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Defining, Valuing, and Providing Ecosystem Goods and Services****

ABSTRACT

Ecosystem services are the specific results of ecosystem processes that either directly sustain or enhance human life (as does natural protection from the sun's harmful ultraviolet rays) or maintain the quality of ecosystem goods (as water purification maintains the quality of streamflow). "Ecosystem service" has come to represent several related topics ranging from the measurement to the marketing of ecosystem service flows. In this article we examine several of these topics by first clarifying the meaning of "ecosystem service" and then (1) placing ecosystem goods and services within an economic framework, emphasizing the role and limitations of substitutes; (2) summarizing the methods for valuation of ecosystem goods and services; and (3) reviewing the various approaches for their provision and financing.

Many ecosystem services and some ecosystem goods are received without monetary payment. The "marketing" of ecosystem goods and services is basically an effort to turn such recipients – those who benefit without ownership – into buyers, thereby providing market signals that serve to help protect valuable goods and services. We review various formal arrangements for making this happen.

I. INTRODUCTION

"Ecosystem service" is the latest environmental buzzword.[1] It appeals to ecologists, who have long recognized the many benefits derived from well-functioning ecosystems. It appeals to resource economists, who

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1. James W. Boyd & H. Spencer Banzhaf, *Ecosystem Services and Government Accountability: The Need for a New Way of Judging Nature's Value*, 158 RESOURCES 16, 16 (2005).

endeavor to measure the value to humans of natural resources. And it appeals to a host of others—public land managers and many private landholders included—who see opportunities for a more efficient and effective provision of basic environmental service flows. With all of this interest, "ecosystem service" has quickly come to represent several related topics, four of which are (1) the measurement of ecosystem service flows and the processes underlying those flows, (2) understanding the effect of those flows on human well-being, (3) valuation of the services, and (4) provision of the services. Despite the breadth of purview, "ecosystem service" brings a unique perspective to environmental dialog, one aimed at using economic tools to improve opportunities for reaching efficient levels of environmental protection.

Our purpose with this article is to summarize and bring some clarity to discussions of ecosystem services. We begin by explaining what "ecosystem service" means and how it fits within an economic context, emphasizing the fundamental contribution of ecosystem goods and services to human wellbeing, but also noting the importance of substitutes in considering the benefits and costs of protecting ecosystems. Next we review valuation of ecosystem goods and services. We then discuss provision and financing, focusing on the conditions that facilitate market exchange and on the various mechanisms that are now used to provide and protect ecosystem goods and services.

II. WHAT IS AN ECOSYSTEM SERVICE?

Ecologist Gretchen Daily offered the following answer to this question:

> Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of *ecosystem goods*, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors....In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well.[2]

Daily's definition makes an important distinction, between ecosystem services and ecosystem goods. Ecosystems goods are the

2. Gretchen C. Daily, *Introduction: What Are Ecosystem Services?*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 1, 3 (Gretchen C. Daily ed., 1997).

generally tangible, material products that result from ecosystem processes, whereas ecosystem services are in most cases improvements in the condition or location of things of value.[3] Daily explains that ecosystem services are generated by a "complex of natural cycles," from large-scale biogeochemical cycles, such as the movement of carbon through the living and physical environment, to the very small-scale life cycles of microorganisms.[4]

Daily lists several ecosystem services, such as purification of water, mitigation of floods, and pollination of plants. As she mentions, these services "are absolutely pervasive, but unnoticed by most human beings going about their daily lives."[5] Unlike these ecosystem services, most ecosystem goods do not go unnoticed, as they are the basic natural resources that we consume on a regular basis. Ecosystem goods have long been recognized as key elements of wealth; it is the grand contribution of modern ecological and hydrological sciences to more fully recognize and appreciate the services that nature also provides.

The tidy distinction between ecosystem services and ecosystem goods was later obscured by Costanza et al.,[6] who, after noting the difference between goods and services, proceeded to lump them into the class of "ecosystem services." This lumping had the advantage of brevity but tended to blur the distinction between the functional nature of ecosystem services and the concrete nature of ecosystem goods. This lumping was adopted by others, including the United Nations' Millennium Ecosystem Assessment.[7] We will maintain the distinction between ecosystem goods and services.

Daily's definition makes another key point about ecosystem services: they "sustain and fulfill human life."[8] The emphasis here is squarely on human well-being and is thus in keeping with an economic perspective. Some might say that such an anthropocentric focus is too limiting—that it devalues the importance of ecosystem structure and processes to species other than humans, or that it runs the risk of ignoring

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3. Like most dichotomies—and the reader will encounter several in the course of this article—the distinction between goods and services is not without exceptions or complications. For example, recreation opportunities do not fit neatly into either category, as they are neither tangible items (as are water, trees, and fish) nor improvements in conditions of goods (as are water purification, flood mitigation, and pollination). We classify recreation opportunities as goods.

4. Daily, *supra* note 2, at 4.

5. *Id.* at 3-5.

6. Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253, 253 (1997).

7. JOSEPH ALCAMO ET AL., ECOSYSTEMS AND HUMAN WELL-BEING: A FRAMEWORK FOR ASSESSMENT 55-57 (2003) (also known as the Millennium Ecosystem Assessment).

8. Daily, *supra* note 2 at 3.

ecosystem processes that contribute to human welfare but are not yet recognized as doing so. Clearly a focus on ecosystem services may turn out, through hubris or ignorance, to have been shortsighted, but, on the other hand, this focus is a vast improvement over business as usual and provides an opening for even greater consideration of ecosystem processes as our understanding of the natural world improves.

Where we differ with Daily's definition is that we, as have others,[9] draw a distinction between ecosystem services and ecosystem processes. *Ecosystem processes* (also sometimes called functions) are the complex physical and biological cycles and interactions that underlie what we observe as the natural world. *Ecosystem services* are the specific results of those processes that either directly sustain or enhance human life (as does natural protection from the sun's harmful ultraviolet [UV] rays) or maintain the quality of ecosystem goods (as water purification maintains the quality of streamflow). For example, the forces of wind and water, made possible by solar energy and gravity, produce the service we call "translocation of nutrients." Similarly, microorganisms in the soil and stream, seeking their own sources of energy and life-preserving conditions, remove contaminants from water, producing the service "water purification."

Although the difference between processes and services is more than semantic, it may not always seem so, especially when the term used to summarize a process is only slightly different from the term used to characterize the service. For example, the process by which water infiltrates into watershed soils, is stored in those soils, and is later released downstream, known as "regulation of hydrologic flows," produces the service "water regulation."[10] The shorthand labels we attach to processes and services must not be allowed to blur the distinction between processes and the services they perform.

Table 1 lists ecosystem goods and services. Ecosystem goods are grouped in two broad categories: renewable and nonrenewable. The nonrenewable ecosystem goods can only be used up, although recycling allows for some recapture and reuse. Renewable ecosystem goods can be received in perpetuity if the stock is managed in a sustained yield fashion (i.e., harvest equals growth). Of course, a stock of renewable resources can be harvested at a rate faster than its natural growth or replenishment rate. In the limit, the entire stock of a renewable resource, such as a timber stand

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9. *See, e.g.*, Boyd & Banzhaf, *supra* note 1, at 17; Costanza et al., *supra* note 6, at 253; Rudolf S. de Groot et al., *A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services*, 41 ECOLOGICAL ECON. 393, 394 (2002).

10. Costanza et al., *supra* note 6, at 254 tbl.1 (listing a number of ecosystem service-function pairs).

or fish population, could be converted to an ecosystem good and consumed in one brief period.

Table 1. Ecosystem Goods & Services

- **Ecosystem goods**
  - Nonrenewable
    - Rocks and minerals
    - Fossil fuels
  - Renewable
    - Wildlife and fish (food, furs, viewing)
    - Plants (food, fiber, fuel, medicinal herbs)
    - Water
    - Air
    - Soils
    - Recreation, aesthetic (e.g., landscape beauty), and educational opportunities
- **Ecosystem services**
    - Purification of air and water (detoxification and decomposition of wastes)
    - Translocation of nutrients
    - Maintenance and renewal of soil and soil fertility
    - Pollination of crops and natural vegetation
    - Dispersal of seeds
    - Maintenance of regional precipitation patterns
    - Erosion control
    - Maintenance of habitats for plants and animals
    - Control of pests affecting plants or animals (including humans)
    - Protection from the sun's harmful UV rays
    - Partial stabilization of climate
    - Moderation of temperature extremes and the force of winds and waves
    - Mitigation of floods and droughts

The ecosystem services of Table 1 are similar to those listed by Daily,[11] with some additions and deletions. The services result from an assortment of complex, sometimes interacting, physical and biological processes, touching many aspects of human life, including the air we breathe, the water we drink, our food, the weather, our health, and our outdoor recreation possibilities.

11. Daily, *supra* note 2, at 3–4.

We define ecosystem goods and services generally as the flows from an ecosystem that are of relatively immediate benefit to humans and occur naturally.[12] As shown in Figure 1, ecosystem goods and services result specifically from ecosystem structure and processes. *Ecosystem structure* refers to the abiotic and biotic components of an ecosystem and the ecological connections among these components. *Ecosystem process* refers to the cycles and interactions among those abiotic and biotic components, which produce ecosystem goods and services. The feedbacks in Figure 1 represent both the negative impacts of human actions on the ecosystem and human efforts to protect and manage the ecosystem. The ways in which ecosystem structure and processes generate ecosystem goods and services (e.g., the natural production or transformation functions) are primarily biological and physical scientists' areas of interest and expertise. The values and provision of ecosystem goods and services that enter directly into consumers' utility functions and also indirectly as inputs into economic production are primarily economists' areas of interest and expertise and the focus of the following sections of this article.

As a final point of clarification, we note that the goods and services of Table 1 derive from more than just the "ecosystem." Indeed, they include nonrenewable resources that accumulated through geologic processes that took millions of years, as well as services that involve global hydrologic and climatic systems. Herein, we will continue with the convention of referring to all of these as "ecosystem" goods and services.

III. ECOSYSTEM GOODS AND SERVICES WITHIN AN ECONOMIC CONTEXT

Current discussions of ecosystem goods and services focus on recognizing the benefits that humans derive from a well-functioning ecosystem. Benefits may be understood from various perspectives, including the physiological, the psychological, and, our focus here, the economic. We first consider how ecosystem goods and services fit within an economic theory framework.

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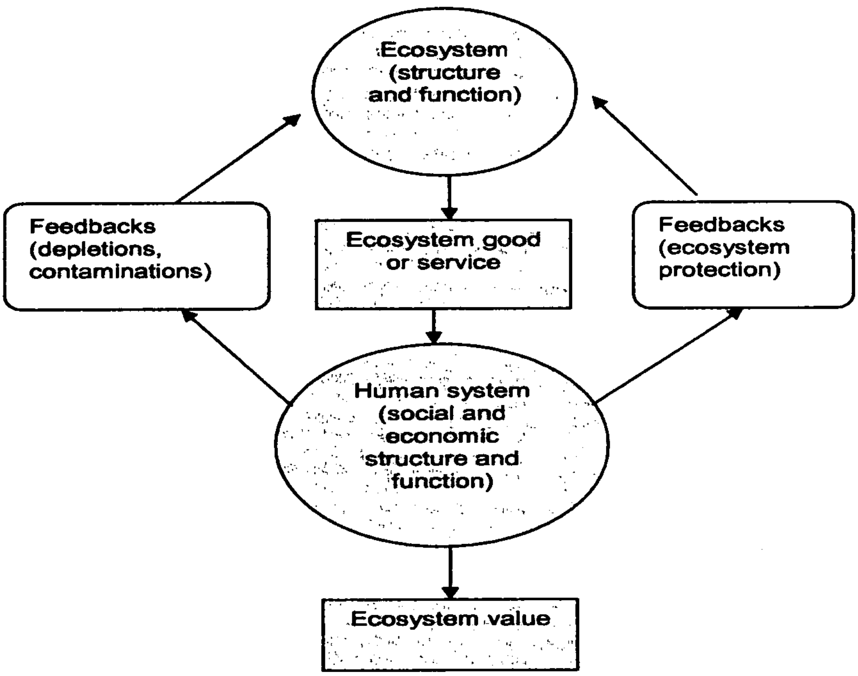
12. Not all taxonomies of ecosystem services limit them to naturally occurring goods and services. For example, among its set of ecosystem services, the Millennium Ecosystem Assessment includes produced commodities such as agricultural crops. ALCAMO ET AL., *supra* note 7, at 56. We limit "ecosystem services" to naturally occurring goods and services; that is, those that exist without human action.

A. The Traditional Roles of Land and Natural Resources in Economic Theory

In the aggregate (macroeconomic) production function or growth model for an economy of the classical economists, the total set of goods and services is produced as a function of land, labor, and capital. Capital refers to produced means of production, such as buildings, tools, roads, and vehicles. Land, the pivotal factor of production to most classical economists, included the entire natural world of land, sea, and atmosphere, although land and agriculture were the primary focus.[13]

Figure 1. Relationship between the ecosystem and the human system



13. Klaus Hubacek & Jeroen C.J.M. van den Bergh, *Changing Concepts of "Land" in Economic Theory: From Single to Multi-Disciplinary Approaches*, 56 ECOLOGICAL ECON. 5, 6 (2006). David Ricardo and Karl Marx were exceptions for whom labor was considered the primary source of wealth.

