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Nature as capital: Advancing and incorporating ecosystem services in United States federal policies and programs

Mark Schaefer^{a,1}, Erica Goldman^b, Ann M. Bartuska^c, Ariana Sutton-Grier^{d,e}, and Jane Lubchenco^f

^aScience and Technology Innovation Program, Woodrow Wilson International Center for Scholars, Washington, DC 20004; ^bCOMPASS, Silver Spring, MD 20910; ^cUS Department of Agriculture, Washington, DC 20250; ^dEarth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740; ^eNational Ocean Service, National Oceanic and Atmospheric Administration, Silver Spring, MD 20910; and ^fDepartment of Integrative Biology, Oregon State University, Corvallis, OR 97331

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The concept of nature as capital is gaining visibility in policies and practices in both the public and private sectors. This change is due to an improved ability to assess and value ecosystem services, as well as to a growing recognition of the potential of an ecosystem services approach to make tradeoffs in decision making more transparent, inform efficient use of resources, enhance resilience and sustainability, and avoid unintended negative consequences of policy actions. Globally, governments, financial institutions, and corporations have begun to incorporate natural capital accounting in their policies and practices. In the United States, universities, nongovernmental organizations, and federal agencies are actively collaborating to develop and apply ecosystem services concepts to further national environmental and economic objectives. Numerous federal agencies have begun incorporating these concepts into land use planning, water resources management, and preparations for, and responses to, climate change. Going forward, well-defined policy direction will be necessary to institutionalize ecosystem services approaches in federal agencies, as well as to guide intersector and interdisciplinary collaborative research and development efforts. In addition, a new generation of decision support tools are needed to further the practical application of ecosystem services principles in policymaking and commercial activities. Improved performance metrics are needed, as are mechanisms to monitor the status of ecosystem services and assess the environmental and economic impacts of policies and programs. A greater national and international financial commitment to advancing ecosystem services and natural capital accounting would likely have broad, long-term economic and environmental benefits.

ecosystem services | natural capital | environmental policy | US federal agencies

Incorporating ecosystem services considerations into decision-making processes supports functional, resilient ecosystems, healthy people and communities, and robust economies, aiding efforts to address a wide range of societal challenges. The concept of nature as capital and the capacity to incorporate into decision making the benefits provided by ecosystems are increasingly influencing government policies and private sector practices in the United States and throughout the world. Although it is not possible or appropriate to monetize all ecosystem services or social values, the enhanced capacity to account for natural capital can improve policy-making, adding important dimensions to decision-making processes. Specifically, an ecosystem services approach enables a more thorough and explicit examination of the impacts and anticipated trade-offs of a policy or decision by predicting or measuring the resulting positive or negative changes in services. An ecosystem services approach can also help further the development of more cost-effective programmatic and regulatory analysis and decision making by providing the means to more rigorously assess the economic and environmental facets of

potential policies or actions. These aspects of an ecosystem services approach facilitate achievement of national environmental, social, and economic objectives.

In recent years, ecosystem services considerations have begun to influence policies and practices ranging from coastal, ocean, and land-use planning, to ecosystem damage assessment and restoration, and water resource management and infrastructure development. Moreover, information about natural capital is influencing cross-agency allocation of resources and harmonization of agency activities. High-level policy direction, along with academic, government, nongovernmental organization (NGO), and corporate research and development programs, is needed to ensure continued progress in incorporating these considerations into policies and programs.

Integrating Ecosystem Services in Decision Making

Early efforts in the United States to incorporate ecosystem services into policies and programs focused on valuing services that could be readily traded in the marketplace and establishing markets for those services. The 2008 Farm Bill (1) called for federal

agencies to explore ecosystem services and their potential application in environmental markets, leading the US Department of Agriculture to establish an Office of Ecosystem Services and Markets. In recent years, a number of environmental markets have advanced to the point that they have become accepted and effective approaches to pursue environmental goals (2). Among the most notable environmental markets are sulfur dioxide trading, wetlands mitigation banking, and nutrient trading, all of which are informed by ecosystem services valuation.

