AGree
Transforming Food & Ag Policy

Agricultural Conservation & Environmental Programs: The Challenge of Measuring Performance

Prepared by

Sarah Bates and Lynn Scarlett

with contributions from

Matthew McKinney, Nathan Stone, and David Whisenand

Center for Natural Resources and Environmental Policy

The University of Montana

April 2013

www.foodandagpolicy.com

Foreword

AGree seeks to drive positive change in the food and agriculture system by connecting and challenging leaders from diverse communities to catalyze action and elevate food and agriculture policy as a national priority. Through its work, AGree will support policy innovation that addresses four critical challenges in a comprehensive and integrated way to overcome the barriers that have traditionally inhibited transformative change. AGree anticipates constructive roles for the private sector and civil society as well as for policymakers.

AGree has developed the foundation for its work by articulating four interconnected challenges:

- Meet future demand for food;
- Conserve and enhance water, soil, and habitat;
- Improve nutrition and public health; and
- Strengthen farms and communities to improve livelihoods.

Meeting these challenges will require work over the long term and cannot be solved quickly or through a single policy vehicle. AGree is taking a deliberative, inclusive approach to developing a policy framework that can meet the challenges ahead. We are undertaking research to understand problems and assess options, and we are engaging a broad array of stakeholders to contribute insights, guidance, and ideas that lead to meaningful, evidence-based solutions.

This AGree backgrounder was prepared by a research team assembled by the Center for Natural Resources and Environmental Policy (CNR&EP) at the University of Montana. The lead authors are Sarah Bates, senior fellow at CNR&EP, and Lynn Scarlett, former deputy secretary of the U.S. Department of the Interior, with contributions from Matthew McKinney, director of CNR&EP, and two students at the University of Montana School of Law, Nathan Stone and David Whisenand. This report—which is based on a literature review and synthesis, as well as consultation with a diverse group of experts—summarizes the challenges of measuring the environmental performance of agriculture and reviews differing types of performance measures and their utility in measuring the effectiveness of practices, programs, and policies. The report seeks to enhance understanding of the ways in which agricultural and environmental policy might be assessed and integrated.

We hope you find this paper a helpful resource and source of ideas. And we hope you will join the effort to transform federal food and agriculture policy to meet the challenges of the future.

Deb Atwood

Deb Atwood
Executive Director

Contents

Executive Summary

While agriculture provides essential social, economic, and environmental benefits, it also impacts environmental quality through land transformation and activities associated with agricultural production. Feeding the world's growing population while reducing or mitigating agriculture's negative environmental impacts is a major global challenge.

Environmental performance evaluation is an emerging field of study, innovation, and debate. In the context of agriculture, environmental performance relates to the impact of agricultural operations, practices, and systems on defined environmental goals and objectives, such as those for water and air quality, wetlands restoration, and native species protection and repopulation. No comprehensive, widely accepted index or assessment tool considers all the factors that comprise the environmental performance of agricultural activities. Attempts to create criteria for assessing the environmental performance of agriculture encounter significant conceptual and methodological challenges, including, for example, determining system boundaries and an appropriate scale for analysis; addressing temporal issues; and understanding the many variables that affect agriculture and its environmental impacts.

Despite these challenges, our research suggests that well-conceived performance measures can benefit agricultural producers and society. They can help producers identify actions most likely to enhance environmental performance, so that producers can mitigate adverse effects while enhancing production. Performance measures can also assist policymakers in determining the effectiveness of programs, practices, and policies. And, such measures can enhance the cost-effectiveness of agricultural conservation and environmental programs by providing information on which areas and activities will show the most significant benefits, so that conservation investments can be better targeted.

Measurement and Evaluation Issues

As the world's population increases and agricultural output expands to feed that population, finding ways to enhance the environmental performance of agriculture is increasingly important. To reduce negative impacts of agriculture on the environment, some agreement is needed on the basic attributes of, and metrics for measuring, the environmental performance of agriculture.[1] However, policymakers, agricultural producers, conservationists, food companies, retailers, and the academic community do not agree on goals, standards, criteria, or methodologies for sampling and analyzing such performance. This is due in part to their different purposes and intended uses for such measures.

A review of various efforts and approaches for assessing the environmental performance of agriculture, and the debates surrounding them, yields some general conclusions about best practices and challenges:

- Most efforts to evaluate performance are limited by insufficient data and monitoring and inconsistent measurement protocols. Often, measures vary in form, purpose, and focus.
- While some national indicators have been developed, their level of aggregation limits their usefulness for purposes beyond providing a general picture of how agricultural systems fit within the larger context of national environmental impacts.
- There is considerable debate over the appropriate scale for evaluating the environmental performance of agriculture. Generally, the choice of scale depends on the purpose of the performance measure.

- Monitoring and modeling are not mutually exclusive approaches to evaluating environmental performance; each may be relevant for different purposes, and some combination may be necessary. High-quality modeling utilizes data obtained through on-the-ground monitoring. Modeling may be essential for scaling up from local, site-based observations, made via monitoring, to assess effects across an entire watershed.
- It may be beneficial to engage farmers and ranchers early on in the collection and interpretation of data.

Strategies for Improving Measurements and Information

Improving the evaluation of agriculture's environmental performance requires more extensive and more consistent data as well as the capacity to interpret those data. Interpretation must include an assessment of trends as well as efforts to understand the relationship between the conditions observed and the policies, programs, and practices intended to affect those conditions. Developing this knowledge requires increased monitoring and the use of consistent protocols to build performance information from the field and farm levels to the watershed and regional scales. Also relevant is the potential use of some metrics for identifying farming practices that contribute to improved environmental performance and improved uses of fertilizer, water, and energy use.[2]

Although there is considerable opportunity to design data protocols to achieve more consistent and useful measures, the variety of purposes for which measurement information is used, and the widely varying conditions of agricultural operations, suggest that different measurements, indicators, and data will be relevant and feasible in different circumstances. While measures may differ in their purposes, and hence design, virtually any set of measures needs to be scientifically robust, reasonably low cost to implement, and reproducible over time and space.

To address some challenges with current performance measures, evaluators could:

- Establish environmental performance measures that are relevant to both agricultural programs and individual producers. Seek input and advice from farmers and ranchers to identify environmental performance data that will help them improve land use and agricultural operations. Communicate the data to farmers and ranchers, once collected.
- Measure multiple environmental values, and monitor and evaluate the environmental performance of agriculture at multiple spatial scales.
- Analyze the impact of conservation incentives on management practices in order to better target and stimulate enrollment in incentive programs.
- Invest in the collection, interpretation, and sharing of field-level information about the costs and benefits of conservation efforts.
- Develop new and more sophisticated indices of economic and environmental performance that strive to capture the interactions between economic and environmental concerns.
- Account for variations across different regions, including differing public preferences and natural responses.

Conclusion

With agricultural lands covering 40 percent of the Earth's non-ice terrestrial surface (over 50 percent in the United States), the relationship between agricultural activities and environmental quality is significant and has profound implications for the well-being of people and ecosystems around the world. Though agricultural and environmental policies (and practices) have distinct purposes, neither can be effectively pursued in isolation of the other. Improving the environmental performance of agriculture requires understanding the interrelationships between diverse agricultural practices and a wide range of environmental outcomes, as well as the relative cost-effectiveness of different practices in achieving improved environmental results. Achieving improvements sufficient to meet national goals for environmental quality will require the clear articulation of objectives and meaningful ways to measure performance against those objectives. As we summarize throughout this report, developing such measures involves complexities associated with the number of variables, geographic scales, timeframes, and other considerations.

Indeed, evaluating the environmental performance of agriculture will remain a confounding process until assessment techniques are improved to consider a broad range of related variables, and until more uniformly and regularly collected data is shared with those who can help interpret it and put it to use in both policy and practice.

Despite these complexities, many useful efforts to develop issue-specific, program-related, and more general measures of the environmental performance of agriculture are underway. These efforts are works in progress and vary in their purposes and robustness. Any meaningful attempt to improve the performance of policies, programs, and practices will require continued investment in and improvement of performance measures.

Aligning agricultural production with improved environmental outcomes at the landscape scale is a long-term goal likely achievable only through long-term collaboration among various agencies and levels of government, agricultural producers, researchers, food and agriculture companies, and civil society. Stakeholders, researchers, and officials will need to work toward agreement on specific objectives and metrics as well as policy and program approaches that can enable and drive continuous improvement through adaptive management across a wide range of circumstances. Objectives, metrics, and policy and program approaches themselves must also be continuously improved as experience and research provide new information.

Meeting national goals for environmental quality will require the clear articulation of objectives and meaningful ways to measure performance against those objectives.

Given the gaps in relevant and consistent data and the critical role of data in determining how best to achieve improvements, a first-order task vital to enabling progress is the development of a core set of agreed-upon indicators and metrics and the collection of baseline data that can be used by growers to improve performance and by program administrators, policymakers, and civil society to assess progress and refine programs and policies. This effort will require a near-term investment of time to reach agreement on relevant indicators and metrics and an investment of financial resources to collect baseline data and establish the infrastructure necessary for ongoing monitoring. Given the degree of variability in soils, geography, climate, agricultural products and processes, and other relevant factors, no single set of measures will have equal relevance in all circumstances. But an overall set of indicators and consistent metrics may provide broad, general information that can be supplemented by regionally and locally applicable indicators and metrics, as well as measures tailored to crop type or other factors.

If done with sufficient collaboration and consideration of the diversity of both agricultural operations and natural systems, the alignment of agricultural production with improved environmental outcomes could transform the American landscape in a manner that benefits farmers and ranchers, rural and urban communities, and our natural heritage.

Introduction

The challenge of improving the environmental performance of the agriculture sector is compounded by the need to significantly increase food production to feed the growing global population. Improving environmental performance will require understanding the many facets of food and agricultural systems and how these systems relate to other economic, social, and natural systems and values. Food production, health, energy, nutrition, natural resources, security, labor, and the broader economy are all interconnected. Changes in one sphere can affect the others. While agricultural and environmental policies have distinct purposes, neither can be effectively pursued in isolation of the other.

This report—which is based on a literature review and synthesis, as well as consultation with a diverse group of experts[3]—summarizes the challenges of measuring the environmental performance of agriculture and reviews differing types of performance measures.

The report seeks to enhance understanding of the ways in which agricultural and environmental policy might be assessed and integrated by reviewing differing perspectives on types of performance measures and their utility in measuring effectiveness.

Current discussions about performance measures and the environmental performance of the agriculture sector unfold against a backdrop of significant national and international policy debates and issues, including debates about:

- local food production versus global sourcing;
- the relative merits of various production methods, technologies, and systems;
- biofuels production and its implications for agriculture, the environment, and the food supply; and
- the environmental impacts and benefits of agriculture.

These issues are interconnected and involve economic, scientific, and social dimensions. Evaluation of these broader policy issues is beyond the scope of this report; however, their evaluation depends, in part, on performance frameworks and the measures applied to the analysis.