This aggregate model underwent changes over the years, including a de-emphasis of the land inputs by the neoclassical school, largely in the first half of the twentieth century,[14] and a re-emphasis on land inputs by environmental economists in the second half of the twentieth century.[15] Other changes that occurred in recent years have been the broadening of the concepts of land and labor. Since the early 1990s, the stock of natural resources important for economic production sometimes has been referred to as "natural capital" rather than "land."[16] This new term encompasses the earth's surface, its species, the nonliving material stocks of the earth's crust, the atmosphere, and even the sun, the source of solar radiation from which input flows are extracted.[17] "Natural capital" returns us to the classical understanding of "land," but with an even richer appreciation of its many different components, as scientific discovery has expanded our knowledge of the natural world. Similarly, the meaning of "labor" has been broadened to include both the knowledge that people bring to the production process and the institutional and social networks (e.g., laws, educational systems, and practices of child upbringing) that underlie the formation of a trained labor force. It is now common to refer to labor and the familial and institutional processes that support it as "human capital." This new formulation of the aggregate production function—where total production of an economy is a function of natural capital, human capital, and built capital—recognizes the importance of the processes underlying inputs of immediate concern (i.e., natural resources and labor) in production of goods and services.

14. By the middle of the twentieth century, land for some economists had essentially disappeared from the production function. Solow, for example, used a production function with no natural or land inputs, stating, "the production function is homogeneous of first degree. This amounts to assuming...no scarce nonagumentable resource like land." Robert M. Solow, *A Contribution to the Theory of Economic Growth*, 70 Q.J. ECON. 65, 67 (1956), *quoted in* Richard W. England, *Natural Capital and the Theory of Economic Growth*, 34 ECOLOGICAL ECON. 425, 426 (2000).

15. The de-emphasis of land by the neoclassical economists, plus a general lack of interest in externalities, set the stage for the rise of environmental economics in the 1960s and 1970s, which formally recognized the importance and uniqueness of natural resources in economic production and growth. *See, e.g.*, Kenneth E. Boulding, *The Economics of the Coming Spaceship Earth*, *in* ENVIRONMENTAL QUALITY IN A GROWING ECONOMY 3 (Henry Jarrett ed., 1966); NICHOLAS GEORGESCU-ROEGEN, THE ENTROPY LAW AND THE ECONOMIC PROCESS (1971); ALLEN V. KNEESE & BLAIR T. BOWER, ENVIRONMENTAL QUALITY AND RESIDUALS MANAGEMENT: REPORT OF A RESEARCH PROGRAM ON ECONOMIC, TECHNOLOGICAL, AND INSTITUTIONAL ASPECTS (1979); JOHN V. KRUTILLA & ANTHONY C. FISHER, THE ECONOMICS OF NATURAL ENVIRONMENTS: STUDIES IN THE VALUATION OF COMMODITY AND AMENITY RESOURCES (1975).

16. HERMAN E. DALY & JOHN B. COBB, JR., FOR THE COMMON GOOD: REDIRECTING THE ECONOMY TOWARD COMMUNITY, THE ENVIRONMENT, AND A SUSTAINABLE FUTURE 72-73 (2nd ed. 1994).

17. England, *supra* note 14, at 427.

Moving to a microeconomic perspective, we may focus on the inputs and outputs in specific locations. At this level, produced goods and services of direct utility to humans result from inputs of ecosystem goods and services, labor, and built capital.[18] Each of these inputs is in turn the result of production processes. Ecosystem goods and services result from ecosystem processes that act on natural capital. An example of an ecosystem good is natural instream flow, which, via ecological and hydrologic processes, is derived from natural capital in the form of precipitation, terrain, soils, aquifers, and biota (plants and animals) found in the ecosystem.[19] Inputs of labor to a production process result from the structure and processes of human systems. Finally, inputs of produced capital result from economic production functions utilizing ecosystem goods and services, labor, and other built capital.

It is important to note that the production of ecosystem goods and services requires no inputs of labor and built capital, except in the sense that in today's complex world ecosystem processes are often damaged by human endeavors and are left to do their work relatively unimpeded by human enterprise only through conscious decisions to protect the ecosystem (Figure 1). However, unlike ecosystem goods and services, production of labor requires not only human capital but also inputs of ecosystem goods and services and of produced capital.

To summarize, each of the components of the production of final goods and services is the result of production functions and underlying processes of their own: ecosystem goods and services result from ecological production functions, labor results from human production functions, and built capital results from economic production functions. But ecosystem goods and services require inputs from natural capital only, whereas labor and built capital require inputs from the ecosystem, labor, and built capital. Thus, final produced goods and services rely on ecosystem goods and services directly and indirectly via their contribution to labor and built capital.

18. For example, production of apples requires ecosystem goods such as soil and water plus ecosystem services such as renewal of soil fertility and pollination; labor, including the grower's knowledge and work; and capital such as the grower's tools as well as seeds and pesticides.

19. Nonrenewable ecosystem goods, such as gold or oil, are a special case. Here the ecosystem functions of interest played their roles over thousands or millions of years past, operating in cycles that take so long relative to our life spans that we think of the goods as nonrenewable.

B. Ecosystem Good or Service Value Concepts

From an economic perspective, things are of value if they are of utility to humans. Among the basic factors of production, ecosystem goods and services are unique in that they may be of either direct utility or indirect utility as they contribute to the production of produced goods and services that are in turn of direct utility. Ecosystem goods and services that are of direct utility include, for example, the air we breathe, natural temperatures, UV protection, and a landscape view. As seen above, all produced goods and services require some inputs of ecosystem goods and services.[20]

All of the ecosystem services of Table 1 contribute to the maintenance or quality of one or more of the renewable ecosystem goods of the table. For example, purification of air maintains air quality, pollination and seed dispersal assist the propagation of wild plants, and maintenance of precipitation patterns assists water supply as well as natural plant and animal survival. In addition, several of the ecosystem services, especially the bottom five on the list, can directly affect utility. For example, moderation of temperature extremes, protection from harmful UV rays, and natural pest control all directly enter the utility function.

In cases where the ecosystem service is not directly consumed, there is a derived demand for the ecosystem service and thus for the processes and the natural capital (e.g., ecosystem structure) required to support ecosystem processes. For example, to produce a drink of water while on a hike, we directly use the instream flow, not the natural production or transformation functions (e.g., ecosystem processes) that produce the flow. Similarly, to produce a fishing trip, an angler combines a recreation opportunity (including instream flow and a fish population), labor (e.g., effort, fishing skills), and built capital (e.g., boat, fishing gear) to produce a fishing experience. The essential point here is that ecosystem goods and services are the components of the natural world that enter our utility function either directly, or indirectly as inputs in the production of final goods and services.

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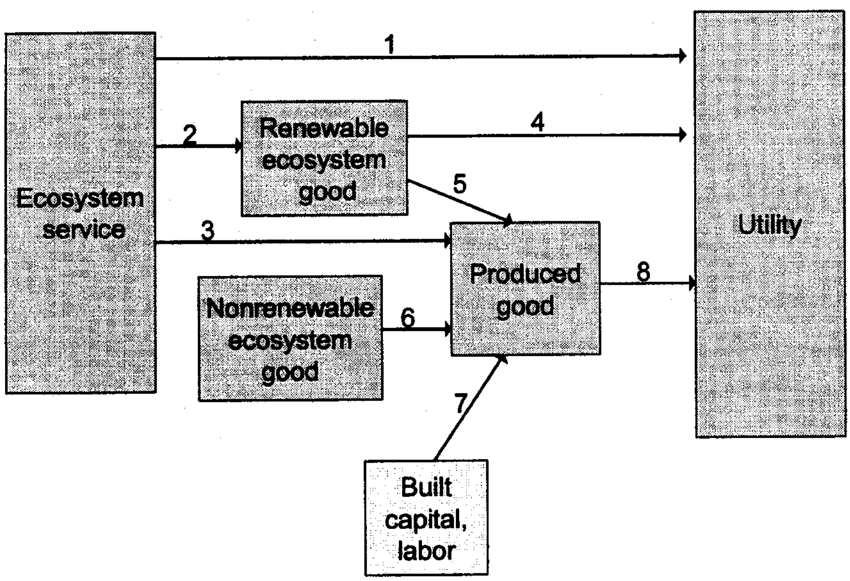
20. The dichotomy between ecosystem goods and services of direct versus indirect utility is somewhat artificial in that there is a continuum from those ecosystem goods and services that require little or no other inputs to be of direct utility to humans to those that require a great deal. Ecosystem goods requiring small amounts of labor and built capital include such things as instream flow for drinking by a hiker and wild mushrooms ready for picking. Only travel to and from the site and minimal harvest effort are needed to enjoy such goods. Examples of ecosystem goods that require much more labor or built capital are timber, which must be cut, hauled, and milled before it becomes lumber, and crude oil, which must be pumped, transported, and refined before it becomes gasoline.

The various pathways by which ecosystem goods and services affect utility are depicted in Figure 2. Ecosystem services can directly affect utility (pathway 1), maintain the quality of ecosystem goods (2), or be used in the production of manufactured or agricultural goods (3). Examples of (1) include protection from harmful UV rays and maintenance of air quality. Examples of (3) include pollination of agricultural crops and protection of the quality of streamflow that is diverted, treated, and delivered for human use. Renewable ecosystem goods can affect utility directly (4) or act as inputs in the production of goods (5) that then directly affect utility (8). Examples of such ecosystem goods include a beautiful landscape view and timber, respectively. Nonrenewable ecosystem goods, such as oil, serve as inputs in the production of produced goods (6). Built capital and labor are also used in the production of produced goods (7).

Figure 2. Pathways from Ecosystem Goods & Services to Utility (not including use of ecosystem goods and services in the production of built capital and labor)



C. Substitute Relationships

The relative quantities of ecosystem goods and services, labor, and built capital that are required to produce a good or service are to some extent substitutable. To take farming as an example, a farmer may substitute capital (in the form of tractors and combines) for labor. Many ecosystem goods and services have similar substitutes in the form of built capital and produced goods and services. For example, considering ecosystem goods, mushrooms may be cultivated, and fir or pine timber for wooden studs may be replaced with iron manufactured into metal studs (see the right-hand column of Table 2). Or, considering ecosystem services, the waste assimilation properties of natural watersheds can be replaced with a waste treatment plant (a form of built capital), and natural pest control can be replaced by pesticides. Of course, all of these produced substitutes require inputs including other ecosystem goods or services, but this does not negate the fact that substitutes generally exist.[21]

It is the nature of economic and population growth that some ecosystem goods and services become depleted and that humans use their technological prowess along with inputs including more plentiful ecosystem goods and services to produce new built capital and goods that compensate for such depletion. Of particular interest is whether the cost of producing substitutes for ecosystem goods and services exceeds the opportunity cost of protecting the original ecosystem goods and services. For example, healthy watersheds control the amount of sediment that enters stream drainage networks during precipitation events and perform natural waste assimilation, keeping costs low for downstream water treatment and delivery. The recent focus on ecosystem services has been in large part an effort to bring attention to the economic importance of natural ecosystems and to the fact that when ecosystems are degraded replacement of lost services, if possible, is often only feasible with more costly substitute investments of human and built capital and other ecosystem goods and services.[22]

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21. That is, substitutes to specific ecosystem goods or services are partly composed of or rely on other ecosystem goods and services, although perhaps of a different class (e.g., wooden studs rely on a renewable resource whereas metal studs rely on a nonrenewable, though recyclable, resource). In addition to these inputs, the substitutes generally also require technological know-how and, in many cases, manufacturing plants (e.g., a waste treatment plant or pesticide production facility). Like natural ecosystems, such engineered systems have limited capacities and fail to function if overloaded.

22. *See* Costanza et al., *supra* note 6, at 257. *See also* ALCAMO ET AL., *supra* note 7, at 64.

