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What's Nature Done for You Lately: Measuring the Value of Ecosystem Services

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The natural world generates a range of valuable goods and services that support human well–being. These goods and services, collectively called ecosystem services, are typically provided free of charge and often have characteristics of public goods. Like other public goods, ecosystem services will not be provided optimally by aggregating the decisions of individuals motivated by self–interest. For example, an individual farmer gains the benefits of increased yields from the application of nitrogen fertilizer but often bears an insignificant portion of the costs from additional release of nitrous oxide, which is a powerful greenhouse gas, increased air pollution from emissions of nitrogen oxides and ammonia, and increased water pollution from release of nitrates into ground or surface water. In such cases, the sum of individual actions may result in the disruption of the flow of valuable ecosystem services thereby making all individuals collectively worse off. Even in cases where ecosystem services provide localized benefits, if individuals are not aware of the consequences of their actions they may still take actions that unknowingly damage ecosystem services on which their long–term welfare depends.

The presence of both incentive problems and information problems means that ecosystem services are often not provided efficiently. There is an important role for economists to play in improving the provision of ecosystem services, which includes understanding how management choices affect ecosystems and the services they provide, understanding of the relative value of ecosystem services to different groups in society and designing appropriate incentive mechanisms for the efficient provision of ecosystem services.

1. *Carbon taxes can apply to carbon emissions only or to a broader array of greenhouse gases. In this paper, we will use the term "carbon tax" to apply to a tax on some or all greenhouse gases.*

The recent focus on ecosystem services grew out of efforts, led primarily by ecologists, to highlight the importance of ecosystems and the natural world to human welfare. Just over a decade ago, the publication of *Nature's Services: Societal Dependence on Natural Ecosystems* (Daily 1997) and a controversial article published in the journal *Nature* entitled *The Value of the World's Ecosystem Services and Natural Capital* (Costanza et al. 1997) brought significant attention and research focus to assessing ecosystem services. The *Millennium Ecosystem Assessment*, a major international research effort to summarize the current condition and potential future trajectories of the world's ecosystems and biodiversity, used ecosystem services as its major organizing principle and emphasized the link between ecosystems and human well–being (MEA 2005). Major research efforts on ecosystem services are underway in government agencies such as the U.S. Environmental Protection Agency, international organizations such as the World Bank and nongovernmental organizations such as The Nature Conservancy and World Wildlife Fund. Many of these efforts are being led by natural scientists and there is a compelling need for greater economic input.

Economists have much to contribute to research on ecosystem services. In fact, properly understood the research agenda on ecosystem services is a continuation of a long–standing set of research objectives in agricultural, resource and environmental economics. Agricultural economists know that soil and climate are necessary inputs to the production of agricultural crops and have studied production functions and agricultural profitability under a wide variety of circumstances. Resource economists know that natural resources (oil, minerals, timber, and fish) contribute to a wide range of intermediate and final products and have studied optimal harvesting and inefficiencies caused by open access. Environmental economists know that people value the environment directly even where there is no market and have developed tools of nonmarket valuation to analyze such things as the value of a scenic vista or clean air. In fact, in the 1970s economists set out a research agenda to measure "the value of services that natural areas provide" (Krutilla and Fisher 1975, p. 12). The "new" topic of measuring the value of ecosystem services can build from a large existing base of prior research on the value of agricultural production (Beattie and Taylor 1985), bioeconomic modeling of fisheries and other renewable resources (Clark 1990), nonrenewable resources (Dasgupta and Heal 1979), and nonmarket valuation of environmental amenities (Freeman 1993).

A Research Agenda for Economists on Ecosystem Services

What is needed now is to bring the full set of economic tools and expertise to bear on the analysis of ecosystem services. To do this, economists will need to engage with ecologists as well as other natural and social scientists. In measuring, valuing and providing proper incentives for the provision of ecosystem services, economics is necessary but not sufficient. Knowledge of ecosystems and how they are altered by human actions, which is more in the domain of natural sciences, is also necessary but not sufficient. In research on ecosystem services, integrating both economics and natural science is essential. In what follows, I briefly describe a research agenda and a set of challenges for economists in addressing issues related to ecosystem services. Challenges for economists exist both in developing new applications and analysis as well as more effectively integrating with other disciplines.

Measuring the value of ecosystem services and providing an efficient level of provision of these services requires tackling three main tasks:

- Provision of ecosystem services ("ecological production functions")
- Value of ecosystem services ("valuation")
- Designing policies for efficient provision of ecosystem services ("incentives")

I briefly discuss each of these three tasks in the following sections.