Natural capital accounting, calculating the stocks and flows of natural resources and services, has progressed at a broad international level, particularly in the financial sector. In 2012, the United Nations Statistical Commission of the System for Environmental-Economic Accounts (SEEA) became the first internationally agreed method to account for

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¹To whom correspondence should be addressed. Email: markschaefer24@msn.com.

material natural resources like minerals, timber, and fisheries in national accounts [e.g., gross domestic product (GDP)] (3). The World Bank-sponsored Global Partnership for Ecosystems and Ecosystem Services Valuation and Accounting and its Wealth Accounting and Valuation of Ecosystem Services (WAVES) program are furthering the incorporation of natural capital considerations into national accounts (4). Recently, the Inter-American Development Bank initiated a Biodiversity and Ecosystem Services program throughout Latin America and the Caribbean. Now, the challenge is to take natural capital accounting beyond marketed resources, such as timber and minerals, to include ecosystem services and other natural resources that are typically not traded and are more difficult to measure. These services include the regulating functions of ecosystems (such as wetlands and forests reducing the impact of flooding, mangroves providing nursery habitat for fish and shellfish, pollinators supporting agriculture, and coral reefs enhancing coastal resiliency) and the cultural services provided by ecosystems (such as educational opportunities, spiritual benefits of sacred natural places, or the aesthetics services provided to all who recreate at the coast or in the mountains, for example).

Nations throughout the world are recognizing the value of natural capital and are taking steps to account for and conserve it. For example, documentation that natural capital is the source of nearly one-third of the wealth of low-income countries is focusing greater attention on conservation and sustainable development activities (5). Globally, businesses and financial institutions are examining the implications of natural capital accounting. More than 40 financial institutions have signed the Natural Capital Declaration (6), an initiative to integrate natural capital considerations into loans, equity, fixed income, and insurance products, as well as in accounting, disclosure, and reporting frameworks. Numerous industries are beginning to apply ecosystem services principles in planning and operations (7).

In the United States, various states have been working to identify ways to better account for natural capital to further resource conservation and sustainable development. NGO and academic researchers have pursued methods to incorporate changes in environmental quality and resource status into GDP and other economic measures although this approach has not yet gained acceptance at the federal level. Several states, including Maryland and Vermont, are examining

alternatives to GDP as a measure of economic welfare (8, 9). For example, the Genuine Progress Indicator (GPI), increasingly used by governments and NGOs worldwide, goes beyond accounting for products and services and includes the economic impacts of environmental degradation and other activities that diminish natural and social capital (10).

The US Congress is also beginning to recognize the importance of ecosystem services. For example, after the high-profile *BP Deepwater Horizon* 2010 oil spill disaster in the Gulf of Mexico, Congress appropriated funds to the National Oceanic and Atmospheric Administration (NOAA) to request a study from the National Academy of Sciences on “the long-term ecosystem service impacts of the Deepwater Horizon oil discharge.” The appropriations language states, “Such a study shall assess long-term costs to the public of lost water filtration, hunting, and fishing (commercial and recreational), and other ecosystem services associated with the Gulf of Mexico” (11), which complemented NOAA’s ongoing incorporation of ecosystem services into the Natural Resource Damage Assessment of the oil spill disaster, and the Natural Resource Damage Assessment Trustee Council’s approach to restoration after the disaster.

Ecosystem services applications for decision support in US federal agencies have advanced on multiple fronts in recent years. Agencies are incorporating a suite of natural capital benefits in crosscutting policy contexts, including benefit–cost analysis, land-use planning, natural resource damage assessment and restoration, infrastructure, environmental assessment, regulation, and evaluation of cost-effectiveness. Ecosystem services valuation and tradeoff analysis have begun to be integrated into a variety of policymaking and program implementation processes and tools. Moving forward, the federal government will be working toward providing a uniform framework for ecosystem services assessment and developing guidance to agencies to institutionalize consideration for ecosystem services in policies and implementation.