Evaluating the environmental implications of different agricultural production approaches is not straightforward. The results of such evaluations depend, in part, on the scope of the analysis—that is, how one draws the analytic boundaries of the evaluation, the choice of variables assessed, and the timeframes applied. Our focus is on the types and uses of environmental performance measures associated with different domestic agricultural and related programs and what they tell us about the effectiveness of these programs and potentially successful strategies.

Background

To comprehend the variety of issues that arise in evaluating the environmental performance of agriculture, it is helpful to first understand the evolution of agricultural policies in the United States and of environmental concerns related to agricultural activities. This section orients the reader with a summary of this historical development, and then introduces key issues and ideas that arise throughout the report's analysis of the environmental performance of agriculture. These issues and ideas include:

- defining environmental performance in terms of impacts and benefits,
- measuring the environmental performance of agriculture, and
- applying these approaches in existing agricultural programs.

These issues generate significant debate about the extent of environmental impacts, the appropriate ways to measure impacts, and approaches to mitigating those impacts. This background section introduces the broad parameters of these debates, which are explored in more detail in the assessment that follows.

Evolution of Federal Agricultural Policy in the United States[4]

Farm policy in the United States may be grouped into five primary (though overlapping) periods, as follows.

1785–1890: Land Distribution and Settlement Expansion

The early years of non-Indian agricultural development in the United States were characterized by tension between a government goal of generating revenues through the sale of land, on the one hand, and government land giveaways for an expanding population, on the other. This tension continued until the 1862 passage of the Homestead Act, which advanced a policy model of promoting small, independent family farm systems.

1830–1914: Improving Farm Productivity

As the number of independent farmers increased, policymakers began to focus on increasing the productivity of agricultural lands. In the 1820s, farmers began to organize into state and local agricultural societies to promote training and research that would lead to increased productivity. Federal productivity programs were instituted based on pressure from long-established farmers, who faced increased competition from new homestead farms. The U.S. Department of Agriculture (USDA) and a national system of agriculture colleges were both established in the 1860s; federal funding for state agricultural experiment stations was appropriated in the 1870s; and the USDA's Cooperative Extension Service was created in 1914.

1870–1933: Limited Market Regulation, Infrastructure Improvements, Provision of Information to Increase Competitiveness

As independent farmers moved beyond frontier self-sufficiency and became increasingly dependent on regional and national markets, there was increased pressure on the federal government to institute some regulation. Clashes between farmers and the railroad and processing industries (as well as other urban industries), combined with chronic national surpluses of farm products that drove down prices, led the government to intervene in the market. Farm cooperatives were exempted from anti-trust legislation, and the USDA increased programs that focused on economic information and better access to markets through infrastructure. Following the end of World War I and the onset of the Great Depression, U.S. farm policy began to focus on regulating production and markets and expanding farm credit and exports. Many of these steps had only minor effects, however, until Franklin Roosevelt's New Deal. The Dust Bowl of the 1930s galvanized efforts to introduce soil conservation practices, which became precursors to the growing focus on the environmental performance of agriculture in the latter part of the 20th century.

1924–Mid-1980s: Direct Farm Income Support

Roosevelt's programs focused primarily on price support, mainly though reductions in supply. That is, farmers were paid to reduce their plantings, and the government purchased surpluses when prices fell below a certain point. Throughout this period, the ongoing debate between proponents of free-market agriculture and those who believed price supports were necessary shaped agricultural policy. Production controls became voluntary, and price supports were set according to the global markets. This era also saw the introduction of programs that provided payments directly to farmers, including the Acreage Reserve Program and the Conservation Reserve Program, designed at that time to conserve soil, maintain farm income, and reduce production of some basic crops. These programs set the stage for many subsequent conservation programs.[5]

1980s and Ongoing: Transition toward Global Markets, Market-Driven Supports, Attention to Environmental Concerns

During this period, the intersection between environmental policy and agricultural policy began to spark significant debate. Prior to the 1980s, agricultural conservation programs focused primarily on soil erosion, motivated by concerns over productivity. More recent conservation efforts have expanded to include goals for water quality, air quality, wildlife habitat, and open space. Many of these goals arise from off-farm concerns about environmental quality and not by concerns about on-farm productivity, although efforts to pursue these goals have focused increasingly on solutions with both environmental and productivity benefits. The 1985 Farm Bill included a Conservation Title, bringing focused attention on conservation beyond issues of soil erosion. By 2008, the Conservation Title had grown to include multiple programs and spending of more than $24 billion over a five-year period.

Issues Related to the Environmental Performance of Agriculture

To date, agricultural activities, which produce most of the food that feeds global populations, have transformed 40 percent of the non-ice terrestrial surface of Earth.[6] In 1700, by comparison, the estimated total worldwide area of cultivated land was 3.7 percent, of which nearly half was located in Asia and just under one-third in Europe.[7] Australia, New Zealand, and the Americas accounted for just a fraction (3.3 percent) of cultivated lands in 1700, but accounted for 27.1 percent of total cropped lands by 2000.[8] While the rate of agricultural land expansion has slowed over the past 40 years, productivity has dramatically increased.[9] Figure 1 provides some indicators of the considerable strides made in agricultural productivity since 1960.

Despite these strides, continued land transformation and the day-to-day activities of agricultural production (e.g., water diversions, applications of fertilizers and pesticides, and other land management practices) impact environmental quality and raise public health concerns.[11] Thus, the nation faces the challenge of feeding its population while reducing or mitigating agriculture's negative environmental impacts.

Defining "Environmental Performance" in the Agricultural Context

Raising crops and livestock requires the manipulation of natural systems. Much farming requires removing native plant cover and then preparing the land for planting. In more arid climates (including most of the farmed lands west of the 100th meridian in the U.S. West), water is diverted from waterways, transported or withdrawn from underground, applied to the growing crops, and returned to streams or aquifers. In areas that receive significant rainfall, the loss of vegetative cover can lead to increased overland flow of water (runoff), which, in turn, can increase soil erosion. Sediments transported into nearby streams can alter water chemistry and otherwise affect aquatic habitat. Improperly managed grazing of domesticated animals likewise can change vegetative cover, increase erosion,

Figure 1 | Measures of Agricultural Productivity, 1960 and 2010

	1960	2010
Feed per pound of pork	6 pounds	3 pounds
Feed per pound of beef	8 pounds	4 pounds
Cattle on farms	96.2 million	92.7 million[10]
Dairy cows on farms	17.5 million	9.2 million
Pounds of milk produced	123 billion	189 billion
Acres of agriculture	355 million	330 million

Source: American Farm Bureau Federation

Figure 2 | Key Environmental Impacts of Agriculture

- Air quality
- Animal waste disposal
- Chemical releases
- Salinization
- Soil impacts
- Water quality
- Water use
- Wildlife

and cause loss of wildlife habitat. The application of fertilizers and pesticides, introduction of industrial-scale farming with large equipment, increased use of irrigation water, and other modern agricultural practices all bring their own environmental impacts. (See Figure 2 for a summary of the key environmental impacts of agriculture.)

At the same time, agricultural activities can offer a number of environmental benefits. In many cases, farmlands protect important remnants of intact wildlife habitat and biological diversity in otherwise developed areas. Where irrigated agriculture occurs, return flows from water applied to crops may provide valuable late-season recharge of shallow water tables. In some cases, pasturelands serve as natural filters for overland water flows, removing sediments and contaminants before the water enters streams or aquifers. Properly managed grazing also maintains pasture and rangeland habitats critical to numerous wildlife species.

The balance of environmental impacts and benefits is commonly referred to as the "environmental performance" of agriculture and is a topic of concern to policymakers, producers, conservationists, and others[12]. Monitoring and evaluating environmental performance, and mitigating for harmful effects while promoting benefits, is an emerging field of study, innovation, and debate.

Challenges and Opportunities in the Measurement of Environmental Impacts

The environmental performance of agriculture may be evaluated in a variety of ways using a wide range of measurement tools, including water-quality trends, rates of soil erosion, and other indicators.[13] There is no comprehensive, widely accepted index or assessment tool that considers all the factors that comprise environmental performance in relation to agricultural activities. However, the Organisation for Economic Co-operation and Development (OECD) has published environmental performance indicators for OECD countries, including the United States, since 1990.[14] That report draws upon a number of OECD databases, including the Inventory of Policy Measures Addressing Environmental Issues in Agriculture.[15] The report uses standardized indicators, where possible, but summarizes deficiencies in data availability, quality, and comparability; notes challenges of spatial aggregation that "can mask significant variations at the regional level;"[16] and generally reports trends and ranges. The report notes the relative contribution of the agriculture sector to land transformation, water use, energy consumption, ammonia emissions, and greenhouse gas emissions (Figure 3).[17]

While broad national indicators such as that used for the OECD report have been developed, their level of aggregation limits their usefulness for purposes beyond providing a general picture of how agricultural systems fit within the larger context of national environmental impacts.

Figure 3 | United States Agri-Environmental and Economic Profile, 2002-04

Measure	Relative Contribution (in Percentage Terms) of Primary Agriculture to the National Total
Land Area	52
Water Use	41
Energy Use	1
Ammonia Emissions	88
Greenhouse Gas Emissions	6

Source: OECD, Environmental Performance of Agriculture in OECD Countries since 1990, p. 532.

Numerous attempts to create criteria for assessing the environmental performance of agriculture have encountered significant conceptual and methodological challenges and thus have provoked debate.[18] Some of the challenges include:[19]

- determining the systems boundaries for analysis, ranging from full lifecycle analyses to on-farm, single-variable analyses;
- determining an appropriate and meaningful scale at which to measure performance (for example, field level, regional, or national);
- addressing temporal issues related to distinguishing when a particular environmental benefit was realized;
- understanding the many variables that affect agriculture and its environmental impacts;
- dealing with climactic variability, landscape changes, and other factors external to agricultural activities;
- addressing gaps in the knowledge of how particular environmental practices affect environmental performance;
- assessing the merits of measurements based on a single indicator vs. a composite index of a variety of factors;
- assessing the respective merits and relevance of monitoring and modeling;
- designing user-friendly performance measures to enable widespread adoption;
- sustaining funding for monitoring and environmental practices; and
- understanding the relative strengths and limitations of performance measures based on outputs or outcomes.

Well-conceived performance measures can benefit producers and society in a number of ways. Broad indicators, such as those used by the OECD, can provide a general sense of how agriculture performs relative to other economic sectors in terms of its overall environmental impacts. Appropriately designed, finer-grained indicators can identify the actions most likely to enhance environmental performance. Access to and use of such information enables producers to promote their products based on meeting particular performance goals, though a lack of consistency, credibility, and consumer knowledge complicates such efforts. In addition, well-designed performance measures provide farmers, ranchers, and landowners with insights into how their actions can be improved to mitigate adverse effects and maximize environmental benefits while enhancing production. Farmers and ranchers are unlikely to change their practices unless they understand how and why particular measures might improve environmental performance and benefit their operations.

