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Ecosystem Services: A 21st Century Policy Challenge

Steven E. Kraft

In the 31 years since Walter E. Westman (1977) published "How much are nature's services worth?" there has been extensive research into the nature of ecosystem services, the ways in which past and existing public policies influence the viability of ecosystem services, the valuation of such services (see NRC 2005), and the challenges of developing markets in which ecosystem services are traded (see Forest Trends 2008). While the scientific literature reporting this research is also extensive and found in the journals of a number of fields, ecological and economic, the informed discussion about ecosystem services by the lay public and policymakers is just beginning.

Notwithstanding these early discussions, in its proposal for the 2007 Farm Bill, the Bush Administration included a program for a "market–based approach to conservation" structured around environmental benefits (i.e., ecosystem services) produced by rural landscapes (USDA 2007). In the final version of the 2008 Farm Bill approved by Congress over the president's veto, the USDA is directed "to establish a framework to measure environmental service benefits from conservation and land management activities" as well as to focus on carbon markets for producers (U.S. Senate 2008); both are references to ecosystem services and rural lands.

While many in the research and academic communities are conversant about the nature of ecosystem services, the same cannot be said for those who are and will be impacted by them: landowners and operators, farmers, local agency personnel, policy designers and implementers, congressional staffers, and the members of the general public whose welfare is tightly bound to the continued vitality and availability of a diverse range of ecosystem services (MEA 2005). In the following papers, the authors provide an introduction to ecosystem services and the policy challenges they provide for the 21st century.

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In his article, Scott Swinton describes agriculture as a managed ecosystem. As a consequence, agriculture has great potential to generate a broad mix of ecosystem services, going beyond the traditional agricultural commodities of food, fiber and biofuels. However, Swinton points out that a better understanding is needed of how ecosystem services can be produced, measured and valued in order to design policy incentives to assure a for greater supply. J.B. Ruhl points out that landowners have incentives to maximize the production of food, fiber, and energy commodities, but little incentive to provide flows of ecosystem services that benefit other lands and members of the public. Ruhl raises the question whether a renewed focus on agricultural multifunctionality using ecosystem services as its fulcrum can lead to new ideas about how to strike a more socially optimal balance for agricultural production: traditional commodities and ecosystem services. Rhonda Skaggs describes how the awareness of the broad array of ecosystem services from rangelands has grown in recent years. Rangelands are primarily viewed as contributing to human welfare through primary production and provisioning services; however, these lands also provide regulating and cultural services. Skaggs points out that rigorous economic analysis of nonprovisioning rangeland ecosystem services remains elusive. Stephen Polasky in his paper points out that while nature provides a range of goods and services of value to people, these ecosystem services may not be provided optimally both because of the lack of information and because of public goods problems. Consequently, economists need to work closely with natural scientists to understand the ecological production functions determining the provision of ecosystem services, apply valuation techniques to generate estimates of the value of ecosystem services, and design policies to internalize externalities and provide correct incentives for the provision of ecosystem services. Stephen Swallow, Elizabeth C. Smith, Emi Uchida and Christopher M. Anderson argue that while governmental and philanthropic actions have been useful for managing the environment and conserving some ecosystem services, little work has been doneto link people's individual values for ecosystem services directly into the economy. The authors show how experimental economics could be used to develop new, market approaches based on demand-side values for ecosystem services, which could stimulate entrepreneurship built around ecosystem services. The authors conclude with an preliminary look at an experimental ecosystem service market for grassland nesting birds on farms.

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Reimagining Farms as Managed Ecosystems

Scott M. Swinton

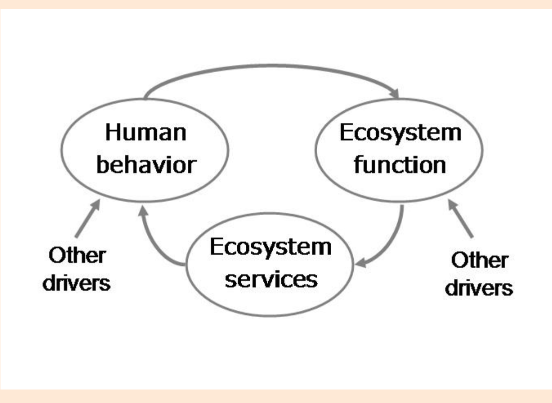
JELclassifications: Q57, Q51, Q12

How scientists perceive people and nature to interact is changing. These changes will likely transform how we perceive farming. Along the way, they are reshaping the research agenda for agricultural and environmental economists. In short order, farmers will be faced with dramatically different management opportunities.

