Prioritizing Resources to Meet Water Quality Goals

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Abbreviations

ACEP	Agricultural Conservation Easements Program
APEX	Agricultural Policy Environmental eXtender
ARS	Agricultural Research Service
ATTAINS	Assessment, Total Maximum Daily Load Tracing and Implementation System
AWWA	American Water Works Association
CART	Conservation Assessment Ranking Tool
CAST	Chesapeake Assessment Scenario Tool
CCA	Certified Crop Advisors
CCC	Commodity Credit Corporation
CoPE	Conservation Practice Effectiveness
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CREP	Conservation Research Enhancement Program
CTA	Conservation Technical Assistance
DEM	Digital Elevation Model
EQIP	Environmental Quality Incentives Program
FCS	Farm Credit System
FFAR	Foundation for Food and Agricultural Research
FLP	Forest Legacy Program
FPAC	Farm Protection and Conservation
FSA	Farm Service Agency
GLRI	Great Lakes Restoration Initiative
GSE	Government Sponsored Enterprise
HSPF	Hydrologic simulation program-Fortran
HTF	Hypoxia Task Force
LiDAR	Light Detection and Ranging
LWCF	Land and Water Conservation Fund
MANAGE	Measured Annual Nutrient loads from Agricultural Environments
MARB	Mississippi/Atchafalaya River Basin
NARS	National Aquatic Resource Surveys
NASS	National Agricultural Statistics Service
NAWCA	North American Wetlands Conservation Act
NAWQA	National Water Quality Assessment
NLCD	National Land Cover Database
NRCS	Natural Resources Conservation Service
NPDES	National Pollution Discharge Elimination System
NRI	National Resources Inventory
NGO	Non-Governmental Organization
NTT	Nutrient Tracking Tool
OCS	Outer Continental Shelf
RMA	Risk Management Agency
RUSLE	Revised Universal Soil Loss Equation
SHD	Soil Health Division
SHIPP	Soil Health and Income Protection Pilot
SMAF	Soil Management Assessment Framework
SPARROW	SPAtially Referenced Regression On Watershed attributes
STEPL	Spreadsheet Tool for Estimating Pollutant Load
STEWARDS	Sustaining the Earth's Watersheds, Agricultural Research Data Systems
SWAT	Soil and Water Assessment Tool
TFP	Total Factor Productivity
TSP	Technical Service Provider
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
VB	Visual Basic
WQP	Water Quality Portal
WQX	Water Quality eXchange
WRE	Wetlands Reserve Easements

Background and Acknowledgements

A partnership to assess agricultural practices and strategies to further improve water quality in the United States was launched in January 2018, by the Sand County Foundation, the Noble Research Institute, Farm Foundation, and USDA's Natural Resources Conservation Service (NRCS).

Project partners assembled a Water Quality Assessment Advisory Group of over 30 agriculture and water quality experts from universities, federal agencies, industries, and non-governmental organizations (NGOs) to advance water quality improvement by identifying action items or needs to effectively address gaps in: (a) the current knowledge and available science on practice performance effectiveness, (b) conservation management approaches for program delivery on a larger and more cost-effective scale, and (c) stakeholder engagement and investment in approaches to improve water quality outcomes. The assessment was intended to serve as a science-based resource written for a diverse set of audiences including farmers, conservation professionals, watershed managers, policy-makers, local or state government agencies, and others interested in water quality.

The Advisory Group compiled recommendations during facilitated discussion sessions in May and September, 2018. We would like to recognize and thank the Water Quality Assessment Advisory Group participants. Without the collaborative efforts endured by the team, the comprehensive information gathered for the report development would not have been possible. The diversity represented by the team members crossed sectors and engulfed many disciplines, which strengthened the value of the material presented and improved the overall quality of the report.

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Executive Summary

Land management decisions impacting the Nation's water quality are often made by private landowners and their operators, with the assistance of conservation professionals, government agencies, agricultural service providers, or extension agents. A challenge in developing a conservation strategy is meeting agricultural production goals while reducing the environmental impact of nutrients on water quality. It is recognized that there is a critical need to direct more financial resources toward the advancement of conservation implementation on actively farmed land across the nation. While the number of national programs has increased and new techniques to address resource challenges continue to emerge, the basic federal approach has remained unchanged - voluntary farmer participation encouraged by financial and technical assistance, education, and basic and applied research. To inform this transition, this assessment identifies gaps to achieving desired conservation outcomes and the action items to address those gaps. Making informed decisions and better understanding the impact of existing efforts to improve water quality, requires access to consistent, high quality data that provide a direct measure of change. While data from agricultural field research proliferates, results must be better summarized, assessed, and interpreted. Improved public-private partnerships for providing technical service and outreach can be an efficient way to promote the use of both NRCS programs and conservation practice systems. The success of any water quality improvement program is dependent upon the availability of willing landowners to implement a conservation practice or adjust their nutrient management.

The need for new conservation finance modes for private land is critical as conservation investments can generate value for farmers and ranchers, as well as municipal water users, water districts and private equity. For a water quality program to have long-term impact, it must also engage private industry organizations, NGOs, and other supply chain companies while considering incentives for downstream ecological enhancement. Nationwide adoption of water quality trading programs will require participation by third parties, who might want to participate or serve as an aggregator, banker, or broker of credits.

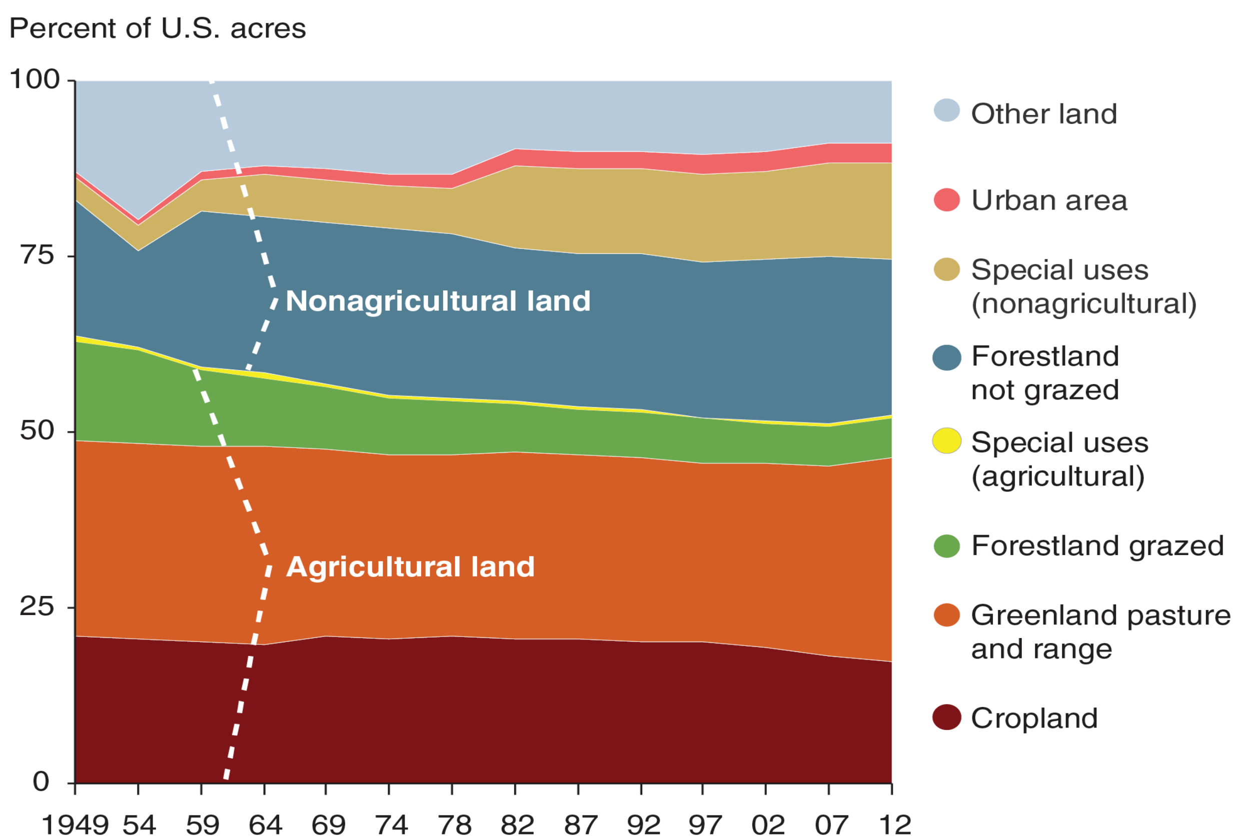
After thorough review of existing conservation programs, funding mechanisms, surveys, and water quality modeling protocols, this national assessment highlights five primary focus areas critical to achieving water quality goals through the advancement of agricultural conservation:

1. **Encourage collaborative-based, conservation initiatives that engage private industry and address broader societal benefits to gain wide-scale momentum and sustain long-term impact.**
2. **Develop rural and urban partnerships to advance conservation while building unity and an understanding that water resources are connected and shared within a watershed community.**
3. **Support shared-access to multidisciplinary data spanning environments, timescales, treatments, and management to encourage proper scaling the effectiveness and impact of conservation practices and systems.**
4. **Build regional and local technical assistance capacity to ensure that federal and state conservation programs and initiatives are successful and that implemented practices are properly sited, designed, installed, and maintained.**
5. **Establish more farmer-led groups and opportunities for farmers to get to know their regional conservation representatives as one way to increase awareness of local and relevant environmental issues, share experience and information on soil and water conservation management practices, and build trusted relationships.**

Introduction

The health of the Nation's water resources is dependent upon past, current, and future land use and management decisions at the local, regional and national scale. Approximately 60% of land across the United States is privately owned (USGS, 2018), of which roughly 70% is used for agriculture cropland, pastureland, or rangeland (Figures 1 and 2). Less than 20% of the Nation's population lives in rural areas (U.S. Census, 2016), yet everyone has a connection to agriculture through the supplied food, fiber and feed. According to USDA's estimates, 45.6 million acres of the Nation's farmland has been lost from 2000 through 2018 to some form of development (USDA, 2019b). Although U.S. farm acres have decreased, productivity and yields have increased due to the adoption of improved agricultural technology, specialization, and increased scale of production (USDA, 2019a).

Agricultural intensification over the last century has led to adverse effects, including changes in water quantity and quality (Capel et al., 2019). Nationally, crop species diversity declined from 1978 to 2012, with the amount of change varying between regions. Changes in crop species diversity not only impact the agroecosystem function, but also the function of surrounding natural and urban areas (Aguilar et al., 2015). Groundwater pumping for irrigation has resulted in lower water tables and ephemeral or dried up rivers (Ferrington, 1993; Perkin et al., 2017). Nutrient and sediment



Note: Special uses include rural parks and wilderness areas, rural transportation areas, defense/industrial lands (all nonagricultural uses), and farmsteads/farm roads (agricultural uses).
Source: USDA, Economic Research Service using data from USDA, U.S. Department of the Interior, U.S. Department of Commerce, and other sources.

Figure 1. Share of land used for agricultural purposes has decreased 11% since 1949 (Bigelow, 2017).

losses have contaminated ground and surface water, affecting drinking water and accelerating eutrophication both locally and far downstream. Although artificial drainage of the agricultural landscape can reduce erosion and surface runoff and make poorly drained soils responsive to agricultural intensification, it increases the connectivity of lower terrain on the landscape and drains water more quickly through the soil profile providing an additional loss pathway for chemicals and nutrients (Capel et al., 2019). Land management decisions impacting the Nation's water quality are made by millions of private landowners and their operators, who are often assisted by conservation professionals, government agencies, crop advisors, agricultural service providers, or extension agents. These complex decisions, often based upon physical, economic and social factors, ultimately influence watershed hydrology (Murphy and Sprague, 2019).

To overcome the complex challenges confronting the agricultural community managing private lands, short-term management decisions must be balanced with long-term planning to both enhance crop production and profitability while addressing environmental objectives (CAST, 2019). Hydrologic processes are a critical component driving environmental losses and contaminant transport pathways. Each agricultural activity and landscape modification has an effect on the movement of water and transport of agricultural chemicals and sediment (Capel et al., 2019). Nutrient reductions can be difficult to detect in the rivers and streams because changes in multiple sources of nutrients, along with natural climatic or landscape processes, can lessen the effects of improved farming practices on downstream water quality. Lag times between conservation implementation and observed nutrient reductions can range from years to decades, depending on the groundwater contribution and amount of legacy nutrients stored within the watershed (Meals et al., 2010; Sharpley et al. 2013).

Conservation management systems implement in-field or edge-of-field practices with nutrient stewardship to reduce the potential for agricultural nutrient loss through leachate and runoff. Although there have been state and regional-based estimates of conservation practice effectiveness (ANRC, 2019; Christianson et al., 2018; IEPA and IDOA, 2015; MPCA, 2014; IDALS, IDNR, and ISU, 2013; Osmond et al., 2012), the nutrient reduction potential of conservation and nutrient management practices is field specific based on landscape characteristics and practice design (Dodd and Sharpley, 2015). The USDA's Agricultural Research Service (ARS) recently launched the Conservation Practice Effectiveness (CoPE) Database, a compilation of data on the effectiveness of innovative practices developed

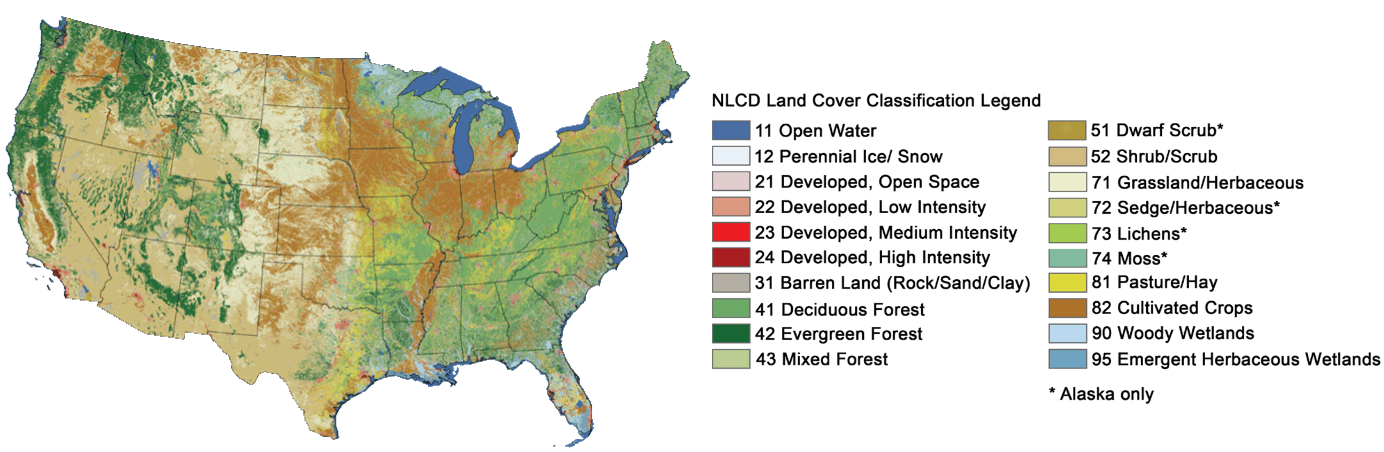


Figure 2. National Land Cover Database (NLCD) classification for the conterminous U.S. (Source: MRLC, 2019).

to treat contaminants in surface runoff and tile drainage water from agricultural landscapes (Smith et al., 2019). This dynamic database is a valuable step to aid watershed modelers in evaluating the scalable impact of conservation management.

The overarching objective of this report is to identify research and program gaps, and establish actionable outcomes for consideration in the future development of a comprehensive strategy towards achieving the Nation's water quality goals. It provides a summary of current water quality initiatives, conservation management incentive programs, and approaches to increase practice implementation. Drivers influencing land management decisions are outlined to provide insight on the social aspect of stakeholder engagement, including the willingness to adopt a practice or management change and make a financial investment towards land stewardship. The final section of the report introduces opportunities to advance wide-scale adoption of agricultural conservation.

State of the Nation's Waters

Since the passing of the Federal Water Pollution Control Act Amendments of 1972, subsequently amended and known as the Clean Water Act, federal, state, and local agencies have invested billions of dollars to reduce the impact of pollutants on the Nation's water bodies. Farm runoff is the leading source of impairments to nationally surveyed rivers and lakes; therefore, it is the emphasis of this report (USEPA, 2017c). Agriculture contributes the largest proportion of the total nitrogen (60%) and phosphorus (49%) load into the Mississippi River Basin, primarily from fertilizers and manure (USEPA, 2017b).

National Water Quality Inventory

In 2017, the EPA National Water Quality Inventory Report to Congress (USEPA, 2017c) was released. It summarized the results of four statistically representative National Aquatic Resource Surveys (NARS) and the site-specific assessment results reported by the states in their Integrated 303(d)/305(b) Reports submitted biennially to the EPA and available online through the Assessment, Total Maximum Daily Load Tracing and Implementation System (ATTAINS) data access system (USEPA, 2017a).

The NARS are collaborative efforts between the EPA, states, and tribes designed to assess the quality of the Nation's water resources. These nationally-consistent surveys, conducted on a five-year cycle, report on the extent of waters that meet the CWA goals of supporting healthy biological communities and recreation. The surveys use a stratified, randomized design to provide unbiased estimates of the condition of the broader population of waters (e.g., rivers and streams, lakes) throughout the nation. Key observations from the NARS in the National Water Quality Inventory Report (USEPA, 2017c) indicated that:

- 46% of river and stream miles are in poor biological condition; phosphorus and nitrogen are the most widespread of the chemical stressors assessed.
- 21% of the Nation's lakes are considered hypereutrophic, meaning excessively rich in nutrients, algae and plants. Phosphorus and nitrogen are the most widespread stressors in lakes.
- 18% of the Nation's coastal and Great Lakes waters are in poor biological condition and 14% are rated poor based on a water quality index. Phosphorus is the leading stressor contributing to the poor water quality index rating.
- 32% of the Nation's wetlands are in poor biological condition, with leading stressors including soil compaction and vegetation removal.