Performance measures can assist policymakers and agencies in determining the effectiveness of voluntary and regulatory programs, thereby facilitating program improvements and the replication of successes. Performance measures can also enhance the cost-effectiveness of agricultural conservation and environmental programs, by providing information about which activities have the greatest benefits and how conservation investments might achieve those benefits.

In agricultural conservation program design, *targeting* refers to the attempt to focus conservation efforts on those regions, farms, and fields likely to produce the most significant or widespread environmental benefits. Effective targeting, which may increase the cost-effectiveness of agricultural conservation and environmental programs, demands credible and adaptable environmental performance measures.[20]

Measuring the environmental performance of agriculture may support the establishment of specific performance goals for categories of farms, crops, and regions. These goals may then be modified based on additional data that indicate gaps in the performance of a certain region or watershed, or by a particular type or method of farming. Environmental performance measures for agriculture can also provide a basis for allocating agricultural program payments to farmers.[21]

Methodology

This report describes different types of measures used to assess the environmental performance of agriculture (including the performance of conservation programs aimed at farmers). It also gives examples of such measurement approaches and describes current debates and challenges regarding those approaches.

The analysis is based on two key types of information:

- An extensive review of literature related to the environmental performance of agriculture, including government studies and reports, scholarly articles and books, and substantive literature and data available from the private sector. All literature relied upon in this analysis is cited in footnotes; in many cases, we provide hyperlinks to original sources or websites with additional information.
- Consultation with 15 experts in agricultural and environmental policy and practice. The list of experts with whom we communicated appears at the end of this report. We originally contacted 23 individuals, spoke directly with nine, and received electronic communications from six. All conversations were confidential, pursuant to our research protocols.

We assembled and summarized this information in consultation with project partners, aiming to produce a user-friendly document highlighting areas of existing knowledge and opportunities for improvement.

We have not undertaken to independently validate the quality or results of the numerous studies on the environmental performance of agriculture. Such an assessment was beyond the scope of this report.

Well-designed performance measures provide farmers, ranchers, and landowners with insights into how to mitigate adverse effects and maximize environmental benefits while enhancing production.

Measurement and Evaluation Issues

To reduce agriculture's impact on the environment requires some agreement on the basic attributes and metrics of the environmental performance of agriculture,[22] but policymakers, agricultural producers, conservationists, food companies, retailers, and the academic community do not agree on goals, standards, criteria, or methodologies for sampling and analyzing such performance. This is due in part to their different purposes and intended uses for such measures. Debates continue about the costs associated with different methods to evaluate the environmental performance of agriculture, as well as the value added in terms of improved environmental outcomes and other benefits.[23]

Agricultural activities provide environmental benefits and adverse impacts. Because this report largely focuses on the challenge of measuring the environmental performance of agriculture, much of the summarized information necessarily describes adverse impacts. However, agricultural activities provide the food and fiber essential to human health and well-being. In fact, "farmers account for less than one percent of the U.S. population yet still manage to adequately feed and clothe America while exporting some $50 billion in agricultural goods, more than six times (in real dollar value) what they did in 1940."[24] More recently, the ecosystem services benefits of agriculture, such as carbon sequestration, have received increasing attention. Most efforts to evaluate the environmental performance of agriculture do not examine the broader lifecycle picture that provides "a systems-based accounting of material and energy inputs and outputs at all stages of the lifecycle: acquisition of raw materials, production, processing, packaging, use, and retirement."[25] While such systemic assessments are complex, involving numerous assumptions, they offer an attempt to evaluate larger trade-offs between, for example, high-intensity agricultural impacts versus potentially greater land transformation from lower-yield practices.

Because attempts at such analyses are scant, this report summarizes information about more direct, farm-based environmental performance measures.

This section describes the primary types of measures for evaluating the environmental performance of agriculture, examples of those approaches currently in use, and the current debates regarding those approaches.

Defining Environmental Performance Measures

Those interested in the environmental performance of agriculture seek to assess the agriculture sector's status in meeting defined environmental goals and objectives, such as for water and air quality, wetland restoration, and native species repopulation. Yet existing performance measures vary in form, purpose, and focus.

In terms of *form*, measures cluster into three categories: inputs, outputs, and outcomes. Measures focused on inputs, also referred to as practice-based measures, essentially define performance in terms of specific actions or practices. These practices are presumed to result in better environmental outcomes and, thus, to serve as proxies for environmental performance rather than as direct measures. Measures focused on outputs assess things such as the extent of geographic area protected, acres of wetlands established, stream miles affected by conservation actions, number of enrollees in a conservation program, and so on. Like inputs, output measures provide, essentially, proxies of performance in which the assumption is that the extent of such outputs provides a rough gauge of environmental benefits. Finally, outcome-based measures are actual measurements of specific environmental results, such as water-quality improvements, erosion reductions, enhancements in biodiversity, or other benefits.

The *purposes* of measures also may vary. Purposes may include, for example, setting priorities for conservation program investments; assessing the relative environmental benefits of different agricultural practices; or assessing the cost-effectiveness of different practices.

In some cases, measures focus on outcomes in terms of both food production and environmental benefits, examining which agricultural modes of production optimize across these two dimensions. Many analysts suggest that meaningful environmental performance measures should include factors beyond environmental or conservation concerns—i.e., factors such as economic impacts, program cost-effectiveness, and social effects.[26] The scope of measures has implications for both the programmatic focus of performance evaluations and how such performance is assessed. For example, broadening environmental performance measures to include economic impacts, cost-effectiveness, and social effects may suggest a need to assess programs that are not directly intended to generate environmental results but may affect agricultural management and therefore environmental outcomes. In addition, situating the evaluation of environmental performance within social and economic contexts can help to illuminate not simply "absolute" impacts and outcomes, but the incremental costs of each unit of improvement, among other insights. Social and economic factors have important implications for program feasibility, durability, and cost-effectiveness, as well as for understanding potential trade-offs between environmental outcomes and the economic or social impacts of investments in certain practices intended to improve environmental performance. At the same time, evaluating both environmental and socio-economic outcomes can point to opportunities to improve both environmental and economic outcomes.[27] Moreover, as one publication notes, "when addressing sustainability it is critical to keep in mind the ultimate societal need that is met by the system in question: in agriculture this is to provide necessary food and fiber."[28]

Finally, environmental performance measures vary in their *focus*. Some measures focus on single benefits; some focus on multiple benefits. For example, measures can focus on a concept such as vegetation biodiversity, which assesses the composition, extent, and pattern of native or semi-native vegetation.[29] Other measures may focus on a single attribute such as water quality, measuring such indicators as temperature, nitrogen content, phosphorus content, and sedimentation. Some research has suggested that rather than focusing on individual indicators of water quality, a number of indicators should be aggregated to create a composite water quality index/score to facilitate comparison across sectors. One of the earliest examples of a composite water-quality index is the Index of Biotic Integrity, which was developed in the early 1980s as a way to assess the health of warm-water streams.[30] Finally, efforts to evaluate environmental performance vary in their geographic focus—ranging from fields and farms to regions or even the whole country.

Examples of Environmental Performance Measurement Approaches

This section provides specific examples of environmental performance measurement approaches. First we look at two approaches currently used by the U.S. government, then at methods employed by other national governments, and then at a variety of tools and approaches used in the private and nonprofit sectors.

Conservation Effects Assessment Project

The USDA's Natural Resources Conservation Service describes the Conservation Effects Assessment Project (CEAP) as a "multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality."[31] CEAP was initiated in response to a call for better accountability regarding the potential benefits of expanded conservation programs under the 2002 Farm Bill.[32]

CEAP activities fall into three categories:[33]

- Bibliographies and literature reviews to establish what is known about the environmental effects of conservation practices at the field and watershed scales, and what kinds of research and data collection are needed to assess the benefits of those practices.
- Watershed assessment studies to provide in-depth quantification of the water-quality and soil-quality impacts of conservation practices at the local level, and to provide insights into what practices are needed and where they are needed within a watershed to meet environmental goals.
- National and regional assessments to estimate the environmental effects and benefits of agricultural conservation practices on the landscape, and to provide suggestions for where further conservation practices are needed.

Prior to the initiation of CEAP, numerous studies at the plot or field levels assessed practices that were intended to improve and protect water quality, water quantity, and soil quality. As one paper noted, however: "Research results from these studies often failed to capture the complexities and interactions of conservation practices, biophysical settings, and land uses within a watershed."[34] Watershed assessment studies were thus incorporated as part of the CEAP research to assess conservation practices at watershed scales.

CEAP has used surveys and field data, as well as field-scale process models that simulate erosion, sediment loss, nutrient loss, pesticide loss, and changes in organic carbon. CEAP has also integrated field-scale modeled results with national models that assess offsite estimates of benefits.

CEAP's broad approach presents several challenges, particularly concerning the integration of measurement, monitoring, and modeling. CEAP's early work was criticized for an overreliance on simulations and extrapolations.[35] Few of CEAP's initial watershed studies were able to develop methods for modeling the actual impacts of the adoption of particular practices, suggesting a lack of data at the appropriate spatial distribution and level of resolution.[36] Some individuals we interviewed also question the accuracy of data regarding grower practices, which are largely self-reported.

A more recent review of CEAP's watershed studies conducted by scientists at the USDA's Agricultural Research Service concluded the following:

The Conservation Effects Assessment Project benchmark watershed studies have facilitated significant progress in watershed and conservation science through modeling and observational studies. Progress during the first five years of this effort could be characterized as achieving critical steps in moving watershed modeling capabilities forward, and recognizing key lessons that begin to capture the complexity and dynamic nature of watersheds through observational studies. Long-term studies have demonstrated the impact of climatic variation, and lagged effects of practice implementation. Continued efforts that integrate observational and modeling studies offer the best opportunity to expand on this progress and move conservation science and policy forward, in cooperation and partnership with landowners and other stakeholders who recognize the critical importance of managing water quality.[37]

It remains difficult to link conservation practices with changes in water-quality outcomes at the watershed scale given available data, models, and resources. Despite the significant challenges, most analysts agree that CEAP is a positive step toward developing meaningful and scientifically credible environmental performance measures for agriculture. Generally, CEAP has garnered support for its focus on research that seeks to identify the environmental effects of particular conservation practices and its potential to help determine which areas and practices have the most significant effects on the environment.

Government Performance and Results Modernization Act of 2010

In 2010, Congress passed the Government Performance and Results Modernization Act, which updated the original Government Performance and Results Act (GPRA) of 1993. The new statute requires that agencies: (1) link performance goals in an annual plan with goals identified in a strategic plan; (2) describe strategies and resources that agencies will use to meet their goals; and (3) provide plans to cover two years instead of one year.