Farming began as a means to produce food more reliably than hunting and gathering. Over time, the scope of farming expanded to fiber and fuel crops. The historic focus on producing goods has led most farmers to view themselves as "producers." While this role will not change, new roles are becoming available as providers of more diverse ecosystem services than food, fiber and fuel.

Broadly speaking, "ecosystem services" are the valued services that people get from nature (Daily, 1997) (Figure 1). They encompass four broad areas (Millennium Ecosystem Assessment, 2005):

Figure 1. Ecosystem services link people and ecosystems



- Provisioning services include food, fiber, wood, fuel and fresh water that provide for human subsistence.
- Regulating services maintain the balance of the Earth's systems at levels that enable human survival. These services include climate, flood, water quality and disease regulation. Examples include vegetation that buffers the effects of natural flooding, or predator–prey systems that limit the spread of pathogens.
- Cultural services include the spiritual, inspirational, aesthetic, heritage, recreational and tourism benefits.
- Supporting services include the myriad natural systems that enable the three tiers above. For example, organic matter cycling contributes to soil creation, which makes food provisioning possible. Photosynthesis transforms solar energy into plant matter, enabling provisioning services, carbon cycling, and various other services.

The idea of ecosystem services transforms the way we think about nature in three ways. First, when viewed as a web of ecosystems, nature is no longer a background resource, but rather a system that can malfunction. Second, the idea of service flows implies a need to maintain the capital base that produces those services. Last, and most important, "ecosystem service" expresses a link between people and ecosystems whereby people enjoy benefits from ecosystems—but also influence their functioning.

Agriculture as Managed Ecosystem

From an ecological perspective, agriculture is an ecosystem that is frequently disturbed to favor desired products. Tillage and herbicides prevent competition from undesired weeds. Veterinary care and housing protect livestock from pathogens and predators. What ecologists call "human disturbance" agriculturalists call "management." But farmers who manage those ecosystems influence flows of many ecosystem services, whether they think about it or not. Herein lie opportunities for farmers and society at large, by perceiving the larger role of agricultural ecosystems. The opportunities are many, for crops and pasture already occupy roughly half the Earth's land area that is not barren rock, desert or permafrost (Millennium Ecosystem Assessment, 2005), and farmland is expanding.

New opportunities for farmers to manage for ecosystem services are emerging from recent research (Swinton, Lupi, Robertson and Landis, 2006). Two specific examples come from pest regulation and climate regulation.

Managing habitat for pollinators and the natural enemies of agricultural pests can enhance farm food, fiber and fuel production. Pollination and the regulation of pests and diseases are two natural ecosystem services. Like food production, they can be enhanced by management. While many farmers rely on the European honey bee for commercial pollination, native bees and other pollinators also play important roles (National Research Council, 2006). Habitat essentials typically involve a nearby landscape with suitable nesting sites and a sequence of flowering plants for food to keep the pollinators from migrating elsewhere. The natural enemies of agricultural pests have shown the ability to suppress potentially damaging populations of such invasive pests as soybean aphid. Their habitat needs are similar, though their food requirements are not.

Farming can play a major role in climate regulation, both by limiting emissions of greenhouse gases and by sequestering carbon in plants and soil (Robertson, 2004). Agriculture generates two particularly potent greenhouse gases. Methane, from rice paddies, manure and livestock digestion, has a global warming potential of 21 CO2 carbon equivalents. Nitrous oxide has over 300 times the global warming potential of CO2. It is generated by excess mineral nitrogen, particularly from heavily fertilized crop fields. More livestock waste management, fertilizer application and efficient machinery use can mitigate these ecosystem disservices. Sequestration of carbon into agricultural soils through no–till farming and production of biofuel crops that remove CO2 from the atmosphere as they grow can directly reduce global warming potential.

Other opportunities abound for farmers to manage for ecosystem services, from wildlife habitat to water quality to aesthetic landscapes.