In addition to the national assessments, the report provides a snap shot of assessment information from state targeted, site-specific monitoring needed to support local management decisions. Using these data, states identified a wide range of assessed waters as not fully supporting at least one of their designated uses.

National Water Quality Assessment

In 1991, Congress established the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) to evaluate changes in water quality over time and to provide insight into how natural variation and human activities have contributed to these changes (Oelsner et al., 2017). Data from the USGS, along with multiple other federal, state, tribal, regional, and local agencies, were aggregated, screened, and standardized to support the most comprehensive assessment conducted to date of surface-water-quality trends in the U.S.

Using this vast collection of data for a comprehensive trend analysis is complex because the precision of the water-quality data varied by site, constituent, and laboratory due to the variations in analytical methods applied, laboratory-specific detection limits, and reporting conventions. Studies that analyze water quality trends are challenged by variations in data density, sample representativeness, and the stability of estimates as new data are added to the calibration record (Oelsner et al., 2017).

Although there is not one consistent trend across the U.S., a successful analysis using data from the NAWQA project compared annual mean concentrations at the start and end of the trend period compared to an environmentally meaningful level of concern (LOC; Shoda et al., 2019). This approach categorized patterns in water-quality changes and included ammonia, chloride, nitrate, sulfate, total dissolved solids, total nitrogen and total phosphorus assessed at 762 sites across the U.S. between 2002 and 2012 (Shoda et al., 2019). Of the 1,956 site-constituent combinations investigated, 30% were above the LOC in 2002, and over the trend period to 2012, only six (0.3%) of those site-constituents shifted either above or below the threshold level. This indicates that overall, water quality trends between 2002 and 2012 cannot be stated as generally improving or degrading. However, the trend review suggests that concentrations above LOCs are more likely to decrease before sites with low concentrations increase to exceed a LOC (Shoda et al., 2019).

Nutrient Reduction Strategies

Nonpoint source pollution is a challenging national water quality problem, and of particular concern are the high nitrogen and phosphorus loads across the Mississippi River basin that ultimately are discharged into the Gulf of Mexico. The hypoxic or "dead" zone in the Gulf of Mexico, an area larger than New Jersey which manifests each summer, is the result of nutrient over-enrichment from an area draining the Arkansas Red-White, Missouri, Mississippi, and Ohio River Basins, 90% of which is due to nonpoint source pollution (Alexander et al., 2008; Robertson and Saad, 2019).

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Hypoxia Task Force; HTF) was established in 1997, with EPA as the chair, to investigate the causes and effects of eutrophication in the Gulf of Mexico. In 2001, the Task Force issued the first Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico. The goals were based upon: (1) encouraging voluntary, practical and cost-effective actions, (2) utilizing existing programs and regulatory mechanisms, (3) following adaptive management, (4) identifying additional funding needs and sources, and (5) providing measurable outcomes (HTF, 2001). The Action Plan established a series of short-term actions and time frames to achieve long-term goals. These actions included an expansion of existing monitoring efforts and active nutrient management planning through state and tribal efforts to implement watershed-based approaches to water quality management. This involved monitoring and assessing waters, developing a water quality restoration plan that identifies the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards (i.e. Total Maximum Daily Load or TMDL), and adopting water quality standards. To accomplish the goals established in the 2001 Action Plan, the first Action Item in the subsequent 2008 Action Plan called for states to develop by 2013 "comprehensive nitrogen and phosphorus reduction strategies encompassing watersheds with significant contributions of nitrogen and phosphorus to the surface waters of the Mississippi/Atchafalaya River Basin (MARB), and ultimately to the Gulf of Mexico (HTF, 2008)." This called upon each of the 12 member states along the Mississippi and Ohio Rivers to develop its own nutrient reduction strategy by 2013.

The Task Force identified that state Nutrient Reduction Strategies would be critical for reducing nutrient loads to the gulf and throughout the basin, as only states have the authorities, with strong support from federal partners, to achieve the nutrient loss reductions needed to meet the goal (HTF, 2008). In 2015, the Task Force announced that it would retain the original 2001 goal of reducing the areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 km^2, but extend the time of attainment from 2015 to 2035. They also agreed on an interim target of a 20% nutrient load reduction by the year 2025 as a milestone toward reducing the hypoxic zone (HTF, 2015).

Since each HTF state worked to independently develop these reduction strategies, the nutrient measurement accounting system is not uniform, making overall tallies difficult. Several of these states have developed science assessments to define relative nutrient removal potential of common conservation practices that are appropriate to the state's conditions, to better ensure comprehensive basin-wide accounting of reductions. This approach allows statewide information to be used with any water quality models developed for the Mississippi River Basin. With support from the Walton Family Foundation, researchers from the land grant universities in the 12 HTF states formed the Nonpoint Source Measures Workgroup to survey the status and methods individual HTF states use or plan to use, to measure progress and inform development of a reporting framework. Forming what is now called SERA-46, Southern Extension and Research Activities committee number 46), the researchers and extension specialists first worked with two pilot states, Arkansas and Indiana, to build a quantitative assessment of practice implementation from state and federal sources, which expanded to include Illinois, Kentucky, and Minnesota. The survey provided a good starting point for measure-related discussions and indicated that there was a lot of variability amongst states regarding their approaches for measuring progress related to practice implementation through federal, state/local and private programs. General consensus was that federal reporting is most consistent while private reporting provides the biggest challenge by having the most variability in data collection methods, and the lowest resolution (HTF, 2018).

The key base parameters of practice data determined by the Nonpoint Source Workgroup are summarized on the next page in Table 1. These parameters were based on widely available information that is pertinent or helpful for modeling. The information connects an activity with a specific timeline to highlight temporal changes (HTF, 2018).

Table 1. Conservation practice key base parameter data determined by Mississippi River Task Force- Nonpoint Source Workgroup (HTF, 2018)

State
County
HUC_8 Watershed
HUC_12 Watershed
Practice Name
Practice Code
Funding Source
Applied Amount
Practice Units
Applied Date
Cost Share Funding
Sunset Date
Total Project Costs
Water Quality Benefits Program
Practice Category
Land Use
Tillage
Area Treated
Ancillary Benefits
Phosphorus Reduction
Nitrogen Reduction

There are other regions outside of the Mississippi River Basin with collaborative, focused efforts to address water quality nutrient reduction issues. The Great Lakes Restoration Initiative (GLRI), was launched in 2010 as a non-regulatory program to accelerate efforts to protect and restore the largest system of fresh surface water in the world, and to provide additional resources to make progress toward the most critical long-term goals for this important ecosystem. The GLRI has been a catalyst for unprecedented federal agency coordination, which has in turn produced unprecedented results. Built upon the foundation of the Great Lakes Regional Collaboration Strategy, GLRI answered a challenge of the governors of the Great Lakes states. Funding is appropriated to the EPA, which then provides funds to 16 federal organizations to strategically target the biggest threats to the Great Lakes ecosystem and to accelerate progress implementing on-the-ground and in-the-water restoration projects. GLRI has accelerated cleanup of the most polluted Great Lakes sites, reduced phosphorus loadings that often cause harmful algal blooms, and helped keep invasive species out of the Great Lakes (GLRI, 2019).

In the Chesapeake Bay Watershed, a TMDL was established in 2010 to restore clean water in the Chesapeake Bay and the region's streams, creeks, and rivers. Each watershed jurisdiction across the Bay watershed (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia) created a Watershed Implementation Plan to document how the jurisdiction would partner with federal and local governments to achieve and maintain water quality nitrogen, phosphorus, and sediment standards. EPA's Chesapeake Bay Program brought together scientific panels, under the direction of goal implementation teams, to quantify expected effectiveness of various conservation practices. The protocol was carefully outlined (Chesapeake Bay Program; 2017), and effectiveness estimates have been conducted for numerous practices through the development of the Chesapeake Assessment Scenario Tool (CAST), a web-based nitrogen, phosphorus and sediment load estimator tool that streamlines environmental planning.

Successful implementation projects apply a systems approach and rely on diverse collaborative partnerships and networks (Rao and Power, 2019). Rather than focusing solely on individual farmer engagement, they also adopt long-term goals and advance adoption through community networks. It is important to consider planning at the landscape-scale to identify potential problematic source areas that may be contributing disproportionally to water quality issues.

Quantifying the Benefits of Conservation

Federally-funded efforts to measure the impacts associated with conservation investments on water quality date as far back to 1975 with the Black Creek Project in Indiana and the Model Implementation Program between 1978 and 1982. The Rural Clean Water Program began in 1980 and funded 21 national experimental watersheds with significant agricultural nonpoint source pollution (Osmond, 2010). Current monitoring on active farms funded by federal or state programs are typically coordinated through individual institutions and land-grant universities, with state level focus. For example, the Discovery Farms program which operates independently by state, expanded from Wisconsin since 2008 and now includes sites in Minnesota, Arkansas and Washington. Combined across the four states, there are over 250 site years of data to share from edge-of-field surface runoff and tile monitoring on a diverse range of agricultural fields. These projects, and others, are important for better understanding the effectiveness of conservation practices systems at regional scales; however, the inconsistency between sites makes it difficult to amalgamate findings into a national database yielding a common frame of reference. However, there was still a growing demand by the public for better accountability of how society and the environment benefits from the Farm Bill's funding of USDA conservation programs (Duriancik et al., 2008; Mausbach and Dedrick, 2004).

A major effort by USDA, building on decades of prior work, was initiated in by USDA in 2003 to evaluate the collective environmental benefits of government conservation programs on agricultural land (Duriancik et al., 2008). The project, known as Conservation Effects Assessment Project (CEAP) is a multi-agency effort to quantify the environmental effects of conservation practices and programs, and further the science base for managing the agricultural landscape for environmental quality. Although USDA does not make the CEAP survey data publicly available, CEAP assessments are accessible and carried out at national, regional and watershed scales on cropland, grazing land, wetlands and for wildlife and progress is reported annually. Through peer-reviewed articles and USDA publications, the three principal components of CEAP including the national assessments, the watershed assessment studies, and the bibliographies and literature reviews, have contributed significantly to building the science base for conservation (Arnold et al., 2014; Duriancik et al., 2008; Maresch et al., 2008; Osmond et al., 2012; Tomer and Locke, 2010; Tomer et al., 2014).

The CEAP watershed studies can serve as validation points for larger scale regional and national modeling assessments, and provide an in-depth analysis and quantification of the measurable effects of conservation practice systems at the watershed scale (Duriancik et al., 2008). Environmental effects and benefits are estimated for water quality, soil quality, water conservation, and wildlife habitat. During its initial five years, CEAP established research and assessment efforts to estimate the effects and benefits of conservation practices through a combination of research, data collection, model development, and model application. Together with USDA's National Institute of Food and Agriculture (NIFA), the NRCS funded 13 projects between 2004 and 2011, to evaluate the effects of cropland and pastureland conservation practices on spatial and temporal trends in water quality at the watershed scale.

A synthesis project to reveal common lessons learned among data generated from these 13 assessment studies was led by North Carolina State University (Osmond et al., 2012). The key take-aways from the synthesis for developing a successful watershed project included:

1. Assess and plan conservation practice implementation at the watershed scale for more effective water quality outcomes.

2. Identify the pollutants of concern and the source of those pollutants before selecting conservation practices. Prioritize conservation practice systems in the critical areas of the watershed—those that generate the most pollution—to ensure the most effective use of resources.

3. Select and apply practices that are effective in addressing the identified pollutants of concern and ensure that they are properly managed and maintained. Practices are more likely to be adopted when they meet farmers' needs and still achieve water quality goals.

4. Keep track of conservation practice implementation and land management activities based on a watershed plan to assess adoption and treatment needs.

5. Not all conservation efforts need to be modeled or monitored. Where conservation practice effectiveness is assessed scientifically, establish water quality monitoring protocols that are designed specifically to evaluate the change in water quality resulting from conservation treatment on the land.

As of 2019, 51 CEAP watershed studies have been initiated, and 23 remain active, including establishment of 4 new projects in the last 2 years. To develop the conservation data used in the large scale National CEAP Cropland Assessments, USDA conducts a national survey of farmers. The first national survey of farmers was completed in 2006 and provided the data layer used in the first series of CEAP National Cropland Assessments. A second national survey was recently completed in 2016, and USDA expects to publish the second CEAP results (CEAP 2.0) beginning in 2020. These two national surveys will provide a method to track progress represented by a decade of conservation adoption and highlight areas in which additional conservation will make the largest impact on delivery of sediment and nutrients to water resources in regions of interest.

CEAP findings continue to guide USDA conservation policy and program development and help conservationists, farmers and ranchers make more informed conservation decisions. Over the past 15-years, progress has been made defining outcomes of conservation practices through this multi-organizational effort. Still, gaps remain and the need persists for a publicly available, comprehensive set of outcomes related to all soil, water, air, plant, and animal resource concerns spanning multiple land-uses (e.g. cropland, pasture, and woodland), and geographic distribution of conservation practice installation.

Funding Conservation Implementation

Federal, state and local agencies, NGOs, universities and other stakeholders engage various sources of funding to support water quantity improvement. Cities and point source regulated communities utilize rate payers and cost recovery models to fund infrastructure improvements. These urban water sector utilities can use bonding or loans to finance the work and service the loans with dedicated rate payer funds. Many water quality projects addressing nonpoint source, non-regulated communities, or rural watersheds, are supported via federal grant programs, state initiatives, or philanthropic fundraising, and support farmer cost share or incentive project agreements for conservation practice system implementation. Background on these sources of funding are further outlined below.

Federal Funding Sources

Environmental Protection Agency

Congress enacted Section 319(h) (§319) of the Clean Water Act in 1987, establishing a national program to control nonpoint sources of water pollution. Through §319, the U.S. Environmental Protection Agency (EPA) provides states, territories and tribes with guidance and grant funding to implement their nonpoint source (NPS) programs. The vast extent and continuous nature of NPS pollution is a daunting challenge that requires problems be addressed through a variety of approaches using multiple funding sources. Although not the entire remedy, §319 funding is an essential part of the solution to the costly challenges of addressing NPS pollution. State NPS programs typically leverage other programs and funding sources to achieve water quality improvements (USEPA 2016b).

Since 1990, the NPS program at the federal, state, tribal and local levels evolved with refinement of NPS management program plans, an improved understanding of suites of best management practices (BMPs), and new monitoring and modeling approaches to increase the likelihood of water quality restoration. In 2013, the §319 program guidelines were updated to specify that a minimum of 50% of the total award should be used to implement watershed projects guided by watershed plans (USEPA 2013).

Watershed projects enable states to restore NPS-impaired waterbodies which provides significant benefits to surrounding communities dependent upon those resources. These projects demonstrate restoration practices that can be adopted and implemented by partner stakeholders, including local, state, and federal agencies. The watershed-based planning and implementation approach has allowed states to effectively identify and target areas-of-concern. The program is most successful when states leverage their base §319 funds to maximize impact for a full range of activities to support the goals of the state's nonpoint source program including but not limited to planning, TMDL development, and water quality monitoring (USEPA, 2011; USEPA 2013). States also have access to Clean Water State Revolving Funds. These federal funds must be matched 20% by the state.

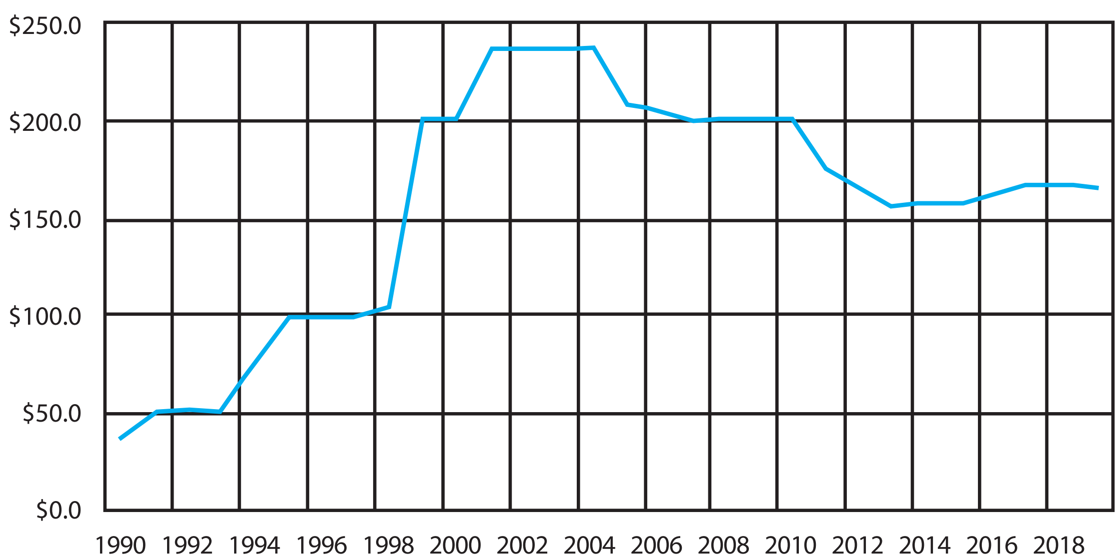


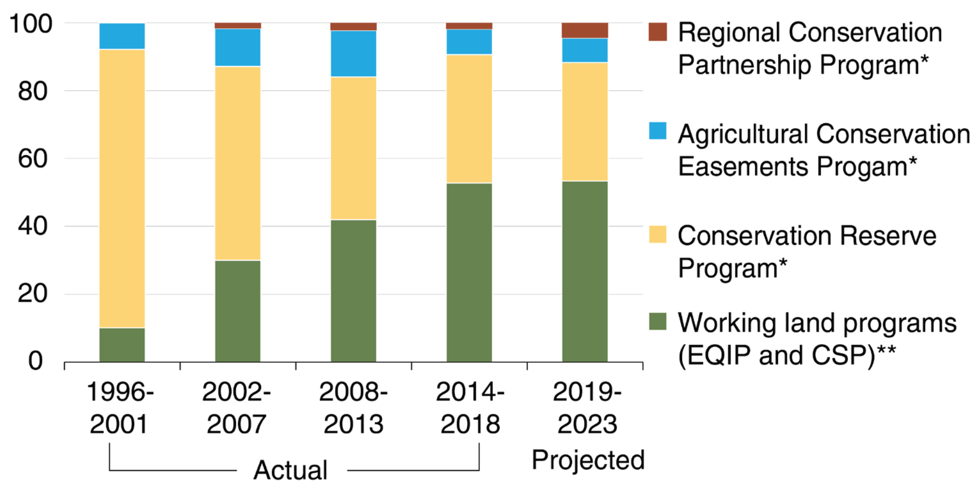
Figure 3. Annual USEPA §319 grant funds 1990 to 2019 (in millions; USEPA 2020a).