Ecosystem Services in the Executive Branch

Executive Office of the President. In the United States, the policy dialogue around ecosystem services spans nearly two decades, sparked in part by the report *Teaming with Life: Investing in Science to Understand and Use America’s Living Capital* (12), issued by the President’s Council of Advisors on Science and Technology (PCAST) during the Clinton Administration in 1998. The report pointed to the value of the nation’s natural capital and brought attention to its decline

due to ecosystem degradation, resource over-exploitation, invasive species, and pollution. In the years that followed, the report influenced interagency activities undertaken by the National Science and Technology Council (NSTC), which was established by Executive Order to coordinate science and technology policy across the Federal research and development enterprise, and policies and programs in individual agencies.

In 2006, during the Bush administration, an Interagency Ecosystem Services working group was established within the NSTC Committee on Environment and Natural Resources (CENR), which worked to guide and coordinate interagency activities in this emerging policy area. In cooperation with the National Academies Science and Technology for Sustainability Roundtable, federal agencies sponsored a workshop entitled “Transitioning to Sustainability through Research and Development on Ecosystem Services and Biofuels” (13) in 2007, with the objective to identify research gaps and opportunities for collaboration among federal agencies. The resulting work plan guided activities within and across agencies.

The Obama administration’s enhanced focus on ecosystem services reflects multiple drivers. In 2011, PCAST revisited the 1998 report, issuing *Sustaining Environmental Capital: Protecting Society and the Economy* (14), which recommended a number of actions to further documentation of natural capital and incorporation of this information into decision-making processes. It called for an assessment of ecosystem services trends, for agencies to improve their capabilities to develop ecosystem services valuations and use, and for an initiative to make biodiversity and ecosystem information, along with socioeconomic and geophysical data, more accessible to facilitate research and policymaking. The NSTC Committee on Environment, Natural Resources and Sustainability (CENRS) was tasked to respond to the PCAST recommendations and is developing a plan for monitoring and assessing trends in ecosystem services using existing assessment processes. The PCAST report also recommended that the United States become a signatory to the international Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). The United States became a signatory in 2012.

An interagency dialogue on ecosystem services that concluded in 2011 brought together federal agencies with natural resource jurisdictions, with a focus on markets and payment for ecosystem services. White House offices have committed to develop guidance to federal agencies to bring high-level visibility

and support for the use of ecosystem services assessment methods where appropriate and practicable, part of a specific commitment under the *Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources* (15).

In addition, Obama administration priorities such as landscape-scale conservation, the clean water framework, National Ocean Policy, and landscape-scale ecosystem restoration are motivating a reexamination of the utility of ecosystem services concepts such as carbon storage and sequestration in existing policy instruments (16, 17). Ecosystem services are also being included in newly written or revised policies for the first time. For example, the recently finalized *Principles, Requirements and Guidelines for Federal Investments in Water Resources* (PR&G) (18) explicitly require application of ecosystem services principles in program management and planning. These policy tools are motivating the development of formal interagency and agency-specific guidelines for the application of ecosystem services frameworks. The revised PR&G includes specific requirements for taking an ecosystem services approach in evaluating all effects—economic, environmental, and social—associated with a potential federal water resources investment.

Despite progress in advancing the data infrastructure related to ecosystem services, considerable research is needed to further valuation approaches and the development of standard metrics and measures, as well as in specific applications such as nature and nature-based infrastructure. White House offices have committed to work with agencies to develop a federal research agenda to chart a course for closing knowledge gaps (15).

Several products that derive from the coordinated federal response to the 2011 PCAST report have also recently been rolled out. EcoINFORMA, along with the Ecosystems theme of the Climate Data Initiative, was launched at the A Community on Ecosystem Services (ACES) conference in December 2014. EcoINFORMA was developed to ensure that federal datasets relating to environmental health and ecosystem valuation are published in machine-readable, interoperable formats. EnviroAtlas (19), a component of EcoINFORMA developed by the Environmental Protection Agency (EPA), is a web-based, interactive tool that integrates more than 300 data layers to help decision makers understand the implications of planning and policy decisions on ecosystem services.