Table 2. Some Ecosystem Goods & Services & Their Substitutes

Ecosystem Stocks	Example of Ecosystem Good or Service Flows	Example of Produced Substitute
Ecosystem goods		
Nonrenewable raw materials		
Fossil fuel deposits	Crude oil, natural gas	Agriculturally produced biofuels
Mineral deposits	Metal for knife blades	Ceramic blades
	Rocks for construction or landscaping	Bricks, concrete rocks
	Ornamental gems	Artificial gems
	Rock & mineral-related recreational opportunities (e.g., rock & gem collection)	Costume gem and jewelry making
Renewable raw materials		
Animal populations	Harvestable wildlife for food and furs	Domestic elk, deer, cattle, sheep for food and furs
	Ornaments such as ivory	Plastic, plaster
	Wildlife-related recreational opportunities (e.g., recreational hunting & wildlife observation)	Recreational hunting at a private game park, viewing animals in zoos
Plant Populations	Trees suitable for lumber	Metal studs, cement
	Medicinal herbs	Synthetic medicines, agricultural products
	Wood for carving	Plastic, plaster
	Harvestable edible plants (e.g., wild mushrooms and berries)	Cultivated edible plants (e.g., cultivated mushrooms and berries)
	Plant-related recreational opportunities (e.g., nature photography)	Non-nature photography
Watershed/aquifers	Water supply from rivers and streams	Desalinized or imported water
	Water-related recreational opportunities	Water parks
Ecosystem services		
Animal	Natural animal pest control	Pesticides
	Natural animal pollination	Managed bee hives
Plant	Natural plant pest control	Pesticides
	Natural plant pollination	Plant nurseries
Climate	Maintenance of regional precipitation patterns	Water importation and irrigation
	Temperature maintenance via carbon storage	Indoor air conditioning
Soil and water	Maintenance of soil fertility	Artificial fertilizers
	Natural nutrient cycling	Artificial fertilizers
	Erosion control	Dredging
	Soil storage of water for later release	Dams and reservoirs
	Waste assimilation	Water treatment facilities
Airshed	UV protection	Sunblock, sunglasses, clothing
	Natural air purification	Air purifiers

Although substitutes abound for many ecosystem goods and services, it is important to note that such substitutes are rarely perfect. To examine this point, consider New York City's oft-cited decision to protect its Catskill watershed water source in lieu of constructing an expensive water filtration plant.[23] Both watershed protection and a filtration plant can provide clean water, but these two approaches to reaching the goal of potable water differ markedly, each approach having advantages and disadvantages. For example, watershed protection will lower the use of chemicals in the watershed that pose problems even with the most sophisticated water treatment plants, but filtration is more certain to remove pathogens.[24] The differences between the original ecosystem good or service and produced substitutes are even more obvious for many of the examples listed in Table 2. For example, artificial pesticides are typically more effective than natural pest control but they pose health risks that natural pest control does not. Similarly, backpacking in a roaded area of national forest is an imperfect substitute for backpacking in a wilderness area. Differences between the original and the substitute are always a matter of degree, and must be considered on a case-by-case basis.

A further point, important when the benefits of environmental protection are being considered, is that ecosystems typically produce

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23. GRETCHEN C. DAILY & KATHERINE ELLISON, THE NEW ECONOMY OF NATURE: THE QUEST TO MAKE CONSERVATION PROFITABLE 61-85 (2002); GEOFFREY M. HEAL ET AL., NAT'L RES. COUNCIL, COMM. ON ASSESSING & VALUING THE SERVICES OF AQUATIC & RELATED TERRESTRIAL ECOSYSTEMS, VALUING ECOSYSTEM SERVICES: TOWARD BETTER ENVIRONMENTAL DECISION-MAKING 159-60 (2005). Relying on water from nearly 2000 square miles of watershed, New York City's water system provides potable water to over nine million people. Because of past efforts at watershed protection, a series of city-owned reservoirs that allowed long detention times and flexibility in meeting demands, and the low population density in the watersheds, the city avoided the need for a filtration plant. However, economic growth in the watershed and related concerns about rising pathogen concentrations brought increased pressures for filtration, leading to a 1997 agreement between the city and the U.S. Environmental Protection Agency (EPA). With the agreement, the city avoided the high cost of filtration, estimated at from $4 to $8 billion plus annual operating costs of approximately $300 million. HEAL ET AL., *supra*, at 157. Instead, the city is investing roughly $2 billion over several years to protect the quality of the water entering the city's water treatment plants. Components of the investment include (1) upgrading wastewater treatment plants that the city operates for upstream communities; (2) rehabilitating and upgrading city-owned dams and water supply facilities; (3) purchasing land and conservation easements in the watershed; (4) funding various efforts of non-City entities, such as local government inspection and rehabilitation of septic systems, improvements of sewer systems, better stormwater management, environmental education, stream corridor protection, and improved storage of sand, salt, and deicing materials; (5) paying farmers to follow best management practices; and (6) enhanced monitoring. In addition, the agreement places restrictions in the watershed on the operation of wastewater treatment plants, siting of new wastewater treatment plants, construction of new septic systems, and storage of petroleum products and hazardous substances. DAILY & ELLISON, *supra*.

24. HEAL ET AL., *supra* note 23, at 159-60.

multiple ecosystem goods and services, many of which may be harmed if the ecosystem is degraded. For example, healthy watersheds not only protect water quality but also maintain aquatic habitats that are critical for fish and other organisms and for recreation. The degradation of a natural ecosystem may lead to a whole list of required replacements. If, as in the Catskill watershed case, protecting the ecosystem is less expensive than the engineered substitute for only one of the ecosystem's services, the other protected goods and services need not complicate the decision about whether to protect the ecosystem. However, if for a particular goal the engineered substitute were less expensive than watershed protection, the other benefits of watershed protection would need to be considered in order to allow a full comparison of costs and benefits.

IV. VALUATION OF ECOSYSTEM SERVICES

The economic value of something is a measure of its contribution to human well-being.[25] Economic values reflect the preferences and actions of people in a society, who are assumed to behave so as to maximize their well-being given the constraints they face. Clearly such values are largely based on an instrumental view of nature and on the assumption that individuals are competent judges of what is in their best interests. These premises are arguable, and much has been written about alternative approaches to value and about the inadequacies of human decision making. However, even with its flaws, quantification of economic values can, and regularly does, provide useful information for public decisions, especially when the limitations as well as the strengths of the values are recognized.

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25. *See generally* A. Myrick Freeman, III, *Economic Valuation: What and Why*, *in* A PRIMER ON NON-MARKET VALUATION 1 (Patricia A. Champ et al. eds., 2003) (providing background on the role of economic valuation in assessing policies and on the nature, definition, and measurement of economic values). Economic value is a type of "assigned" value, assigned value being the relative importance or worth of something to a person or group in a particular context. Thomas C. Brown, *The Concept of Value in Resource Allocation*, 60 LAND ECON. 231, 233 (1984). Assigned value is one of several value realms, others being held value (an enduring conception of the preferable that influences choice and action, such as honesty and beauty) and functional value (dealing with biological or physical relationships of one non-human entity to another). When ecologists talk of, for example, the value of riparian vegetation in controlling stream temperature or the value of nitrogen in tree growth, they are talking of functional value. Functional values exist whether or not we are aware of them and are the object of scientific discovery. Assigned and held values are indications of human preference, and are an object of investigation by economists and psychologists, among others. *See id.* at 231–34.

A. Role of Economic Valuation

It is legitimate to ask, why bother to estimate the economic value of ecosystem goods and services? Surely it cannot be done perfectly, and even if it could, doesn't reducing the value of ecosystem goods and services to a monetary metric somehow downplay their real or full values? The answer to these questions is that decisions are commonly made about whether to protect or degrade ecosystem goods and services, and those decisions are more likely to be made in the best interests of the relevant publics if decision makers have comparable information about what is gained and what is lost if a certain policy option is chosen.[26] Monetary estimates of the values of ecosystem goods or services, even if inexact, may be far better than a complete lack of such estimates, especially if the direction of the error in estimation—whether the value estimate is taken to be a lower bound or an upper bound of the actual value, for example—is known.

Economic valuation has a greater chance of providing an accurate estimate of value if the ecosystem change being evaluated is small relative to the total production of the good or service in the geographical area of interest. For example, it is easier to value a small change in water yield than to value a large change. This is because existing prices indicate the marginal value of the resource, and the marginal value applies best to a small change in quantity or quality. Large reductions would typically be undervalued if the entire change were valued at the marginal value. Fortunately, most realistic policy changes cause only relatively small changes in the production of a given ecosystem good or service.

Economic values may be used as input to benefit-cost analysis or to cost effectiveness analysis. With benefit-cost analysis, the benefits of a prospective policy change are compared with the costs. For example, if the prospective policy change is the commercial development of a wetland, the benefits of the development (perhaps estimated as the market price of the land once the wetland is filled in and the land is thus available for development) are compared with the costs (estimated as the cost of infilling plus the loss in ecosystem services provided by the wetland). With cost effectiveness analysis, a decision has already been made to provide some good or service (i.e., it has essentially been decided that the costs, whatever they are, are less than the benefits), and the task is to determine the most cost effective way to provide the benefits. The New York City water supply case cited above exemplifies this situation, where the U.S. Environmental Protection Agency (EPA), via amendments to the Safe Drinking Water Act, mandates water quality standards and the city considered the option of

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26. *See, e.g.*, HEAL ET AL., *supra* note 23, at 27, 97.

protecting its Catskill watershed source in lieu of constructing and maintaining a filtration plant.[27] Because the city must meet EPA standards, the issue is whether building and operating a filtration plant, or protecting the source watershed, is less expensive.

B. Dimensions of Economic Value

The economic value of an ecosystem good or service may consist of both use and nonuse values. *Use value* may result from either direct or indirect use.[28] Direct use involves some form of direct physical interaction with the good or service. With ecosystem goods, direct use may be consumptive (e.g., hunting) or non-consumptive (e.g., bird watching). Consumptive uses involve some form of extraction or harvesting, whereas non-consumptive use leaves the quantity of the good or service undiminished. However, non-consumptive uses may affect the quality of the resource or service, perhaps by pollution or crowding. Indirect use involves ecosystem services that contribute to the quality of an ecosystem good or a produced good. For example, natural water purification that occurs in a watershed contributes to the quality of the streamflow, and natural pollination of crops enhances the farmer's yield.

Nonuse value, also called passive use value, arises for ecosystem goods or services that people value simply for their existence. Nonuse value can be thought of as the difference between total value and use value—if use of the good or service is impossible but total value remains positive, the remaining value is nonuse value. *Bequest value,* the value of knowing that the resource will be available for others, including future generations, is a form of nonuse value, but bequest motives are not a necessary condition for nonuse value. Nonuse values can be substantial but are difficult to quantify.[29]

The *economic value* of something to an individual is the maximum amount the person would pay to get it (willingness to pay, WTP), or the minimum amount he or she would accept to give it up (willingness to accept compensation, WTA). Maximum WTP for a gain is the payment amount that leaves the individual just as well off as before the trade. Similarly, minimum WTA for a loss is the amount of compensation that leaves the individual just as well off as before the trade.[30] The choice of WTP

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27. *See supra* note 23 and accompanying text.

28. *See supra* Part III.A.

29. HEAL ET AL., *supra* note 23, at 47, 142.

30. These measures assume that the individual has a right to her current utility level. Other possible economic measures are WTP to avoid a loss (which leaves the individual at a lower utility level) and WTA to give up a gain (which leaves the individual at a higher utility level). *See* Nicholas E. Flores, *Conceptual Framework for Nonmarket Valuation, in* A PRIMER ON

or WTA as the measure of something depends on whether or not the person has property rights to it. For private goods, property rights are generally well-established, but for public goods, environmental conditions, or goods available on public land, property rights are not so obvious or easily established. For example, the right to a certain level of streamflow quantity and quality along a river, say to a person with property along the river or to a kayaker who floats the river, is a complicated matter of state and federal law. The difficulty over property rights would matter little if WTP did not differ from WTA. In some cases, such as when close substitutes to the good or service at issue are not available, WTA can substantially exceed WTP.[31] Lack of close substitutes may easily be the case with some ecosystem goods or services, such as unique recreation and educational opportunities or maintenance of habitats for endangered species. Unfortunately, WTA is often difficult to measure, so consequently WTP is often used even where WTA would be more appropriate, resulting in an underestimate of value.[32] An underestimate may still be a useful input to a policy decision, as long as it is recognized as a lower bound on the true value.

C. Methods for Valuing Ecosystem Goods and Services

Four principal categories of methods are available for valuation of ecosystem goods and services:

- Household revealed preference methods, including the travel cost, hedonic, and averting behavior methods
- Stated preference methods, including contingent valuation and attribute-based methods
- Production function methods
- Replacement cost method.

We will briefly describe these methods.[33]

The first two categories focus on individual choices and preferences, based on the fundamental assumption that individuals act so as to maximize their utility (thus providing true indications of value).

Household Revealed preference methods utilize the observed behavior of individuals as indicators of their WTP for an environmental attribute or condition. These methods rely on a complementary relationship between

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NON-MARKET VALUATION, *supra* note 25, at 27, 38.

31. W. Michael Hanemann, *Willingness to Pay and Willingness to Accept: How Much Can They Differ?*, 81 AM. ECON. REV. 635, 637 (1991).

32. HEAL ET AL., *supra* note 23, at 49.

33. For more detail on the full set of methods, see HEAL ET AL., *id.* at 95–152. For a more thorough description of the first two categories, see A PRIMER ON NON-MARKET VALUATION, *supra* note 25. For more detail on production function methods in the context of water resources, see ROBERT A. YOUNG, DETERMINING THE ECONOMIC VALUE OF WATER: CONCEPTS AND METHODS 50–117 (2005). Many other sources are available that give thorough descriptions.

a market good and the nonmarket good or service at issue. The *travel cost* method uses travel to recreation sites, and the costs of that travel, to infer the WTP for the recreation visits. With data for multiple sites that differ in their characteristics, the modern approach to the travel cost method, using random utility models, allows estimation of the value of site characteristics, which may include things like fishing quality or scenic beauty. In its most common application, the *hedonic* method uses data on property sales to statistically isolate WTP for the attributes of the properties. Among the attributes may be environmental attributes such as the distance to open space, access to scenic vistas, or ambient air quality. Of course, all relevant attributes must be represented in the data in order to avoid incorrectly estimating the value of the attributes that are included. *Averting behavior* methods use peoples' expenditures to avoid potential health problems to estimate WTP for improved health. Where these health problems are caused by a loss of ecosystem services, the method can infer WTP for the service, but typically the inference is only approximate because people can rarely take actions that result in optimal protection levels, and because the measure will underestimate WTP if the averting behavior costs less than the individual is willing to pay.