They are state implemented and operated, allow for flexibility in the type of assistance and loan term, and can fund a wide variety of water quality protection efforts, allowing each individual state to target a specific water quality priority. Local and state water managers can utilize the EPA's Water Infrastructure and Resiliency Finance Center to find funding sources and financing resources for implementing rural or urban water improvement projects (USEPA 2020b).

Department of Agriculture

The USDA was reorganized in 2017 to include a Farm Production and Conservation (FPAC) mission area to focus on domestic agricultural issues. This brings the Farm Service Agency (FSA), the Risk Management Agency (RMA), and the Natural Resources Conservation Service (NRCS) together under one mission focused on mitigating significant risks of farming through crop insurance, conservation programs and technical assistance, and commodity, lending, and disaster programs (USDA, 2019e). The U.S. Forest Service is in the Natural Resources and Environment mission area.

The largest current source of federal conservation financing is the Conservation Title (Title II) of the Farm Bill. The 1985 Farm Bill significantly increased funding for conservation. Funding for the Conservation Title peaked under the 2008 Farm Bill. Adjusting for inflation, between 1996 and 2011, conservation spending grew by roughly 50%, but declined slightly under the 2014 Farm Bill. Under the 2018 Farm Bill, mandatory conservation spending is estimated at $29.5 billion over 5 years, approximately $560 million more than 2019 to 2023 projections of spending if the programs and provisions of the 2014 Farm Bill had been extended (Figures 4 and 5; USDA, 2019b). The 2018 Farm Bill reallocates mandatory funding within the conservation title among the larger programs. There are five major conservation programs funded under the 2018 Farm Bill; the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) (combined as "working lands"), the Agricultural Conservation Easements Program (ACEP), the Conservation Reserve Program (CRP), and the Regional Conservation Partnership Program (RCPP) (Figure 4; Wallander, 2019).

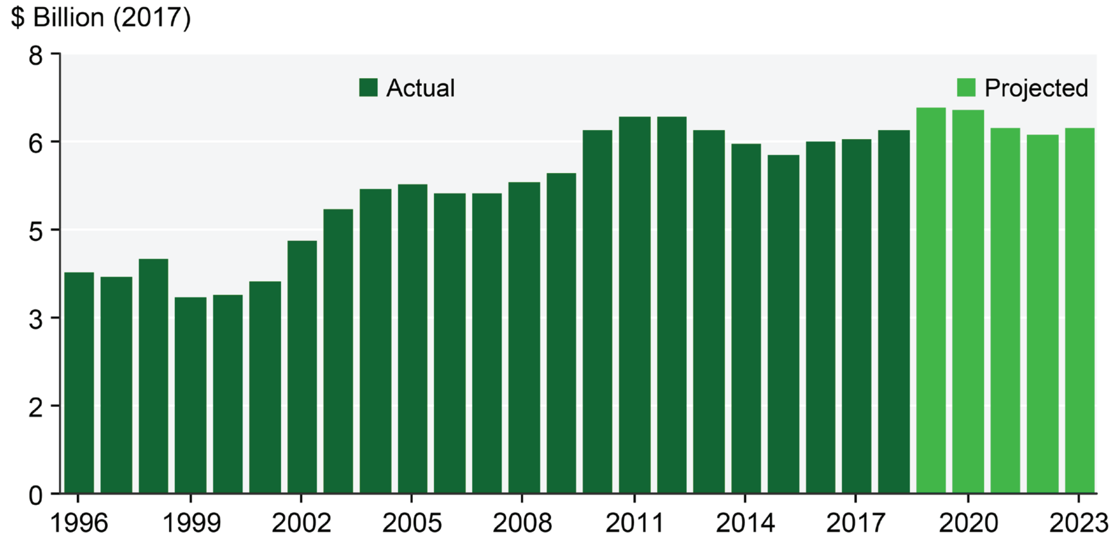


*Includes predecessor programs

**Includes the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) and predecessor programs. The programs are shown together because they are combined in the CBO estimates.

Sources: ERS analysis of Office of Budget and Policy Analysis data for 1996-2017 and Congressional Budget Office Estimates for 2018-2023.

Figure 4. Share of conservation spending by major USDA programs in the 2018 and previous Farm Acts (USDA, 2019b).



1/ Includes these programs and predecessors: Conservation Reserve Program, Agricultural Conservation Easement Program, Environmental Quality Incentives Program, Conservation Stewardship Program, Regional Conservation Partnership Program, and Conservation Technical Assistance (CTA). CTA is funded annually through appropriations; here it is assumed constant at $769 million (nominal). Spending is adjusted to constant (2017) dollars, with assumed annual inflation of 2 percent for 2019-23.

Figure 5. Inflation-adjusted annual spending for major USDA conservation programs, 1996-2018, with projections to 2023 (USDA, 2019b).

Farm Service Agency

FSA supports the delivery of farm loans, commodity, conservation, disaster assistance, and related programs. FSA utilizes the Commodity Credit Corporation (CCC), which funds most of the commodity and export programs, and some of the USDA conservation programs. FSA farm loan programs provide credit to farmers when they are temporarily unable to obtain credit from commercial sources. The majority of FSA's direct and guaranteed farm ownership and operating loans are targeted to underserved populations such as beginning farmers and socially disadvantaged producers, who generally have had a more difficult time obtaining credit to maintain and expand their operations. In 2018, FSA provided over 34,600 direct and guaranteed loans to farmers and ranchers, totaling more than $5.5 billion.

FSA land retirement programs authorize USDA to make payments to private landowners who retire land from production for less intensive uses. The Conservation Reserve Program (CRP) is the largest land retirement program and provides 10 to15-year contracts to remove environmentally sensitive land from agricultural production and planting species that will improve environmental quality. CRP has contributed to a number of environmental benefits including reduced soil erosion, improved water quality through wetlands and field buffers, reduced fertilizer use, and increased wildlife habitat (Stubbs, 2014). In 2018, USDA enrolled about 295,000 acres under the continuous signups and about 438,000 acres under grasslands signups (USDA, 2019f). The 2018 Farm Act also created a new Soil Health and Income Protection Pilot (SHIPP) program under CRP to convert less productive farm land from production into low-cost perennial cover crops, in exchange for annual rental payments. The Conservation Reserve Enhancement Program (CREP) was created from the CRP program, and also removing land from production in exchange for annual rental payments, CREP targets high-priority conservation issues identified by state government and NGOs.

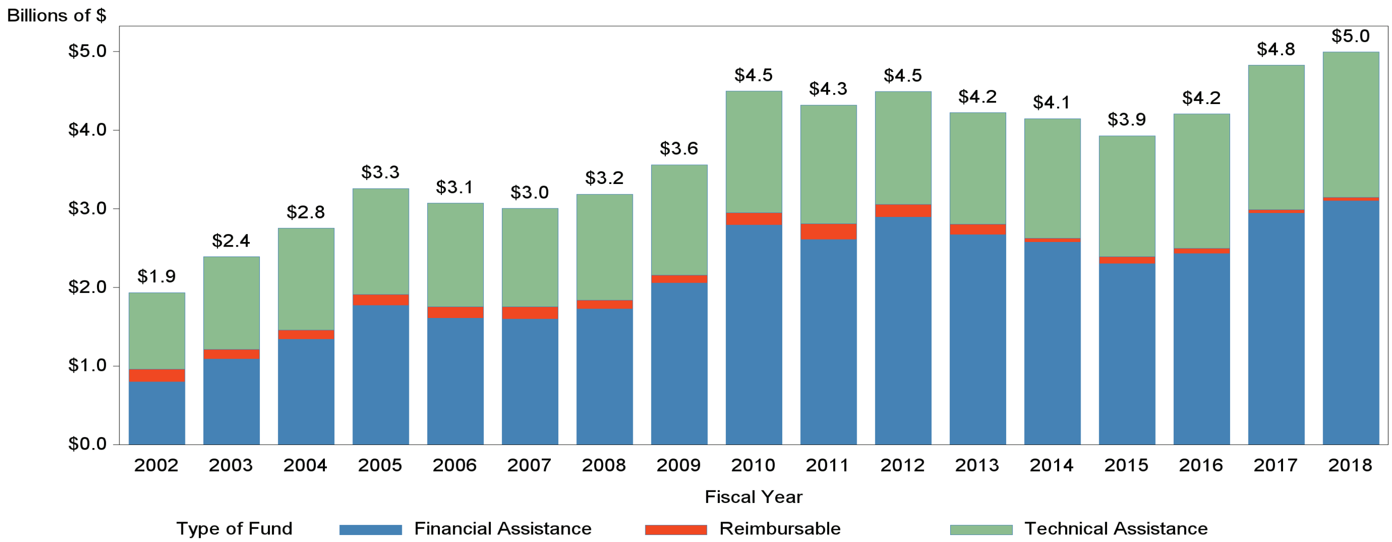


Figure 6. Distribution of the total funding obligation for technical assistance, financial assistance, and reimbursable funds reported at the end of each fiscal year between 2002 and 2018 by the USDA (2019f).

Interest in USDA conservation funding programs fluctuates based on a number of factors, particularly commodity crop prices. High commodity prices, changing land rental rates, and new conservation technologies have shifted farm bill conservation policy away from programs that retire land from production, such as CRP, toward programs that provide assistance to lands still in production, like EQIP and CSP (Stubbs, 2019a). Strong prices can encourage farmers to put CRP acres back into production, which could potentially reduce the number of CRP acres offered for reenrollment once they have expired or cause existing CRP participants to seek an early release from their CRP contract. Some participants, based on region, have indicated a low CRP rental rate compared to the market rental rate as a reason for decreased enrollment interest. Despite these limiting factors, enrollment has increased under continuous sign-ups and in general, demand for CRP contracts still exceeds the maximum enrollment capacity, which was 24 million acres in 2018, and expected to increase to 27 million by 2023.

Natural Resources Conservation Service

Conservation programs through the USDA's NRCS work in partnership with private landowners, conservation organizations, local governments, and other stakeholders to reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damage from floods and other natural disasters. While the number of national programs has increased and new techniques to address resource challenges continue to emerge, the basic federal approach has remained unchanged, voluntary farmer participation encouraged by financial and technical assistance, education, and basic and applied research.

NRCS funding supports two classes of activity: technical assistance to help landowners and operators plan for conservation actions, and financial assistance to support implementation of conservation practices. Figure 5 summarizes the distribution of the total funding obligation for technical assistance, financial assistance, and reimbursable funds reported at the end of each fiscal year by the USDA (2019e). Reimbursable funds can be used to provide technical or financial assistance, but are received from sources other than the NRCS.

Previously NRCS offered "cost-share" funding, which reimbursed the landowner for approximately 50%-75% of the costs of a conservation practice. Now NRCS follows a "financial assistance" approach, which pays a flat payment rate based on prevailing material and labor costs by state. Financial assistance is not intended to necessarily cover the full cost of the conservation practice, or the costs of management labor or production loss associated with practice adoption. However, for programs, foregone income is included in the payment of certain scenarios when land is removed from production or income is reduced due to practice implementation.

Working lands programs provide financial assistance to farmers who adopt, install, or maintain conservation practice systems on land in production and include both EQIP and CSP. EQIP provides financial assistance to farmers who adopt or install conservation practice systems on land in agricultural production. Under the 2018 Farm Bill, new EQIP stewardship incentive contracts were created. They are limited to select priority resource concerns within specific geographic regions; no more than three priority resource concerns may be identified in each geographic region. EQIP incentive contracts extend for five to ten years and provide annual payments to incentivize increased conservation stewardship and the adoption, installation, management, and maintenance of conservation practices (Stubbs, 2019a). EQIP has a number of state and national initiatives that focus on a specific region or priority, including the National Water Quality Initiative (NWQI), which was implemented in 2012. Through NWQI the NRCS offers financial and technical assistance in small watersheds to farmers and forest landowners interested in improving water quality and aquatic habitats. These priority watersheds have impaired streams and the targeted funding accelerates focused practice implementation where it will have the greatest benefits for clean water. NWQI is a partnership among NRCS, EPA, state water quality agencies and other partners, who contribute additional resources for watershed planning, implementation and outreach. These partnerships may also support monitoring efforts to help measure the impact of the adopted conservation practice systems on water quality over time.

CSP supports conservation efforts for producers who meet farm-wide stewardship requirements on working agricultural and forest lands. Funding for CSP was previously based on an acreage limitation; however, with the 2018 Farm Act, it better aligns with EQIP and is now based on a funding limit. Under both the 2014 and 2018 Farm Acts, working land program funding accounted for 53% of major conservation program funding.

Voluntary easement programs impose a permanent land-use restriction on the land in exchange for a government payment. The Agricultural Conservation Easements Program (ACEP) provides long-term or permanent easements for preservation of wetlands (wetland reserve easements; WRE) and the protection of agricultural land from development (agricultural land easements; ALE).

RCPP provides assistance to partners to solve problems on a regional or watershed scale through the coordination of NRCS conservation activities with partners that offer value-added contributions to expand the capacity to address on-farm, watershed, and regional natural resource concerns. Through RCPP, NRCS seeks to co-invest with partners to implement projects that demonstrate innovative solutions to conservation challenges and provide measurable improvements and outcomes tied to the resource concerns they seek to address. RCPP was amended in the 2018 Farm Act by shifting the program away from enrolling land through existing conservation programs, to a standalone program with separate contracts and agreements. Under the revised program, USDA is to continue to enter into agreements with eligible partners, and these partners are to continue to define the scope and location of a project, provide a portion of the project cost, and work with eligible landowners to enroll in RCPP contracts (Stubbs, 2019a). Although conservation funding for CRP is projected to decline slightly between 2019 to 2023, funding will increase for ACEP and RCPP (Wallander, 2019).

Risk Management Agency

RMA was created in 1996 to strengthen the economic stability of agricultural producers and rural communities. RMA's programs are designed to allow farmers and ranchers to effectively manage their risk through difficult periods, helping to maintain America's food supply and the sustainability of small, limited resource, socially disadvantaged and other underserved farmers. Crop insurance is one of RMA's best-known programs providing effective coverage that helps farmers and ranchers recover after severe weather and bad years of production. In crop year 2018, the Federal Crop Insurance Program provided protection for more than $100 billion in agricultural production (USDA, 2019f). Flood and prevented planting provisions in insurance policies provide funding to growers when they are unable to plant their crops due to an insurable cause. This keeps farmers out of their fields at times that might be detrimental to soil health and water quality. As late spring precipitation events continue to impact spring planting dates, RMA has incorporated flexibility in planting requirements and date restrictions to better align with NRCS requirements on conservation practice standards and specifications, such as planting cover crops or forages and permitting farmers to hay, graze or chop the fields later in the season to reduce barren soil surfaces.

Forest Service

The Forest Legacy Program (FLP) is a conservation program administered by the U.S. Forest Service in partnership with State agencies to encourage the protection of privately-owned forest lands through conservation easements or land purchases. Loss of forested areas poses an increasing threat to the integrity of the nation's natural resources. As these areas are fragmented and disappear, so do the benefits they provide. By providing economic incentives to landowners to keep their forests as forests, we can encourage sustainable forest management and support strong markets for forest products. Since its creation in 1990, FLP has conserved over 2.6 million acres of forest land and expanded across the country to 53 states and territories. These "working forests" protect water quality and provide wildlife habitat, forest products, opportunities for recreation and other public benefits.

North American Wetlands Conservation Act (NAWCA) grants increase bird populations and wetland habitat, while supporting local economies and American traditions such as hunting, fishing, bird watching, family farming, and cattle ranching. Wetlands protected by NAWCA provide valuable benefits such as flood control, reducing coastal erosion, improving water and air quality, and recharging ground water.

Fish and Wildlife Service

The Cooperative Endangered Species Conservation Fund (section 6 of the Endangered Species Act) provides grants to states and territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to states and territories for species and habitat conservation actions on non-federal lands. States and territories must contribute a minimum non-federal match of 25% of the estimated program costs of approved projects, or 10 percent when two or more states or territories implement a joint project. A state or territory must currently have, or enter into, a cooperative agreement with the Secretary of the Interior to receive grants. Most states and territories have entered into these agreements for both plant and animal species.

Other Conservation Funding

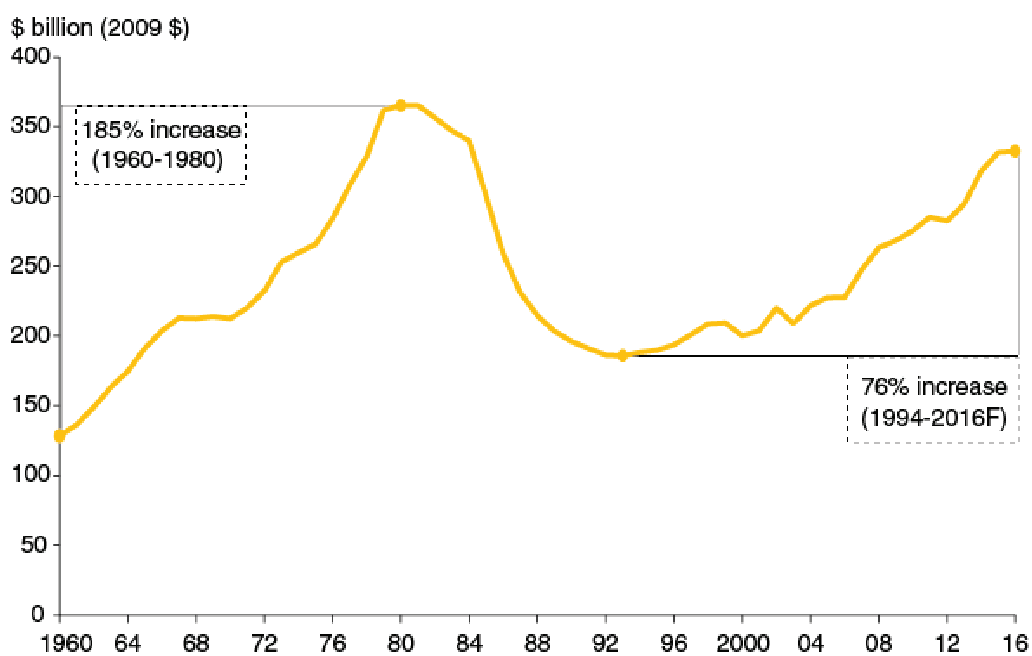
The Land and Water Conservation Fund (LWCF) was established by Congress in 1964 with a strong bipartisan commitment to protect natural, cultural and water resources including national parks and forests, land by rivers, lakes and oceans, working forests, farms and ranches, fish and wildlife refuges, trails, and state and local parks. Revenues from the depletion of one natural resource, offshore oil and gas, are used to support the conservation of another precious resource, our land and water. Every year, $900 million in royalties paid by energy companies drilling for oil and gas on the Outer Continental Shelf (OCS) are put into this fund. The money is intended to protect national parks, areas around rivers and lakes, national forests, and national wildlife refuges from development, and to provide matching grants for state and local parks and recreation projects. Over the years, LWCF has also grown and evolved to include grants to protect working forests, wildlife habitat, critical drinking water supplies and disappearing battlefields, as well as increased use of easements.