Federal Agencies. Few federal agencies are presently required to incorporate ecosystem services considerations in program planning

or regulatory analysis although many have begun to do so on a voluntary basis, largely through pilot programs (Table 1). Once guidance on ecosystem services assessment is issued from the Executive Office of the President, agencies will have the impetus to apply these approaches to a greater degree and will begin to build capacity at the field level. The guidance will provide agencies that are early adopters of ecosystem service principles additional authority and support for expanding their pilot approaches.

Agency motivations for including ecosystem services approaches fall into five general categories: (i) enhancing investment in conservation and natural resource management, (ii) improving the cost-effectiveness of programs, (iii) making trade-offs transparent and avoiding unintended negative consequences of policy actions on ecosystems, (iv) enhancing resilience, and (v) supporting public participation in the planning process (22).

The National Ecosystem Services Partnership, sponsored by Duke University, worked with federal agencies over a 2-year period, concluding in December 2014, to develop an online guidebook for federal agencies on ecosystem services approaches, including case examples of the ways different agencies are currently using them (22). These case examples provide an overview of experiences in natural resource agencies, including the Bureau of Land Management, US Environmental Protection Agency (EPA), US Fish and Wildlife Service, US Forest Service (USFS), and NOAA.

At a programmatic level, USFS is a leader in institutionalizing ecosystem services approaches, largely due to specific guidance on ecosystem services in the 2012 US Forest Service Planning Rule (Box 1) (23). Other agency applications of these approaches span the range from habitat protection for the greater sage-grouse to energy infrastructure siting to habitat protection. They represent diverse geographies as well, from the Great Dismal Swamp National Wildlife Refuge in North Carolina and Virginia, to the San Diego National Wildlife Refuge. In the coastal-marine environment, ecosystem services approaches are being piloted to understand the benefits of carbon sequestration in coastal wetlands, as well as to inform decisions related to coastal and marine planning. In a regulatory context, EPA is working to incorporate ecosystem services in quantifying the public welfare effects of air pollutants, particularly in the risk assessment and policy assessment for the review of secondary National Ambient Air Quality Standards for nitrogen oxides and sulfur oxides (24).

Most agencies are in the early stages of applying ecosystem services principles; consequently, it is difficult to document how they have influenced management outcomes across the board. In addition, an ecosystem services approach may not always result in a change in policy outcomes. In the years ahead, it will be helpful to better understand under what conditions or in which situations an ecosystem services approach leads to improved outcomes. New and emerging initiatives typically require a substantial time and financial commitment, including an investment of administrative resources. Future evaluations of the impacts of these early applications will be important in advancing ecosystem services in more programs and other federal agencies.

Agencies, with limited exception, do not currently have the mandate to invest substantial resources and capacity in ecosystem services approaches. However, this investment is necessary to demonstrate the effectiveness of ecosystem services approaches and bring them into the mainstream. Demonstrating effectiveness will be especially important for agencies in which natural resource management is not the primary mission and ecosystem services concepts are less visible. In agencies such as the Department of Transportation, US Army Corps of Engineers, and Department of Housing and Urban Development, proofs of concept through mature and diverse examples of applications, particularly those that demonstrate the impact of ecosystem services approaches in promoting cost-effective decisions and avoided negative consequences of policy actions, will be important in promoting the use of these approaches. Therefore, natural resource agencies can serve as test beds for the broader family of federal agencies in developing the methodologies, guidelines, proof-of-concept, and conditions under which an ecosystem services approach will be beneficial.

Several factors can have a significant impact on supporting the uptake of an ecosystem services approach in federal agencies, including leadership, capacity and training, and communication.

Leadership. The guidance and support of the leadership within an agency is essential. In implementing ecosystem services approaches, a change may be required in the way an agency implements a policy, there may be a need to collect additional data, or additional funding may be required. Leadership must support these kinds of changes in policy implementation or budget priorities.