In addition, GPRA now requires more frequent reporting and reviews (quarterly instead of annually), which is intended to increase the use of performance information in decision making. GPRA requires that agencies produce Strategic Plans, Annual Performance Plans, Performance Updates, and Quarterly Priority Goal Progress Reviews.[38] The timing of agency Strategic Plans now aligns with presidential terms, to allow for the changing of objectives and priorities by a new administration. Lastly, the revised GPRA process created a forcing mechanism whereby the Office of Management and Budget takes action on "unmet" agency goals.[39] Under the Act, the USDA's performance measures have typically focused on outputs, such as the number of acres enrolled in a particular program, dollars spent, and the number of participating farmers.[40]

European Union's Agri-environmental Footprint Index

The European Union (EU) has attempted to address the issue of environmental performance measures for agriculture through the development of its Agri-environmental Footprint Index (AFI). Through the AFI, EU countries must monitor and evaluate the environmental, agricultural, and socio-economic impacts of their environmental programs.[41] The AFI uses a multi-criteria methodology and is applied at a farm level to determine the effectiveness of environmental programs.[42]

Canadian Approach to Assessing Environmental Performance in Agricultural Watersheds

A 2012 *Journal of Environmental Quality* "Special Collection" summarized four years of research in Canadian agricultural watersheds looking at the development of environmental performance measures for agriculture, focusing on scientific credibility. The authors noted that global increases in the consumption of chemical nutrients, the application of pesticides, and water withdrawals to enhance agricultural yields have resulted in degraded water quality and reduced water availability, and suggested that, as "humans, livestock, and wildlife (both terrestrial and aquatic) experience greater pressures to share the same limited water resources, innovative research is needed that incorporates a landscape perspective, economics, farm practices, and ecology to advance the development and application of tools for protecting water resources in agricultural watersheds."[43]

This research aimed to develop "ideal performance standards" and "achievable performance standards." Ideal performance standards refer to the desired environmental state necessary to maintain ecosystem health. Achievable performance standards refer to the environmental conditions achievable using currently available and recommended best-available processes and technologies.[44] The rationale for constructing ideal and achievable performance standards was to allow the ideal performance standards to serve as the ultimate objective, while the achievable performance standards would serve as the technologically achievable standard. This approach could be described as an attempt to encourage innovation in agriculture practices, while supporting use of the best technologically available agricultural practices.

Environmental Performance Measurement Tools for Agriculture

Numerous organizations have developed metrics for evaluating the environmental impacts and related attributes of agriculture. Such approaches may look at a limited number or a wide range of impacts and may range in geographic focus from a global scale to the impact of an individual grower's practices.

Examples of environmental performance measurement tools in use today include the following:

- The Stewardship Index for Specialty Crops, a multi-stakeholder initiative to develop a system for measuring sustainable performance throughout the specialty crop supply chain.[45]
- The Cool Farm Institute's Cool Farm Tool, which calculates on-farm greenhouse gas emissions for crop and livestock production.
- Walmart's Global Produce Sustainability Assessment, part of the corporation's overall Sustainability Index.
- The Keystone Alliance for Sustainable Agriculture's Fieldprint Calculator, a tool that growers can use to estimate how their management choices impact natural resources and operational efficiency.

Leonardo Academy's Sustainable Agriculture Standard

In 2012, the Leonardo Academy, a sustainability-focused nonprofit, produced a National Sustainable Agriculture Standard for the American National Standards Institute.[46] This standard is intended to constitute a "comprehensive framework and common set of environmental, social, and quality standards by which to demonstrate that an agricultural product has been produced and handled in a sustainable manner, from soil preparation and seed planting through production, harvest, post-harvest handling, and distribution for sale."[47]

The Academy used a consensus-based approach to generate the standard. This approach met a challenge in 2010 when most of the large agricultural groups pulled out of the process because of concern that it was not committed to a balanced and open analysis of modern agriculture.[48] Despite the withdrawal of ten voting members, the process proceeded, resulting in the release of a working draft in April 2012.[49]

The withdrawal of the agriculture groups demonstrates the challenge of using consensus-based approaches in the face of diverse and sometimes conflicting interests, analytic perspectives, and knowledge sets. While the withdrawal likely undermines the acceptance and perceived credibility of the resulting standard, the Academy nonetheless initially pulled together a diverse set of agricultural interests that demonstrated general interest in standards or an awareness of their potential significance. In addition, the work of the first two years of the process yielded a significant amount of important information regarding the various interests and potential areas of agreement and disagreement.

Private-Sector Environmental Performance Indicators and Agriculture

A number of firms—both agricultural producers and agricultural product retailers—have begun developing sustainability or environmental indicators. These indicators include measures for on-farm practices, as well as much broader lifecycle assessments of agricultural and food production processes and products.[50] For example, the California Sustainable Winegrowing Alliance uses online performance metrics to calculate, manage, and track performance, including environmental outcomes such as water and energy use in vineyards and wineries.[51] Beyond product-specific measures, some agricultural firms have explored development of ISO 14000 standards for environmental performance in the agricultural sector.[52] Because of the relatively recent advent of some of these performance-measurement efforts, independent review of their scope, utility, significance, and mid- to long-term effects generally has not been undertaken.

Specialized Standards or Measures

A number of academic, programmatic, and site-specific efforts to develop performance measures have also been undertaken.[53] These include, for example, specialized testing and measures for soil nitrates, as well as measures applied in the context of particular conservation initiatives such as the Willamette Partnership, which uses multi-criteria measures of water quality and fish habitat. These specialized measures also include, notably, practice-based performance measures associated with the implementation of various Farm Bill conservation programs. These approaches are discussed in the analysis section on existing programs, below.

Another specialized measure is "recovery credits" in the context of Endangered Species Act (ESA) program implementation. Recovery credits have a single purpose—to measure benefits from certain agricultural and conservation practices to specific species listed under the ESA. The initial "credit" for species conservation, expressed in "recovery credit years," essentially used output measures based on acres, extent, and connectivity of protected lands. But program managers are now exploring the development of "functional acre credits," which are intended to provide better informational links between the measures and practices undertaken by landowners to improve species habitat.[54]

In addition, various nutrient-trading and ecosystem services payment programs have generated specialized metrics associated with those programs and their transactions.

Another area of specific performance focus is water quantity. With the critical importance of water for farming and ranching, combined with the projected impacts of climate change on water availability, water allocation and competing uses (especially among agricultural, urban, and environmental demands) are expected to become increasingly important and divisive issues. Various efforts to measure water quantity have been used in specific circumstances, particularly relating to demands for instream flows to assist in endangered species recovery.[55]

Current Debates about Environmental Performance Measures

Efforts to measure the environmental performance of agricultural practices and of conservation programs focused on agriculture provoke a variety of debates and suggestions for improvement. There are two basic types of debates: analytical and programmatic.

Analytical debates focus on the methods by which environmental performance is evaluated, looking, for example, at the difficulties and uncertainties of measuring changes across large landscapes, over long timeframes, and in contexts involving multiple variables. These debates center on the challenge of designing performance measures that provide the most accurate and meaningful portrayal of environmental (and other desired) conditions. The first six items described below are examples of analytical debates.

Programmatic debates, by contrast, focus on whether conservation programs are achieving their policy objectives and intended, on-the-ground outcomes. Programmatic debates also relate to the feasibility of implementing measurement systems and requirements, and how to create adequate incentives for farmer participation. The final seven items described in this section are examples of programmatic debates.

These two types of debates are interrelated in many instances, and both are compounded by challenges in obtaining consistent and relevant data.

Temporal Issues

There are often significant time lags between the implementation of conservation practices and the realization of benefits.[56] Conservation measures such as land retirement and buffer strips, for example, may take several years or more before they begin to show measureable environmental benefits. Also, some metrics may need to account for environmental effects that are a legacy of agricultural practices used several decades ago.[57] For example, many aquatic systems are loaded with sediment deposited prior to the 1950s. Efforts to assess sediment loading from modern farming operations may in some cases be detecting the delayed release of these older sediments from stream bank erosion and flooding events.

In large-scale monitoring, it may be difficult to isolate the effects of a particular conservation practice or program, especially if multiple programs and regulations are in place across a landscape. For example, in a large landscape that includes Conservation Reserve Program (CRP) lands and conservation practices implemented under the Conservation Stewardship Program (CSP) and Environmental Quality Incentives Program (EQIP), it may be difficult to differentiate the benefits of each program, as well as to factor in the impacts of growers not participating in the programs.

Despite these temporal challenges, it is possible to measure the shorter-term impacts of improved field-level (or farm-level) practices. Cumulatively over time and aggregated across multiple sites, these measurements provide some insights regarding longer-term performance.

Climactic Variability, Landscape Changes, and Other Factors External to the Producer's Control

Weather variability, including large events such as flooding and drought, may affect measures of environmental performance. As climate and rainfall patterns shift, background levels of environmental contaminants may also shift.[58]

Landscape patterns may also change over time due to natural shifts and development pressures, making it difficult to isolate and measure long-term changes in the environmental performance of agriculture. And, regional diversity in landscapes and agricultural methods may be stifled if performance measures are applied universally without regard to location-specific circumstances.

Standard measures—such as the number of farmers participating in a program and the practices they employ—are not sufficient to demonstrate that a particular program stimulated the adoption of observed practices. Experts recommend collecting additional data to separate the effects of conservation program incentives from the effects of concurrent changes in market prices, weather, other policies, and technology.[59]

Single Factor vs. Comprehensive Approach

Environmental performance measures of agriculture can focus on an individual indicator, such as the levels of nitrogen or phosphorous, or involve a composite of multiple environmental factors.

Some programs administered by the U.S. Fish and Wildlife Service, for example, are wholly focused on recovering at-risk species. While the practices for improving species habitat may provide benefits beyond that for species recovery, program measures may be constrained by the legal context such that they can only focus on measures relating to species recovery. By contrast, some measurement tools, such as the Soil Conditioning Index[60] (SCI), attempt to evaluate the sustainability of agriculture by combining a range of indicators into one score.[61]

A Continuum of Measurement Methods, from Modeling to Monitoring[62]

Environmental performance may be evaluated based on quantified, specific observations (monitoring) or by projecting information over a larger area using defined variables and assumptions (modeling). Many different types of modeling are used to assess environmental performance or project outcomes. One type of modeling used in assessing agricultural performance is spatial interpolation—i.e., the extrapolation of a limited number of geo-referenced observations. Statistical models can be used to deal with uncertainties in space and time and with multiple variables, as can simulations, among other tools.

Some discussions of the environmental performance of agriculture contrast monitoring with modeling. However, these are not mutually exclusive approaches, as high-quality modeling utilizes data obtained from on-the-ground monitoring. The challenge in improving environmental performance assessment is not one of selecting between modeling and monitoring; each may be relevant for different purposes, and some combination of both may even be necessary. Such combinations are used for other environmental performance measures. For example, a combination of monitoring and models are widely used to assess compliance with the Clean Air Act for both stationary and mobile air emissions. Modeling may be a cost-effective way to identify high-priority areas in which to focus conservation activities as well as to identify potential sources of negative environmental effects.[63]

Under any circumstance, models are only as good as their assumptions, their variables, and the data on which they are based. A particular challenge in the agricultural context, noted by several experts interviewed for this report, is the difficulty of modeling agricultural performance beyond a local or regional scale, due to the high diversity in land forms, hydrologic systems, vegetative cover, climate, soils, agricultural products and practices, and so on.