Agricultural Lending

While private and government-related agricultural lenders indirectly provide financing for some conservation projects, this is not their primary mandate and the extent of financing is not specifically tracked.

The Farm Credit System (FCS) is a government sponsored enterprise (GSE) that was established by Congress in 1916 and expanded during the Great Depression. The Farm Credit Administration (FCA), established under the Farm Credit Act of 1953, is an independent agency in the executive branch of the U.S. government responsible for regulating and supervising the FCS including its banks, associations, and related entities, and the Federal Agricultural Mortgage Corporation, also known as Farmer Mac. Today FCS functions as a for-profit cooperative lender with a mandate to serve agriculture. Farmer Mac is also a GSE and is a secondary market for agricultural loans.

The FCS is a nationwide network of borrower-owned financial institutions that provide credit to farmers, ranchers, residents of rural communities, agricultural and rural utility cooperatives, and other eligible borrowers. Congress established



F= Forecast. Values are adjusted using the chain-type GDP deflator, 2009=100.
Source: USDA, Economic Research Service, Farm Income and Wealth Statistics. Data as of February 9, 2016.

Figure 7. Farm debt growth has been more gradual during period since 1994 than in the decades leading up to the 1980s farm financial crisis (USDA, 2016).

the System to improve the income and well-being of farmers and ranchers by providing a permanent, reliable source of credit and related services to agriculture and aquaculture producers, farmer-owned cooperatives, and farm-related rural businesses. Congress formed the FCS as a system of farmer-owned cooperatives to ensure that farmer- and rancher-borrowers participate in the management, control, and ownership of their institutions. The participation of member-borrowers helps keep the institutions focused on serving their members' needs.

Following a period of decline due to the farm financial crisis in the 1980s, the agricultural sector debt has trended upward as a whole since 1994, at a slower pace than growth in the 1970s, with the increase primarily driven by growth in loans held by commercial banks and FCS, the two largest lenders to the U.S. farm sector (Figure 7). Between 1994 and 2014, the combined percentage of debt outstanding attributable to these two groups of financial institutions increased from 64% in 1994 to over 81% in 2014 (FCA, 2018). The FSC market share of total farm business debt has been relatively stable in recent years and except for brief periods, has typically had the largest market share of farm business debt secured by real estate.

Government-related entities and private institutions (commercial banks and life insurance companies) each account for approximately 45% of outstanding agricultural debt (Figure 8). Agricultural real estate debt accounts for 61% of total outstanding debt and represents loans secured by farmland. The remaining 39% of agricultural debt represents short-term debt, typically used to finance operations.

Farm Economy Overview

The U.S. farm economy is comprised of a diverse landscape of farming operations across the country with annual crop and livestock farms accounting for 79% of sector revenues (Figure 9; USDA, 2017).

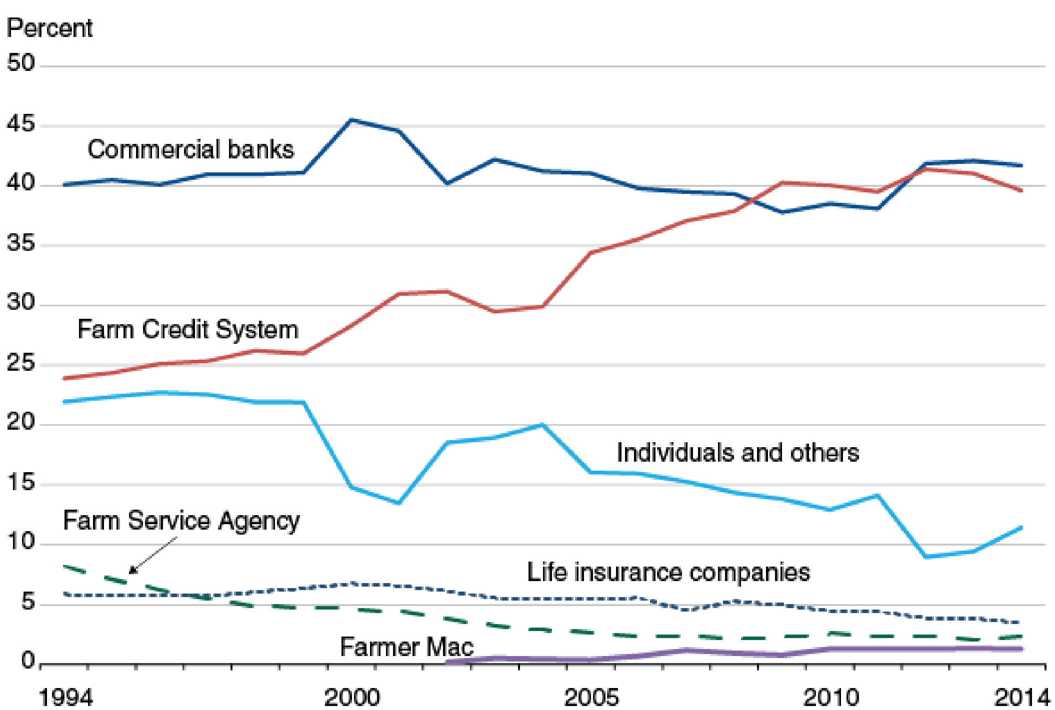


Figure 8. Commercial banks and the Farm Credit System hold the largest share of farm sector debt (USDA, 2016).

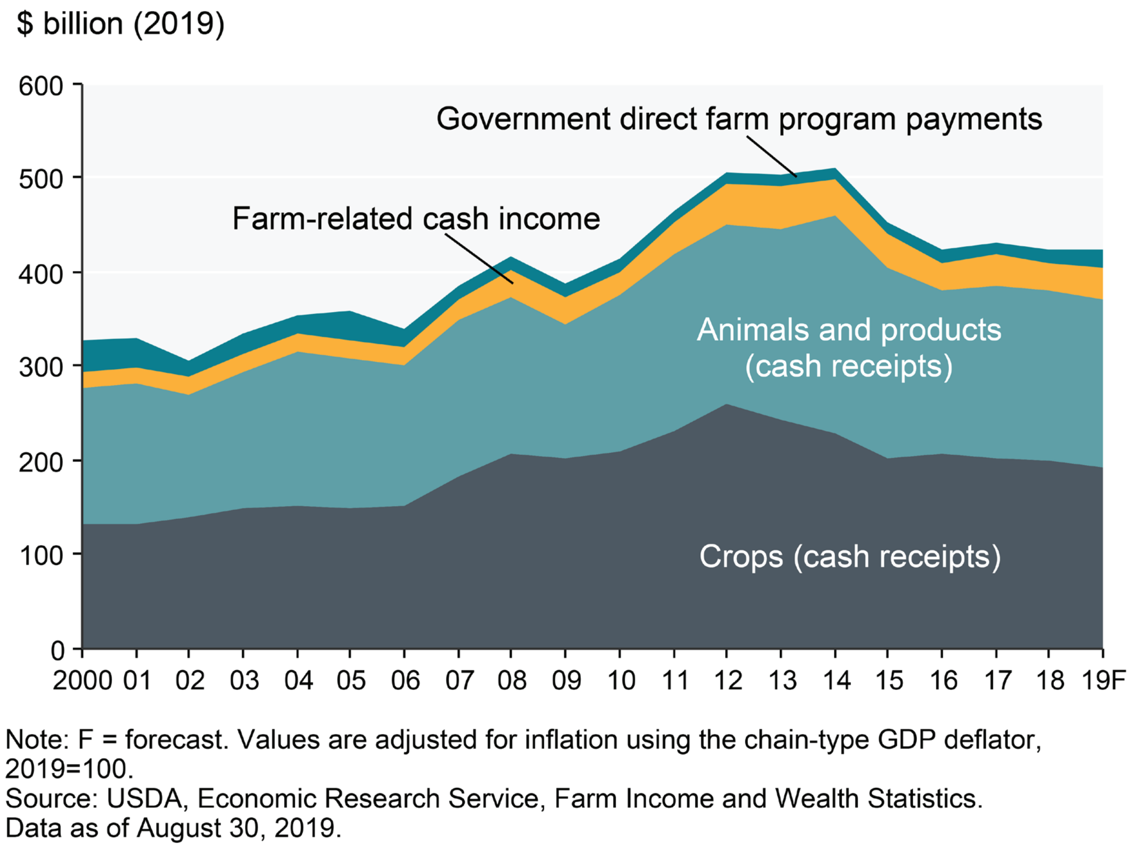
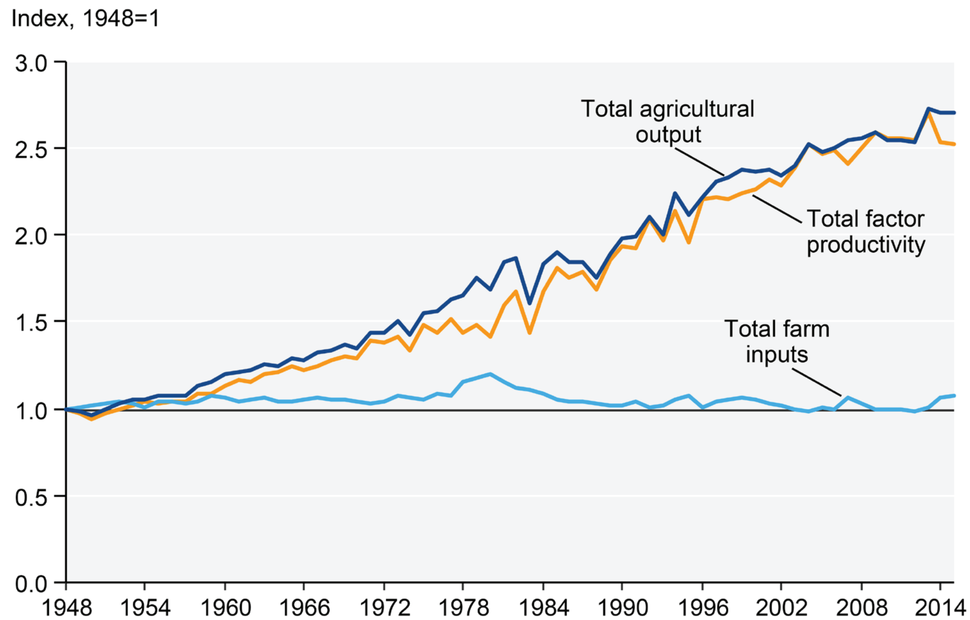


Figure 9. Gross cash farm income components for 2000 to 2019, adjusted for inflation (USDA, 2019d).

As Figure 10 illustrates, post-war U.S. agriculture has been characterized by substantial improvements in productivity driven by the development and adoption of new technologies. U.S. farm output grew by 170% between 1948 and 2015 at an average annual rate of 1.48% (USDA, 2017). Total factor productivity (TFP), depicted on Figure 10, considers all input contributions (i.e., capital, land, labor, and intermediate inputs such as seed, chemicals, fuel). If total output grows faster than total inputs, TFP has improved. While total inputs have remained relatively stable, they have shifted from less labor and land toward more from farm machinery (part of capital goods) and intermediate inputs (USDA, 2017).

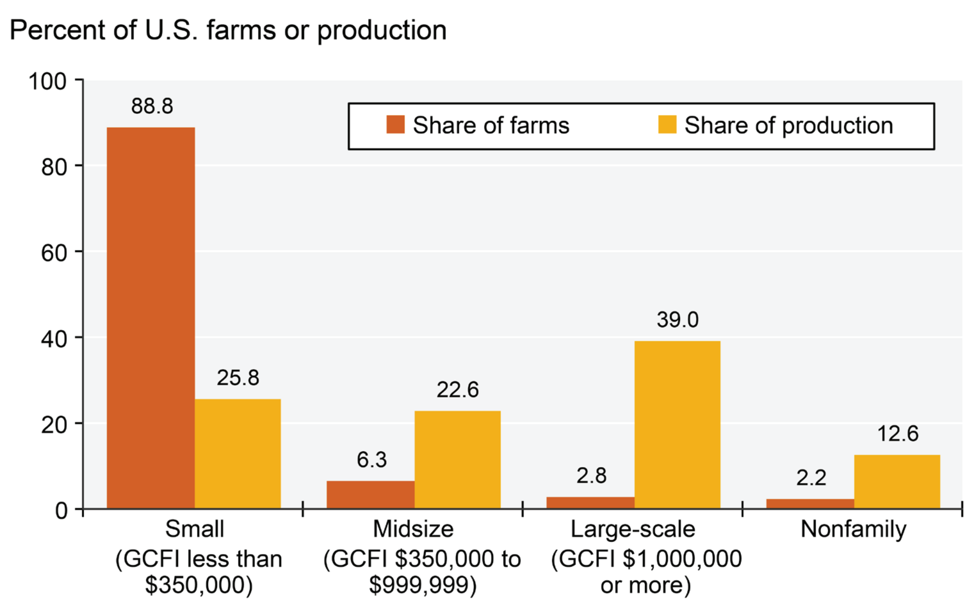
Increased productivity has also created pressure for the sector to consolidate, resulting in a decline in the number of farms from 6.1 million in 1940 to roughly 2.1 million in 2017 (USDA, 2018a). However, the sector remains highly fragmented. USDA data from 2017 indicates 98% of farms are family-owned and 89% are small, family farms with annual revenues less than $350,000. Additionally, while large farms only represent 3% of total farms, they account for 39% of total value of production (Figure 11). The agricultural sector's fragmentation is a significant barrier to developing scalable conservation financing solutions, which will be discussed in greater detail later in the document.

From 2003 to 2014, U.S. farmers experienced a period of rising profitability driven by growing international demand (Figure 12). Additionally, changes in U.S. energy policy to increase use of ethanol created significant domestic demand for corn. Ethanol use accounted for 45% of U.S. corn consumption in 2017. This period of rising profits was amplified in 2012 and 2013 as global stockpiles of annual crops reached historically low levels due to adverse weather events. However, since 2013, U.S. farm incomes have declined by



Source: USDA, Economic Research Service, *Agricultural Productivity in the U.S.* series; data as of October 2017.

Figure 10. U.S. agricultural outputs, inputs, and total factor productivity (TFP) between 1948 to 2015 (USDA, 2017).



Note: GCFI refers to annual gross cash farm income before expenses; ERS refers to Economic Research Service. Nonfamily farms are those where neither the principal operator, nor individuals related to the operator, own a majority of the farm business.
Source: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resource Management Survey. Data as of November 30, 2018.

Figure 11. Farms and their 2017 value of production by USDA, Economic Research Service farm type (USDA, 2018a).

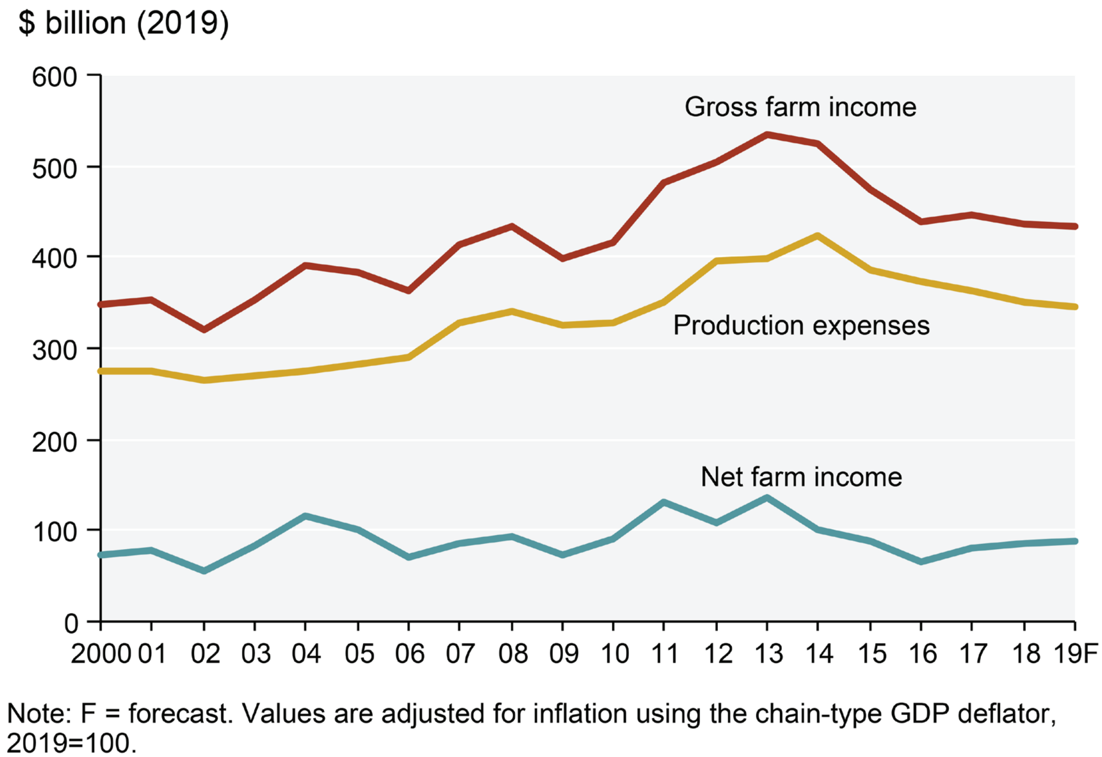


Figure 12. Gross farm income, production expenses, and net farm income from 2000 to 2019 adjusted for inflation (USDA, 2019d).

roughly 50% and are near the 20-year average (USDA, 2019d). Despite the recent decline in farm incomes (Figure 12), U.S. farmers enjoy a strong solvency position with debt accounting for just 13% of total assets.