Capacity and training. Agencies are more likely to embrace ecosystem services approaches if new policies and practices are

Table 1. Examples of ecosystem services-related activities in federal agencies

Department/agency	Example program areas or activities
Department of Agriculture (USDA) Economic Research Service (ERS) Natural Resources Conservation Service (NRCS)	Markets for ecosystem services Conservation programs with landowners on water quantity and quality trading, programs to quantify environmental effects of conservation practices and programs
US Forest Service (USFS)	Forest management, project-level planning, public–private partnerships, forest plan revisions
Department of the Interior (DOI) US Fish and Wildlife Service (FWS) US Geological Survey (USGS)	Habitat and species conservation, conservation banking, refuge management Valuation of ecosystem services, natural disaster preparation and response, science and decision support
Bureau of Land Management Bureau of Reclamation	Habitat protection, renewable energy siting Water projects, cost/benefit analyses
Environmental Protection Agency (EPA) National Center for Environmental Economics Office of Research and Development	Benefits assessment methods, science-policy analysis Classification of ecosystem services, data infrastructure, impacts of policy on ecosystem services,
Office of Water Office of Air and Radiation Office of Sustainable Communities	Clean water trading, classification, valuation Clean air offset trading, secondary review of air quality standards Urban planning, green building, clean water, clean air, environmental justice
Department of Commerce (DOC) National Oceanic and Atmospheric Administration (NOAA)	Coastal/marine conservation, resiliency, natural disaster preparation and response, climate adaptation, fisheries management, natural resource damage assessment, restoration
Bureau of Economic Analysis (BEA) Economics and Statistics Administration	Economic and environmental information for businesses, environmental accounting Collaboration with businesses on natural capital valuation
Department of Defense (DoD) Service Departments US Army Corps of Engineers (USACE)	Installation and resource management Water resources management, wetland mitigation, flood management, ecosystem restoration, project evaluation
Department of Transportation (DOT) Federal Highway Administration	Ecosystem-wide considerations for planning and mitigation
Department of Homeland Security (DHS) Federal Emergency Management Agency	Mitigation of risks of floods and other natural disasters, benefit–cost analysis of disaster mitigation activities
Department of Housing and Urban Development	Urban planning, natural disaster preparation and response

Tracking ecosystem services-related activities across the federal government is a significant challenge. The first comprehensive effort to evaluate United States government participation in ecosystem services approaches was completed by researchers from EPA, surveying a period between 2010 and 2012. This study identified 207 programs across nine federal agencies, counting only ecosystem services research programs. The authors found that 76% of the federal ecosystem services research was undertaken at USDA, EPA, and DOI, focusing most commonly on biophysical classification and resource management research (20). This effort established a public database as part of the Ecosystem Commons Community of Practice (21), but it has not been actively maintained since the study's conclusion. The federal government does not maintain a systematic inventory of ecosystem services efforts, but, without doubt, the number of programs and projects incorporating ecosystem services has been increasing steadily since 2012, and they exist in areas beyond research and development. Terminology can present a challenge in describing the extent of activities within and across agencies. For example, agencies may be applying elements of an ecosystem services approach without explicitly describing it as such, making it difficult to document and assess programs and practices. As ecosystem services evaluations become more mainstream, standardized reporting requirements for agency programs and projects will aid in building a baseline of activity across the government. Effective information sharing across agencies will further institutionalization of best practices, evaluation, and adaptive learning. The table provides examples of current program areas in which ecosystem services approaches and considerations are being applied by a range of federal agencies. It is not a comprehensive list of activities.

clearly defined and can be readily implemented. To this end, agencies will benefit from robust technical guidance on ecosystem services assessment, including a decision support framework that can be tailored to different agency missions and decision contexts, along with training on ways to implement necessary changes.