In contrast to modeling, monitoring produces data tied to specific observations, and thus provides feedback that is directly applicable to producers and program managers. But this approach can be costly and time-consuming. Moreover, monitoring may not generate information relevant to understanding the links between specific practices and the overall conditions of, say, a large watershed. The geographic scale and multitude of variables affecting observations at a watershed level may make it difficult to track the impacts of particular actions on environmental conditions.

Modeling may be essential for scaling up from local, site-based observations (made through monitoring) to assess effects across an entire watershed. For this reason, monitoring is now incorporated into CEAP watershed assessments, which also involve modeling. To some extent, the utility of monitoring depends on the sort of performance assessment undertaken. If there is a specific performance goal, and a way of measuring whether the specific goal has been achieved, monitoring can be particularly useful. It may be less useful when a program or performance assessment has broad goals and many potential interpretations and ways of measuring progress toward those goals.

Scale

The appropriate scale for evaluating the environmental performance of agriculture depends on the purposes of the performance measures. All monitoring has spatial and temporal contexts, and these can vary considerably (e.g., carbon flux from a 10 cm-diameter soil chamber over 60 seconds, versus atmospheric carbon measured by a NASA flyover). On-farm performance measures, if well-structured, provide information to managers that can guide the adjustment of operations to improve performance.

However, unless all producers in an area participate, and measurements are aggregated at the watershed or regional scale, such on-farm performance measures may not be ecologically meaningful. Thus, field-level monitoring may not be adequate to measure regional, statewide, or nationwide environmental performance.[64] CEAP collects data at the field and watershed levels, which then feeds into a regional and, ultimately, national assessment.

Measures at a broader scale are more difficult to translate to on-farm actions. Larger-scale monitoring also may be difficult to calibrate against background environmental effects, because replication or experimental controls may be difficult to find. It may also be challenging to isolate the effects of a particular conservation practice, given the multiple conservation programs and regulations that may be in place across a landscape.[65] Some authors have suggested that a key consideration in designing performance measures and monitoring results is implementing such measures at multiple scales.[66]

Integrating Information and Filling Data Gaps

If statistically reliable comparisons of the environmental impacts of different practices are to be made, growers must provide a great deal of information. To support or refute a correlation between practices and conservation effects, data are needed on:

- The location of farming and the types of farming utilized by farmers participating in agricultural conservation programs and those farmers not participating;
- The circumstances under which a farmer determines whether or not to participate in a conservation program, and how incentive structures affect those decisions;
- The effects of regional and other factors.

Moreover, the relationships between agriculture and the numerous and dynamic variables associated with environmental outcomes raise a number of questions suggesting the need for additional research. For example:

- How can watershed-level performance studies be scaled up to the regional or national scales?
- What are the relative merits of different standards or criteria for the environmental performance of agriculture?
- Given the limited application of the performance measures and tools that do exist, how will these work when applied more broadly?[67]

Emerging technologies may help to overcome some data challenges—for example, through farmer-reported data using tools such as smartphones and web-based computer applications. Statistical mining methods can also facilitate the reporting and interpreting of data, and such efforts are already in use. In Nebraska, for example, Natural Resource Conservation Districts collect field-level data, which can then be used to provide accurate estimates of some environmental performance indicators that potentially could be aggregated to larger spatial scales using models, spatial statistics, and other methods. Farmers may benefit from the use of these data to identify improved management practices that increase yields and profit.[68]

Multiple (and Sometimes Conflicting) Program Purposes and Goals

Individual programs may have a variety of goals with different criteria for success. For example, the voluntary Conservation Reserve Program ranks candidates for incentive payments using an Environmental Benefits Index, which considers factors such as:

- Wildlife habitat benefits resulting from ground cover on contract acreage;
- Water-quality benefits from reduced erosion, runoff, and leaching;
- On-farm benefits from reduced erosion;
- Benefits that will likely endure beyond the contract period;
- Air-quality benefits from reduced wind erosion; and
- Cost.

CRP participants may achieve a mix of these goals, and measures of success naturally differ for each goal. The challenge for many conservation programs is how to integrate the variety of different measures into a single, meaningful evaluation tool that relates to defined policy objectives.

Programs also may work at cross-purposes with one another, complicating efforts to achieve and evaluate environmental performance. For example, federal crop insurance programs, marketing loan benefits, and disaster assistance can encourage farmers to cultivate more land, including native grassland, than they otherwise would.[69] At the same time, federal agricultural conservation programs like the CRP and EQIP may encourage producers to return cropland to grass cover or otherwise enhance wildlife habitat.[70] Thus, the federal government may simultaneously provide incentives to convert grassland to cropland and cropland to grassland. High crop prices and technological advances have also played significant roles in native grassland conversion.[71]

In some cases, one federal agency's regulatory action (such as approving a pesticide for agricultural and other applications) contradicts or complicates another agency's regulatory mandate (such as protecting threatened and endangered species from harms such as pesticide poisoning). In such cases, litigation may be necessary to sort out the controlling authority and mandate coordination to resolve the conflict.[72]

Many federal conservation programs are managed and implemented at the state level without significant federal oversight. As a result, there is some variation in policy choices and implementation among states, making the comparison of environmental performance across states or regions difficult. For example, a recent survey of state programs found that, although 19 states have at least some mandatory requirements for agricultural nonpoint sources, only four (California, Kentucky, Vermont, and Wisconsin) have "anything approaching a comprehensive enforceable regulatory program" for such sources.[73]

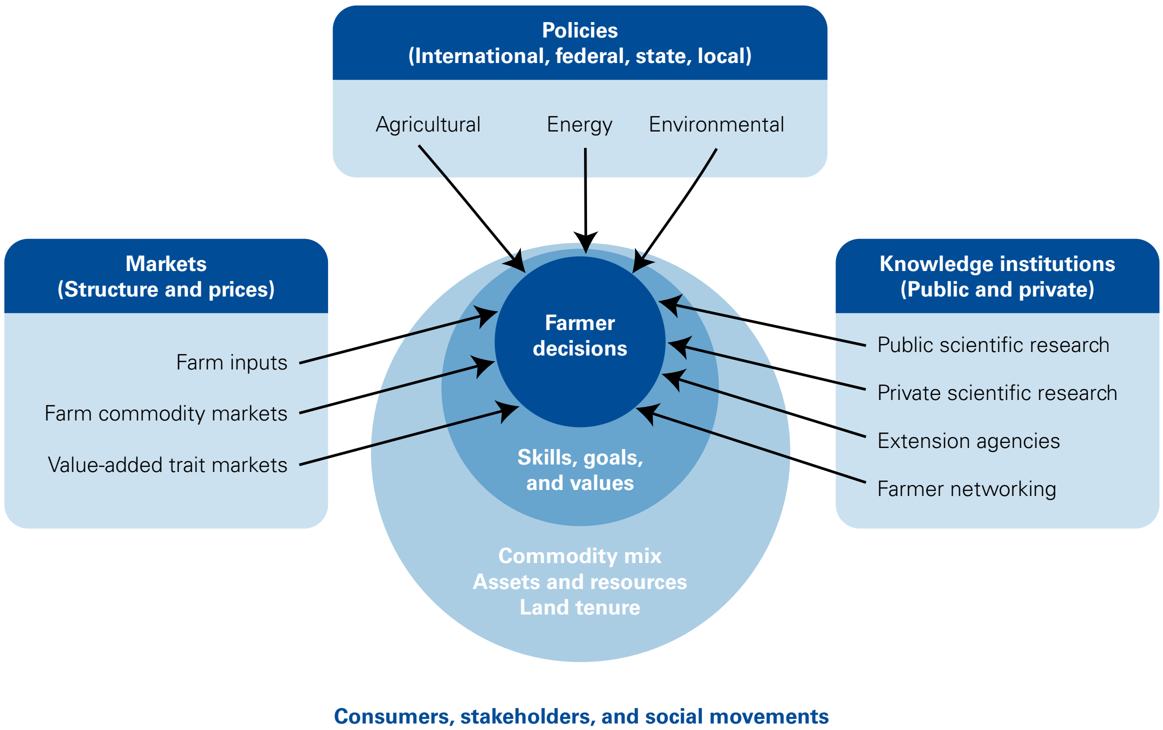
Linking Farmers' Behavior with Program Incentives

The first step in measuring the success of agricultural conservation programs is to determine whether farmers' stewardship behavior changed in response to the program being evaluated. Because many other factors (including other government programs) influence farmers' choices, demonstrating such links is challenging. Only by separating the influence of program incentives from other factors that affect farmers' conservation choices can the program evaluator assess whether the program being evaluated had an effect.[74]

To judge the success of a conservation program, simply identifying changes in farmers' practices (and accompanying improvements in environmental quality) is insufficient; that's because farmers may adopt conservation practices for reasons unrelated to the conservation program (Figure 4).[75] Farmers may be motivated to change their behavior by a number of factors, ranging from environmental values to avoiding regulatory consequences to the influence of equipment, fertilizer, pesticide, and other product manufacturers. In many cases, conservation practices may simply be more efficient and thus offer significant cost savings; these types of practices are more likely to be adopted without additional pressure from federal program mandates or incentives.[76]

On the other hand, as researchers have noted, "[e] nvironmental performance is multifaceted and improvement in one area may come at the expense of another. For example, use of [crop residue management] sometimes requires higher pesticide use, in which case reduced soil erosion must be weighed against a greater potential for pesticide runoff."[77] Thus, any assessment of behavior changes must look at all relevant changes and their impacts, not just those linked to the program objectives.

Figure 4 | Drivers and Constraints that Affect Farmer Decisions



Drivers and constraints that affect farmers' decisions. Farmers make choices based on market structures, policy incentives, and knowledge institutions -- all affected by consumers, stakeholders, and social movements

Source: J.P. Reganold, et al., "Transforming U.S. Agriculture," Science, Vol. 332 (2011):670. (Used with permission.)

Ensuring Participation

The rates of farmer participation in a conservation program—as measured both by enrollment and by actual adoption of new practices to achieve environmental or conservation benefits—are an important consideration in designing and assessing environmentally relevant, cost-effective performance measures and monitoring systems. For example, producers may resist participating in a program if they are concerned that they will have to reveal confidential information or expose themselves to new regulations or higher compliance costs.