Capital has been identified as the best financial predictor of conservation adoption (Baumgart-Getz et al., 2012). Understanding the current trends of agricultural markets, farm specialization and productivity is an important aspect of identifying barriers to implementing conservation practices (Roesch-McNally et al., 2018). Recent declines in crop prices and broader concerns about farm program funding, coupled with farmer awareness of environmental issues, may provide an impetus to advance on-farm conservation, including nutrient management opportunities.

Quantifying Conservation Practice Effectiveness

Tracking and quantifying regional water quality benefits requires spatial, temporal, and persistence measures of what is being adopted on the landscape. In the absence of direct monitoring, these data can be incorporated into accurate watershed/water quality models to encourage cost effective and science-based implementation. Quantifying the effects of conservation practice systems on water quality requires tracking the implementation of practices and procedures for translating practice implementation to reductions in sediment and nutrient losses from agricultural land (Figure 13). Although such procedures result in only general estimates since effectiveness is site-specific and dependent on variables that cannot all be tracked, the results can still be useful for identifying viable options to meeting watershed scale nutrient reduction goals, driving policy changes, implementing NRCS initiatives, and informing private financial tools.

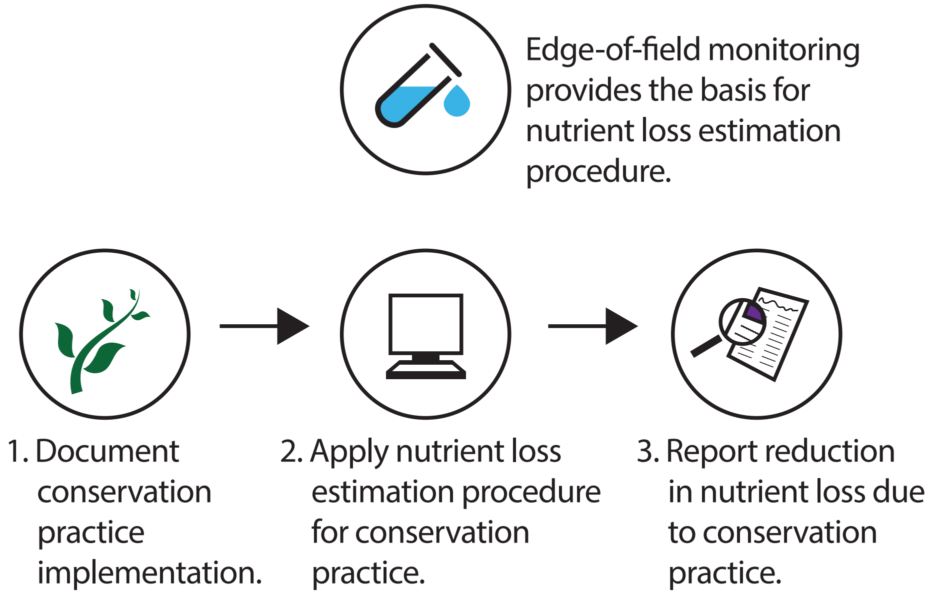


Figure 13. Documentation of practices and nutrient loss estimation procedures are necessary for reporting nutrient loss reductions resulting from the adoption of conservation practices.

NRCS Conservation Practices for Water Quality

Conservation practices implemented with NRCS program assistance are planned and applied at the land unit level, which is the smallest unit of land that has a permanent or contiguous boundary, a common land cover and land management, and a common owner or farmer. Although practices may affect resources beyond the land unit boundary, or be applied only on part of the land unit, the NRCS uses the land unit area as the common metric to aggregate practices.

Figure 14 summarizes NRCS conservation practices for water quality as a percentage of land acreage. When looking at the values, note that land unit acres may be counted by the NRCS multiple times within each fiscal year, once for each program that has been used to apply at least one practice, and potentially counted multiple times across fiscal years. Additionally, although Figure 14 presents conservation practices with a water quality benefit, some practices address multiple resource concerns. When the land unit acres are depicted to represent another resource benefit, such as soil quality, the acres could be counted under each resource that is enhanced.

Figure 14 illustrates that the implemented water quality conservation practice covering the largest percentage of land unit acres between fiscal year 2005 and 2018 was prescribed grazing. This is an important example of how conservation practices have multiple system services. Prescribed grazing is not a practice commonly promoted for water quality improvement, but rather is often adopted as a method to benefit livestock production and improve soil quality. However, the reduction in soil compaction and increase in vegetative cover also reduce soil erosion and sediment runoff, which is a water quality benefit. Prior to 2014, the NRCS Grassland Reserve Program, and since 2014, the Agricultural Conservation Easement Program, have both promoted grazing practices.

To date, prioritization for conservation practice implementation has been based predominantly on national initiatives, state priorities, and local desires. NRCS prioritization seeks out the biggest environmental benefits for conservation investments with the principle of locally led conservation. Locally led conservation is a statutory requirement for State Conservationists, which includes convening State Technical Committees, comprised of a prescriptive representation from state agricultural, forestry, and

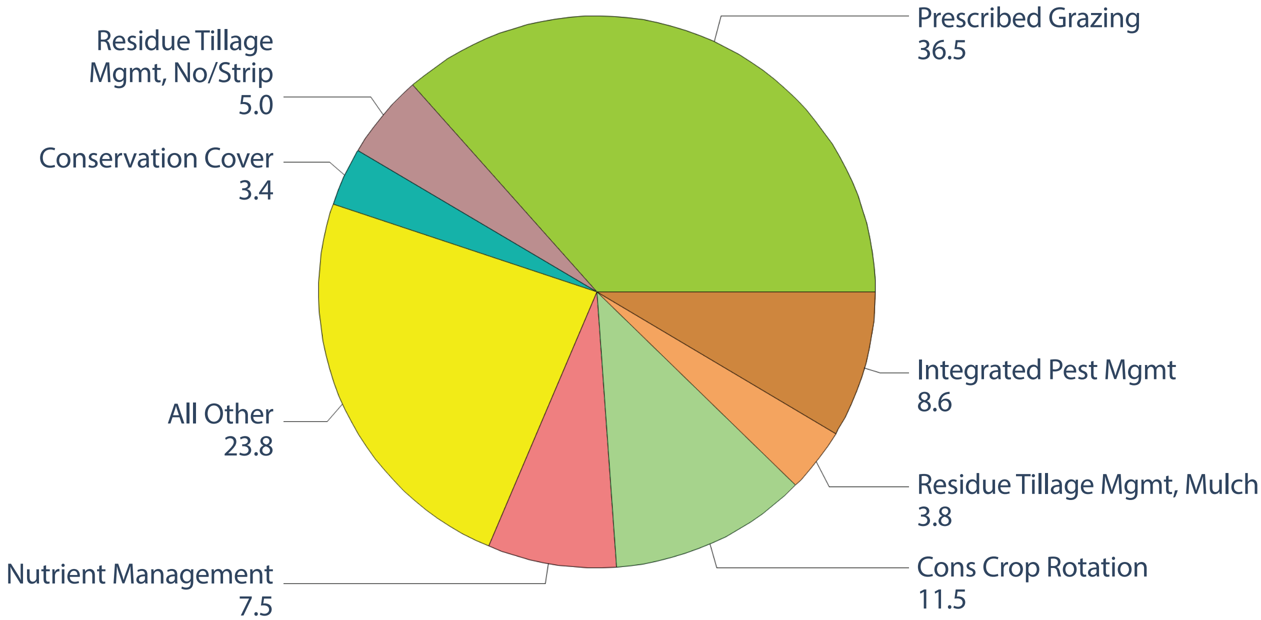


Figure 14. Percentage of land unit acres (which may be counted multiple times within each fiscal year) receiving a specific water quality conservation practice for fiscal years 2005 through 2018; all other category represents practices combined that otherwise alone do not represent a significant portion of the total (USDA, 2018c).

other natural resource interests, to assist in making recommendations, as well as Local Work Groups to provide input from local agricultural, forestry, and other natural resource organizations.

Data informing decision-making related to the impact of conservation practices has historically been related to the number of practices installed, amount of funding offered, and number of landowners serviced. Interest in quantifying the impact conservation practices have on natural resources is increasing, and is influencing priorities related to future conservationinvestments.

Metrics of Practice Effectiveness

Many of the earliest methods to estimate nutrient loss reductions were based on actual field measurements carried out on small controlled plots, farm-size fields, or small watersheds. For example, the USLE was developed from the statistical analyses of more than 10,000 plot-years of data collected at 49 erosion research stations in the United States (Wischmeier and Smith, 1978). Over the last 40 years, in-field and edge-of-field nutrient losses have continued to be measured at hundreds of research sites across the US by universities and agencies working on independent projects, rarely combining site data into comprehensive, multi-site regional analyses. In the early 1980s, Beaulac and Reckhow (1982) compiled nutrient export data and corresponding site characteristics from 40 studies on agricultural land to provide a comprehensive source of field-scale nutrient export data. This became known as the "Measured Annual Nutrient loads from Agricultural Environments" (MANAGE) database. MANAGE was developed to be a readily-accessible, easily-queried database of site characteristic and field-scale nutrient export data (Harmel et al., 2006). Initial funding for MANAGE was provided by USDA-ARS to support CEAP and the Texas State Soil and Water Conservation Board as part of their mission to understand and mitigate agricultural impacts on water quality (Harmel et al., 2017).

In 2008, nitrogen and phosphorus load data from 15 additional studies, together with runoff concentration data for these 15 sites plus the initial 40 studies were added to the database (Harmel et al., 2008). A third update occurred to MANAGE in 2016, when 30 runoff studies from forested land uses, drainage water quality from

91 drained sites, and 12 cultivated or pasture/rangeland runoff studies were incorporated (Christianson and Harmel, 2015). At that same time, fertilizer application timing, crop yield, and nutrient update data were added. MANAGE was the first published attempt to facilitate a spatial analyses and improved understanding of regional differences, management practice effectiveness, and impacts of land use conversions and management techniques, and it provides valuable data for modeling and decision-making related to agricultural runoff (Harmel et al., 2008).

More recently, as a means to meet nutrient reduction goals set out by the Gulf of Mexico Hypoxia task force, state-level efforts have generated state-specific literature reviews on conservation practice efficacy. Merriman et al. (2009) provided data for Arkansas, and FTN Associates (2019) incorporated a science assessment into their nutrient strategy (ANRC, 2019). The Iowa Nutrient Reduction Strategy (IDALS, IDNR, and ISU, 2013) brought together data from studies in Iowa and neighboring states. Minnesota and Illinois conducted similar assessments, which were compared by Christianson et al. (2018). Conducting these region-specific literature reviews to compile data from multiple studies over a broad timescale can provide a basis for nutrient load reduction estimates; however, these efforts relied on long-term averages and professional judgement which may reduce the degree of accuracy at a site-specific scale since there is not necessarily consistency amongst the sites, data collected methods, or spatial and temporal characteristics.

Water Quality Models and Tools

Water quality models have served an integral role in the management of the Nation's surface waters and their development began with the availability of mainframe computers in the 1960s (Ambrose et al., 2009). To be widely accepted and used, estimation procedures need to be generally accurate and accessible to the public. Improved accuracy can come at a cost of increased complexity and reduced transparency, therefore, balancing these is a challenge for gaining acceptance.

One of the first examples of a simple, transparent procedure that has been widely used for decades is the Universal Soil Loss Equation (USLE), developed to estimate erosion and the effects of conservation practices (Wischmeier and Smith, 1978). Despite known limitations in accuracy, and the development of more complex models to accomplish the same purpose, USLE is still the most widely used erosion prediction tool worldwide (Alewell et al., 2019). In the early 1990s, the Revised USLE (RUSLE) was released as a DOS-based computer system in which the mathematical operation of the model was retained, but some of the factors were adjusted and improved based on new research undertaken since the mid-1960s. One of the more significant updates was to the cover-management factor which incorporated subfactors to integrate prior land use, surface roughness, canopy cover, surface cover, and soil moisture. In 2003, RUSLE2 an advanced version of RUSLE was released. RUSLE2 runs in a modern graphical user interface and has the capacity to use county-specific climatic data and calculate soil loss for each day of the year. It is still used by NRCS field offices for conservation planning. A meta-analysis of published articles using USLE-type modelling to estimate soil loss by water erosion from local to continental scale showed an increasing trend, especially in the last 20 years after the launch of RUSLE2 (Alewell et al., 2019). A limitation to most complex models is that despite their ability to predict both runoff and soil loss at a variety of scales, little quantification is made of uncertainty and error associated with model output (Alewell et al., 2019). Despite decades of research, a wide array of available models of varying complexity, and increased pressure toward quantifying conservation effects, no single method has achieved anywhere near global acceptance for estimating nutrient loss reductions from conservation practice implementation.

Model development was driven by regulation and more specifically, the Clean Water Act (Ambrose et al., 2009). Quantitative models help watershed managers better understand the source of the watershed impairment, estimate how water quality will change with time, develop TMDLs, and identify possible remediation scenarios. One of the first publicly available, comprehensive watershed models that simulates nutrient and pesticide transport and fate in land and water was Hydrologic simulation program-Fortran (HSPF), which developed in the 1960s but publicly released in 1980 (Ambrose et al., 2009). HSPF, supported by the EPA, is one of few models that can simulate the continuous and dynamic storm events of hydrologic and water quality processes in a watershed, with an integrated linkage of surface, soil, and stream processes, including nonpoint and point sources of pollution. Although HSPF is a powerful water quality model supporting both regulatory and planning applications, it is highly complex with a steep learning curve and data intensive.

SPARROW (SPAtially Referenced Regression On Watershed attributes) is a statistically based watershed modeling technique that was developed in the 1990s by USGS scientists for relating water-quality measurements made at a network of monitoring stations to attributes of the watersheds such as contaminant sources and environmental factors that affect rates of delivery to streams and in-stream processing. The core of the model consists of a nonlinear regression equation describing the non-conservative transport of contaminants from point and non-point sources on land to rivers and through the stream and river network. Stream processes and model output are based on statistical relationships that were developed using national and regional water quality datasets (Shoemaker et al., 2005). SPARROW has been utilized by the USGS in regional water-quality assessments to better explain the factors that affect water quality, to examine the statistical significance of contaminant sources, environmental factors, and transport processes in explaining predicted contaminant loads, and to provide a statistical basis for estimating stream loads in unmonitored locations (Smith et al., 1997). The model is limited to broadly estimating pollutant loads and fate/transport characteristics at an annual time-scale and is only applicable to large watersheds (Shoemaker et al., 2005).

An event-based model that has been evolving since the 1980s, to evaluate small, agricultural watersheds is the Agricultural Non-Point Source Pollution Model (AGNPS). It was developed by the USDA's ARS, and is a tool for evaluating the effect of management decisions impacting water, sediment and chemical loadings within a watershed system. It began as a single event model, but in the 1990s was enhanced to improve the usability and capacity of the model to assess larger, more complex watershed systems. Currently, in the Annualized AGNPS (AnnAGNPS) Version, the model can compute loads from an event, or on a monthly or annual basis. It has evolved to include a GIS-assisted program with enhanced ephemeral gully features, automated calibration for many pollutants, capacity to integrate an unlimited number of climate stations, and evapotranspiration and soil evaporation improvements (Bingner et al., 2017). It also incorporates practices such as fertilizer and manure application. AnnAGNPS is an appropriate model to evaluate the effect of agricultural conservation practices (Shoemaker et al., 2005).

One of the most frequently used, best documented, and popular simulation models, which continues to lead in published research analyses is the USDA's soil and water assessment tool (SWAT). It is a physical-based, spatially distributed, watershed-scale model developed to predict impacts of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds over long periods of time (Ambrose et al., 2009). SWAT is one of the few agricultural models that incorporate irrigation and drainage processes (Shoemaker et al., 2005). SWAT was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time; however, outputs are summarized by Hydrologic Response Units (HRU), rather than an individual field.

The Environmental Policy Impact Climate (EPIC) model is a field-scale cropping systems model that was developed to estimate soil productivity as affected by erosion as part of the Soil and Water Resources Conservation Act analysis for 1980, which revealed a significant need for improving technology for evaluating the impacts of soil erosion on soil productivity. Similar to SWAT, EPIC has been extensively applied to examine the effects of soil erosion and agricultural processes; however, the documentation is not transparent on how or if tile drainage is simulated. Although both EPIC and SWAT evolved with significant improvements over time, there are still weaknesses and gaps in the ability to simulate key landscape processes at the farm or small watershed scale (Gassman et al., 2010). These weaknesses were identified at the onset of the National Pilot Project for Livestock and the Environment (NPP), which was commissioned in the early 1990s to address water quality and other environmental problems associated with intensive livestock production (Osei et al., 2008). To address these gaps, the Agricultural Policy Environmental eXtender (APEX) model, a tool that is capable of simulating management and land use impacts for whole farms and small watersheds, was developed. Although APEX can model single fields similar to EPIC, it can also work for a whole farm or watershed that is subdivided based on fields, soil types, landscape positions, or subwatersheds (Williams et al., 2008).

While there is no shortage of water quality models with the goal of providing an accurate method to assess conservation practice effectiveness, there will always be an ongoing need for updates and improvement. The models discussed above are just a few of the over 65 available for TMDL development or to quantify agricultural water quality, many of which have undergone continued development with time to enhance their capacity to meet the needs of changing policy and land management (Shoemaker et al., 2005). Technology has improved and continues to evolve to address the complex questions that are being asked by society regarding the effects of agricultural management on water resources.