The revealed preference methods each rely on somewhat specialized situations (i.e., recreation trips, property sales, health effects) and thus are limited in the ecosystem goods and services they can be used to value. *Stated preference* methods do not face such constraints; in principle they can be used to value any good or service, real or imagined. However, these methods face their own set of difficulties, having to do with respondents' ability to accurately predict (and willingness to reveal) their own behavior and researchers' ability to construct meaningful and realistic payment scenarios. *Contingent valuation* may be used to value a public program, recreation experience, habitat condition, or any other policy-relevant change. This method can zero in on a specific ecosystem good or service as long as a realistic payment scenario can be posited. Not all goods or services lend themselves to realistic payment scenarios; for example, protection and management of open-access ecosystem services requires an entity to enforce payment and control access, and if that entity does not exist and is not likely to exist, a realistic payment scenario is not possible. *Attribute-based* methods, also called conjoint or choice analysis methods, typically ask respondents about a series of similar multi-attribute goods or services that differ in the levels of their common attributes. In the most common application, respondents are presented with several sets, usually containing two or three items each, and asked for each set to choose the item they prefer. For economic valuation, price must be one of the attributes. Another of the attributes can be the environmental good or service at issue. For example, the attributes of camping opportunities may include natural scenic beauty in addition to camping fee and produced features such as quality of tent sites, availability of picnic tables, and ease of access. Like contingent valuation, attribute-based approaches are quite flexible in the kinds of goods or services they can be used to value but require a realistic payment scenario.

Economic *production function* approaches are used to value inputs in the production of a marketed good. These approaches require observing, and perhaps modeling, the behavior of producers, including their response to changes in environmental conditions that influence production of the market good. The effect of the environmental change on the costs or output level of the production process yields an estimate of the economic value of the change. Production function approaches have several variants. One of the simplest is to observe a set of producers that are similar in all aspects except for the quantity or quality of some environmental input. Differences in the level of output among these producers, and thus in their net revenues, holding all other inputs constant, indicate the value of the environmental input. Another, more complex approach is to carefully model the behavior of firms under conditions that differ in the level of the environmental input. For example, irrigated agricultural production may be modeled as a way to estimate the value of increments in water availability or quality to irrigated farming. Such modeling requires detailed understanding of how firms respond to varying levels of their different inputs, including the input of primary interest, the environmental condition. A key requirement for using production function approaches is that the output and the other inputs are competitively priced (e.g., subsidies do not seriously affect their prices), or, if not competitively priced, the market interference can be adjusted for.

Unlike the first three categories of methods, the *replacement cost* method, also called the alternative cost method, does not rely on observing or modeling the behavior of persons or firms as they respond to existing or posited conditions. Rather, this method computes the cost of replacing a lost environmental good or service, or conversely the replacement cost avoided if the environmental good or service is preserved. Because the replacement cost is a measure of cost, not of value, it is not truly a method for measuring benefits.[34] However, the method—or, more precisely, the estimate of cost that it entails—is commonly used with ecosystem services and thus deserves a closer look.

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34. The averting behavior method, described above, also relies on a measure of cost as an indication of benefit. The averting behavior method enjoys more acceptance among economists than does the replacement cost method because, in part, the averting behavior method relies on observation of consumer behavior, in contrast to the replacement cost method, which relies at best on the existence of a legislative mandate—a collective decision that only indirectly reflects consumer desires.

Although some applications of the replacement cost method seem without merit,[35] the following special case is especially deserving of attention: when there are two substantially different options for achieving the same goal and the second option is legislatively mandated and will go forward unless the first option is implemented, the cost avoided by achieving the goal using the first option may serve as a proxy for the benefits of that first option.[36] This is because the legislative mandate requires that the costs of the second option will otherwise be incurred. In this situation, an avoided cost can be treated as a benefit, as the money saved becomes available for other uses.[37] For example, if the first option were to protect an ecosystem service and the second option were a produced substitute, the cost of the produced substitute that would be avoided if the ecosystem service were protected is a measure of the benefit of that protection if laws require that the ecosystem service be replaced (by the second option) if it is lost (and, of course, if the second option is a perfect, or at least nearly perfect, substitute for the ecosystem service).

However, this special case is best viewed within the framework of cost-effectiveness analysis, not benefit-cost analysis.[38] That is, in the presence of a legislated goal, a measure of the benefit of that goal is actually beside the point—by law, the goal *will* be met. With a legislated goal, only the costs matter, and the decision is simply one of comparing the costs of the options for reaching that goal and choosing the least expensive option.

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35. The replacement cost approach has been criticized, at least in part, because it can be easily misused. The classic case of misuse occurs when, in an effort to support a proposed project whose benefit is difficult to measure, the agency proposing the project simply searches for a more expensive option for producing the same benefit and uses the cost of that option as a measure of the benefit of their pet project. Correct use of the replacement cost approach relies on satisfying two conditions. To consider them, assume two ways of achieving the same goal: option 1 and option 2, each with associated costs (C_1 and C_2) and benefits (B_1 and B_2). When the benefit of one option, B_1, cannot be directly measured, the replacement cost method uses the cost of the other option, C_2, as a measure of B_1. Although the cost C_2 is not a measure of B_1, C_2 is considered a proxy for B_1 if the following two conditions hold: (1) $B_2 \leq B_1$ and (2) $B_2 \geq C_2$. If these conditions hold, clearly $B_1 \geq C_2$, and C_2 serves as a lower bound on B_1. The main problem in evaluating these conditions, of course, is estimating B_2. If B_2 were known, and if it truly were also an estimate of B_1, then B_1 would also be known and use of the method would not be necessary. When B_2 is not known, and condition 2 must be assumed, we have not necessarily gained anything.

36. Peter O. Steiner, *The Role of Alternative Cost in Project Design and Selection*, *in* WATER RESEARCH 33, 46 (Allen V. Kneese & Stephen C. Smith eds., 1966).

37. It is important to distinguish between the avoided (i.e., replacement) cost and the cost savings. The replacement cost is considered the gross benefit of pursuing the first option. The cost savings is the difference between the larger (replacement) cost and the lower cost.

38. This argument was first made by ORRIS C. HERFINDAHL & ALLEN V. KNEESE, ECONOMIC THEORY OF NATURAL RESOURCES 267–70 (1974).

Thus, in this special case we avoid the issue of whether an alternative cost is actually a measure of benefit.[39]

The New York City water supply case is an example of the situation just described, where water quality standards were mandated and the city considered the option of protecting its Catskill watershed water source in lieu of constructing and maintaining a filtration plant. The cheapest option was to protect the watershed. Given the mandate to protect drinking water quality, the benefit of protecting the watershed (to be compared with the cost of watershed protection) can be considered at least as great as the cost of building the filtration plant, but an estimate of benefit is beside the point once the benefit is mandated and cost effectiveness is the only remaining issue.

Based on a review of the literature, de Groot et al. tabulated the methods that have been used to value different ecosystem goods and services.[40] The overall impression from their survey is that the production function approach has typically been used to value ecosystem goods and the replacement cost method has typically been used to value ecosystem services. The nonmarket approaches, about which so much has been written, have typically found application for just a few of the ecosystem goods and services.

V. PROVIDING AND FINANCING ECOSYSTEM GOODS AND SERVICES

Many ecosystem services and some ecosystem goods are commonly received for free. For example, water users downstream of a forested area receive for free the water quality protection afforded by the forest, and farmers receive for free the waste assimilation provided by the stream into which their agricultural wastes drain. The marketing of ecosystem goods and services is basically an effort to turn such recipients—those who benefit without ownership—into buyers.[41] Some formal arrangement, like purchase, is needed to make this happen. Typically the sellers are landowners where the good or service originates or the public via its environmental laws. We consider these two cases in turn.

39. A situation where benefit-cost analysis is still relevant is where the benefit at issue is one of several that make up the total benefit of the project, which is then compared to total cost. For example, in benefit-cost analysis of a dam, the hydropower the dam could produce might be valued using the cost savings in avoiding reliance on thermoelectric power, whereas the recreation benefits might be valued using the travel cost method. Given a goal of economic efficiency, the sum of these two benefits would need to exceed the cost of the dam.

40. de Groot et al., *supra* note 9, at 405–06.

41. Michael Jenkins et al., *Markets for Biodiversity Services: Potential Roles and Challenges*, 46 ENVIRONMENT 32, 41 (2004).

In the first case, we may want to protect an ecosystem good or service that is under the control of another party. For example, we may want to continue to enjoy the view of a local forest or have access to clean streamflow (which, let us imagine, would require averting the sediment produced by an upstream rancher who is letting his cattle graze along the stream). To assure the desired ecosystem protection in such situations, we have two basic options: buy the land or, less expensively, arrange to pay only for the ecosystem good or service we wish to enjoy (or for the management change needed to protect the good or service). Various arrangements are possible, including conservation easements and direct payments for an agreed management change. In the second case, individuals or firms who are enjoying access to the environment as a sink for their waste products may be forced to pay for that privilege if environmental laws restrict the right to pollute. Economic mechanisms include a cap-and-trade scheme and a direct pollution tax or other charge. In both of these cases the payments internalize externalities. In the former, beneficiaries of a positive externality begin paying for the benefit; in the latter, entities causing negative externalities begin paying for the harm they cause.

By internalizing externalities, payment provides signals that encourage behavior more accurately reflecting the full value of the resources at issue, thereby helping to ensure continued enjoyment of the ecosystem good or service. This section focuses on the conditions that enable or enhance opportunities for marketing of ecosystem goods and services and on the mechanisms whereby the goods and services are marketed. We begin by considering the basic conditions for exchange, where exchange includes simple two-party agreements as well as exchanges that occur within active markets.

A. Conditions of Exchange

1. *Conditions That Allow Exchange*

For exchange to occur for any good or service, three basic conditions must exist (Table 3). First of all, the good or service must be scarce. If a good or service is not scarce (i.e., if supply is unlimited relative to demand), there is no incentive for anyone to pay for it because they can get all they want for free. Currently this is an issue with some of the ecosystem goods or services listed in Table 1, such as ambient air. In most places, ambient air (air in the atmosphere) is not scarce; we can all breathe as much air as we want for free. As long as ambient air is not scarce, no one will pay for it in a private market.[42]

42. Although ambient air is not scarce, clean ambient air often is, especially in urban areas.

Table 3. Conditions of Exchange

Conditions that allow exchange
- Scarcity
- Non-attenuated property rights
  - Clear definition and precise measurement
  - Consistent and reliable enforcement
  - Excludability
  - Transferability
- Low transaction costs
  - Ready market information
  - Inexpensive measurement, monitoring, and enforcement

Conditions that lead to a competitive market solution
- Many buyers and sellers
- Lack of third-party environmental effects
- Rivalness
- Ample identical units
- Perfect information

Conditions that further improve the likelihood of exchange
- Perceived fairness of transactions
- Institutions aiding exchange (e.g., customs, brokers, banks)

A second requirement is the establishment of non-attenuated property rights for the good or service. Non-attenuated property rights are unambiguous, transferable, exclusive, and enforced.[43] Non-attenuated property rights to normal commercial goods and services, such as bread or tickets to a concert, are taken for granted because they are so obvious. Such goods are easily defined and transferred, they belong solely to the owner, and a person's right to such a good is unquestioned and protected via widely available law enforcement. However, these characteristics are not so easily established for many ecosystem goods and services.

Excludability of goods and services is discussed in detail below in the section "Classification of Ecosystem Goods and Services." In this section we focus on definition and measurement of ecosystem goods and services. Definition and measurement of ecosystem goods is fairly straightforward, but for ecosystem services definition and measurement can be a major stumbling block. For example, the amount of water purification, or conversely the amount of water pollution, that occurs on a given parcel of land, either in soils or wetlands, is extremely difficult to quantify because

43. ALAN RANDALL, RESOURCE ECONOMICS: AN ECONOMIC APPROACH TO NATURAL RESOURCE AND ENVIRONMENTAL POLICY 157-58 (2nd ed. 1987).

of the multiple points at which the water enters the stream.[44] The issue is further complicated by the fact that water quality is a matter of numerous different constituents. If parties cannot agree on a measurement protocol or do not have faith in the measurement that occurs, possibilities for exchange are seriously compromised.

Enforcement of exchange agreements is another hurdle. With ecosystem goods, contracts for delivery rely on fairly well-established laws that are unlikely to change in the foreseeable future. However, arrangements for provision and financing of ecosystem services are often fairly new and typically rely on unique rules announced by the government. Such rules may be subject to change, leaving uncertainty in the minds of private participants. If potential participants lack confidence that the agreements will endure and be enforced, they may decline to participate despite the announced benefits. For example, farmers may be enticed to plant trees in place of annual crops on sensitive slopes with a promise of future payments from a governmental agency, but if the farmers have any doubt about the payments—perhaps because the agency's funding is uncertain—they are likely to continue to plant their annual crops.

Once non-attenuated property rights are established for a scarce good or service, as Coase showed, market trade will automatically develop for the good or service as long as transaction costs are not excessive.[45] Transaction costs include costs of getting information, finding willing sellers or buyers, and transferring title, which are commonly borne by the parties to the exchange. Transaction costs also include the underlying costs of establishing and enforcing non-attenuated property rights to the good or service, which are commonly borne by a governmental entity.[46] These underlying costs may involve monitoring, either of environmental conditions such as ambient water or air quality or of emissions of point- or nonpoint-source pollution. If transaction costs borne by the parties to the transaction exceed the benefits of the exchange, exchange will not occur. If transaction costs borne by a government entity are excessive relative to the perceived public benefits of the resultant transactions, exchange is also unlikely to occur.