In some cases, farmers have not participated in conservation programs due to limited experience or past discriminatory practices. Farm legislation in 2002 and 2008 targeted such farmers to participate in conservation programs by making them eligible for more favorable payment and enrollment terms than other farmers received. A study published by the USDA's Economic Research Service in 2009 found that such programs effectively encouraged higher rates of participation among targeted farmers.[78] "While not definitive," the authors concluded, "evidence shows that targeted farmers tended to operate on more environmentally sensitive land than other farmers, had different conservation priorities, and received different levels of payments. Those differences suggest that economic and environmental outcomes could change if the proportion of targeted farmers enrolled in the programs increases significantly." [79]

User-Friendly Design versus Precision

A primary challenge in measuring the environmental performance of agriculture is designing a system that compiles data that is both detailed enough to be meaningful and relatively easy to use for making decisions. There may be tradeoffs between the richness of information generated, and ease of use. And, depending on the circumstances, both farmers and researchers may need some combination of simplified information and detailed information and analysis.

At a broad scale, indicators inform social and political dialogues by simplifying complex information, highlighting issues and trends, countering misinformation, and illuminating choices. At the other end of the decision spectrum, farmers involved in data gathering and interpretation are more likely to use indicators to inform their own management decisions, as well as to understand the broader policy issues.

Standards for designing indicators of environmental performance are still emerging, but one recent survey of practices around the world provided useful case studies and concluded that effective data collection and interpretation play a key role in successful initiatives.[80] Effective data collection requires clear and consistent data standards and protocols; an extent and scale of monitoring that provides statistically relevant information; and ongoing data collection to provide consistent information over time. Simply gathering data is insufficient to guide improvements in practices and programs. The data must be interpreted in terms of what trends the data indicate, what (if any) insights can be discerned about the relationships between measured results and management actions, and so on.

Financial and Institutional Commitment

If performance assessments are intended to influence practices using adaptive management, baseline information and ongoing monitoring and assessments are necessary. A key challenge is securing and maintaining sustained funding for adaptive management efforts, including for the experiments and pilot programs necessary to assess the effects of different farming practices.[81]

More broadly, it may be necessary to support agricultural research that examines interconnections among environmental and other resource impacts and looks holistically at combinations of farm practices and their environmental and other effects. Along these lines, a group of leading agricultural researchers called for "a new research vision and commitment to addressing these issues in a broad and integrated fashion rather than the traditional research-reactive and problem-specific research approach."[82]

Validation/Verification Issues

Related to the challenge of determining an appropriate scale for measuring environmental performance is the challenge of validating or verifying collected data relating to farmer participation and environmental outcomes. Moreover, approved best management practices within various Farm Bill programs are often only a subset of practices that may have beneficial results, raising questions about what universe of practices should be verified, particularly if the purpose is to better understand overall environmental performance. Direct verification of outcomes is even more challenging.

Standards for validating environmental performance are in place for some sectors of economic activity. For example, the International Organization for Standardization (ISO) promotes the development and implementation of voluntary international standards, both for particular products and for environmental management issues such as environmental auditing, environmental performance evaluation, environmental labeling, and lifecycle assessment. ISO standards for agriculture relate to soil analysis, fertilizer and pesticide application, and equipment.

Assessing Success by Performance versus Practice

Gains in the environmental performance of agriculture are often measured according to an increased number of acres enrolled in, or dollars spent on, a practice-based program or policy.[83] While such measures might be improved by expanding the universe of accepted best practices, measuring success in terms of such practices provides, at best, a proxy for environmental performance. Understanding these limitations, program managers are shifting toward measuring success in terms of actual performance (i.e., measurable outcomes) rather than the extent of adoption of particular practices.[84]

The most frequently cited benefits of performance-based systems include a clearer program focus on high-priority or high-results areas and increased flexibility for farmers to select practices best suited to their circumstances.[85] In addition, tying payments to performance may lead to more enduring outcomes—both by motivating producers to maintain performance (and therefore payments) over a long period rather than engage in a one-time project where the cost is split between the producer and the government, and by stimulating continuous improvement rather than generating a single, incremental improvement.[86]

Many proponents of performance-based systems view farmers as best positioned to determine which practices will be the most cost-effective.[87] An analysis by the USDA's Economic Research Service determined that performance-based conservation programs could "generate more than two times the environmental quality per dollar spent compared to practice-based programs."[88] However, it is unclear what the administrative costs of implementing a truly performance-based program would be, and it is possible such costs could be significant given the extensive amount of information necessary and the personnel needed to collect and analyze that information.[89]

For some agricultural conservation programs, performance-based systems could lay a foundation for future markets for ecosystem services and reductions in nonpoint source pollution.[90] That is, performance-based programs could establish metrics to measure performance increments that could then become units of trade in pollution-reduction programs.

Many proponents of performance-based systems view farmers as best positioned to determine which practices will be the most cost-effective.

But performance-based systems are subject to some of the same challenges as other systems of measurement. One major challenge is how to meaningfully determine the connection between change in a particular practice and the environmental performance benefit. As noted earlier, performance-based systems require some monitoring to determine changes in environmental performance, which invokes longstanding issues about how best to evaluate performance—i.e., must performance be directly measured, or can it be modeled with sufficient accuracy?[91]

Performance-based systems also require determination of an appropriate scale for measurement. Should performance be measured at the farm level, the watershed level, or even the regional level in order to evaluate the effectiveness of a program? CEAP measures performance across multiple scales; the project collects data at the field and watershed levels, and then aggregates that data into regional and national assessments. In the absence of widespread monitoring across many sites within an ecosystem or region, field-level data can be incorporated into modeling efforts to support the scaling up from an individual farm or highly localized level to a broader ecosystem scale. The problem with plot- or field-level monitoring and data collection is that such data are not necessarily useful in assessing performance at the watershed or regional level, unless such data are sufficiently comprehensive to cover multiple sites across an entire watershed or region.[92]

Key Findings

The key findings of our assessment of environmental performance measurement approaches and evaluation issues are as follows:

- Most efforts to evaluate performance are limited by insufficient data and monitoring and by inconsistent measurement protocols. Measures vary in form, purpose, and focus.

- While some national indicators have been developed, their level of aggregation limits their usefulness for purposes beyond providing a general picture of how agricultural systems fit within the larger context of national environmental impacts. Developing a national standard for measuring environmental performance presents conceptual and analytical challenges. Differences in land types, agricultural production, and other variables may limit the utility of a national set of standards.

- Different metrics and performance measures may be required for assessing the environmental performance of agriculture, depending on information goals or program purposes. There is no comprehensive, widely accepted index or assessment tool that assesses all the factors that comprise environmental performance in relation to agricultural activities.

- There is considerable debate over the appropriate scale for evaluating the environmental performance of agriculture. Generally, the choice of scale depends on the purpose of the performance measure. Performance measures can be used, for example, to measure the effectiveness of different practices, improve program efficiency, and target funding toward issues or regions of highest concern.

- Many analysts suggest that meaningful performance measures should include factors beyond environmental or conservation concerns, such as economic impacts, program cost-effectiveness, and social effects.

- Policymakers, agricultural producers, conservationists, and the academic community do not agree on goals, standards, or criteria. Nor do they agree on the methodologies for assessing performance, in part reflecting their different purposes and intended uses for such measures.

- Monitoring is an essential component of outcome-based environmental performance measures. Monitoring and modeling are not mutually exclusive approaches to evaluating environmental performance; each may be relevant for different purposes, and some combination of both may be necessary. Monitoring provides direct feedback applicable to producers, but this approach can be costly and time-consuming. Monitoring also may not generate information relevant to understanding links between specific practices and overall conditions.

- Engaging farmers and ranchers early on in the collection and interpretation of data may enhance their buy-in and how they perceive the relevance of the information. However, they may have little incentive to participate in such efforts.

- A key step in measuring the success of agricultural conservation and other programs is to determine whether the stewardship behavior of farmers has changed in response to the program being evaluated. Because farmers may adopt conservation practices for reasons unrelated to the conservation program, simply identifying changes in farmers' practices (and accompanying improvements in environmental quality) is insufficient for judging the success of a conservation program.

- The evaluation of how well a conservation program drives environmental improvements is complicated by overlap among multiple programs that differ in scope, focus, and geographic area.

- Most analysts agree that CEAP is a positive step toward developing meaningful and scientifically credible environmental performance measures for agriculture.

Strategies for Improving Measurements and Information

Improving the evaluation of agriculture's environmental performance requires more extensive and more consistent data as well as the capacity to interpret those data. Interpretation includes an assessment of trends as well as efforts to understand the relationship between the conditions observed and the policies, programs, and practices intended to affect those conditions. Developing this knowledge requires increased monitoring and the use of consistent protocols to build performance information from the field and farm levels to the watershed and regional scales. Also relevant is the potential use of some metrics for identifying farming practices that contribute to improved environmental performance and improved uses of fertilizer, water, and energy use.[93]

Although there is considerable opportunity to design data protocols to achieve more consistent and useful measures, the variety of purposes for which measurement information is used, and the widely varying conditions of agricultural operations, suggest that different measurements, indicators, and data will be relevant and feasible in different circumstances. While measures may differ in their purposes, and hence design, virtually any set of measures needs to be scientifically robust, reasonably low cost to implement, and reproducible over time and space.

To address some challenges with current performance measures, evaluators could:

1. Establish environmental performance measures that are relevant to both agricultural programs and individual producers. Seek input and advice from farmers and ranchers to identify environmental performance data that will help them improve land use and agricultural operations.

Improving the evaluation of agriculture's environmental performance requires more extensive and more consistent data as well as the capacity to interpret those data.

2. Communicate environmental performance data to farmers and ranchers so they have the opportunity to use the information to improve their land use and agricultural operations. The information collected through many programs is rarely communicated to farmers and ranchers.
3. Measure multiple environmental values, including but not limited to impacts on water quantity, water quality, carbon emissions and sequestration, and impacts (both positive and negative) to biodiversity.
4. Monitor and evaluate the environmental performance of agriculture at multiple spatial scales.
5. Analyze the impact of conservation incentives on management practices in order to better target and stimulate enrollment in incentive programs.
6. Invest in the collection, interpretation, and sharing of field-level information about costs and benefits of conservation efforts, which is critical to the ability to improve the targeting of agricultural conservation programs.
7. Improve program targeting by: (1) developing new and more sophisticated environmental and economic indices that strive to capture the interactions between economic and environmental concerns; and (2) accounting for variations across regions, including differing public preferences and natural responses.

Conclusion

With agricultural lands covering 40 percent of the Earth's non-ice terrestrial surface (over 50 percent in the United States), the relationship between agricultural activities and environmental quality is significant and has profound implications for the well-being of people and ecosystems around the world. Though agricultural and environmental policies (and practices) have distinct purposes, neither can be effectively pursued in isolation of the other. Improving the environmental performance of agriculture requires understanding the interrelationships between diverse agricultural practices and a wide range of environmental outcomes, as well as the relative cost-effectiveness of different practices in achieving improved environmental results. Achieving improvements sufficient to meet national goals for environmental quality will require the clear articulation of objectives and meaningful ways to measure performance against those objectives. As we summarize throughout this report, developing such measures involves complexities associated with the number of variables, geographic scales, timeframes, and other considerations.