The Provision of Ecosystem Services: The Ecological Production Function

Policy and management actions chosen to accomplish certain objectives, such as increasing the yield of agricultural commodities or allowing development of industry, often have a range of effects, both intended and unintended, on ecosystems and the services they provide. For example, expanding agricultural land will increase crop production but may also lead to greater release of greenhouse gases and a decline in water quality downstream. Evaluating alternative policy or management actions in terms of ecosystem services involves understanding the full range of consequences the action has on ecosystems and how these consequences translate into changes in the suite of ecosystem services provided. Like a typical production function that predicts output of goods (e.g., crop production) as a function of inputs (e.g., land, fertilizer, water), an ideal "ecological production function" would predict the outputs of a range of ecosystem services given ecosystem structure and function.

Though considerable ecological knowledge exists about the structure and function of ecosystems, the translation to how these contribute to the provision of important ecosystem services is sometimes lacking. Ecological production functions for some services, such as above–ground carbon sequestration in plant material are well understood. But understanding carbon sequestration or release in soils or the net production of other greenhouse gases (e.g., nitrous oxide or methane) is less predictable. Sequestration or release of greenhouse gases in soil is a complex function that depends on whether chemical reactions are aerobic (with air) or anaerobic (without air), temperature, soil water content, the presence of various organic compounds and minerals.

In general, estimating the provision of the complete range of ecosystem services from any particular ecosystem is beyond our ability at present (NRC 2005). Key limitations that prevent complete understanding of ecological production functions include imprecise understanding of ecological processes, complex interaction among ecosystem processes, and lack of data.

Despite these limitations, ecological understanding is often sufficient to provide reasonable estimates of many important ecosystem services. The intense interest focused on ecosystem services at present is also helping to advance our understanding of ecological production functions for important services. In fact, framing issues in terms of ecosystem services has helped to redirect ecological research creating more rapid progress and easier links between ecological and economic analysis.

The Value of Ecosystem Services: Market and Nonmarket Valuation

The provision of ecosystem services yields outcomes in terms of physical units (e.g., bushels of crops, tons of carbon sequestered, concentrations of nitrate in water). But comparing outcomes of alternative management options is difficult when there are impacts on multiple ecosystem services and when each service is measured in

2. *We set aside here the distributional implications of climate change itself.*

its own physical units. Is a management option that increases crop yields but also results in increased carbon release and decreased water quality beneficial for society? The answer to this question depends on how one views the trade–offs between various services. In a standard economic problem, economists compare consumption bundles that might differ in many dimensions by converting the measures to a common metric of value measured in monetary terms. The same conversion to a common metric of value can be done with ecosystem services through the application of market and nonmarket valuation techniques.

Some ecosystem services result in outputs of marketed commodities (e.g., agricultural crops, commercial fisheries, timber) making valuation relatively straightforward. The analysis of the value of these ecosystem services only requires the application of standard tools of market analysis to assess the change in consumer and producer welfare with a change in the provision of ecosystem services. Ecosystem services that provide a necessary input to the output of a marketed commodity can be analyzed in a similar fashion. For example, the value of pollination services can be assessed by looking at the change in the quantity and quality of crop production when pollinators are present versus when they are absent. The only danger in analyzing the value of ecosystem services that are inputs to the production of other ecosystem services (e.g., pollination for crop production) is that one cannot count both the value of the input and the value of output at the same time because this would result in double–counting.

Most ecosystem services, however, are public goods that are not traded in markets. As mentioned above, the lack of markets is one of the main reasons for concern over the inadequate provision of ecosystem services. For such ecosystem services, nonmarket valuation methods (revealed preference, stated preference) are needed. The value of some nonmarket ecosystem services has been well studied by economists. For example, there are numerous applications of random utility models to assess the value of outdoor recreation (hunting, fishing, bird watching, backpacking), and numerous applications of the hedonic property price model to assess the value of various environmental amenities (access to open space, access to water resources, local air quality). The strengths of weaknesses of applying both revealed and stated preference methods to value aspects of the environment are well understood and a number of excellent summaries of this literature exist (e.g. Freeman 1993, Champ, Boyle and Brown 2003, Haab and McConnell 2003). Though estimating nonmarket values can be challenging, valuing ecosystem services is not inherently more difficult than applying nonmarket valuation to other areas of environmental economics. In fact, many things that are now called ecosystem services are things for which economists have routinely applied nonmarket valuation techniques.