Assuming transaction costs are not prohibitive, private markets for ecosystem services that achieve *economic efficiency* could theoretically develop as envisioned by Coase.[47] Economic efficiency is a common policy

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44. This difficulty is one reason for the relative lack of success in the United States in controlling nonpoint-source water pollution in contrast to point-source water pollution. *See* U.S. ENVTL. PROT. AGENCY, NATIONAL WATER QUALITY INVENTORY: 1994 REPORT TO CONGRESS 11-12 (1995), *available at* http://www.epa.gov/305b/94report/index.html.

45. R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 5-6 (1960).

46. *See* Alan Randall, *The Problem of Market Failure*, 23 NAT. RESOURCES J. 131, 133 (1983).

47. Coase, *supra* note 45, at 5-6, 8.

and management goal with respect to providing and paying for any good or service. Economic efficiency is generally defined as *Pareto efficiency*, a situation in which it is not possible to reallocate production or consumption in a way that makes one individual or group better off without making another individual or group worse off.[48] Voluntary exchanges will naturally enhance economic efficiency as long as all parties affected by the exchange are party to the exchange (i.e., as long as externalities are not present).

Applying the strong version of the Coase Theorem, if transaction costs are negligible, the final, economically efficient provision of ecosystem goods and services will be independent of the initial assignment of property rights.[49] As an example, consider the ecosystem service of streamflow and for simplicity assume there are two parties interested in the water, an upstream party and a downstream party. The strong version of the Coase Theorem would imply that the final economically efficient allocation of water between the upstream party and downstream party resulting from market trade of the water would be independent of the initial assignment of property rights. Thus, we could assign initial water rights to either party and then let market trade between the two lead to the unique economically efficient allocation of water between the parties.

The weak—and more realistic—version of the Coase Theorem drops the assumption of negligible transaction costs. Because of the presence of positive (but not prohibitively high) transaction costs, the weak version of the Coase Theorem implies that the final economically efficient level of ecosystem goods and services will depend upon the initial assignment of property rights. For example, consider again the upstream and downstream parties in the example in the previous paragraph. Under the weak version of the Coase Theorem, if water rights were initially assigned to the upstream party, we would expect the final economically efficient allocation of water resulting from market trade to favor the upstream party (i.e., the upstream party would end up with more of the streamflow than in the case of zero transaction costs). However, if water rights were initially assigned to the downstream party, theoretically we would expect the final economically efficient allocation of water resulting from market trade to favor the downstream party. Whether we initially assign water rights to the upstream or downstream party, the final allocation of water between the two parties will be economically efficient.[50]

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48. Freeman, *supra* note 25, at 15.

49. An additional condition is that income effects are negligible, where income effects refer to increased (decreased) demand for ecosystem goods and services based on increased (decreased) income resulting from who gets paid by whom for ecosystem goods and services.

50. *See* RANDALL, *supra* note 43, at 186–93; Randall, *supra* note 46, at 139.

2. *Conditions That Lead to a Competitive Market Solution*

Isolated trades are not the only or even the most common exchanges of ecosystem goods and services. Markets—institutions or settings in which numerous individuals voluntarily trade units of a good or service, typically using money as the means of exchange—are common. Markets exist for many of the goods listed in Table 1. If the conditions described above are met, and if a sufficient number of units of the good or service are available, an active market may develop. Economic efficiency is naturally enhanced through such markets if they are competitive. Voluntary exchange, however, does not assure competitiveness.

Under competitive conditions, market price and the quantity traded are such that the price is the point at which the marginal cost of providing the good equals the marginal benefit of its consumption. Competitive markets have several characteristics (Table 3), the most important for the current discussion being that (1) they have many buyers and sellers, (2) they internalize all costs and benefits (i.e., there are no externalities to a transaction), and (3) the good or service is rival. Lack of any one of these requirements will lead to inequality of marginal cost and marginal benefit, and thus to inefficiencies. The "rival" characteristic is discussed in the section "Classification of Ecosystem Goods and Services." Here we focus on the number of participants and on externalities.

Markets lacking a sufficient number of participants may be monopolistic or monopsonistic. In a *purely monopolistic (monopsonistic)* market, a seller (buyer) would have such a strong hold on market supply (demand) as to be able to set price at will with no concerns about competitors stepping in to capture a larger share of the market. In a competitive market, no individual or firm can control the price or the total quantity offered for sale.

Technical externalities arise when a transaction leads to environmental changes that affect individuals or firms not party to the exchange. Externalities may be negative or positive. For example, when water rights are transferred from one basin to another, water quality in the river of origin may drop because there is less water to naturally assimilate waste products, and water quality in the receiving river may rise because there is more water for waste assimilation. Externalities are avoided if all affected entities are involved in the transaction, but such involvement may entail substantial transaction costs, and the mere opportunity for involvement may depend on laws and environmental quality regulations protecting third parties.

Only some ecosystem goods and services are amenable to provision in relatively competitive markets. In other cases, as described in more detail in the following section, "Classification of Ecosystem Goods and Services," some government intervention is needed to move provision toward an efficient outcome.

3. Conditions That Further Improve the Likelihood of Exchange

We have identified three general requirements for exchange to occur—scarcity, non-attenuated property rights, and non-prohibitive transaction costs—and additional conditions for competitive market exchange. These requirements or conditions alone, however, are not necessarily sufficient for exchange to occur. One potential hurdle is that, because the gains from trade in an ecosystem good or service market will depend on the initial allocation of rights, the resulting distribution of resources and incomes may be viewed as unfair (Table 3). Inequity, especially involving lower income providers of ecosystem services, is a potential barrier to exchange, particularly if the exchange is of a good or service with public good qualities.[51] Thus, for the long-term support and sustainability of an ecosystem service market, passing an economic fairness or social justice test may be another necessary condition.

Another impediment to market development is political, social, or even moral opposition to the idea of trading an ecosystem good or service. Some people, for example, hold the strong opinion that the public has inherent rights to some ecosystem goods or services and that provision and protection of these things should not be left up to private market transactions. For example, many people may view access to clean air and water as a fundamental human right and morally object to forcing people to pay for this right through market transactions. This group would likely rather see the government provide and protect clean air and water through general tax revenues, regulation and pollution taxes under the "polluter pays" principle.[52]

Related to the matters of fairness and acceptability of exchange is the question of negative externalities. The existence of either technical externalities, mentioned above, or pecuniary externalities can lead to opposition to exchange. Pecuniary externalities arise when a transaction financially harms individuals or firms not party to the exchange. For example, when water rights are transferred from one basin to another, leading to a drop in water use in the basin of the seller, businesses or local government agencies (and the services they provide) that relied on the

51. *See* Natasha Landell-Mills, *Developing Markets for Forest Environmental Services: An Opportunity for Promoting Equity While Securing Efficiency?*, 360 PHIL. TRANSACTIONS ROYAL SOC'Y 1817, 1821 (2002).

52. *Cf.* RANDALL, *supra* note 43, at 360-64 (discussing Pigouvian tax and direct regulation solutions to pollution problems).

economic activity related to that water use may be harmed.[53] The existence of either kind of externality may lead to legal and political opposition to an exchange.[54]

Another factor that facilitates exchange is the presence of institutions aiding exchange, such as laws and customs that treat the item at issue as a marketable commodity, brokers that help bring buyers and sellers together, and middle-men that buy the item from sellers and then sell it to buyers. For example, water marketing in the western United States is facilitated by laws and customs that allow for transfer of water rights, real estate brokers that deal in water, and water banks that have no use for water themselves but serve as a clearing house, temporarily holding commitments for water delivery.[55]

B. Classification of Ecosystem Goods and Services

The degree to which a good or service is rival and exclusive determines the feasibility and appropriateness of different provision and financing mechanisms, as well as the level to which government must be involved to produce an economically efficient allocation.[56] A *rival* good is one for which consumption by one person reduces the amount of good or service available to others, as is the case with apples and haircuts. A non-rival good or service is one for which consumption by one person does not reduce the amount available to anyone else, as with radio signals, climate regulation, and UV ray protection.[57] An *exclusive* good or service is one from which consumers can be excluded unless they meet the conditions prescribed by the party controlling the good or service. Goods offered for sale are exclusive goods. Conversely, a non-exclusive good or service is one from which consumers cannot be excluded, even if they do not pay for it.

A good or service may be non-exclusive because of its physical characteristics and distribution. For example, natural water storage in soils, lakes, and wetlands benefits all downstream riparian land owners and water users in the form of flood control and paced release of water. It would

53. *See, e.g.*, Charles W. Howe & Christopher Goemans, *Water Transfers and Their Impacts: Lessons from Three Colorado Water Markets*, 39 J. AM. WATER RESOURCES ASS'N 1055, 1064 (2003).

54. *See, e.g.*, Ellen Hanak, *Stopping the Drain: Third-Party Responses to California's Water Market*, 23 CONTEMP. ECON. POL'Y 59, 60 (2005).

55. *See generally* A. DAN TARLOCK ET AL., NAT'L RES. COUNCIL, WATER TRANSFERS IN THE WEST: EFFICIENCY, EQUITY, AND THE ENVIRONMENT 70–105 (1992) (describing the elements of the law of water transfers).

56. RANDALL, *supra* note 43, at 164–69, 175–76.

57. For a non-rival good or service, "consumption" must be thought of in a broader, passive sense. For example, in the absence of congestion, when a nature lover looks out over a scenic view, he or she "consumes" enjoyment of the view without using up any of the view—thus, a scenic view is a non-rival good.

be very difficult for a private company or a government entity to establish exclusive rights over this service and charge beneficiaries depending on how much they benefit; thus, natural water storage is non-exclusive.

Crossing these bipolar dimensions, rivalry and exclusiveness, yields four categories of goods and services: rival, exclusive; rival, non-exclusive; non-rival, exclusive; and non-rival, non-exclusive. In the four cells of Table 4 we list some ecosystem goods and services that typically represent the four categories.

Free market provision and financing of goods and services (i.e., with only minimal government involvement, for things like enforcement of property rights) is best suited to rival, exclusive goods and services. As shown in Table 4, most tangible ecosystem goods, but few services, potentially can be traded efficiently in unfettered private markets. Private markets, in fact, already exist for many of the rival, exclusive goods shown in Table 4 (e.g., fossil fuels, timber, and big game hunting opportunities).

In the case of non-rival, exclusive goods and services (Table 4), because exclusion can be established, private market provision is possible. For example, a private land owner could fence off her land and charge people who enter through a gate to view and photograph natural plants on the land. As long as congestion is not a problem and people do not destroy the plants they are viewing and photographing, use and "consumption" will be non-rival. From an economic efficiency standpoint, however, the private owner is likely to charge "too high" an entrance fee and turn away "too many" people; that is, any entrance fee above the generally low marginal cost of allowing one more person into the area to view plants would be economically inefficient.

Many non-rival, exclusive recreational opportunities are provided by the government. For example, Rocky Mountain National Park in Colorado, although a large public park, has few automobile access points. The Park Service controls access at these entry points and charges an entrance fee. Thus, the Park Service has made recreational opportunities within the park exclusive. Once inside the park, recreational opportunities are non-rival if congestion is not a problem. However, when congestion sets in (which it very much does on nice summer days), recreation opportunities (such as hiking) can become rival (e.g., with people literally bumping into each other on the hiking trials).[58]

58. The economically efficient price depends on the number of visitors. If the area were truly non-rival, the fee would be very low, but if it were rival, as on a nice summer day, the efficient fee would be high enough to avoid severe reduction of marginal benefits.

Table 4. Ecosystem Goods & Services Classified by Rivalness & Exclusiveness Characteristics

	Exclusive	Non-exclusive
Rival	• Nonrenewable ecosystem goods extracted from contained (i.e., controlled-access) deposits (e.g., fossil fuels, metals, minerals) • Renewable ecosystem goods harvested from contained ecosystems (e.g., water, fish, wildlife, trees, fuel wood, edible plants, medicinal plants) • Consumptive recreation opportunities (e.g., hunting, fishing) on contained properties • Non-consumptive recreation opportunities (e.g., hiking, viewing) on congested, contained properties • Ecosystem services the effects of which are contained within a property ownership (e.g., maintenance of soil fertility)	• Renewable ecosystem goods harvested from uncontained (i.e., open-access) ecosystems (e.g., water, fish, wildlife, trees, fuel wood, edible plants, medicinal plants) • Consumptive recreation opportunities (e.g., hunting, fishing) on uncontained properties • Non-consumptive recreation opportunities (e.g., hiking, viewing) on congested, uncontained properties • Ecosystem services the effects of which are not contained within a property ownership but are realized in the quality of rival goods (e.g., erosion control, natural water storage, waste assimilation) • Natural animal and plant pest control and pollination services
Non-rival	• Non-consumptive recreation opportunities (e.g., hiking, viewing) on uncongested, contained properties	• Non-consumptive recreation opportunities (e.g., hiking, viewing) on uncongested, uncontained properties • Maintenance of regional precipitation patterns • Temperature maintenance via carbon storage • UV protection • Ambient air purification • Natural water storage as it lowers the probability of floods and droughts

If exclusion is not feasible, economically efficient free market provision and financing of goods and services are also not feasible. Indeed, private markets of any type typically fail to develop for non-exclusive goods and services, leading to their under-provision. For example, a landowner with the capability to protect the quality of the streamflow leaving his property will have little incentive to do so if his efforts are enjoyed for free by those downstream—a situation known as the "free-rider" problem. Therefore, goods and services that are non-exclusive are typically regulated or provided by the government and financed with tax revenues.