Value of Ecosystem Services

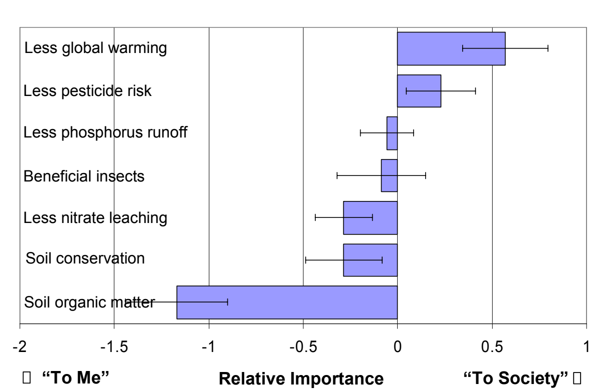
Why would farmers bother to provide ecosystem services that lack markets? To be sure, certain ecosystem services contribute to private profitability, but others do not. In 2007 focus group interviews, Michigan crop farmers identified increased soil organic matter as offering private benefits to their farms, but found reduced global warming to chiefly benefit society at large (Figure 2).

Of course, if there are clear benefits to society at large from ecosystem services that lack markets, then policymakers have justification to create incentives that stimulate more supply. In order to make such incentives operational, four steps are needed, 1) understand how humans can affect the production process for ecosystem services, 2) find cost–effective ways to measure those services, 3) estimate the value of ecosystem services to humans, and 4) design policies that fit both the environmental setting and existing legal institutions.

Agricultural ecosystems offer special opportunities to generate other ecosystem services as joint products along with food, fiber or fuel production (Wossink and Swinton, 2007). Hence, costs of providing joint ecosystem services can be much lower than if they were produced alone. Understanding how agricultural practices affect ecosystem functioning and generate ecosystem services is highly complex. For management purposes, performance indicators are needed that track high–priority ecosystem service in a cost–effective way across space and time (Dale and Polasky, 2007).

The valuation of ecosystem services that lack markets can be viewed from two perspectives: what consumers would be willing to pay for it, or what producers would be willing to accept to supply it. Many techniques exist to estimate consumer willingness to pay, including responses to questions about hypothetical purchases and calculations based on what consumers already spend. In the latter category, for example, expenses made to travel to a distant site for fishing or hiking can be used to estimate the value of the

Figure 2. Farmer ratings of the relative importance of the environmental benefits "to me" (negative) versus "to society" (positive), 34 Michigan farmers, 2007. (Likert scale paired difference t–test error bars = 1 std error).



fishery or the aesthetic ecosystem services. Land prices can be analyzed to infer the values of ecosystem services in the vicinity. Producers' willingness to accept payment in exchange for providing ecosystem services can be estimated from the implied costs due to changes in farming costs and foregone crop revenues. Because farm locations vary in potential commercial productivity and potential abundance of ecosystem services, farmers' willingness to supply ecosystem services will vary from place to place (Antle and Valdivia, 2006). These methods are discussed in greater detail in a recent special section of the journal, Ecological Economics, devoted to the topic, "Ecosystem Services and Agriculture" (Swinton, Lupi, Robertson and Hamilton, 2007).

Incentives for Farmers to Provide Ecosystem Services

If we understand how ecosystem services are produced, how to measure them, and what they are worth to consumers and producers, then incentives for their provision can be designed. Incentive programs can be divided between government programs and private sector ones. U.S. farm policy has a history of cost–share support for clearly observable practices, such as soil conservation investments, and land retirement policies, such as the Conservation Reserve Program. In the 2002 farm bill, the Conservation Security Program created payments for environmental stewardship.

Private sector activities include business–to–business payments and markets for pollution credits (Kroeger and Casey, 2007). One rapidly developing example of a market for pollution credits is the global carbon market. The Chicago Climate Exchange has developed rules for buying "carbon management offsets" from U.S. farmers whose use of reduced tillage practices can sequester atmospheric carbon in soil (Chicago Climate Exchange (CCX), 2007). Payment levels are very modest at present ($2–3/acre/year for 5–year commitments on the most productive lands). Related offset payments are available for livestock farmers who collect and burn methane, so that it is not released into the atmosphere. If international agreements to limit global warming become more binding—especially if the United States joins in—then opportunities for farmers to profit by providing climate regulation services are likely to grow in number and value.

Business–to–business payments for environmental services are also developing, particularly linked to water markets (Pagiola, Bishop and Landell–Mills, 2002). In most successful programs, such payments have compensated farmers or foresters for maintaining vegetative cover so as to protect drinking water supplies. More recent efforts are underway to pay for more diverse ecosystem services, such as biodiversity and soil conservation.