Some prominent examples of the value of ecosystem services have been derived using replacement cost, i.e., what would it cost to replace a naturally provided ecosystem service with a human–engineered alternative. For example, the value of providing clean drinking water to New York City by protecting watersheds in the Catskills has been estimated to be worth \$6–8 billion dollars because this is the cost of building and operating a water filtration plant (Chichilnisky and Heal 1998). Though popular, especially with noneconomists in part because it is easier to understand than methods to estimate willingness–to–pay, the replacement cost approach should be used with caution. Costs are not the same thing as benefits and estimates of cost can only be used to give an estimate of the value of ecosystem services under certain conditions: i) there are alternatives to provide the service, and ii) people would be willing–to–pay the cost of the alternative if the ecosystem service is not available (Shabman and Batie 1978).

What the Millennium Ecosystem Assessment labeled "cultural services," which includes aesthetic and spiritual values, can be quite important and is perhaps the most difficult type of value to assess using economic tools. Critics of economic valuation of the cultural or spiritual significance of nature raise both practical and philosophical objections. For some noneconomists, attempting to "put a price on nature" is deeply troubling (e.g. Sagoff 1988). One critique of the ecosystem services approach is that conservationists should use ethical arguments based on moral principles: "Nature has an intrinsic value that makes it priceless, and that is reason enough to protect it." (McCauley 2006, p. 28) Most economists including myself find it hard to apply arguments about "intrinsic value" to typical policy and management questions. For example, should we view decisions by farmers to convert a wetland to an agricultural field, or to increase the amount of fertilizer application, each of which will have an impact on an ecosystem, as a moral issue with clear right and wrong? These types of decisions seem better suited to weighing the full set of costs and benefits rather than being subject to moral absolutes.

Setting aside the philosophical debate, practical difficulties in assessing value in a manner that will be viewed as objective, authoritative and accurate is difficult for some ecosystem services like cultural services. This difficulty may argue for simply providing information about potential trade–offs among services without attempting to measure all services in the same monetary metric. For example, Polasky et al. (2008) derive a production possibility frontier showing trade–offs between feasible combinations of the value of commodities produced measured in dollars and species conservation measured in biological units. This approach illustrates consequences of alternative land use decisions but avoids the difficult task of putting a dollar value on species conservation. It is then up to the decision–making process to make value judgments about the relative value of species conservation versus commodity production and choose which land use alternative is most preferred.

Valuation of ecosystem services is likely to become more important in the future. With improvements in our understanding of ecological production functions there is greater understanding of the impacts of human actions on ecosystems and the consequences these impacts have on the provision of a suite of valuable ecosystem services. Application of valuation methods can help illuminate what policy or management options generate the greatest social welfare.

Policies and Institutions for Efficient Provision of Ecosystem Services

Though there are many interesting and worthwhile scientific questions to pursue, the prime motivation for assessing the value of ecosystem services is practical. Understanding the full consequences of policy or management decisions and comparing the net benefits to society of alternative choices can result in better policy and management decisions for use of land, water and natural resources. The title of a National Research Council report on valuing ecosystem services sums it up nicely: *Valuing ecosystem services: towards better environmental decision–making*. Integrating ecological and economic analysis to value ecosystem services can improve decision–making by clearly illustrating the consequences of alternative choices.

Information on ecological production functions and on values will almost surely be incomplete. Such incomplete information, however, should not paralyze decision making. In some cases, enough information will be available to make good decisions. In the Catskills watershed example, watershed protection could be justified on the basis of avoiding building a filtration plant, making it unnecessary to know the value of other ecosystem services. In other cases, decision–makers may have to make choices based on the best available information, with an eye to learning and adjusting policy or management based on new information ("adaptive management").

The supply of ecosystem services is often influenced by a different set of individuals than those who benefit from the provision of these services. For example, the farmer who maintains wetlands and limits fertilizer application provides benefits of cleaner water and lower probability of flooding to individuals who live downstream. The mismatch between those who influence the supply of services and those who benefit from services gives rise to a classic externality problem. Numerous potential solutions have been proposed for internalizing externalities, including payments for ecosystem services, tradable development rights, taxes on activities that result in damages to services, or some form of direct regulation (e.g., zoning laws, restrictions on actions that harm endangered species). Research that studies the incentive properties of these approaches and empirical analysis of results of implementation should be a high priority.

In the end, more efficient provision of ecosystem services will require that society overcome both information and incentive problems. The challenge for economists in the first case is to be able to work closely with natural scientists to build understanding of ecological production functions and to apply appropriate valuation methods. The challenge in the second case is to design policies simple enough to be implemented yet sophisticated enough to do justice to the underlying biophysical and socioeconomic complexities involved. These are important tasks and the sooner and more fully that economists tackle them the better.

For More Information

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