When an ecosystem good or service is non-exclusive because of its physical nature and distribution, such as tuna fish in the open ocean and temperature maintenance via carbon storage, correcting this situation—making it exclusive—can be very expensive. Such costs are a form of transaction cost. For example, the transaction costs of attempting to privatize tuna in the open ocean and assigning non-attenuated property rights to one or more owners would be prohibitive because of the physical difficulties of containing tuna to a specific place in the ocean. In the case of temperature maintenance via carbon storage, there are literally billions of individual beneficiaries. The transaction costs to an individual provider of these ecosystem services involved in securing payment from all beneficiaries (or even a relatively small portion of these beneficiaries) would be prohibitive.

Other ecosystem goods and services, such as recreational opportunities provided in public parks on a no-fee basis, may for political and cultural reasons be managed as non-exclusive even though the costs of exclusion would not be prohibitive. For example, access to a city park may be kept free to encourage community or for equity reasons (e.g., to avoid letting ability to pay interfere with enjoyment of such a basic good).

Although some ecosystem services may be confined within a given property and thus are exclusive (e.g., maintenance of soil fertility), most ecosystem services are non-exclusive (Table 4). Non-exclusive ecosystem services may be rival, as when their effects are realized, in part, in the quality of rival goods (for example, waste assimilation in a river is realized in the quality of the streamflow diverted for domestic use). However, many non-exclusive ecosystem services are non-rival, such as maintenance of precipitation and temperature patterns.

In summary, economically efficient free market provision and financing is limited to rival, exclusive ecosystem goods and services. With respect to the other three categories of ecosystem goods and services listed in Table 4, self-organized markets for some of these goods and services could develop, but the resulting prices and quantity of provision would be economically inefficient. Because of problems related to non-rivalry or non-exclusiveness, the ecosystem goods and services listed in the other three cells in Table 4 are likely subject to *market failure* defined as the failure of private individual-buyer, individual-seller markets to achieve economic efficiency or Pareto Efficiency in the provision and financing of goods and services. Hence, the government is more likely to be involved in providing these latter three categories of goods and services and financing them through tax revenues or user fees (when it is feasible to exclude those who do not pay the fee), or in regulating them via cap and trade or other mechanisms.

C. Mechanisms of Exchange

Because ecosystem goods and services fall into all four cells of Table 4, they are subject to many different mechanisms of exchange. Ecosystem goods such as trees and forage, being excludable physical inputs in common production processes, are commonly purchased by those intending to use them. Ecosystem services, such as natural flood regulation and pollination, being generally non-excludable flows, are not directly transferable. Because of this quality, many ecosystem service flows are typically protected by controlling or at least influencing the practices that are allowed on the land where the services originate.

The most obvious way to constrain the practices permitted on a plot of land is to own the land. When conservation-minded entities—either public (e.g., the U.S. Forest Service, county open space programs) or private (e.g., the Nature Conservancy, progressive individual landowners)—own land, they may protect the ecological health of that land and thereby enable the provision of ecosystem services. Nowadays additions to the set of protected land typically occur either by market purchase or by set-asides of what is already public land. Land purchases on the open market are commonplace. Alternatively, existing public land may be moved to a more restrictive category of use such as a wilderness designation.

Short of owning the land, ecological functions may be protected by constraining the practices that are allowed on the land. Possible methods include conservation easements, special use designation (e.g., designation of a riparian area that includes private land as a Wild and Scenic River), zoning, subsidies to land owners to follow certain practices, and enforcement of environmental protection legislation such as the Clean Water Act and the Endangered Species Act.[59]

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59. In contrast to land and water resources, air quality protection is not so much a matter of land ownership or management. Typically air quality protection has relied on taxes or government regulations aimed at limiting emissions. Taxes have included excise taxes on use of polluting fuels (e.g., gasoline). Regulations have taken a variety of forms including caps on point-source emissions (e.g., SO_2), temporary bans on use of some fuels when local air quality drops below a threshold (e.g., wood burning bans), constraints on installation of offending

Mechanisms for exchanging ecosystem goods and services fall into the four general categories shown in Table 5. Private individuals (including non-governmental organizations, firms, and other groups) can be either buyers or sellers of ecosystem goods and services. Government entities (including federal, state, and local governments) can also either be buyers or sellers of ecosystem goods and services. Thus, the four general categories for exchanging ecosystem goods and services are (1) individual buyer, individual seller; (2) individual buyer, government seller; (3) government buyer, individual seller; and (4) government buyer, government seller. These four categories are discussed in more detail below.

Table 5. Provision & Payment Mechanisms for Ecosystem Goods & Services

		Sellers	
		Individuals*	**Governments**
Buyers	**Individuals***	• Markets for privately held ecosystem goods (e.g., crude oil, water in a stream or aquifer, timber, gems, fee hunting and fishing, commercial whitewater rafting) • Private trust purchase of land or conservation easements (e.g., Nature Conservancy, Ducks Unlimited) • Private environmental quality incentive payments (e.g., Perrier-Vittel, Trout Unlimited) • Consumption-based donations (e.g., green certification, wind power rate premium, organically grown coffee) • Cap-and-trade markets (e.g., wetland credits, SO_2 permits, carbon permits and credits, land development rights)	• Public goods and services financed by taxes (e.g., national parks, national forests, national wildlife refuges, county or city open space, conservation easements) • Fees to government agencies for access to ecosystem goods (e.g., timber harvesting, energy and mineral extraction, grazing, hunting, fishing, recreation opportunities) • Fees (taxes or charges) for license to discharge (e.g., pollution taxes) or use of a polluting good (e.g., gasoline tax)
	Governments	• Incentives to private parties for provision of ecosystem services (e.g., CRP, WRP, EQIP, FRPP, GRP, CSP, FEP) • Land purchase	• Federal grants for environmental protection (e.g., U.S. EPA water quality protection grants to local governments, U.S. AID ecosystem protection grants to foreign governments)

* Firms and NGOs are categorized as individuals.

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appliances (e.g., banning wood burning stoves in new construction), and fuel economy standards for vehicles. In addition, government programs have subsidized alternatives to polluting practices (e.g., public transportation) and funded research into improved technologies.

1. Individual Buyer, Government Seller

Ecosystem goods and services are commonly financed via individual tax payments to government entities that manage public land to provide the goods and services. Non-excludable ecosystem goods and services tend to be provided by government entities to users without direct charge. For example, in the United States, the water quality protection afforded by management of land as a national park or national forest is available to downstream water users without charge, except for the tax payment that enables the land management in the first place.

In the case of excludable ecosystem goods and services, fees may be charged for use or access rights to an ecosystem good or service. For example, in the United States, federal, state, and local governments charge fees for many types of outdoor recreational opportunities (e.g., entrance fees to public parks). In addition, states charge for fishing and hunting licenses. In most cases, the money generated from outdoor recreation fees goes back to protecting the ecosystems and natural resources that support the recreational opportunities. The federal government in the United States also charges fees for stumpage, grazing rights, and mineral and energy extraction on public lands. Government fees are typically determined administratively and may reflect a mixture of efficiency and equity considerations.

Another individual-buyer, government-seller arrangement is the so-called price-based approach to pollution control, whereby a governmental entity imposes a tax or fee per unit of emission. Unlike a quantity-based approach, such as the cap-and-trade approach described below, a price-based program does not announce a precise limit on the amount of pollution, either per emitter or in aggregate across all emitters; rather, the program imposes a price, which may be amended periodically so that the desired level of pollution control is approximated.[60] Such a fee leaves decisions about the level of emissions and ways to limit emissions up to the emitters, preserving individual flexibility to adapt, thereby containing the overall cost of reducing emissions. An example of a price-based approach is the 1993 law in Columbia that directs regional environmental regulatory authorities to collect fees from individual wastewater emitters per unit of biological oxygen demand and of total suspended solids that the emitters add to rivers and streams.[61] A price-based program has also been

60. Another difference between a price-based approach and cap and trade is that with the former the complicated and contentious process of allocating permits to emitters is avoided.

61. Allen Blackman, *Economic Incentives to Control Water Pollution in Developing Countries: How Well Has Colombia's Wastewater Discharge Fee Program Worked and Why?*, 161 RESOURCES 20, 22 (2006).

proposed for worldwide control of greenhouse gases, where the fees would be "harmonized" across countries via international negotiations in light of the nations' different levels of economic development, in a manner similar to that of tariff agreements in the international trade arena.[62] The success of such programs depends on the government's ability to monitor emissions and collect the fees.

A somewhat different price-based instrument is a tax on consumption of a commodity the use of which causes pollution, such as the gasoline tax. Although in the United States the federal gasoline tax has not been set with pollution control as the primary objective, the tax nevertheless helps to discourage gasoline use and thereby limit pollution. Placing the tax on consumption avoids the complicated process of monitoring individual emissions.

2. Government Buyer, Individual Seller

Payments from government entities to individuals for the protection of ecosystem services are generally known as subsidies or incentive payments. The payments, often in the form of tax incentives or cost sharing, induce landowners such as farmers and non-industrial forest owners to alter their behavior in a way that benefits others. Such arrangements are voluntary, naturally tend to be popular with recipients, and increase economic efficiency as long as the benefits exceed the costs.

In the United States, many incentive programs are administered by agencies of the U.S. Department of Agriculture, including the Natural Resource Conservation Service and the Forest Service.[63] Perhaps the best known of these programs is the Conservation Reserve Program (CRP), under which selected landowners are paid to remove environmentally sensitive cropland from production.[64] Other, more recently established USDA programs include the Wetlands Reserve Program (WRP), the Environmental Quality Incentives Program (EQIP), the Farm and Ranch Lands Protection Program (FRPP), the Grasslands Reserve Program (GRP), the Conservation Security Program (CSP), and the Forestland Enhancement

62. William D. Nordhaus, *After Kyoto: Alternative Mechanisms to Control Global Warming*, 96 AM. ECON. REV., May 2006, at 31, 31.

63. *See* U.S. Dep't of Agric., Nat. Resources Conservation Serv., NRCS Conservation Programs, http://www.nrcs.usda.gov/PROGRAMS/; U.S. Dep't of Agric., Forest Serv., State and Private Forestry, http://www.fs.fed.us/spf/. *See also* Thomas C. Brown et al., *Laws and Programs for Controlling Nonpoint Source Pollution in Forest Areas*, 29 WATER RESOURCES BULL. 1, 5 (1993) (summarizing state forestry programs).

64. Zachary Cain & Stephen Lovejoy, *History and Outlook for Farm Bill Conservation Programs*, 19 CHOICES, 4th Q. 2004, at 37, 40.

Program (FEP).[65] Of these seven programs, the CRP and WRP remove land from agricultural production, whereas the other programs use payments to improve management practices or establish easements to limit future possible management practices on working agricultural landscapes.

Because these programs have only one buyer (the government agency), an efficient solution will not result naturally. Because of the difficulty of estimating the social benefits of the programs, to say nothing

65. For descriptions, acreages covered, and costs of the USDA programs, see U.S. DEP'T OF AGRIC., CONSERVATION AND THE ENVIRONMENT 5–8 (2006), *available at* www.usda.gov/documents/FarmBill07consenv.doc. The CRP, established in 1985, originally focused on erosion control but was later expanded to include wildlife habitat maintenance and other objectives. Food Security Act of 1985, Pub. L. No. 99-198, tit. XII, §§ 1231–1236, 99 Stat. 1509 (codified as amended at 16 U.S.C. §§ 3831-3836 (2000)). Farmers receive an annual "rental" payment plus partial reimbursement for the cost of planting and maintaining vegetation (grasses, trees, and other cover crops), restoring wetlands, or establishing buffers. In 2005, annual rental payments averaged $48 per acre, and payments for all purposes totaled $1.8 billion on 35 million acres. The WRP, established in 1990, uses cost-sharing and purchase of easements to restore and preserve wetlands that have been converted to cropland. Food, Agriculture, Conservation, and Trade Act of 1990, Pub. L. No. 101-624, tit. XIV, § 1438, 104 Stat. 3584 (codified as amended at 16 U.S.C. § 3837 (2000)). WRP payments totaled $161 million in 2005.

The EQIP, established in 1996 and consolidating several earlier programs, provides cost sharing and other financial incentives to farmers who build structures and alter their farming practices to improve air, soil, and water quality. EQIP payments totaled $444 million in 2005 and involved 94.5 million acres. Federal Agricultural Improvement and Reform Act of 1996, Pub. L. No. 104-127 tit. III, § 334, 110 Stat. 996 (codified as amended at 16 U.S.C. 3839aa (2000)). FRPP, also established in 1996, provides financial help to state or local governments or nonprofit organizations in purchasing conservation easements for the purpose of protecting cropland by limiting nonagricultural uses of the land. FRPP payments totaled $112 million in 2005. *Id.* tit. III, § 388, 110 Stat. 1020 (codified at 16 U.S.C. 3830 n. (2000)). Thus far almost 450,000 acres have FRPP-assisted easements.