Indeed, evaluating the environmental performance of agriculture will remain a confounding process until assessment techniques are improved to consider a broad range of related variables, and until more uniformly and regularly collected data is shared with those who can help interpret it and put it to use in both policy and practice.

Despite these complexities, many useful efforts to develop issue-specific, program-related, and more general measures of the environmental performance of agriculture are underway. These efforts are works in progress and vary in their purposes and robustness. Any meaningful attempt to improve the performance of policies, programs, and practices will require continued investment in and improvement of performance measures.

Aligning agricultural production with improved environmental outcomes at the landscape scale is a long-term goal likely achievable only through long-term collaboration among various agencies and levels of government, agricultural producers, researchers, food and agriculture companies, and civil society. Stakeholders, researchers, and officials will need to work toward agreement on specific objectives and metrics as well as policy and program approaches that can enable and drive continuous improvement through adaptive management across a wide range of circumstances. Objectives, metrics, and policy and program approaches themselves must also be continuously improved as experience and research provide new information.

Given the gaps in relevant and consistent data and the critical role of data in determining how best to achieve improvements, a first-order task vital to enabling progress is the development of a core set of agreed-upon indicators and metrics and the collection of baseline data that can be used by growers to improve performance and by program administrators, policymakers, and civil society to assess progress and refine programs and policies. This effort will require a near-term investment of time to reach agreement on relevant indicators and metrics and an investment of financial resources to collect baseline data and establish the infrastructure necessary for ongoing monitoring. Given the high degree of variability in soils, geography, climate, agricultural products and processes, and other relevant factors, no single set of measures will have equal relevance in all circumstances. But an overall set of indicators and consistent metrics may provide broad general information that can be supplemented by regionally and locally applicable indicators and metrics, as well as measures tailored to crop type or other factors.

Done with sufficient collaboration and consideration of the diversity of both agricultural operations and natural systems, aligning agricultural production with improved environmental outcomes could transform the American landscape in a manner that benefits farmers and ranchers, rural and urban communities, and our natural heritage.

Experts Consulted

Interviewed

Michael Bean, Counselor to the Assistant Secretary for Fish, Wildlife and Parks, U.S. Department of the Interior

Doug Domenech, Secretary of Natural Resources, Virginia

Steve Elmore, Global Economics Director, Dupont/Pioneer

Lawrence Elworth, Chief Agriculture Counselor, U.S. Environmental Protection Agency

Sara Hopper, Agricultural Policy Director, Environmental Defense Fund

Bruce I. Knight, Principal & Founder, Strategic Conservation Solutions

Ann Mills, Deputy Undersecretary for Natural Resources & the Environment, U.S. Department of the Interior

Kevin Morse, North Puget Sound Program Director, The Nature Conservancy

Don Parrish, Senior Director, Regulatory Relations, American Farm Bureau Federation

Submitted Comments

Jimmy Daukas, Managing Director, American Farmland Institute

Alex Echols, Program Director, Sand County Foundation

Tom Hebert, President, Bayard Ridge Group

Arlen Lancaster, Conservation Initiatives Director, The Nature Conservancy

Reese Peck, Director, Virginia Department of Conservation & Recreation

Sara Vickerman, Senior Director, Defenders of Wildlife

Endnotes

1 P. Koohafkan, M.A. Altieri, and E.H. Gimenez, “Green Agriculture: Foundations for Biodiverse, Resilient and Productive Agricultural Systems,” *International Journal of Agricultural Sustainability*, Vol. 10, No. 1 (2012):61–75.

2 P. Grassini and K.G. Cassman, “High Yield Maize with Large Net Energy Yield and Low Global Warming Potential,” *Proceedings of the National Academy of Sciences*, Vol. 109 (2012): 1074–1079; P. Grassini, et al., “High-Yield Irrigated Maize in the Western U.S. Corn Belt: II. Irrigation Management and Crop Water Productivity,” *Field Crops Research*, Vol. 120 (2011):133–144; P. Grassini, J. Thornburn, C. Burr, and K.G. Cassman, “High-Yield Irrigated Maize in the Western U.S. Corn Belt: I. On-Farm Yield, Yield Potential, and Impact of Agronomic Practices.” *Field Crops Research*, Vol. 120 (2011):144–152.

3 The list of experts consulted appears at the end of the report. The observations and conclusions in this report are those of the authors and do not necessarily reflect the opinions of these experts or the positions of the organizations they represent.

4 This history is adapted from A.B. Effland, *U.S. Farm Policy: The First 200 Years,* Agricultural Outlook Special Article (Washington, DC: USDA Economic Research Service, 2000).

5 J.D. Helms, “Brief History of the USDA Soil Bank Program,” *Historical Insights,* No. 1 (Washington, DC: USDA Natural Resources Conservation Service, January 1985).

6 J.A. Foley, “Global Consequences of Land Use,” *Science,* Vol. 309 (2005):570–574.

7 P.G. Pardey and P.L. Pingali, *Reassessing International Agricultural Research for Food and Agriculture,* Report prepared for the Global Conference on Agricultural Research for Development, Montpelier, France, March 28-31, 2010.

8 Ibid.

9 P.A. Matson, W.J. Parton, A.G. Power, and M.J. Smith, “Agricultural Intensification and Ecosystem Properties,” *Science,* Vol. 277 (1997):504.

10 Due to data availability, this figure is for 2011.

11 J.B. Ruhl, “Farms, Their Environmental Harms, and Environmental Law,” Ecology Law Quarterly, Vol. 27 (2000):263, 265.

12 M.D. Tomer and M.A. Locke, “The Challenge of Documenting Water Quality Benefits of Conservation Practices: A Review of USDA-ARS’s Conservation Effects Assessment Project Watershed Studies,” Water Science and Technology, Vol. 64, No. 1 (2011).

13 A complicating factor is that assessments typically look at “nonpoint” sources of pollution, such as nutrients, sediments, pesticides, and salts that enter surface water diffusely from agricultural runoff. Compared with “point” sources, such as factories and municipal wastewater treatment plants, which produce measurable discharges through pipes, ditches, or smokestacks, nonpoint sources are harder to measure; moreover, their environmental impacts are the result of aggregated individual actions. K. Smith and M. Weinberg, “Measuring the Success of Conservation Programs,” *Amber Waves* (Washington, DC: USDA Economic Research Service, September 2004).

14 Organisation for Economic Co-operation and Development, *Environmental Performance of Agriculture in OECD Countries since 1990,* (Paris, France: Organisation for Economic Co-operation and Development, 2008), 532.

15 Ibid.

16 Ibid., 211.

17 Ibid., 532.

18 Koohafkan, Altieri, and Gimenez, “Green Agriculture.”

19 Many of the listed challenges were discussed during a 2012 conference titled “Providing Environmental Services from Agriculture in a Budget-Constrained Environment,” sponsored by the USDA Economic Research Service, the Farm Foundation, and Resources for the Future, in Washington, DC, April 17-18, 2012.

20 L. Hansen and D. Hellerstein, *Conservation Program Design: Better Targeting, Better Outcomes*, Brief No. 2 (Washington, DC: USDA Economic Research Service, March 2006). M. Ribaudo, *Water Quality Benefits from the Conservation Reserve Program*, Report No. 506 (Washington, DC: USDA Economic Research Service, 1989). The latter report suggests that greater environmental benefits may be derived by targeting those areas where there is an optimal cost/benefit ratio. Modeling the effectiveness of targeting Conservation Reserve Program enrollment in different regions of the United States showed that greater per-acre water-quality benefits would be derived from enrolling lands in the eastern portion of the nation, whereas per-acre benefits in the Great Plains and mountain regions were relatively low.

21 R. Claassen and M. Morehart, *Greening Income Support and Supporting Green*, Economic Brief No. 1 (Washington, DC: USDA Economic Research Service, March 2006).

22 Koohafkan, Altieri, and Gimenez, "Green Agriculture."

23 L.F. Duriancik, et al., "The First Five Year s of the Conservation Effects Assessment Project," *Journal of Soil and Water Conservation,* Vol. 63, No. 6 (2008), cited in P. Nowak and M. Schnepf, Eds., *Managing Agricultural Landscapes for Environmental Quality II: Achieving More Effective Conservation* (Ankeny, Iowa: Soil and Water Conservation Society, 2010), 19.

24 D.L. Hoag, *Agricultural Crisis in America: A Reference Handbook* (Santa Barbara, California: ABC-Clio, 1999), cited in M.C. Heller and G.A. Keoleian, *Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System,* Report No. 2000-4 (Ann Arbor, Michigan: University of Michigan, Center for Sustainable Systems, December 6, 2000), 7.

25 Ibid., p. 7.

26 S.S. Batie, "Green Payments and the U.S. Farm Bill: Information and Policy Challenges," *Frontiers in Ecology,* Vol. 7, No. 7 (2009):380–88.

27 T.J. De Koeijer, G.A.A. Wossink, P.C. Struik, and J.A. Renkema, "Measuring Agricultural Sustainability in Terms of Efficiency: The Case of Dutch Sugar Beet Growers," *Journal of Environmental Management,* Vol. 66, No. 1 (2002):9–17.

28 Heller and Keoleian, *Life Cyle-Based Sustainability Indicators*.

29 Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

30 U.S. Environmental Protection Agency, *An Introduction to the Index of Biotic Integrity*, adapted from T.P. Simon and J. Lyons "Application of the Index of Biotic Integrity to Evaluate Water Resource Integrity in Freshwater Ecosystems," Chapter 16 in W.S. Davis and T.P. Simon, Eds., *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making* (Boca Raton, Florida: CRC Press, 1995).

31 See http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap.

32 Ibid.; M.J. Mausbach and A.R. Dedrick, "The Length We Go: Measuring Environmental Benefits of Conservation Practices," *Journal of Soil and Water Conservation,* Vol. 59, No. 5 (2004):96A–103A; Nowak and Schnepf, *Managing Agricultural Landscapes for Environmental Quality II*.

33 Duriancik, et al., "The First Five Years."

34 Ibid.

35 Soil and Water Conservation Society, *Final Report from the Blue Ribbon Panel Conducting an External Review of the U.S. Department of Agriculture Conservation Effects Assessment Project* (Ankeny, Iowa: Soil and Water Conservation Society, 2006).

36 P. Nowak and F.J. Pierce, "The Disproportionality Conundrum," Chapter 3 in M. Schnepf and C. Cox, *Managing Agricultural Landscapes for Environmental Quality: Strengthening the Science Base* (Ankeny, Iowa: Soil and Water Conservation Society, 2007).

37 Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

38 Nowak and Pierce, "The Disproportionality Conundrum."

39 J. Kamensky, *Government Performance and Results Modernization Act of 2010 Explained* (Washington, DC: IBM Center for the Business of Government, 2011).