Biodiversity conservation is particularly challenging for policy design, because it often calls for coordinated action among multiple landowners. Many large mammals and migratory species require contiguous habitat over large areas. Recent research involving experimental games has shown that land owners can rapidly learn to cooperate if offered policy incentives that favor cooperating by agglomerating contiguous habitat (Parkhurst and Shogren, 2007).

Demand for Research on Economics of Ecosystem Services

Because so many ecosystem services have intrinsic value yet lack markets, scientists and policy makers are keen to see economic measures of their value. The twin challenges of lucid communication and sound economic methodology are formidable. Scientists and policy makers would like clear numbers, while economists want to explain that "it depends" on various parameters. Can economists meet these twin challenges? Ecosystem services pose broad, complex valuation problems, but the benefit transfer literature has progressed impressively in recent years (Wilson and Hoehn, 2006).

Research opportunities on the economics of ecosystem services are proliferating. A growing consensus among science research administrators seeks to fill a perceived void in research efforts on multidisciplinary problems, notably those associated with global change. The National Science Foundation has just converted a temporary initiative into a permanent program in Coupled Natural and Human Systems—its first such multidisciplinary program. It is currently evaluating follow–on ideas for its successful initiative in Human and Social Dynamics. New opportunities in these areas involve multidisciplinary teams, especially focused on socioecological research.

Rethinking farming as ecosystem management offers fresh and promising ways to imagine contributions from agriculture. Agriculture's history as a managed ecosystem and its scale, coupled with society's growing needs for a broad mix of ecosystem services, create a formidable research and policy agenda. That agenda calls for multidisciplinary research into how farmers can produce a wider range of ecosystem services, what those services are worth, and what policy designs could effectively induce more such services to be provided. Successful answers will capitalize on the unique productive potentials of diverse ecosystems using incentives tailored to fit farmers' objectives, resources and property rights. The challenge is great, the rewards as well.

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Farms and Ecosystem Services

J.B. Ruhl

JEL Classifications: Q57, K32, Q18,Q01, Q32, Q38.

Over the past decade two themes have emerged as organizing principles in natural resources policy. One, ecosystem management, builds a framework for landscape–level decision making (Christensen et al. 1996). The other, ecosystem services, opens a new dimension for thinking about what we hope to achieve through ecosystem management (Daily 1997; Costanza et al. 1997). The convergence of these two themes has become a driving force behind the concept of agricultural multifunctionality, the idea that farms can have multiple outputs—not just commodities—and thus can contribute to several societal objectives simultaneously (Jordan et al. 2007; OECD 2001).

Agriculture has been engaged in ecosystem management since long before the term came into the natural resources policy lexicon. Farms alter and then manage ecological processes and functions on small and large scales. In so doing, farms reconfigure ecological attributes to maximize what are known as *provisioning services*—the food, fiber, energy, and other commodities supplied by nature (Millennium Ecosystem Assessment (MEA) 2005). Farms manage these provisioning services to optimize on–site farm production, often at the expense of off–site environmental conditions. Farms are associated, for example, with soil erosion, nutrient and pesticide runoff, and groundwater depletion (Ruhl 2000; Vitousek, Mooney, Lubchenco and Melillo 1997).

Another off–site impact of farming heretofore little noticed, however, is the depletion of *regulating services*. These are the economically beneficial results of ecosystem functions that modulate ecological conditions, such as gas sequestration, water recharge, pollination, temperature and humidity regulation, and stormwater adsorption (Millennium Ecosystem Assessment 2005). Unlike provisioning services, the market value of which is embedded in commodity prices and thus easily measured and monitored, regulating services tend to behave more like nonmarket public goods (Costanza and Farber 2002). Farms thus have all the incentive to optimize provisioning services available to them, but little incentive to provide regulating services that benefit other lands (Swinton, Lupi, Robertson and Landis 2006). The question is whether a renewed focus on agricultural multifunctionality using the balance between provisioning and regulating services as its fulcrum can lead to new ideas about how to strike a more socially optimal balance for agricultural production (Abler 2004; Dobbs and Pretty 2004; Smith 2006). This essay outlines the factors that must be considered as that conversation unfolds.

A Framework for Thinking about Farms and Ecosystem Services

In *The Law and Policy of Ecosystem Services* (2007), Steven Kraft, Christopher Lant, and I build an analytical framework for identifying obstacles to socially optimal management of ecosystem services and designing effective policy responses. The framework moves through three stages. First, place the problem in its ecological, geographic, and economic contexts. Second, examine and assess the capacity of existing property rights, regulations, and social norms. Third, identify policy drivers and models, the trade–offs of different policy approaches, and the instruments and institutions that are well suited to transition to new policy designs. The question of whether and how farms can move to new ecosystem service production frontiers presents an opportunity for application of our framework.