The GRP, established in 2002, makes rental payments to landowners or purchases easements with the objective of restoring and protecting grasslands. Protected areas may remain in livestock grazing but must be managed under an approved conservation plan. Farm Security and Rural Investment Act of 2002, Pub. L. No. 107-171, tit. II, § 2401, 116 Stat. 258 (codified at 16 U.S.C. §§ 3838n–3838q (Supp. 2003)). The CSP, authorized in 2002, pays farmers and ranchers for ongoing environmental stewardship on working lands and provides financial incentives for them to adopt additional conservation practices, focusing on farmers and ranchers who are proactively engaged in natural resource and environmental conservation and stewardship practices that go above and beyond addressing current environmental problems and regulations. *Id.* tit. II, §§ 2001-2006, 116 Stat. 223 (codified as amended at 16 U.S.C. § 3838a (Supp. 2003)). CSP payments totaled $206 million in 2005.

Finally, the FEP, established in 2002 and replacing two earlier forestry conservation programs, provides cost sharing funds to non-industrial forest owners who develop and follow a plan for sustainable forest management. *Id.* tit. VIII, § 8002, 116 Stat. 468 (codified at 16 U.S.C. § 2103 (Supp. 2003)). Similar programs exist in other countries, such as Costa Rica and Mexico, which authorize payments to individual forest landowners to follow certain land conservation practices. *See* Daily & Ellison, *supra* note 23, at 165–88.

about the difficulties of obtaining efficient levels of funding, it is unlikely that the programs will be funded at an economically efficient level. In any case, funds are generally insufficient to enroll all parties wishing to participate, and the programs use a variety of mechanisms for selecting properties for participation and determining the payment amount and have gradually moved toward more sophisticated methods of selecting properties for participation as a way to improve the efficiency of use of available funds. This may involve comparing potential participants on the basis of the environmental benefits that participation would yield, the costs of enrolling the property, or both. For example, landowners wishing to participate in CRP now prepare a bid that includes both the benefits that enrollment would provide—based on onsite characteristics such as the slope and soil type of the property as well as offsite benefits such as downstream erosion avoided or wildlife habitat improved—and the rental payment that they require for participation. These benefit and cost features are used to compute an environmental benefit index (EBI), a crude B-C estimate, which CRP administrators then use to rank proposals for selection, providing the greatest net benefit for the available funds.

3. *Government Buyer, Government Seller*

Governments may also pay (or subsidize) other governments to help provide and protect ecosystem goods and services. For example, the U.S. Environmental Protection Agency provides funds to local governments to assist with development of wastewater treatment plants that help to protect surface water and groundwater quality. The U.S. Agency for International Development provides funds to foreign government entities to foster resource conservation and environmental protection in their countries.

In the United States, situations where local or state governments pay the federal government to provide and protect ecosystem goods and services are uncommon, although such payments may make sense. For example, a city may rely for its water supply on water flowing from a national forest. The national forest may not have sufficient funding to remove forest fuels to the extent necessary to significantly lower the risk of serious wildfire. Such a wildfire could result in a decrease in water quality, which in turn could impose costs on the city.[66] It may make sense in such a case for the city to contribute toward the costs of fuel treatment. For non-excludable ecosystem services, government-to-government payments are feasible because governments are the proper entities to provide such goods.

66. *See, e.g.*, U.S. DEP'T OF AGRIC., FOREST SERV., ROCKY MTN. RES. STATION, HAYMAN FIRE CASE STUDY 333 (Gen. Tech. Rep. RMRS-GTR-114 (rev. 2003)) (listing costs imposed on the Denver Water Board following the Hayman fire), *available at* http://www.fs.fed.us/rm/pubs/rmrs_gtr114.pdf.

4. Individual Buyer, Individual Seller

There is much current interest in providing and financing ecosystem services through new private markets characterized by individual-buyer, individual-seller transactions.[67] Mechanisms where individuals pay individuals include both familiar markets for rival, exclusive ecosystem goods such as timber and mineral resources, nontraditional arrangements to protect ecosystem services, and cap-and-trade markets where permits or credits are traded.

Self-organized private markets and transactions with minimal government involvement (except to establish and enforce property rights and agreements) typically organize production and distribution of rival, exclusive goods. As mentioned above, such markets have existed for many years for many of the ecosystem goods listed in Table 1, ranging from global markets for crude oil, timber, precious gems, and wildlife-related products (e.g., furs, ivory) to local markets for water and some forms of commonly available recreation. Some of these markets are very competitive, but others, sometimes called "thin markets," lack a sufficient number of buyers or sellers to be considered competitive.[68]

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67. For a recent popular book on the use of market mechanisms to protect and pay for ecosystem services, see DAILY & ELLISON, *supra* note 23, at 19-34. Daily and Ellison describe the Katoomba Group, a dedicated, informal group of people from academia, government agencies, and private business who share a vision of a world where ecosystem services are bought or sold in economic markets akin to the New York Stock Exchange. The Katoomba Group has helped to launch a web site with the purpose of facilitating ecosystem service markets by providing a clearinghouse for information on prices, regulation, science, and other issues related to ecosystem markets at www.ecosystemmarketplace.com. *Id.* Other authors are more cautious on the prospect of markets for ecosystem services, considering economic efficiency, sustainability, and equity issues. *See generally* Landell-Mills, *supra* note 51; Jim Salzman, *The Promise and Perils of Payments for Ecosystem Services*, 1 INT'L J. INNOVATION & SUSTAINABLE DEV. 5, 9-16 (2005) (exploring "disturbing policy implications" of ecosystem service markets).

68. The global market for crude oil is considered an uncompetitive market with relatively few sellers and many buyers. Some of the relatively few sellers in the global market for crude oil have formed a powerful cartel (OPEC) that can control the world supply and price of crude oil. The uncompetitive nature of the global crude oil market leads to economic inefficiency in the provision and price of crude oil (e.g., supply is lower and price is higher than they would be in a competitive market). The global market for timber is considered a competitive market with many sellers and buyers; no single block of buyers and sellers currently controls world supply and price of timber. Thus, provision and price of timber will be more economically efficient. *Compare, e.g.*, Mehdi Noorbaksh, Foreign Pol'y Ass'n, Analysis: The Price of Oil, http://www.fpa.org/topics_info2414/topics_info_show.htm?doc_id=436343 (last visited Feb. 27, 2007); U.S. Dep't of Energy, Energy Info. Admin., International Energy Outlook 2006, http://www.eia.doe.gov/oiaf/ieo/oil.html (last visited Feb 27, 2007) (OPEC production decisions determine prices) *with* BRENT SOHNGREN, AN ASSESSMENT OF FOUR LARGE SCALE TIMBER MARKET MODELS 3 (1998), http://www-agecon.ag.ohio-state.edu/people/sohngen.1/forests/modcomp.pdf ("prices will equilibrate demand and supply").

Established markets with self-organized private transactions exist for many recreational opportunities, including those for hunting, fishing,[69] and whitewater rafting.[70] To take hunting as an example, private markets have existed for hunting opportunities for many years. The typical hunting market arrangement is one where an individual or group of individuals leases hunting rights on private land for a negotiated payment to the landowner. In some regions of the United States, there are many hunters (buyers) and many landowners (sellers) willing to lease hunting rights; thus, prices of private land hunting leases are fairly competitive. The rival, exclusive nature of markets for hunting, fishing, and rafting opportunities means that provision and price of these opportunities may be economically efficient, although lack of supply sometimes limits the number of suppliers so that prices are higher than marginal operating costs.

In recent years, markets with self-organized private transactions have developed for scenic landscapes. For example, private land trusts have been established that purchase conservation easements from private landowners to protect scenic landscapes from development. The price of a conservation easement is negotiated between the trust and the landowner. In a particular area, there are likely to be only one or few land trusts (buyers) who have the legal authority and funds to purchase conservation easements, but many landowners (sellers) who would like to sell conservation easements. Transaction costs are substantial in setting up a trust and successfully negotiating a purchase. Because of the limited number of buyers, the market for such conservation easements is likely to be uncompetitive.

Another type of individual-to-individual mechanism is that of private organizations granting funds to private individuals or groups to

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69. With respect to saltwater fishing, an individual or group of individuals may charter a boat and crew to go fishing in a saltwater bay or the ocean. There are typically many saltwater anglers (buyers) and charter boats and crews (sellers), so the price of a charter is fairly competitive. With respect to freshwater fishing, an angler may pay the owner of a private pond for the right to fish in the pond. Payment to the pond owner is usually a price per fish or per pound of fish caught. Because there are typically many freshwater anglers (buyers) and pond owners (sellers), the price per fish or pound per fish caught is fairly competitive.

70. Commercial outfitters provide white water rafting opportunities to clients who pay a fee per head to participate in a guided white water rafting trip down a river. In some parts of the United States, there are only a few commercial outfitters (sellers) and many people who would like to go rafting (buyers). In these cases, the market is likely to lack competition with resulting economic inefficiency (e.g., rafting prices will be too high and too few opportunities will be offered). Rationing of rafting opportunities by government agencies that control river access (e.g., National Park Service, U.S. Forest Service) may also limit rafting opportunities resulting in high prices. In other parts of the United States, there may be many commercial outfitters (sellers) and many potential clients (buyers). In these cases, the market is likely to be fairly competitive and economically efficient.

provide and finance ecosystem goods and services. For example, Trout Unlimited provides grants to landowners to help improve trout stream habitat, and the World Wildlife Fund provides grants to landowners to protect many different types of wildlife and wildlife habitat. Other private conservation groups provide grants to purchase land to protect unique ecosystems and biodiversity (e.g., tropical rainforests). The amount of a private grant to protect ecosystems and provide goods and services may involve some negotiation between the donor organization and recipient. Grant amounts, however, are constrained and heavily determined by the amount of money a private organization has to give. Most private organizations depend on donations from private individuals for their funding. Economic theory suggests that donation mechanisms will not provide an economically efficient level of funding for ecosystem goods and services because of free-riding.[71] Many people are unwilling to contribute toward the provision of public goods, especially if they know that others will also avoid paying—hence the role for government in enforcing payment and then providing public goods.

Self-organized private transactions for water are not common, but are occurring. Perhaps the most famous case is that of Perrier-Vittel, the bottled water company, which spent several million dollars to alter the farming practices in the watershed affecting the quality of the springs where the firm acquires its water.[72] In the western United States, 150 market sales or leases of water for environmental purposes (generally for maintaining instream flow) were reported during the period 1990 to 2003.[73] Most of these purchases were by government agencies, but 14 were by private environmental organizations, and in 13 of those cases the sellers were farmers or other private parties.

Another category of individual-to-individual transactions involves price premiums for commercial goods paid by consumers who want to encourage or reward environment-friendly production methods. These premiums are essentially donations. For example, it is now common for power companies to offer electricity customers the opportunity to pay a premium in support of wind power. The companies use the donations to cover the production cost differential between traditional thermal and wind power. The wind-generated power is fed into the electricity grid so that all customers receive a mixture irrespective of whether they paid the price premium. Price premiums often are associated with certification programs

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71. Patricia A. Champ et al., *Using Donation Mechanisms to Value Nonuse Benefits from Public Goods*, 33 J. ENVTL. ECON. & MGMT. 151, 152-53 (1997).

72. DAILY & ELLISON, *supra* note 23, at 65-66.

73. Thomas C. Brown, *Trends in Water Market Activity and Price in the Western United States*, 42 WATER RESOURCES RES. W09402, at 5 tbl.2 (2006).

warranting that the goods were indeed produced using such methods. For example, the Forest Stewardship Council certifies timber operations that follow approved production and harvesting practices, and coffee grown organically, certified as such, receives a price premium.[74] In the forestry case, the end product is essentially the same regardless of the production methods, so that the premium is totally a donation, whereas in the coffee case the consumer receives not only the satisfaction of having encouraged eco-friendly production but also may directly benefit from the improved product.

5. Cap-and-Trade Programs

A widely used approach to control negative externalities is that of cap and trade. These programs utilize permits to emit a regulated pollutant or credits that offset (i.e., mitigate or compensate for) the emission. Cap and trade is listed with individual-to-individual trades in Table 5 because permits or credits are indeed traded among individuals, but unlike the other types of individual-to-individual trades, cap-and-trade programs require substantial government involvement.

With a cap-and-trade program, a government entity (1) imposes an aggregate limit or cap on some emission or activity, (2) distributes permits for the specified amount of emission or activity and allows individuals or firms to trade the permits under certain institutional rules or allows credits to be obtained and traded that allow a specified amount of emission, and (3) monitors the emissions or activity in question and assesses a penalty if an individual's emissions exceed those allowed given their permits or credits. The ecosystem protection under such a program occurs with setting and enforcing the cap (thus cap and trade is known as a quantity-type approach). The trade part of cap and trade then allows firms in aggregate to most cost-effectively reach the cap. With permit schemes, firms that can lower their emissions at low cost do so and sell their permits to firms for which the cost of cutting emissions is higher than the cost of purchasing permits. With credit schemes, firms that desire to exceed their individual limits must purchase credits that offset the increase in emissions.

