient water quality. WEPS is a model, rather than a tool, and it is intended for use by NRCS staff and technical service providers, rather than for the public. Please visit nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/weps.

LANCE CHEUNG/USDA

American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

1150 Connecticut Avenue NW, Suite 600
Washington, DC 20036
(202) 331-7300 • farmland.org