Context

Farms, individually and in working agricultural landscapes, have ecological, geographic, and economic attributes that influence the stream of ecosystem services they manage and provide. In this respect farming is perhaps the classic case study of the obstacles society faces in designing policy around the goal of yielding appropriate flows of regulating ecosystem services.

Almost nothing takes place on a farm without ecological impacts somewhere else. In this respect a farm is like any other ecological unit—changes in one ecosystem usually affect other ecosystems, however we draw the boundaries. But as highly managed ecological units, farms significantly tilt the production frontier for ecosystem services toward provisioning services and away from regulating services (MEA 2005; OECD 2001). Ecological practices at a cornfield are designed to produce corn efficiently within the relevant regulatory environment. Putting aside the question whether regulation of farms has established appropriate environmental performance baselines (Ruhl 2000), unless paid to provide regulating services such as carbon sequestration, one would not expect to find significant flows of off–site regulating services from farms except as incidental to management of provisioning services. Hence, the ecological context for agriculture with respect to ecosystem services is that we need to know more about the geographic and economic contexts before we can assess the prospects of realigning the ecological profile.

Agriculture presents a difficult geographic scenario for purpose of developing generalized strategies for ecosystem services. Farms are numerous, dispersed, come in all sizes, and produce many different commodities under many different climate and landscape conditions. Farms also manage ecological resources for relatively small spatial scales (the farm) and short temporal scales (the next harvest). The focus on optimizing on–site provisioning services also tends to sever farms and larger agricultural landscapes from surrounding ecological resources. Managing ecosystem services sustainably, by contrast, requires multi–scalar approaches that integrate connected ecological units across space and time (Holling, Gunderson and Peterson 2002).

These geographic disconnects strongly influence the economics of farming and the bias toward provisioning services. The payoff for providing regulating services, assuming some mechanism for compensation, is likely to be marginal compared to commodity production or, worse, selling to urban development interests. In the absence of any compensation, economically rational farmers will not provide free regulating services to off–site lands unless doing so is incidental to optimization of on–site commodity production or is forced by regulation (Daly and Farley 2003). Promoting farm multifunctionality, therefore, is a balancing exercise between providing farms the flexibility to continue benefiting from their skill at managing provisioning services on the one hand, and providing the impetus to produce more regulating services for society on the other. Moreover, market distortions from subsidies, which have promoted intensive production on marginal and environmentally sensitive lands, have made it only that much more difficult to integrate ecosystem service values into agricultural production decisions. Society cannot assume that the flow of regulating services off of farms (or any land for that matter) will continue to be provided for free, lest they not be provided at all, nor can we expect farmers to forego the incentives the collection of production and insurance subsidies deliver. Ideally, the economics of farming, including market distorting subsidy policies, can be worked on to change the flow of services, rather than forcing the issue through command–and–control regulation.

Existing Capacity

Farms are often portrayed in policy circles as the "first stewards of the land." As noted above, however, what this really means is that agriculture has done a very effective job at stewarding land for provisioning services, and the evidence is that this has come at considerable cost to not only the environment, but also the supply of regulating services to society. The negative environmental externalities of farms, though well documented to be significant and pervasive, have persisted for decades even while other polluting industries have been subjected to intense social pressures to change (Ruhl 2000). This legacy will make it all the more difficult to overcome the associated effect that farms are depleting regulating services of tremendous value to society.

To a large extent we are in this position as a result of an even longer history of the development of property rights in such a way as to deter the production of regulating services. Although true stewardship was promoted by the British common law of property as a result of its densely settled agricultural landscape, the open frontier of American settlement prompted common law courts, gradually but unmistakably, to shift away from doctrines promoting stewardship and toward pro–development doctrines (Sprankling 1996). In short, there is nothing in American property law to suggest to a landowner that there is any advantage to continuing to supply regulating services to society, much less an obligation to do so.