Accuracy cannot be the sole consideration in identifying a method for quantifying nutrient reduction, since an acceptable method must also have transparency in its assumptions, be usable by agencies that will conduct the assessment, and fit within a conservative budget. A complex model with inaccurate inputs and assumptions will lead to unrealistic expectations, providing little benefit to the watershed. Therefore, there is also a need for simplistic, water quality quantification tools. Although they may not have the accuracy or rigor of more complex models, they are often less expensive to develop and provide a user-friendly platform to produce outputs with general water quality or nutrient reduction expectations. For example, spreadsheet-based models have been developed for both national and regional applications. The Spreadsheet Tool for Estimating Pollutant Load (STEPL) and Region 5 model were both developed for the EPA Office of Water (USEPA, 2018b; 2018c). These spreadsheet tools have internal calculations that will estimate sediment and nutrient load reductions from the implementation of conservation practices using known efficiencies from regional studies.

STEPL provides a user-friendly Visual Basic (VB) interface to create a customized spreadsheet-based model in Microsoft (MS) Excel. It computes watershed surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5); and sediment delivery based on various land uses and management practices. STEPL calculates annual sediment load using the RUSLE2, which is often the basis of many spreadsheet or user-friendly tools. The Region 5 Model is an Excel workbook that provides a gross estimate of sediment and nutrient load reductions from the implementation of agricultural and urban management practices. Models like these that base their nutrient estimates on sediment loss can have considerable inaccuracy where dissolved constituents dominate loss processes. Overall, however, these simple tools are based on sound science, and can serve an important decision-making support and tracking role in conservation planning.

Since complex, more accurate research models can be difficult for watershed managers to navigate or view the underlying inputs and processes influencing the results (i.e., "a black-box" output), some developers have been creating model user-friendly, input interfaces to appeal to a more general user rather than a hired consultant modeler. For example, in order to make APEX, accessible and transparent to watershed managers, developers have integrated it into a simple user interface, called the Nutrient Tracking Tool (NTT; Saleh et al., 2011). This interface provides APEX users, including watershed managers, farmers and technical service providers, with a fast and efficient method of estimating nitrogen and phosphorus credits for water quality trading, as well as other water quality, water quantity, and farm production impacts associated with conservation practices (Saleh et al., 2011). The use of a model interface can promote more realistic results since the watershed manager or technician can enter the landscape characteristic input data rather than relying solely on the input assumptions from a hired modeling consultant, who may not be familiar with the local watershed or field characteristics. Ideally, for the most accurate outputs there is interaction between the two parties, which is more feasible with a model interface.

Models can be important tools for bringing together multiple data sets, studies, and process-based knowledge, which is particularly important when information is needed outside the range of where a conservation practice has been applied and tested. This system approach is critical because land management and climate are not stationary and both influence the effectiveness of a practice to reduce runoff and leachate losses into water resources. The conditions that a conservation practice will experience in the future may be outside historic observation, making long-term data collected even over a wide range of historic conditions inadequate. However, complex models with poorly documented metadata will not suffice as a system for accepted pollutant reduction estimates. Models must be open source and properly documented so that scientists can test, validate, and potentially identify errors or inadequate regional assumptions. Thorough documentation is needed to assess the scientific merit and allow others to ensure that the calibrated model is appropriate for the intended use. This is particularly critical when models are used to support technical, policy, and legal decision-making (Saraswat et al., 2015).

Landscape Characteristic Data Sources

The availability of accurate land management and landscape characteristic data is necessary for properly modeling the benefits of conservation practice systems adoption on reducing environmental losses. The resolution of landscape characteristics varies by region and are often based upon topographic maps and digital surface models. The availability, resolution, and quality of these data sources are mixed, as are the conclusions that can be drawn based on the information.

The National Resources Inventory (NRI) program, conducted by the USDA's NRCS in cooperation with Iowa State University's Center for Survey Statistics and Methodology, collects and produces scientifically credible information on the status, condition, and trends of land, soil, water, and related resources on the Nation's non-federal lands in support of efforts to protect, restore, and enhance the Nation's lands and waters. The NRI Database consists of over 800,000 nationwide points on the ground with measurements from 1982, 1987, 1992, 1997, and annually from 2000 to 2015 (USDA, 2018d). As there are NRI Database updates, the new releases do not just stack the results, but rather, it adds the data to the earlier data which goes through a backward checking to ensure that the change over time is real and not due to variations in collection methods. Data is collected at each point to allow aggregate estimates on land cover and use, soil characteristics, erosion rates, water and wetland observations, and conservation methods.

One of the most commonly accessed land management data sources is the USDA's National Agricultural Statistics Service (NASS) Cropland Data Layer, published on the NASS CropScape web application (USDA, 2018b). The Cropland Data Layer provides annual raster, geo-referenced, crop-specific land cover beginning in 1997, and expanding its capability since 2008 through today, at a ground resolution of 30 or 56 meters, depending on the state and year. The data provides supplemental acreage estimates for the state's major commodities and can be used to produce digital, crop specific, categorized geo-referenced output products. The data layer is aggregated to 85 standardized agricultural land cover categories for display purpose. These data can be used as an overall land-use-change metric or to evaluate site-specific changes over time; however, these data are not linked to management activities.

At a coarser resolution, county-level estimates about nitrogen and phosphorus fertilizer application have been made based on fertilizer sales (Ruddy et al., 2006, David et al., 2010, Jacobson et al., 2011). Similarly, estimates for tillage have been done for large portions of the country (Baker, 2011, CTIC, 2017) and even one-time tile drainage estimates have been made (Sugg, 2007, Nakagaki et al., 2016). This data is sought after, extremely useful, and work well for regional analyses, though the data sets are not necessarily available continuously with stable funding. The "snapshot" nature of many data sources provides a nice illustration of current circumstances; however, evaluating change over time, by comparisons with other similar data sources developed with differing assumptions, is difficult.

The development of Light Detection and Ranging (LiDAR)-derived digital elevation model (DEM) data, which is an active remote sensing technology that uses laser light to detect and measure the Earth's surface features, was a game changer for many cultural and ecological fields. Traditionally, topographic maps, aerial photographs, and digital elevation models (DEMs) were used to investigate a watershed's surface characteristics and to quantify the terrain. DEMs have relatively low levels of resolution and accuracy, whereas high-resolution LiDAR data can penetrate water and tree canopies, which enables a more accurate delineation analyses of ground features and landscape geomorphology. When LiDAR is available for a region, it can significantly improve watershed modeling and terrain analysis results. LiDAR has been used for water quality assessment, erosion analyses, siting and design of conservation practices, habitat restoration projects, cover crop and tillage quantification, and flood control. Due to its expense and processing requirements; however, there are few states with full LiDAR coverage. Extending this coverage across all 50 states would allow assessments and models to run across boundaries to improve our understanding of the agricultural landscape, water flow paths, chemical and soil movement, and other environmental factors necessary to make informed agricultural policy and land management decisions.

Big Data in Agricultural Management

Making informed decisions and better understanding the impact of existing efforts to improve water quality, requires access to consistent, high quality data sources that allow a direct measure of change. The combination of technology and advanced analytics for processing useful and timely information has been termed *big data*. Big data is more than the data alone, it also encompasses the methods available for processing the data (Stubbs, 2016). There are already ongoing initiatives to collect precision conservation data; however, the collection, control, and use of the data has created much debate regarding privacy issues in both the legal community and society as a whole (Ferris, 2017). Both private and public big data play a key role in the use of technology and analytics that drive a producer's evidence-based decisions, which is why it could be a critical piece to conservation assessments.

Big data is often a product of precision agriculture, which integrates digital and spatial tools that are constantly evolving to tailor specific aspects of crop production to meet the unique needs of a specific land unit. Precision agriculture tools have the capacity to collect extremely large quantities of data from the farmers who utilize the technology in their farming practices. Precision agriculture and big data are applicable to water quality because the technological development has increased the efficiency and productivity of crop production systems. For example, variable-rate fertilizer application equipment is used together with soil fertility maps to inform and apply the most appropriate fertilizer rates (Stubbs, 2016). Management information may include details on the timing or adoption of field operations, as well as the specifics pertaining to nutrient application. This reduces both the opportunity for over-application and potential surface runoff or leachate losses.

A tremendous amount of data resides with the USDA NRCS, FSA, and RMA, not to mention state agricultural, environmental, and natural resource agencies. Simply evaluating the federal data sources shows potential to develop a comprehensive picture of past and present agricultural management. In addition to these government-based sources, there are many agricultural companies working with farmers to collect field specific data. Publicly funded and private data all have privacy restrictions, which requires a level of responsibility to protect the data (Stubbs, 2016). Although more can be done to remove the digital silos and make this data more accessible to conservation groups working directly with the farmers, currently there are at least opportunities for the farmer to share their field data directly with a third-party for analysis. Value-added companies are being developed to start filling this data management and use gap, though they have largely been focused on farmers, as the business model behind these platforms is typically fee-for-service. With this in mind, outputs align with agronomic decision-making, enhancing yields, and maximizing profits, leaving little room for valuation of ecosystem services. The current need is to directly integrate this information into a digital, spatial database with a precision conservation emphasis (Delgado et al., 2019). This would allow data analysis to move from a field-to-field assessment to a watershed-based, regional, or even global evaluation with the possibility of integrating multiple resources, embracing a system approach.

In addition to advancing precision agriculture, improvements in space science and computer applications have increased the availability and accessibility of remote sensing data for water quality assessment. Although remote sensing techniques have been in use since the 1970s, sensors and satellite use to monitor waterbodies over the past 20 years have reinforced the abilities of water resources researchers and decisionmakers to observe spatial and temporal variations more effectively (Gholizadeh et al., 2016). Due to model calibration and validation constraints and public perceptions, water management decisions do not typically rely solely on satellite-derived water quality results, but rather combine remote sensing and Geographic Information System (GIS) based-modeling with traditional water quality sampling (Gholizadeh et al., 2016).

Measured data is the key element to a scientifically defensible assessment, for stakeholder-accepted management and decision-making, and for calibration or validation of model estimates (Harmel et al., 2008). There are a number of national repositories of water quality data. For example, the USDA Agriculture Research Service (ARS) maintains STEWARDS: Sustaining the Earth's Watersheds, Agricultural Research Data System. STEWARDS is a data delivery system with a geographic information system interface, which uses space, time, and topic as key search fields for the extensive soil, water, climate, and land management database warehousing data from multiple long-term research watersheds. The USGS's National Water Information System (NWIS) Database compiles hydrologic and water quality data for surface water gauges and groundwater wells into a searchable database that includes both historic and real-time data. EPA's Water Quality eXchange (WQX) is the mechanism in which organizations publish water quality data to be made available via the Water Quality Portal (WQP). The WQP is the Nation's largest source for water quality monitoring data with currently over 375 million results with access to data from WQX/STORET, NWIS, and STEWARDS. National water quality databases are a tremendous resource, but the nexus between conservation practice installation, and their impacts on water quality remains elusive making our ability to define outcomes of conservation investments a complex venture at multiple geographic scales.

There is a need for wide-spread access to more reliable information on fertilizer use, livestock waste, agricultural management practices, urban inputs, and wastewater treatment improvements in order to better understand the influence of contributing factors on water quality trends (USEPA, 2017b). This knowledge is critical for establishing realistic water-quality expectations.

Conservation Practice Adoption

The success of any water quality improvement program is dependent upon the availability of willing landowners to implement a conservation practice or adjust their nutrient management. The long-term effectiveness of a conservation practice system to provide water quality improvements is driven by proper placement on the landscape and adaptive management. Watershed managers may be able to target the optimal location in a watershed for conservation implementation using water quality data and model simulations; however, this is not practical without a commitment from the landowner or farmer to adopt the practice and provide upkeep. Three factors that contribute to the decision-making process of farmers and ranchers on whether to adopt nutrient management and conservation practices into their farm operations include 1) information and awareness, 2) economic drivers, and 3) social norms (Liu, Bruins and Heberling, 2018).

Information and Awareness

Educational programs increase the farmers' likelihood of implementing conservation practice systems on their farms (Bayard, Jolly, & Shannon, 2006). Field days have been identified as the quickest way to communicate new information on conservation practices to farmers (Murage et al., 2011). Farmer-to-farmer outreach is also an effective method of information dissemination (Murage et al., 2011). Fertilizer dealers and certified crop advisors (CCA) are trusted educators who can also effectively introduce farmers to new conservation-minded management practices (Luloff et al., 2011; Moody, 2018).

There is often a learning curve involved when a farmer changes a practice, so it is important to have that in-person contact, whether it is farmer-to-farmer or conservation agent-to-farmer. When interviewed, Corn Belt farmers praised local conservation agents who came to their farms with information and encouragement about their improved management practices (Atwell et al., 2009). Technical support that meets the farmer on the land that they manage, is critical to advance adoption. An evaluation of Ohio's Great Miami Water Quality Training program found that using trusted agents from county-level soil and water conservation district offices to recruit and advise farmers was essential to achieving relatively high rates of farmer participation in water quality training (Newburn and Woodward, 2012).

Networking and knowledge sharing about conservation practices is a significant predictor on whether a farmer will adopt the conversation practices (Prokopy et al., 2008). Many groups can provide farmers with knowledge, but a functioning network of extension services provide timely and effective information on new management practices (Rezvanfar et al., 2009; Tamini, 2011).

Economic Drivers

Economic drivers play an important role in motivating farmers to adopt conservation practices (Prokopy et al., 2008). The availability of governmental grants and subsidies are crucial to a farmer's decision to implement conservation management practices because construction and maintenance often require high initial investment (Shiferaw & Holden, 1998). Early adopters are generally encouraged to implement a new management practice when the financial risk is reduced (Welch and Marc-Aurele, Jr., 2001). Few small farms could afford implementing new conservation practices without governmental grants and subsidies (Shiferaw & Holden, 1998). Resource-poor farmers or farmers who receive most of their income from farming are better motivated by financial tools, while wealthier farmers are more likely to adopt practices with a regulatory push (Welch and Marc-Aurele, 2001).

Social Norms

Social norms and peer pressure affect farmers in a variety of ways. If well-respected farmers in the community had success with new agricultural technology or equipment, then other farmers will likely follow their lead. As this process continues to occur, the new technology is likely to spread throughout the agricultural community (Figure 15). Late adopters can be driven to adopt new technology through community and peer pressure (Welch and Marc-Aurele, 2001). Farmers derive satisfaction from social conformity and are likely to make adoption decisions based on their neighbors' acceptance (Läpple and Hennessy, 2015). When farmers and landowners are connected to community groups, they are also more likely to maintain conservation practices over time (Prokopy et al., 2014).

Successful conservation programs should have an implementation focus targeting farmers most likely to adopt management changes (Baumgart-Getz et al., 2012; Rao and Power, 2019). This should function with ongoing outreach to increase individual capacity and awareness by using networks to inform other farmers about the benefits of adoption (Baumgart-Getz et al., 2012). Regardless, we are still left with a question about when adoption has occurred and when a management activity has become a social norm.

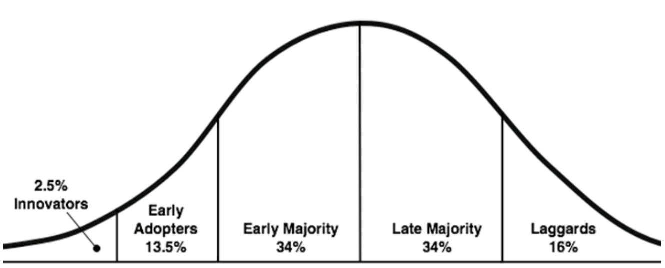


Figure 15. Diffusion of innovation theory (Rogers, 1962).

Strategies with a Trajectory toward Achieving Water Quality Goals

Global population is projected to increase by two billion people to reach 9.7 billion in 2050 (FAO, 2017). As the population grows over the next 30 years, so will the demand for food, fiber, and feed; projections indicate a 25% to 70% increase by 2050 in global meat and grain consumption (Hunter et al., 2017). To meet this demand, sustainable nutrient management will be critical for global food and water security. A rise in the use of nutrient inputs, specifically nitrogen and phosphorus, will be critical for improved crop productivity (Stewart and Roberts, 2012). Although grain yields have been increasing linearly over the past 20 years, the relative rate of yield increase has decreased below the yield needed to meet the global demand (Ray et al., 2013). The challenge for the future is developing a strategy to meet these agricultural production goals while reducing the environmental impact, and more specifically the impact of nutrients on water quality.

One of the major challenges to improving water quality is that practices do not achieve the same degree of effectiveness because of the large spatio-temporal variation in soil, topography, and ecological systems. Figure 16 was developed to illustrate the complexity to draw a direct connection between practice implementation and effectiveness. With integration and improvement between each key step, those connections can be made more functional, transparent, effective and economical if considered as an iterative, feedback framework.

The shaded area in Figure 16 encompasses the needed research to improve our ability to assess how field-scale responses can be synthesized to improve our understanding of the effectiveness of different practices and how that information can be used either to improve information available to farmers or provide an assessment of the watershed impacts. This latter step is necessary because there is a need to develop a synthesis of the impacts of a range of practices across large geospatial areas to determine if the programs are being effective.

This process as represented in Figure 16 incorporates several feedbacks, and as one improves, it offers the opportunity to improve others. For example, better technologies to monitor water quality leads to better data, which in turn leads to improvements in the practices themselves. The philosophy encompassing this approach contributes to an outcome of continuous improvement in the conservation practices available, the methods to assess their effectiveness, the quality of the data to quantify outcomes, the policies that support the conservation programs, better decision-making at multiple scales from individual farms to conservation districts to basins, and the desired outcome of cost-effective improvements in water quality locally, regionally, and nationally.

Building Collaborative-Based Initiatives

Conservation adoption can compete with other regional-based agricultural priorities, such as profitability, practice awareness, and access to technology (Knowler and Bradshaw, 2007). Although the financial cost associated with conservation implementation accrue at the farm level, most of the broader environmental benefits are captured by society (Knowler and Bradshaw, 2007). To advance away from just the perceived profitability at the individual farm scale, these wider societal benefits should be used as the foundation toward the development of regional, national or even global incentive programs. In order for a water quality program to have long-term impact, it must also engage private industry organizations, NGOs, and other supply chain companies while considering incentives for downstream ecological enhancement. One of the earliest initiated agricultural based collaboratives is Field to Market, a multi-stakeholder sustainability alliance connecting retail companies to agribusinesses, farmers, NGOs, agencies and universities (Thompson et al, 2017). Field to Market focuses on environmental outcomes of production as the determinant of sustainability.