Ecosystem services approaches do not always require economic valuations, which can require significant expertise, time, and funding. Identification, classification, and mapping of ecosystem services can provide significant input into decision making in the absence of valuations. When valuations are necessary,

they should be driven by a specific need, question, or policy opportunity. Information gathering should be tailored to particular questions, geographic regions, or community needs to inform planning and decision making. And collected data should be organized in a way that ensures policy relevance and accessibility in decision-making processes. To this end, it is valuable to include policy and decision makers, the ultimate users of the information, in the design and implementation of research programs and studies (25).

Communication. Outreach and communication about the benefits of an ecosystem services

approach, including concrete examples of applying it successfully, are important in gaining the support of leadership. Successful applications will help justify the investment in data collection, training, and staff time that is likely to be needed. At NOAA, for example, demonstrating how restoration practices can be improved through a more robust accounting of the benefits of coastal habitats for carbon sequestration and storage helped make the case for a change in practice. Clear examples of how policy outcomes improve when ecosystem services approaches are used are key to gaining support for broader applications.

Box 1. Institutionalizing ecosystem services approaches in US Forest Service programs and operations

The experience of the US Forest Service illustrates the power of an enabling policy directive in incentivizing innovation and application throughout an agency structure. Although ecosystem services concepts have influenced US Forest Service research, programs, and operations since 2006, the 2012 Planning Rule marked a key milestone in calling for addressing ecosystem services in forest plans, assessments, and project implementation.

After the completion of the draft Planning Rule, the National Ecosystem Services Strategy Team (NESST) was created to guide implementation of the Planning Rule. NESST was chartered to (i) develop a shared language and understanding of ecosystem services to clearly articulate the ecosystem services concept both within the agency and externally with Forest Service stakeholders, and (ii) assess opportunities to integrate ecosystem services approaches into Forest Service programs and activities through investigation of legal authorities, current guidance, best management practices, managerial tools, and needs and capacity requirements. To date, NESST has developed an inventory of Forest Service programs and activities with potential for integrating an ecosystem services approach into operations. These opportunities fall into three categories: analysis and decision making, measurement and reporting, and investment in ecosystem services partnerships.

With respect to analysis and decision making, several “early adopter” forests are now working to respond to the Planning Rule directive in their forest plans. Others are incorporating ecosystem services consideration into National Environmental Policy Act (NEPA) analyses. The Forest Service is also helping states address ecosystem services flows, benefits, and values in statewide forest action plans. For reporting purposes, the Service is developing ecosystem services measurements to better capture the outcome and impacts of agency activities. The Service is also increasingly involved in innovative financial partnerships. For example, it collaborated with the Denver Water Board to cooperatively commit \$32 million for improved forest restoration work in Denver’s municipal watershed to avoid damage to water quality caused by large wildfires. The Service is also exploring partnerships with the electric utilities interested in contributing to fire risk reduction in areas that may threaten power lines (22).

The codification of ecosystem services approaches in US Forest Service policy played a critical role in promoting uptake and institutionalization. As higher level policy directives for ecosystem services emerge, the Service’s experiences may offer a valuable model for other agencies and programs on ways to build capacity and institutional acceptance of ecosystem services approaches.

Intersector and Interdisciplinary Collaboration

Much of the progress in advancing ecosystem services concepts, including valuation methods, can be credited to creative collaboration among government, academia, nongovernmental organizations, and industry. Because ecosystem services are at the intersection of ecosystem science and socioeconomic, interdisciplinary teams working across sectors are furthering methodology development and applications. Applying ecosystem services considerations in decision making requires an integrated understanding of nature’s production of goods and services, the delivery of these services to people, and policy applications (and, in some cases, valuation). This integration requires complementary roles for natural scientists (including ecologists and geographers), social scientists (including economists, anthropologists, and sociologists), engineers, and policymakers, working in teams across sectors.