40 U.S. Department of Agriculture, *Strategic Plan FY 2010-2015* (Washington, DC: U.S. Department of Agriculture, 2011); U.S. Department of Agriculture, *Strategic Plan FY 2010-2015 Addendum* (Washington, DC: U.S. Department of Agriculture, 2012).

41 K. Knickel and N. Kasperczyk, "The Agri-Environmental Footprint: Assessing the Agri-Environmental Performance of Farms in Participatory and Regionally Adaptive Ways," *Outlook on Agriculture,* Vol. 38, No. 2 (2009):195–203; Schnepf and Cox, *Managing Agricultural Landscapes for Environmental Quality*.

42 J.A. Finn, I. Kurz, and D. Bourke, "Multiple Factors Control the Environmental Effectiveness of Agri-Environment Schemes: Implications for Design and Evaluation," *Irish Journal of Agri-Environmental Research,* Vol. 6 (2008):45–56.

43 P.A. Chambers, J.M. Culp, E.S. Roberts, and M. Bowerman, "Development of Environmental Thresholds for Streams in Agricultural Watersheds," *Journal of Environmental Quality,* Vol. 41 (2012):1-6.

44 Ibid.

45 S. O'Brien, *Defenders of Wildlife Biodiversity Metric for Agriculture* (Washington, DC: Defenders of Wildlife, April 2012). O'Brien describes how field testing identified several shortcomings in this approach. For example, the metric included too many variables and was too time consuming for the user to complete; key terms were undefined, leaving users unsure what information was being requested; and multiple parts of the metric yielded a score but there was no mechanism for converting the disparate parts into single biodiversity score.

46 Leonardo Academy, *Draft Sustainable Agriculture Standard LEO-4000* (Madison, Wisconsin: Leonardo Academy, April 16, 2012).

47 Organisation for Economic Co-operation and Development, *Guidelines for Cost-Effective Agri-Environmental Policy Measures* (Paris, France: Organisation for Economic Co-operation and Development, 2010).

48 Soyatech, *ASA Withdraws from Leonardo Academy's Sustainable Ag Standard Development Process*, Press Release (Southwest Harbor, Maine: Soyatech, Oct. 20, 2010).

49 Leonardo Academy, *Draft Sustainable Agriculture Standard LEO-4000*.

50 Heller and Keoleian, *Life Cyle-Based Sustainability Indicators*.

51 See http://www.wineinstitute.org/resources/pressroom/03192012.

52 E. Wall, A. Weersink, and C. Swanton, "Agriculture and ISO 14000," *Food Policy,* Vol. 26, No. 1 (2001).

53 Many of these approaches were discussed during a 2012 conference titled "Providing Environmental Services from Agriculture in a Budget-Constrained Environment," sponsored by the USDA Economic Research Service, the Farm Foundation, and Resources for the Future, in Washington, DC, April 17-18, 2012.

54 D. Wolf, Environmental Defense Fund, *Fort Hood Recovery Credit System,* presentation given at a conference titled "Providing Environmental Services from Agriculture in a Budget-Constrained Environment," sponsored by the USDA Economic Research Service, the Farm Foundation, and Resources for the Future, Washington, DC, April 17-18, 2012.

55 Several major partnerships involving federal agencies seek to recover threatened and endangered fish and wildlife species through efforts to restore more natural hydrographic conditions, sometimes including restrictions on agricultural irrigation diversions. See, e.g., Platte River Recovery Implementation Program.

56 D.W. Meals, S.A. Dressing, and T.E. Davenport, "Lag Time in Water Quality Response to Best Management Practices: A Review," *Journal of Environmental Quality,* Vol. 39, No. 1 (2010):85–96.

57 Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

58 Ibid.

59 Smith and Weinberg, "Measuring the Success of Conservation Programs."

60 The SCI predicts the consequences of cropping systems and tillage practices on soil organic matter in a field—a primary indicator of soil quality and carbon sequestration.

61 J.E. Quinn, J.R. Brandle, and R.J. Johnson, "Development of a Healthy Farm Index to Assess Ecological, Economic, and Social Function on Organic and Sustainable Farms in Nebraska's Four Agroecoregions," in Alan J. Franzluebbers, Ed., *Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes* (Ankeny, Iowa: Soil and Water Conservation Society, 2010), cited in Nowak and Schnepf, Eds., Managing Agricultural Landscapes for Environmental Quality *II*, 111.

62 See, for example, the discussion in Chapter 2 of Coalition on Agricultural Greenhouse Gases, *Carbon and Agriculture: Getting Measurable Results* (Washington, DC: Coalition on Agricultural Greenhouse Gases, April 2010), 20–25.

63 Nowak and Schnepf, Eds., *Managing Agricultural Landscapes for Environmental Quality II.*

64 Koohafkan, Altieri, and Gimenez, "Green Agriculture"; Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

65 Koohafkan, Altieri, and Gimenez, "Green Agriculture"; Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

66 Tomer and Locke, "The Challenge of Documenting Water Quality Benefits of Conservation Practices."

67 Ibid.; P. James and C.A. Cox, "Building Blocks to Effectively Assessing the Environmental Benefits of Conservation Practices," *Journal of Soil and Water Conservation,* Vol. 63, No. 6 (2008).

68 See, for example, Grassini and Cassman, "High-yield maize." The authors describe the challenges of using structured experimental approaches that require experiments performed at many sites over many years and the potential of alternative approaches that "use farmer-reported databases, collected over a large population of field-years, to perform direct analysis of on-farm energy balance and GWP [global warming potential]" (p. 1074).

69 Only a small fraction of original native grasslands remain, and it is estimated that, between 1997 and 2007, about 1 percent of remaining native grasslands were converted to cropland. R. Claassen, A. Cattaneo, and R. Johannson, "Cost-Effective Design of Agri-Environmental Payment Programs: U.S. Experience in Theory and Practice," *Ecological Economics,* Vol. 65 (2008):737–752.

70 R. Claassen, F. Carriazo, J.C. Cooper, and D. Hellerstein, "Do Farm Programs Encourage Native Grassland Losses?," *Amber Waves,* Vol. 9, Issue 3 (2011).

71 Studies indicate that the carbon benefits derived from biofuels may be offset by the increased conversion of native lands for crop production. (Ibid.)

72 For example, a federal judge in 2004 ruled that the U.S. Environmental Protection Agency (EPA) had violated the Endangered Species Act because it had failed to take steps to ensure that its authorized uses of 54 pesticides (pursuant to another federal law, the Federal Insecticide Fungicide and Rodenticide Act) would not jeopardize the survival of threatened and endangered salmon. The court order required designation of no-pesticide buffers along salmon-supporting waters throughout the Pacific Coast until one of two events occurs for a particular pesticide or a particular population of salmon: (1) the EPA finds that a pesticide is "not likely to adversely affect" salmon, or will have "no effect" on salmon; or (2) the National Oceanic and Atmospheric Administration's Fisheries Service issues a biological opinion under the ESA regarding the pesticide's effects on salmon. For background on the litigation and updated information on the interagency consultation process, see http://www.epa.gov/espp/litstatus/wtc/maps.htm.

73 R. Kundis Craig and T. Schley Noto, *State Nonpoint Source Control Programs for Agriculture: A Look at Agricultural Regulatory Certainty,* Draft (Washington, DC: Environmental Defense Fund, 2012).

74 Smith and Weinberg, "Measuring the Success of Conservation Programs."

75 Ibid.

76 J. Hopkins and R. Johansson, "Beyond Environmental Compliance: Stewardship as Good Business," *Amber Waves* (Washington, DC: USDA Economic Research Service, April 2004).

77 Ibid.

78 C. Nickerson and M. Hand, *Participation in Conservation Programs by Targeted Farmers: Beginning, Limited-Resource, and Socially Disadvantaged Operators' Enrollment Trends*, Economic Information Bulletin No. EIB-62 (Washington, DC: USDA Economic Research Service, 2009).

79 Ibid, page 3.

80 N. Walker, *How Indicators Are Being Used Around the World to Improve Environmental Management and Policy,* (New Haven, Connecticut: Yale Center for Environmental Law and Policy, April 12, 2012).

81 Nowak and Schnepf, Eds., *Managing Agricultural Landscapes for Environmental Quality II*, 9.

82 G. Robertson, et al., "Rethinking the Vision for Environmental Research in U.S. Agriculture," *BioScience,* Vol. 54, No. 1 (2004):61, 62. The authors called for "a vision that anticipates problems stemming from new agricultural technologies and offers integrated strategies for their solution; that facilitates systems-based approaches to understanding rural landscapes and watersheds and provides improved ways to measure environmental performance within them; and that gives appropriate incentives for agriculture to go beyond food and fiber production to deliver environmental benefits to society."

83 F. Casey and G. Boody, *An Assessment of Performance-Based Indicators and Payments for Resource Conservation on Agricultural Lands* (Minneapolis, Minnesota: Land Stewardship Project, 2007).

84 Ibid.

85 J.R. Winsten, "Improving the Cost-Effectiveness of Agricultural Pollution Control: The Use of Performance-Based Incentives," *Journal of Soil and Water Conservation,* Vol. 64, No. 3 (2009).

86 Casey and Boody, "An Assessment of Performance-Based Indicators."

87 Winsten, "Improving the Cost-Effectiveness of Agricultural Pollution Control."

88 M. Weinberg and R. Claassen, *Rewarding Farm Practices versus Environmental Performance*, Economic Brief No. 5 (Washington, DC: USDA Economic Research Service, March 2006).

89 Winsten, "Improving the Cost-Effectiveness of Agricultural Pollution Control."

90 Casey and Boody, "An Assessment of Performance-Based Indicators."

91 Winsten, "Improving the Cost-Effectiveness of Agricultural Pollution Control," 18.

92 Weinberg and Claassen, *Rewarding Farm Practices versus Environmental Performance*.

93 Grassini and Cassman, "High yield maize"; Grassini, et al., "High-yield irrigated maize in the Western U.S. Corn Belt: II"; Grassini, Thornburn, Burr, and Cassman, "High-yield irrigated maize in the Western U.S. Corn Belt: I."

About AGree

AGree is designed to tackle long-term food and agriculture issues. The initiative seeks to drive positive change in the food and agriculture system by connecting and challenging leaders from diverse communities to catalyze action and elevate food and agriculture policy as a national priority. AGree also recognizes the interconnected nature of agriculture policy globally and seeks to break down barriers and work across issue areas.

AGree is a collaborative initiative of nine of the world's leading foundations, including the Ford Foundation, Bill & Melinda Gates Foundation, The David and Lucile Packard Foundation, W.K. Kellogg Foundation, The McKnight Foundation, Robert Wood Johnson Foundation, Rockefeller Foundation, and The Walton Family Foundation, and will be a major force for comprehensive and lasting change.

Contact us:

1920 L Street, NW • Washington, DC 20036 • 202-354-6440

www.foodandagpolicy.org

AGree