The 4R Nutrient Stewardship initiative provides an example of how engaging private industry can effectively increase conservation adoption. The financial benefits of improving nutrient use efficiency are well known and understood by farmers. Farmers have already made great strides in improving their fertilizer use efficiency. Between 1980 and 2014, U.S. corn farmers nearly doubled their yield per pound of nitrogen, phosphorus and potassium fertilizer nutrients (IPNI, 2015). However, to achieve greater awareness on increasing nutrient

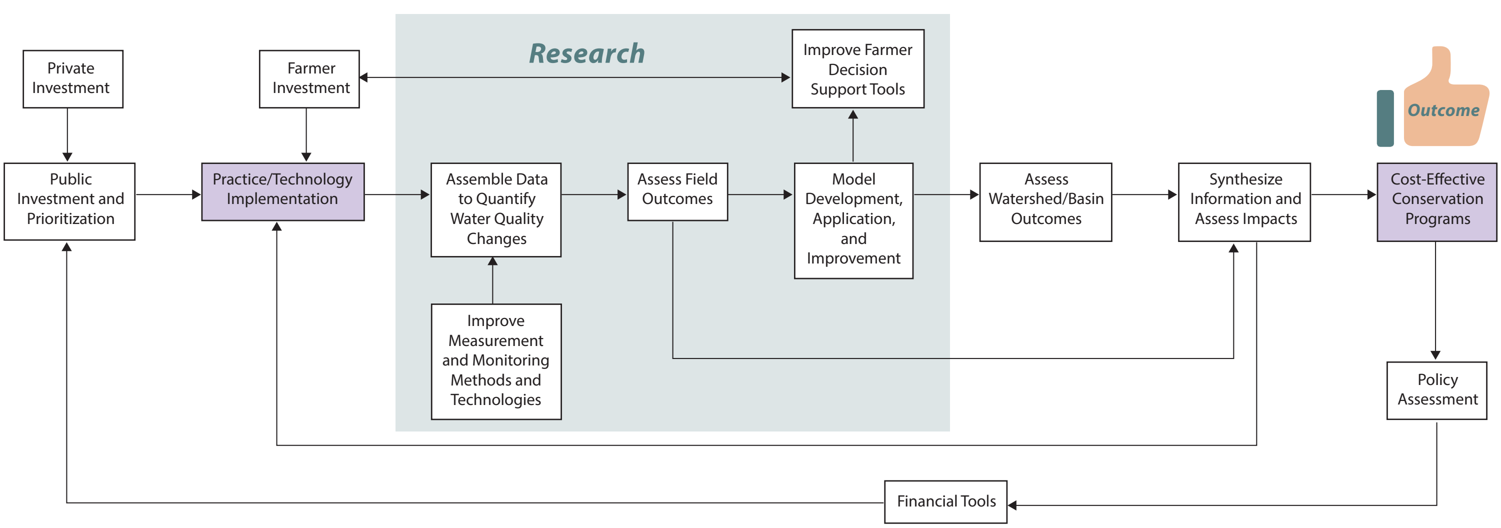


Figure 16. Diagram of the continual improvement process for assessment of water quality practices and technologies; included in the shaded research area are steps where enhanced understanding is necessary.

use efficiency and reduce the risk for losses, the fertilizer industry led and supported one of the most successful, privately funded, conservation initiatives.

The 4R Nutrient Stewardship initiative promotes principles that focus on applying the right source of fertilizer, at the right rate, at the right time, and in the right place (IPNI, 2012). It provides a framework to increase production and farmer profitability, enhance environmental protection, and improve overall agricultural sustainability. Farmer adoption of practices that improve nutrient use efficiency have been highly successful largely because of the immediate economic benefits in the form of reduced input costs, but also because of the direct understanding of how over-application of nutrients on their fields, regardless of source, may impact runoff or leachate losses. Improved nutrient use efficiency can provide societal benefits in the form of reduced soil erosion, improved water quality, and reduced greenhouse gas emissions. The agricultural industry has recognized improved nutrient management as one part of the multi-tiered solution toward a comprehensive approach to addressing water quality, and are supporting state-based 4R Nutrient Stewardship certification programs. This voluntary approach has been successful because it applies a collaborative approach that brings together a broad group of private and public agricultural and conservation stakeholders with a diverse perspective and solutions-oriented attitude (Vollmer-Sanders et al., 2016).

Another initiative that has advanced rapidly due to collaborative efforts between public and private organizations is the increased focus on improving soil health as an outcome and a system level approach to conservation. The improved understanding of how the current predominant soil management practices have led to degradation is encouraging locally adapted soil health management systems to reverse these trends. Agricultural researchers, farmers, conservationists and the general public are paying more attention to improving soil health to improve resiliency and farm land regeneration. In 2006, a study was initiated to assess the effects of conservation practices on soil quality within the USDA-ARS's CEAP experimental watersheds. The Soil Management Assessment Framework (SMAF), which was developed to assess conservation effects on soil, and uses multiple soil quality indicator measurements to compare soil functioning, was the metric applied in the CEAP analyses. After completion of this effort, it was determined that consistent assessment tools are needed to evaluate the impact of management systems on critical soil functions related to soil quality, including nutrient cycling and water partitioning (Stott et al., 2010).

Although soil quality indicators were proposed by the NRCS in the early 2000s, the Soil Health Division (SHD) was not established until 2014, after a two-year NRCS outreach and education campaign to "unlock the secrets in the soil" (Stott and Moebius-Clune, 2017). The SHD was created to facilitate implementation of science-based, effective, economically viable soil health management systems on agricultural lands and the goals include capacity building in soil health training, assessment, management planning, and implementation. In collaboration with internal and external partners, the SHD evaluated publicly available soil health assessments and frameworks to facilitate a nationally applicable, standardized approach and mechanisms for updating standards as the science advances, for comprehensive assessment of soil health that can inform soil health management planning and implementation (Stott and Moebius-Clune, 2017). The protocol was open for public review in 2018 and formalized in 2019.

To properly address soil health issues on our Nation's agricultural lands, production paradigms must emphasize training on and demonstration of new management systems and their benefits in diverse production systems (Stott and Moebius-Clune, 2017). Soil health management must be promoted in a consistent manner that considers the complex interaction of nutrient cycling processes and produces realistic expectations for farmers (Duncan et al., 2019). Although there is a need for additional meta-analyses to quantify trade-offs associated with the adoption of soil health practices, discussion of these trade-offs and guidance for adjusting existing nutrient management practices should be provided in order to achieve water quality goals (Duncan et al., 2019). Concurrently with the formation of the SHD, the Soil Health Partnership was founded by a diverse group of non-governmental organizations and private companies with a shared vision of developing a farmer-led research network to measure the impacts of implementing soil health practices on working farms. Administered by the National Corn Growers Association, the Nature Conservancy, Bayer, and the Environmental Defense Fund joined the collaboration to see this vision through to fruition. By applying the available science and data, the Soil Health Partnership utilizes a team of field managers to work alongside partnering farmers to design and implement field experiments.

Concentrated collaborative efforts with multi-stakeholder funding partnerships to improve soil health outreach has helped to demonstrate the potential return on the Nation's conservation investment at both the farm and societal scale (Stott and Moebius-Clune, 2017). However, understanding how the principles of soil health influence water quality is driven by complex, site-specific nutrient cycling processes and requires continued applied research to support evidence-based farm management decision making (Duncan et al., 2019). Establishing funding sources to leverage federal conservation resources through engagement with industry companies and organizations is critical for improved program cost-effectiveness and longevity (CAST, 2019). This approach of investing private capital into addressing agricultural water quality initiatives requires a commitment and prioritizes objectives to more efficiently decrease nutrient loss from agriculture.

Establishing Rural and Urban Partnerships

Improvement in water quality rests on conservation programs that are cost-effective in achieving benefits for the expenditures, whether those are public or private funds. Investments pay for technical support and payments for practices that can be implemented within a field or on the landscape to reduce water impacts at the edge of the field. There is a need to focus on watershed transactions that track nutrient reductions along with the multitude of other benefits that may include water quantity and quality but also ancillary benefits such as habitat development and source water protection. While point sources may achieve certain regulatory incentives for these transactions, the focus of incentivizing these investments should be on identifying the various motivations of both rural and urban stakeholders interacting within their watersheds.

The tracking of both nutrient reductions and ancillary benefits serves to inform and calibrate point source decisions under state-based nutrient strategies and promote collaboration between point and nonpoint sources while assuring and verifying the impact of the reduction can provide confidence in the investment. Collaborations between water utilities and agriculture through which utilities achieve point source pollution reduction by investing in watershed management rather than by installing more expensive additional filtration technology have proven successful as cost-effective ecosystem service projects or programs. For example, there is great potential for private exchanges or trading to create new revenue streams for financing conservation practices with public benefits. Entities in need of reducing nutrient discharges to meet TMDL wasteload allocations on their National Pollution Discharge Elimination System (NPDES) permits will likely be motivated to find lower cost options. Investing in farmer-implemented conservation practices, or green infrastructure, may be exponentially cheaper than investing in plant treatment upgrades, or grey infrastructure. For instance, nutrient treatment wetlands can reduce nitrogen loading at a cost of approximately \$1.27 per pound, whereas the cost to complete wastewater treatment facility infrastructure upgrades to meet effluent standards is substantially higher depending on the treatment system (Christianson et al., 2013; Collins and Gillies, 2013). Therefore, trades or exchanges between downstream point source entities and landowners implementing conservation practices with public benefits could be advantageous to both parties.

The inability to present a business case with an investible proposition has limited conservation projects access to significant private capital. Contributing to the problem are complex projects with high transaction costs, complicated valuation metrics and small investible units. There is a tremendous opportunity to create new markets and incentives for the provision of water quality benefits, and, ultimately, a wide array of ecological services which could be provided by those who traditionally made their living on the land including, but not limited to, agricultural producers. To make this vision a reality will demand the creation of new institutions that can serve as aggregators, brokers, and bankers who can bring sellers and buyers together, reduce transaction costs, overcome the barriers of asymmetrical information in the marketplace, and navigate the Clean Water Act's regulatory regime. Policymakers have attempted to reduce pollution from agricultural sources through subsidies under the Farm Bill and from recent, innovative efforts to encourage point-to-nonpoint source trading to achieve water quality objectives. In 2003, EPA first began to encourage water quality trading as a cost-effective means of compliance which, over time, could aid in the remediation of environmental issues and allow for the realization of multiple ecosystem services, over and above simple compliance by regulated point sources.

Progress is on the horizon in advancing this "commerce of conservation." In 2018, the EPA and USDA announced that they are committed to working with states, tribes, and stakeholders to identify watersheds and basins where market-based approaches can supplement traditional regulatory programs to promote meaningful reductions in excess nutrients and improved water quality. This could include providing technical and financial support and participating in problem solving at the local level to explore approaches including water quality credit trading, public-private partnerships, pay-for success, supply chain programs, and more (USEPA, 2018a).

Trading and other market mechanisms are now supported and even encouraged by both the EPA and USDA. A memorandum was issued in February 2019 to reiterate that the EPA strongly supports water quality trading and other market-based programs that can promote water quality improvements at a lower cost. Although the Clean Water Act did previously allow water quality trading, which was included in the 2003 Water Quality Trading Policy, these mechanisms had not been used to their fullest potential due to the previous policy being too prescriptive and not widely effective or implementable (USEPA, 2019). The 2019 memorandum articulates six key points:

1. States, tribes, and stakeholders should consider implementing water quality trading and other market-based programs on a watershed scale.
2. The EPA encourages the use of adaptive management strategies for implementing market-based programs.
3. Water quality credits and offsets may be banked for future use.
4. The EPA encourages simplicity and flexibility in implementing baseline concepts.
5. A single project may generate credits for multiple markets.
6. Financing opportunities exist to assist with deployment of nonpoint land use practices.

This recent policy clarification gives state water personnel more confidence that commerce between sectors is an appropriate and federally sanctioned strategy available to better meet water quality objectives.

By allowing one source to meet its regulatory obligations by using pollutant reductions created by another source, be it regulated or unregulated, that has lower pollution control costs, trading creates economic incentives to improve water quality. The standards remain the same, but efficiency is increased, costs decreased, and, as we shall see, benefits are multiplied. An alliance between urban users and agriculture can build support for financial instruments to advance conservation while supporting farm economic viability.

The World Resources Institute (WRI) conducted three case studies on the cost of controlling phosphorus in watersheds within Minnesota, Michigan, and Wisconsin (Faeth, 2000). The study identified that the cost of reducing phosphorus from point sources was considerably higher than those based on trading between point and nonpoint sources. The estimates for point source controls ranged from $10.38 per pound in the Wisconsin watershed to $23.89 in the Michigan one. Using trading between point and nonpoint sources, these costs could be lowered to $5.95 per pound in Wisconsin, a reduction of over 40%, and to $4.04 in Michigan a reduction of over 80% (Faeth, 2000). As the WRI case studies illustrated, the cost differentials between the two classes of sources are significant and offer real opportunities for point source cost savings and nonpoint source profits. There appears to be room for incentivizing agricultural producers to generate credits for sale to the regulated point sources above any baseline set by the regulatory agencies to meet a load allocation for such sources within a given trading area.

In developing effective partnerships with agricultural producers in their watersheds, utilities focus on source water protection (SWP), which is related to watershed protection but with a tighter focus on sources of potable water and public health. All water, including nonpoint source agricultural water, eventually become source water for drinking water. Consideration of more constructive relationships with farmers has been spurred by recognition that source waters for human consumption are impacted by nutrient over-enrichment in high profile situations such as Toledo and the Ohio River. Surveying the current situation, including the vibrancy of the USDA's many and varied conservation programs available to the agricultural communities, the American Water Works Association (AWWA), as part of its 2014 Total Water Solutions initiative, embarked on a sustained effort to reach out to the USDA, Congress and the agricultural community to forge effective partnerships with the object of promoting SWP in watersheds and source areas benefiting from such collaborations. The result was legislation that included a robust fund allocation in the 2018 Farm Bill over a 10-year period for conservation practices that protect drinking water sources and benefits for farmers who employ practices that benefit downstream water. The administrative language to the bill's conservation title places an emphasis on SWP as a specific goal of conservation, and effectively a more formalized programmatic emphasis at USDA and NRCS. The funding allows community water systems to work with state technical committees to identify local priority areas for source water protection. This is a powerful example of the benefits that can be gained by working collaboratively across historical silos.

Nationwide adoption of water quality trading programs will require participation by third parties, such as entrepreneurs, a conservation or agriculture commodity association, or land trusts, who might want to participate or serve as an aggregator, banker, or broker of credits. This would provide many, widely dispersed and separate non-point water contamination sources with technical support and better understanding of transaction opportunities, as well as pitfalls that there might be within the regulatory process. The development of such brokering institutions would provide a means of dealing with the inevitable change or removal of management practices over time considering changing economic conditions or a landowner's individual circumstances (e.g., plowing under buffer strips, cutting trees or selling property).

In an effort to add the needs for national water quality trading, the Foundation for Food and Agriculture Research (FFAR) contributed $10.3 million in 2019, to establish an innovative collaboration called the Ecosystem Services Market Consortium (ESMC) that is creating a functional ecosystem services market. FFAR was established by the 2014 Farm Act to support food and agriculture research, foster collaboration, and advance and complement the mission of the USDA. FFAR builds public-private partnerships to support innovative science addressing today's food and agriculture challenges. The ESMC is a coalition of farmers, environmental NGOs, government agencies, businesses, university researchers, and other agricultural organizations that is developing a trading system to encourage farmers and ranchers to improve soil health systems that benefit society. They are scaling sustainable agricultural sector outcomes to include not only improved water quality and water use conservation, but also increased soil carbon and reduced net greenhouse gases.

The coalition will provide farmers technical support to improve their soil and tools to measure the changes. The improvements will generate credits, which are similar to carbon credits and can be sold on the market to help farms invest further in sustainable practices. The Ecosystem Services Market is due to launch in 2022. Under the scheme, farmers will reap the benefits of improved farm management practices that enhance overall operational efficiency in the form of higher yields, increased resiliency to severe climate shifts, and improved water and soil quality. Additionally, the farmers will increase their competitive edge when it comes to selling to commodities buyers and food companies, many of which are working to meet their own environmental goals.

With so many potential stakeholders, conservation infrastructure financing will not be adequately addressed by a single "silver bullet" approach. Federal programs and regulations, state programs and regulations, local governments, taxpayers, utility ratepayers, environmental advocates, farmers, landowners, food safety and security advocates, and tourism and recreation enthusiasts all have an interest in, and will exert influence over, the development of conservation infrastructure financing. As a result, any set of recommendations must include multiple, flexible options that can be implemented as local political demands, revenue needs, and administrative capacity require. As conservation stakeholders discuss financing approaches, it is helpful to keep in mind a few critical principles if new ideas and programs are to achieve viability:

Core principles of sustainable financing

- Financing solutions should be broadly replicable in multiple states.
- Financing solutions should be scalable to the size of the problem.
- Financing solutions should recognize the critical nexus that exists between environmental and social benefits.
- Financing solutions should be implemented at the watershed level seeking maximum return on investment (ROI).
- The implementation and administration of financing programs should be devolved to the local level.
- Financing solutions that generate new, non-federal revenues should assess costs at the lowest possible rate from the largest possible number of payers.

Connecting farmers' conservation practices with financing will facilitate both public and private investment to implement even more and better practices.

Scaling Conservation Practice Effectiveness and Impact

Although treatment effectiveness has been well researched for many traditional or commonly implemented conservation practices, much of the data quantifying water quality impacts are region-specific, highly variable within and across field locations and years, crop dependent, and influenced by study scale (Dodd and Sharpley, 2015; Lenhart et al., 2017; Smith et al., 2019). These and other confounding factors can influence the outcome of a study and are common in observational data, making it difficult to draw wide-spread conclusions about practice effectiveness (Nummer et al., 2018).