University-based natural and social scientists have provided the foundational elements of ecosystem services concepts; they and NGO scientists and other experts are advancing methodologies to make valuation determinations. Nongovernmental organizations have applied extensive expertise in advancing approaches to delineate species and habitats and the services they provide in the context of conservation activities, as well as key convening roles. Government scientists and program experts at the state and federal levels have contributed a wide range of expertise on ecosystem structure and functioning, economic assessment, and regulatory mandates and implementation strategies. Industry experts have provided practical knowledge in applying ecosystem principles to business practices and have offered insights on the implications of traditional regulatory and incentive-based strategies for achieving environmental goals.

Academic institutions and NGOs have played central roles in advancing ecosystem services and have provided both conceptual framing and tools to assist federal efforts. As referenced earlier, the National Ecosystem Services Partnership (NESP) of Duke University, in partnership with A Community on Ecosystem Services (ACES), led the Federal Resource Management and Ecosystem Services (FRMES) project, aimed at cultivating a community of practice and creating an online guidebook to aid program planning and management (19). The online guidebook was developed in partnership with multiple federal agencies and was launched publicly at the ACES meeting in 2014. Other nongovernmental organizations have played complementary convening roles. COMPASS, which works to empower scientists to become more effective communicators in policy dialogues, has helped connect emerging science and conceptual framing around the value of ecosystem services approaches to policymakers within the Executive Office of the President and across federal agencies (26). In addition, Portland State University and Defenders of Wildlife convened a collaborative process to identify principles to guide robust, comprehensive assessments of the social, economic, and ecological benefits derived from ecosystem services (27).

Universities, NGOs, and federal agencies have collaborated to develop decision support tools to further the practical application of ecosystem services concepts and information. The Natural Capital Project, spearheaded by Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund, has developed practical approaches to evaluate ecosystem services, including InVEST, Integrated Valuation of Environmental Services and Tradeoffs, a software tool designed to assist users in valuing natural capital and applying this information in making natural resource management decisions (28). This tool was used in pilot studies on Department of Defense (DoD) land, as well as in coastal resilience mapping, risk reduction, and conservation activities in the Gulf of Mexico region and the Northeast. Earth Economics has worked with federal agencies to advance ecosystem services valuation, including its application in the natural disaster response activities of the Federal Emergency Management Agency (FEMA) and the US Army Corps of Engineers (USACE) in the wake of Hurricanes Katrina, Rita, and Sandy. Their engagement catalyzed the effort to change the FEMA mitigation rule to explicitly allow for ecosystem services valuation in benefit–cost analysis (29).

The Path Forward

In the years ahead, the federal government has much to gain by continuing to incorporate ecosystem services concepts and practices into its policies and programs. Nationally, more cost-effective regulatory programs, greater use of market-based strategies, more informed investments, and a stronger scientific basis for decision making will further the simultaneous achievement of environmental and economic goals. Over the last decade, intersector, interdisciplinary collaborative activities have catalyzed the rapid development of ecosystem services concepts, principles, and applications. To foster continued progress in the years ahead, we suggest attention to three major needs and opportunities.

Intersector and Interdisciplinary Collaboration. We should pursue effective policies and more strategic, systematic approaches to use ecosystem services considerations by engaging representatives across nations and sectors to define strategic goals and the objectives and pathways to achieve them. The science underlying ecosystem services concepts, as well as the applications of this science, are evolving rapidly. Given the international, multisector, and multidisciplinary nature of ecosystem services-related activities, there is benefit in fostering communication and forging common perspectives about opportunities to advance both the scientific foundation and applications of ecosystem services in the context of global and national environmental challenges. Policies and programs related to ecosystem services will benefit greatly from a strong commitment to collaboration within and across government agencies, NGOs, academic institutions, and corporations.

Intersector, interdisciplinary research and development programs are needed to provide the scientific foundation to attain these goals and objectives and foster natural capital accounting. Sharing knowledge and leveraging capacity among social and natural scientists and engineers within and across the public and private sectors will further the development and implementation of policies and programs. The design and implementation of programs will advance more rapidly if they build on the perspectives and expertise of a wide range of stakeholders. Neutral conveners can facilitate collaborative planning activities by bringing together representatives from businesses, NGOs, academia, and government at multiple levels to devise practical strategies based on diverse experiential knowledge. The recent production of the

Federal Resource Management and Ecosystem Services Guidebook (30) by a diverse team of individuals underscores the value of working collaboratively across disciplines and sectors.