As with the price-type approach mentioned above, cap and trade relies critically on the ability to accurately monitor emissions or impacts. Monitoring may focus on outputs (e.g., SO_2 leaving power plant smoke stacks), inputs (e.g., quantity purchased of a certain pesticide), or change in environmental conditions (e.g., acres of wetland of a certain quality). Many factors affect the feasibility of cap and trade and the choice of monitoring strategy, including the availability of measurement technology and the

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74. DAILY & ELLISON, *supra* note 23, at 112 (timber); Julie Grossman, Coffee FAQ, http://people.cornell.edu/pages/jmg225/coffee.html (last visited Feb. 27, 2007).

number and locations of emissions or changes.[75] Cap and trade also relies on the government's willingness and ability to assess penalties for noncompliance.

Cap and trade is being used in several important programs, including the U.S. effort to control acid rain by limiting SO_2 emissions.[76] Fossil fuel electric power plants are issued permits by the U.S. EPA for a certain amount of SO_2 emissions. The initial cap was set in 1995 for the eastern United States; in 2000 the program was extended to the rest of the United States. The permits may be traded among the utilities, either in private transactions or during a government-sponsored auction. Compliance is encouraged via a penalty per ton of emissions that exceed the permitted level.

One of the most well-established cap-and-trade credit markets in the United States involves wetland mitigation banks. Conversion of wetlands to non-wetlands (e.g., draining wetlands for development) is regulated under section 404 of the Clean Water Act. In 1989 President H.W. Bush capped wetland losses with a policy of "no net loss." The no-net-loss policy for wetlands stipulates that if development of a property causes the loss of wetlands, the developer must mitigate the loss by providing new wetlands or enhancing an existing wetland. The no-net-loss policy precludes the issuance of tradable permits but creates a role for credits. The new wetlands do not have to be on the same property. The task of finding a new wetland is facilitated by wetlands banks, which are large constructed wetlands created for the purpose of providing future offsets for developers.[77] Wetland banks are available in all states of the United States.[78] Credits in a wetlands bank are created when a person or business creates new wetlands and sells the credits to the bank. Interaction between buyers and sellers through the wetlands bank generates a market price for

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75. *See* Inho Choi, *Global Climate Change and the Use of Economic Approaches: The Ideal Design Features of Domestic Greenhouse Gas Emissions Trading with an Analysis of the European Union's CO_2 Emissions Trading Directive and the Climate Stewardship Act*, 45 NAT. RESOURCES J. 865, 902 (2006).

76. *See generally* Robert N. Stavins, *Lessons Learned from SO_2 Allowance Trading*, 20 CHOICES 53 (2005); Robert N. Stavins, *What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading*, 12 J. ECON. PERSPECTIVES 69 (1998).

77. *See generally* Leonard Shabman & Paul Scodan, *The Future of Wetlands Mitigation Banking*, 20 CHOICES 65 (2005). A no-net-loss program could also operate without a bank or market for credits. Absent those aids, the developer would have to mitigate the wetland loss by directly creating a wetland (and perhaps buying the land on which the new wetland would sit) or paying another landowner to do so. The purpose of the bank is to lower the cost of complying with the no-net-loss policy by lowering the cost of finding a viable wetland credit possibility.

78. Alan Randall & Michael A. Taylor, *Incentive-Based Solutions to Agricultural Environmental Problems: Recent Developments in Theory and Practice*, 32 J. AGRIC. & APPLIED ECON. 221, 226 (2000).

wetlands credits. Although there may be many buyers (developers) for wetland credits, typically there are few sellers (suppliers of new wetlands), so markets for wetlands credits tend to be less than competitive.

Cap-and-trade markets also include the emerging international market for carbon initiated by the 1997 Kyoto Protocol.[79] The Kyoto Protocol created scarcity for carbon emission permits when signatory countries agreed to reduce their emissions. The protocol allows a market that essentially combines permits with credits. In a country with a binding carbon cap, if a new business activity generates carbon emissions that would cause the cap to be exceeded, these new emissions must be balanced either by purchasing emission permits from other parties or by obtaining credits. Credits can be earned by reducing carbon emissions somewhere else (perhaps by assisting another party to improve energy use efficiency) or creating a sink that will sequester carbon (perhaps via reforestation). Because rising atmospheric carbon is a global problem, trading may occur across countries. Specific rules, called the Marrakesh Accords, were recently agreed upon among Kyoto signatories for operation of carbon credit markets.[80]

Another type of cap-and-trade market is that for transferable development rights (TDR). In the United States, TDR programs are typically implemented at the county level, where the county government places a cap on development in the county through land use planning and regulations. In one approach, a development located in a designated high-density area would need to purchase development rights from a low-density development area, such as an area of farms and open-space that provide ecosystem goods and services. The purchase of development rights from the low-density area keeps that area in low-density development. The price of development rights is determined by interaction between buyers and sellers with government oversight. Of course, as with other markets, for a TDR market to approach the level of economic efficiency possible in a purely competitive market, there must be many buyers (developers) and sellers (land owners willing to give up development rights on their land for a price).

D. Likelihood of Market Exchange

Much of the current interest in developing markets for ecosystem goods and services is driven by the desire to move provision and financing

79. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 22 (U.N. Doc. FCCC/CP/1997/L.7/Add.1), *available at* http://daccessdds.un.org/doc/UNDOC/LTD/G98/601/15/IMG/ G9860115.pdf?OpenElement.

80. Odd Godal & Ger Klaassen, *Carbon Trading Across Sources and Periods Constrained by the Marrakesh Accords*, 51 J. ENVTL. ECON. & MGMT. 308, 308 (2006).

of ecosystem goods and services away from mechanisms with heavy government involvement toward those relying less on governments and more on private market exchange (e.g., individual-to-individual transactions). We summarize the potential for private market exchange of ecosystem goods and services by considering a selection of these goods and services in light of some of the major conditions for market exchange (Table 6). Ecosystem goods—including, for example, oil, timber, water for diversion, and developed recreation opportunities—tend to be measurable, excludable, and rival. Further, confidence is high that exchange contracts will be enforced and, with the exception of water for diversion (which requires complicated monitoring), their exchange tends to incur relatively low transaction costs. Thus, as indicated in Table 6, the likelihood of market exchange with minimal government involvement for many ecosystem goods is relatively high. Where these goods present problems is with externalities. For example, use of oil leads to air pollution and global warming, harvest of timber alters habitats and lowers scenic beauty, at least in the short-run, and downstream water users bear the cost of upstream diversions.

Dispersed recreation opportunities on public land are an unusual ecosystem good in that such opportunities are typically not excludable without substantial effort. Attempts to charge people for taking advantage of dispersed recreation would incur substantial transaction costs in the form of administering the exclusion policy. Thus, as indicated in Table 6, the likelihood of market exchange with minimal government involvement is fair to poor.

Ecosystem services, assuming that they are enjoyed beyond the specific property where they originate, show a decidedly different pattern from ecosystem goods (Table 6). Negative externalities are largely absent with ecosystem services.[81] However, on all other criteria the services do not easily lend themselves to market exchange. They typically are non-excludable and non-rival and thus require some government involvement if markets are to be established and sustained. Further, the task faced by the government agencies would be formidable and expensive due to the difficulty of defining and measuring the services and monitoring compliance with any scheme established for protection and marketing.

Consider, for example, water purification and flood mitigation in the context of wetland protection. Wetlands both purify water and help mitigate floods. Lack of excludability from the benefits of wetlands led to government involvement in wetland protection. Federal, state, and local

81. Negative side-effects of ecosystem services, although generally minor, may exist, including, for example, bee stings during natural pollination and the presence of bothersome species as part of biodiversity maintenance.

Table 6. Likelihood of Market Exchange for Ecosystem Goods & Services (♦♦♦ = good, ♦♦ = fair, ♦ = poor)

Selected ecosystem goods and services	Selected conditions for market exchange: Clear definition & measurement	Excludability	Low transaction costs	Lack of negative externalities	Rivalness	Many buyers & sellers
Goods						
Oil	♦♦♦	♦♦♦	♦♦♦	♦	♦♦♦	♦♦
Timber	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦
Game Fish & Wildlife	♦♦	♦♦	♦♦	♦♦	♦♦♦	♦♦
Water flow for diversion	♦♦♦	♦♦	♦	♦	♦♦♦	♦♦
Developed recreation opportunities	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦
Dispersed recreation opportunities on public land	♦♦	♦	♦	♦♦	♦♦	♦
Services (assumed to extend beyond an individual property ownership)						
Water purification	♦	♦	♦	♦♦♦	♦	♦
Erosion control	♦♦	♦	♦	♦♦♦	♦	♦
Flood mitigation	♦♦	♦	♦	♦♦♦	♦	♦
Pollination	♦♦	♦	♦	♦♦♦	♦♦	♦
Climate regulation via carbon sequestration	♦	♦	♦	♦♦♦	♦	♦
Biodiversity maintenance	♦	♦	♦	♦♦♦	♦	♦
Protection from the sun's UV rays	♦♦	♦	♦	♦♦♦	♦	♦
Moderation of temperature extremes	♦	♦	♦	♦♦♦	♦	♦
Maintenance of regional precipitation patterns	♦	♦	♦	♦♦♦	♦	♦

governments have responded with both subsidies (e.g., the federal Wetlands Reserve Program) and regulation (e.g., the U.S. no-net-loss policy). Regarding the no-net-loss policy, difficulties in defining wetlands have led to failures to comply with the policy and to expensive court cases over the extent of federal control.[82] Difficulties in measuring and monitoring the functions provided by a wetland have led to uncertainty about whether constructed wetlands are sufficiently mitigating natural wetland loss.[83] The complex administrative tasks of inspecting each wetland proposed for conversion and monitoring compliance with the policy, plus the burdens imposed on developers who must understand and determine how to comply with the regulations, result in high transaction costs. The WRP incentive program is also not without its difficulties, as it also faces the problems of definition and measurement, and the expense of monitoring.

We mention some of the difficulties with market exchange of ecosystem services not to discourage government involvement in helping to establish such market or market-like exchange, but rather to highlight the need for adequately funding whatever program is instituted, and thus also to note the importance of verifying beforehand that the benefits of a government program are worth the costs. Ecosystem goods and services with fair to poor potential for market exchange, indicated in Table 6, will require more intensive government involvement and expense to establish and sustain market or market-like exchange mechanisms.

VI. CONCLUSIONS

We have defined and characterized ecosystem goods and services, described why they are of economic value, briefly reviewed methods for quantifying that economic value, and examined the prospects for provision and marketing of ecosystem goods and services. We stress that ecosystem goods and services are those that arise "naturally" from natural capital, with little human input other than the effort to protect the ecosystem from degradation, that ecosystem goods and services are distinct from the underlying ecosystem processes upon which the goods and services rely, and that as our understanding of ecosystem processes improves we may add to the list of ecosystem services.

Ecosystem goods and services improve human well-being by either directly or indirectly affecting our utility. Indirect effects occur as ecosystem goods and services serve as inputs in the production of other goods or services of value to humans. The direct effects on human well-being often can be monetized using stated preference techniques such as contingent valuation and attribute-based methods, or the replacement cost approach.

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82. *See generally* Jonathan H. Adler, *Wetlands, Waterfowl, and the Menace of Mr. Wilson: Commerce Clause Jurisprudence and the Limits of Federal Wetland Regulation*, 29 ENVTL. L. 1 (1999).

83. Randall & Taylor, *supra* note 78, at 226. The approach used to compensate for the difference between the lost wetland and substitute wetland has been to use roughly estimated mitigation ratios specifying how many acres of constructed wetlands are needed per acre of natural wetland loss.

The indirect effects on human well-being are more likely to be quantified using production function or replacement cost methods. An important economic issue that these methods can help with is the quantification of the costs of loss or degradation of ecosystem goods and services, as foreknowledge of these costs may show that ecosystem protection is the more efficient social choice.

As ecosystem goods and services become scarcer, the values of most will increase. The rising scarcity and value of ecosystem goods and services will enhance opportunities for their provision and marketing, assuming that proper legal frameworks and marketing mechanisms exist. Marketing is particularly likely for ecosystem goods and services from which the owner can exclude non-payers and therefore fully capture the revenues associated with supplying the goods and services. However, many ecosystem goods and services, especially services, are non-excludable, and also non-rival. For these ecosystem services, like maintenance of habitats, it will be difficult, if not impossible, for private competitive markets to emerge that will efficiently supply them. With non-excludable and non-rival ecosystem goods and services, if the benefits of protecting the natural capital outweigh the costs, public financing through taxes may be necessary to ensure an optimal protection of the natural capital upon which an efficient supply of ecosystem goods and services depends. We survey several such public markets in which the government pays individual landowners or other governments for ecosystem goods and services.

The increasing scarcity of ecosystem goods and services will also lead to the development of additional substitutes. Generally, opportunities for developing adequate substitutes are greater for ecosystem goods and services that are inputs to the production of other goods and services; the likelihood of providing adequate substitutes for others, especially those ecosystem services that enter the utility function directly, is much lower. A key question before society and policy makers today is whether the human creativity and vigor that threatens the natural capital upon which ecosystem goods and services depend can be harnessed to design institutions and incentive mechanisms to maintain natural capital and ecosystem goods and services into the future. The growing awareness of the importance of ecosystem goods and services, not only among scientists but also among policy makers, offers hope that effective policies will be forthcoming.