There is a need for more data quantifying conservation practice effectiveness. Edge-of-field monitoring, though expensive and not always conclusive, provides the most reliable basis for estimating effectiveness of practices (Dressing et al., 2016). The best way to address the limitations due to spatial and temporal variability is to collect more data at different sites and over more years. Studies have attempted to model field-scale data to better understand the effectiveness of conservation practices and nutrient management in reducing runoff losses. To properly address challenges, access to multidisciplinary data spanning environments, timescales, treatments, and management is necessary.

Meta-analysis, or statistical synthesis of results from a series of studies, can be used to look at the entire body of evidence rather than looking at one study in isolation (Borenstein et al., 2011). Meta-analysis is often used for understanding the broad impact of conservation practices (Eagle et al., 2017). Averages from such meta-analyses, including those using the CoPE Database, are not necessarily applicable to a specific location or crop; therefore, they should be used with caution so that they do not lead to unrealistic expectations. For example, if the intention is to treat particulate forms of phosphorus and nitrogen, then review region-specific practice information for more implementation guidance. Dissolved nutrients are not currently addressed by most of the traditionally adopted conservation practices such as grassed waterways, buffers, or filter strips; therefore, implementation options would be focused primarily on alternative fertilizer or manure management options (CAST, 2019). Assessments of both individual practice effectiveness and comparisons of effectiveness across multiple practices are critical to guiding conservation investments (Smith et al., 2019).

When the influence of confounding factors is not properly accounted for, the impacts of conservation practice adoption can produce misleading results (Harmel et al., 2006, 2008). For example, when conducting an exploratory analysis using the MANAGE database, no clear tendency for decreased nutrient loss with the implementation of conservation practices was identified. The MANAGE database does not include confounding factors such as land use and soil type that influence vulnerability of erosion and nutrient loss (Harmel et al., 2006). While the MANAGE database includes nitrogen and phosphorus runoff data from agricultural fields, as well as some drainage water, it does not focus on conservation practice effectiveness (Harmel et al., 2006; Smith et al., 2019). However, when a meta-analysis within the MANAGE database was conducted with an expanded dataset and applying an approach to remove the influence of confounding factors, fields with conservation practices also had higher fertilizer application than the fields without a conservation practice (Nummer et al., 2018). This demonstrates how difficult it can be to make a direct comparison of conservation practice effects between studies, and suggests that individual, field-scale studies should quantify and report as many relevant variables as possible (Nummer et al., 2018). Although the studies in MANAGE included adequate information for the original study, more complete data collection and reporting would facilitate improved regional assessments, increase accuracy, and allow for the exploration of conservation practice effects (Nummer et al., 2018).

The ability to address the most critical research questions around agriculture, climate, and sustainability, have become increasingly complex and require a coordinated, multifaceted approach for developing new knowledge and understanding (Herzmann et al., 2014; Kladivko, et al., 2014). In 2010, nine states and 11 institutions collaborated on the largest USDA funded, corn research project through the National Institute for Food and Agriculture (NIFA) called “The Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP),” also referred to as “Sustainable

Corn." The USDA's request for proposals included specific language on establishing a regional research network, which included developing standardized evaluation methodologies (Herzmann et al., 2014; Kladivko et al., 2014). As the scientists came together to form this large, Coordinated Agricultural Project (CAP) team to increase the efficiency and resiliency of corn-based cropping systems while working to decrease the environmental footprint under climate change, it was critical that members actively participated in discussions across discipline boundaries, to develop a well thought out approach to field data collection procedures at 35 research sites. To improve the ability to compare data across sites and make inferences about soil and cropping system responses to climate across the region, detailed research protocols were developed to standardize the types of measurements taken and the specific details such as depth, time, method, numbers of samples, and minimum data set required from each site (Herzmann et al., 2014; Kladivko et al., 2014). The team's effort to develop a consistent data management approach and comprehensive "Climate and Cropping Systems" research database generated a number of positive outcomes and insights applicable to future research for increased collaboration, synthesis, and greater deliverables to the USDA. There efforts resulted in: (1) the standardization and decoding of soil, water, and crop datasets for greater application across disciplines, (2) expedited discovery of relevant project data through integrated search provided by a Google cloud platform, (3) minimal loss of data and supporting information due to centralized storage and metadata assigned to data (4) improved transparency and reproducibility of findings, and (5) increased speed and mobilization for addressing emerging issues or grand challenges (Herzmann et al., 2014).

Journal publications and research funders, especially publicly supported projects, should include guidelines and requirements for data sharing and management to support repositories with effective technical support (Eagle et al., 2017). Newer requirements by funding agencies to make data publicly available after projects are finished will greatly enhance the situation in the future, but past data should not be lost and making it usable will require an investment of resources. Although scientists support the idea of shared data, barriers to making this widespread include time constraints, limited funding, lack of incentive, and data reuse concerns (Wolkovich et al., 2012). Federal requests for proposals should continue to include language that encourages and rewards collaboration between multidisciplinary teams (Herzmann et al., 2014). The integration of physical, biological, and social sciences will contribute to a greater ability to improve agricultural systems (Kladivko et al., 2014). This will require that the funded data is collected and compiled into a format that is accessible by persons not originally involved in the analysis, and necessitates robust procedures for linking metadata with the data and clearly defining rules for future use and publication (Herzmann et al., 2014; Kladivko et al., 2014).

The ever-increasing volume of data from agricultural field research must be better summarized, assessed, and interpreted. Concerted efforts should be made to bring together data from both existing literature and unpublished data. Scientists who have collected the data should be incentivized to participate in database upkeep and compilation of historic data, as entering the raw data will inevitably be time-consuming and difficult. Data and reporting deficiencies are a limitation to achieving this efficiently (Eagle et al., 2017). As demonstrated by the Sustainable Corn team, this is a large endeavor, but there is a need for standardization and consistency across studies to facilitate data synthesis (Herzmann, et al., 2014; Kladivko et al., 2014; Eagle et al., 2017). This would require collection and reporting of farm management operations and field conditions, as well as clearly defined treatments and controls. Use of consistent units and terminology, including conformity of sampling protocol will increase the transparency and extend the value of agricultural field research.

Instilling these changes into future conservation research will facilitate more robust meta-analyses and data synthesis efforts. Although some farmers are reluctant to share their personal data, the best evidence to encourage practice adoption is local, on-farm demonstration of cost effectiveness, yields, and impact on the environment from farms that have been successfully implementing the practices. Sharing of anonymized farm data across agencies like NRCS, the Farm Service Agency, Risk Management Agency, and the Economic Research Service could also improve the quality of data that is available to farmers to evaluate potential conservation practice options. Additionally, public-private partnerships that allow for anonymized data sharing could be used to help develop tools that allow farmers an opportunity to examine the financial benefits or implications of a new practice on individual farms or fields.

Building Capacity for Conservation Technical Assistance

With the increase in agricultural intensification, conservation practice systems adoption including more efficient crop and nutrient management will be critical for protecting the Nation's water resources and overall environmental quality (Kleinman et al., 2018). U.S. farmers will likely be called on to produce much more food from a declining land base as development takes land out of farm production. Effective conservation programs encourage field conservationists to establish and maintain collaborative working relationships with landowners and managers (Nowak, 2011). Adequate and consistent funding to support NRCS field staff and build local capacity of soil and water conservation professionals is critical to the successful advancement of conservation implementation across the landscape.

Although not all water quality related, there are approximately 180 NRCS-approved conservation practice standards that require proper siting, installation and maintenance in order to achieve the greatest benefit. Conservation Technical Assistance (CTA) is funded through Conservation Operations (Stubbs, 2019b) to support NRCS field staff with local voluntary conservation efforts promoting proper practice implementation. Technical assistance prior to a producer entering into a contract for financial assistance is typically considered CTA. Once a producer signs an actual financial assistance contract, the technical assistance is then funded by the individual mandatory program. As the financial assistance contract is completed, technical assistance funds are no longer available to support ongoing assistance to maintain conservation plans or practices. Many conservation practices require continued management to be effective; however, without this technical assistance, the follow up to ensure that the practice continues to properly function and provide a water quality benefit is often lacking.

Hiring freezes due to flat or decreasing CTA budgets restrict the ability of on-the-ground NRCS staff to reach more producers or sign-off on engineering standards, which can delay or discourage implementation all-together. The cumbersome process to sign up for a federal contract, hire an approved technical service provider (TSP), and align the farm schedule with the conservation program timeline can discourage farmers and ranchers from enrolling in implementation programs. NRCS is often able to fund only a fraction of the applications received from farmers for development of conservation plans or implementation of practices due to funding levels. In some instances, farmers and ranchers may prefer to design and install a practice on their own rather than work through their local NRCS field office. This could lead to improper installation or inadequate long-term maintenance.

Improved public-private partnerships for providing technical service and outreach can be an efficient way to promote the use of both NRCS programs and conservation practice systems. This approach could improve turnaround times from the start of a contract to the implementation of a new practice on the ground. For example, by training Certified Crop Advisors (CCA) on soil and water conservation management, and building upon the expertise and existing relationships that the CCAs have with their clients, the CCAs can incorporate a system approach to nutrient management with their customers and inform them on NRCS programs and incentives. Currently, there is a 4R Nutrient Management Specialist Certification available to CCAs that builds upon the nutrient, soil and water components of the CCA certification to meet the growing demand for qualified advisers with focused knowledge and skills to address nutrient management (IPNI, 2012). Public-private partnerships could also include opportunities to share conservation related information and case-studies in publications sponsored by agricultural commodity groups to encourage farmers to inquire about applying these practices to their own operations.

As part of a concerted effort to modernize and streamline NRCS's conservation planning and program delivery, reduce workload on field staff, and improve the customer experience by creating an efficient application process, the NRCS launched a 2019, test version of the Conservation Assessment Ranking Tool (CART). CART is intended to increase efficiency, incorporate innovative technology, and improve communication and data availability. Previously, farmers and ranchers would be required to submit multiple conservation program applications for the same land to be ranked and prioritized under different programs. With CART only one application is required and one contract is executed, regardless of the program. To run an assessment in CART, NRCS staff select land units for evaluation and a base land inventory will be completed. The tool applies a geospatial analysis to identify resource concern potential, vulnerabilities, and priorities, intersecting program ranking tools, and special resource concern areas. Planners can also select conservation practices to create alternative management plans for the client to assess options for addressing resource concerns.

Overcoming Barriers to Adoption

In addition to the technical assistance provided through federal programs, there are opportunities to increase conservation adoption by building outreach capacity through other methods. Being aware of a conservation program or practice and having a positive experience or attitude associated with the program or practice is critical for acceptance and adoption (Prokopy, et al., 2019). Local or state partnerships that encourage farmers to field test a management practice before implementing on a large scale can build confidence and acceptance. Incorporated in the 2018 Farm Bill, On-Farm Conservation Innovation Grants (CIG) encourage the adoption of innovative conservation approaches, practices, and systems that have yet to be widely adopted on working lands. Farmers and ranchers are more likely to adopt practices if they have direct contact with neighbors or natural resource professionals who can directly share soil and water conservation information (Prokopy et al., 2019). When a farmer updates their overall conservation strategy with appropriate conservation practice systems with the resource needs addressed, their neighbors are likely to ask them questions which could lead toward increased local adoption. Access to a social network is an important aspect of conservation adoption decision making and presents a logical way to combine and extend the reach of outreach efforts (Baumgart-Getz et al., 2012). Establishing more farmer-led groups and enhancing opportunities for farmers to engage with their local agency representatives is an effective way to increase the farmer's awareness of region specific resource concerns, share experiences with other community farmers, transfer information on soil and water conservation management practices, and build trusted relationships that can help break down policy or financial barriers to adoption.

Education in a formal setting does not necessarily encourage conservation practice system adoption; however, the efforts of extension services and other one-on-one, more personal training with a conservation-minded producer or professional, has a positive outcome for implementation (Baumgart-Getz et al., 2012). Along with in-person training, government and private entities should provide additional outreach programs, such as field-days and on-farm demonstration opportunities, for farmers to learn more about region specific conservation practices. Providing educational programs will give the farmers a strong foundation to better understand how their farm management impacts both local and down-stream water quality. Having specific familiarity of regional program goals and efforts has the largest impact on conservation adoption (Baumgart-Getz et al., 2012).

Approximately 40% of U.S. farmland is owned by non-operating parties, and rented out to a third party (Ranjan et al., 2019). These properties have a lower adoption of conservation than owner-operated properties. Conservation incentives do not often pass through to renters and with short lease-terms, there are no financial incentives for renters to invest in conservation practices that do not improve productivity or reduce cost in the short term.

There are five categories of barriers to the adoption of conservation practices on rented farmland (Ranjan et al., 2019): (1) cash rent lease terms, (2) rental market dynamics, (3) information deficit, (4) lack of communication, and (5) non-operating landowner (NOL) financial motivations.

NOLs are commonly unaware of incentives and the benefits of conservation actions (Ranjan et al., 2019). There is a critical need for outreach to build awareness and educate NOLs on conservation practices, how they can be integrated into a farming operation, and their on-farm and off-farm benefits. NOLs may not be aware of the federal incentive programs and how in many cases, not only can conservation outcomes, like improvements in water quality, be strengthened by adoption of conservation practices, but farm economic viability and profitability can also be improved.

Upfront financing for conservation practices or operational changes can be a hurdle preventing implementation, especially by farmers and rancher who rent their land. Open dialogue between the NOL and the operator will help establish a better understanding of market dynamics, uncertainties, and the successes and failures associated with farm management. Negotiations regarding flexible lease terms or multi-year leases can improve the NOLs understanding of the obstacles to adopt a new management practice that requires an initial investment in new machinery or construction expenses (Ranjan et al., 2019).

Access to public or private programs that provide credit, results in greater opportunities to advance conservation practice adoption (Miheretu & Yimer, 2017). An entire sector of infrastructure exists to oversee the leasing and operation of farm lands for non-operating owners. These farm or land management firms often have the capacity to bring substantial management expertise to landowners (and operators) that they may not have themselves. One of the areas of expertise that some leading firms in this industry are interested in offering is improved conservation management. This gives the land management firm an additional service to bring to NOLs that differentiates them from parties not offering this service. Land management firms know that while it is the size of the check that is the most common question asked by NOLs, many are also interested in the environmental outcomes and long-term sustainability of their operations. This coupled with additional financial incentives to deliver conservation can make an attractive package.

Conclusion

The industry processes and past management that have shaped food and agricultural water policies are continuing to be challenged by the desire to meet water quality goals while increasing productivity, creating tension that opens opportunities for new approaches to solve environmental issues across the agricultural landscape. Costly urban and suburban water infrastructure requirements are contributing to the debate about the need for environmental regulatory policy changes in rural watersheds to reduce agriculture-related pollutants, including manure, fertilizers and pesticides. A growing number of NGOs, universities, and members of the general public who have not been traditionally involved in shaping food and agriculture policy are mobilizing. Moreover, food and beverage companies are becoming more engaged in state and federal policy discussions to meet their respective corporate environmental pledges to consumers to reduce impacts on climate, water quality and quantity, in the absence of federal, state or local goals. Furthermore, there continues to be pressure from state governments for regulation to meet nutrient reduction needs and from lawsuits brought by citizens for a variety of environmental practices.

As the Nation's water quality continues to be an emphasis for measuring the success and efficiency of federal agricultural conservation programs, both private and public initiatives must progress to address identified needs, issues, and barriers. After thorough review of existing conservation programs, funding mechanisms, surveys, and water quality modeling protocol, **this national assessment has identified five primary focus areas critical to achieving water quality goals.**

Efforts to **build collaborative-based conservation initiatives** that involve farmers and engage private industry at all scales and address broader societal benefits are necessary to gain wide-scale momentum and sustain long-term impact towards measured change. Investing private capital to address agricultural water quality initiatives requires a full-commitment and a shared priority to more efficiently decrease nutrient loss from agriculture.

Establish rural and urban partnerships to advance conservation while building unity and an understanding that water resources are connected, shared within a watershed community, and can have downstream impact. Connecting farmers' conservation practice systems with financing will facilitate both public and private investment to further advance implementation. Alliances between urban and rural partners must form based upon common goals to access financial support instruments to meet conservation needs and encourage agricultural economic viability.

The ever-increasing volume of data from agricultural field research must be better summarized, assessed, interpreted, and accessible to outside organizations. To properly **scale conservation practice effectiveness and impact**, access to multidisciplinary data spanning environments, timescales, treatments, and management is necessary. Concerted efforts by the federal agencies should be made to support the compilation of data from both existing literature and unpublished sources to support more robust meta-analyses and data synthesis to inform decisions about public, private, and producer investment into specific practices.

Adequate and consistent funding is vital to delivering effective conservation programs that encourage field conservationists to maintain relationships with landowners and operators. **Build regional and local technical assistance capacity** to ensure that federal and state conservation programs and initiatives are successful and that implemented practices are properly sited, designed, installed, and maintained. Improved public-private partnerships for providing technical service and outreach are short-term ways to promote the use of federal programs and NRCS conservation practices.

Establishing more farmer-led groups and opportunities for farmers to get to know their local agency representatives is an effective way to increase awareness of environmental issues, share experience and information on soil and water conservation management practices, and build trusted relationships, all of which are critical if we want to **overcome barriers to conservation practice adoption**. Providing outreach programs that prepare farmers and ranchers with a strong foundation to understand how their personal farm management decisions impact local water quality will increase their willingness to implement a conservation practice. There is an urgent need to also design and execute outreach programs that specifically address NOLs.

These five areas of emphasis present opportunities where federal resources should be prioritized to develop solutions to address the Nation's agricultural water quality challenges. These solutions must include building trust, finding common ground, developing shared strategies, engaging people with diverse perspectives, and creating a collective commitment to seek change. Outcomes should lead to continuous improvement in the available conservation practices, methods to assess their effectiveness, quality of the data to quantify outcomes, policies that support the conservation programs, better decision-making at multiple scales from individual farms to conservation districts to basins, and the desired outcome of cost-effective improvements in water quality locally, regionally, and nationally.

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