Decision Support. Increase methodological rigor in approaches to incorporating both qualitative and quantitative information into decisions. Newly available data will help advance the next generation of decision support tools to apply ecosystem services principles, information, and practices at the national, regional, and local levels, leveraging advances to construct an interoperable data infrastructure. Stronger connections are needed between social and ecological data to further understanding of the relationships between changes in ecosystem services and human well-being.

Individuals and organizations involved in environmental protection and natural resource management activities will benefit from tools that organize information, inform the development and consideration of alternative policies and practices, and help monitor and assess progress as programs proceed. Intersector, interdisciplinary collaborative efforts will be invaluable in the development of decision support tools to further the practical application of ecosystem services concepts and principles. Practitioners need tools that are readily accessible, have a transparent user interface, and add value in pursuing management goals.

Monitoring and Evaluation. Advance national, regional, and local programs to monitor the status of ecosystem services and assess the environmental and economic impacts of policies and programs. Documenting and monitoring the status of ecosystems, habitats, and species, and the services they provide, remain some of the great challenges in furthering environmental, natural resource conservation, and sustainability goals nationally and globally. And documenting and monitoring natural capital in the context of traditional economic accounting is an emerging and equally demanding challenge. Programs to monitor, assess, and report on ecosystem services at multiple scales are critical to efforts to maintain and enhance natural capital.

Monitoring the status and trends of ecosystem services provides information about the “stock” of natural capital but does not provide information about “flow,” which is necessary for scenario planning and evaluating return on investment. Performance metrics based on flows of ecosystem services are essential in evaluating the cost-effectiveness of

programs. Metrics for project and program evaluation often measure only the success of project implementation in terms of traditional programmatic goals. The use of enhanced performance metrics that account for changes in the flows of ecosystem services at relevant scales will help identify and encourage projects that result in tangible ecological and socioeconomic outcomes. Advancing these metrics will require the coupling of ecological and social monitoring data to changes in environmental conditions and their impacts on people.

Additionally, cultural ecosystem services, including the educational, spiritual, and recreational or aesthetic benefits ecosystem provide, are some of the least well understood, particularly how experiencing these benefits impacts human health and well-being, and thus are some of the most difficult ecosystem services to incorporate into the current decision-making framework. However, these cultural services are arguably some of the most valuable benefits that people receive from experiencing nature. Recent evidence suggests that these benefits have important psychological and physiological benefits to humans as well as potentially influencing overall human health and well-being via immune system function and disease prevention (31). It is important to include monitoring of cultural services as well as provisioning and regulating services to improve our ability to incorporate these services into policymaking and decision making.

Conclusion

Because federal agencies are responsible for managing extensive public lands and waters and enforcing environmental regulations, the widespread adoption of ecosystem services approaches in planning and regulatory contexts could drive a fundamental shift in environmental governance, positively impacting multiple sectors. Given the power of ecosystem services concepts, principles, and applications to influence national economies and further the achievement of natural resource conservation and sustainability goals, additional policy direction and financial capital to support these activities will likely result in a major return on investment.

As ecosystem services efforts begin or mature, the ecosystem services community should monitor and critically assess which approaches are most successful under different conditions to determine how, when, and why taking an ecosystem services approach can be the most effective way to improve policymaking and decision making. The future

direction and pace of innovation and accomplishment relative to ecosystem services depend on policy direction, enhanced capacity, and the commitment of institutions and individuals in all sectors of society. Federal agencies have a vitally important and unique role to play in land and resource management;

consequently, they are well-positioned to foster collaborative efforts to further the identification of research needs, spur the development of new analytical methods and valuation approaches, and incorporate ecosystem services concepts into a wide range of policies and practices.

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