Nor has regulation filled this gap. While other industries are evolving through second and third generations of environmental regulation, the regulation of agriculture is decades behind the curve in terms of scope and innovation. To be sure, the task of regulating hundreds of thousands of farms raising different crops and livestock under different conditions around the nation would be daunting. But rather than try, federal and state legislatures have provided farms what amounts to a safe harbor from environmental regulation, and agriculture has fought tooth–and–nail against any retreat (Ruhl 2000). To this day there is no clear message in regulatory frameworks for what the baseline norm of environmental performance is for farms, other than there is none. As a consequence, opening a discussion of farms and ecosystem services runs headfirst into the ecological, geographic, and economic problems discussed above, with capacity for building policies existing in what is truly a vacuum in so far as property rights, regulations, and norms are concerned.

Policy Design

Farming thus typifies what Kraft, Lant, and I (2007) call the Tragedy of Ecosystem Services. In the absence of regulation or incentives to steer them toward production of regulating services, farms naturally manage their ecological resource base toward the provisioning services associated with the production of agricultural commodities. Unlike Hardin's famous Tragedy of the Commons (1968), which resulted in an over–exploitation of the resource base, the Tragedy of Ecosystem Services results in undersupply of valuable regulating services. And whereas better design of property rights, regulations, and norms has been shown to overcome the Tragedy of the Commons (Ostrom, Burger, Field, Norgaard and Policansky 1999), as noted above there has been little traction gained on the effects of farming from either of those sources.

Of course, it is important to stay focused on what the goal of agricultural multifunctionality is. We *do* want farms effectively to manage provisioning services to provide society food, fiber, and energy. And we should *not* force farms unfairly to bear the cost of supplying regulating services to society in addition. We pay farmers for corn; how much should we also pay them for supplying carbon sequestration and groundwater recharge? The answer to the Tragedy of Ecosystem Services when it comes to agriculture cannot be simply to regulate farms toward greater production of regulating services. That is not only politically unrealistic, it may also be economically inefficient and normatively inappropriate. On the other hand, just like all landowners, we should demand that farmers meet a minimum baseline of environmental performance as part and parcel of respecting the property rights of others before it would be appropriate to consider paying them for higher performance levels.

An intelligent approach, therefore, must start with identification of the drivers at the interface between agriculture and ecosystem services and developing a model of how these drivers operate. How do farm subsidy programs influence farm behavior toward ecosystem services? How do the upstream and downstream food and fiber industries affect farm behavior toward ecosystem services? If we were to change these or other conditions, how would farms respond with respect to ecosystem services? And which regulating ecosystem services do we wish to promote?

As we understand more about how and why farms manage ecosystem services in particular ways, we must then widen the lens to consider the trade–offs associated with different policy approaches (Rodruiguez et al. 2006). How would encouraging farms to shift toward greater production of regulating services, however accomplished, affect farm income, food prices, and land costs? Who would benefit, and by how much, where, and when? Would moving a significant portion of existing agricultural lands into, say, carbon sequestration, simply prompt conversion of undisturbed lands into farming to replace lost food supply? Would promoting a particular regulating service such as carbon sequestration, have a trade–off effect with other regulating services, such as groundwater recharge? How will other services that farms might provide, such as providing cultural and historical context for surrounding communities, be enhanced or degraded by moving to greater farm multifunctionality?

Once these trade–offs are better understood, the difficulties of transitioning to new policy regimes can be identified. The costs and benefits of new policies almost never are evenly distributed. For example, are global, national, regional, or local regulating services to be favored, and which interests are affected positively and negatively by that decision? What new skill sets will farmers need to acquire to take advantage of the new policies, and how much will gaining them cost? Will agricultural communities prosper with increased farm multifunctionality? Those who stand to "lose" under new policy regimes are likely to oppose them unless their interests are appropriately accounted for in the transition. After decades of habituating farms (and farm communities) to subsidies designed around provisioning services, it may be unfair and unwise to shift to new policies without addressing the impact to those interests most affected. Should those farms be exempt from new programs, or compensated for losses suffered, or simply forced to play under the new rules?

Ultimately, if promoting greater production of regulating services is the goal for agricultural policy over the next decade, we must choose the instruments and institutions to make it happen. As with almost all else in agricultural policy, political expediency will point toward incentive programs administered through federal agencies. Indeed, putting aside the politically charged question of what baseline of performance to demand from farms, a strong case can be made for incentive–based approaches, as it is appropriate for farms to receive at least some compensation for satisfying public demand for economically valuable regulating services. But federal agencies may be poorly equipped to administer the incentives for all relevant services. Ecosystem services are, after all, benefits to human populations, meaning they satisfy demand at different scales. Some services relevant at national and global scales, such as carbon sequestration, seem well suited for incorporation into federal programs designed to influence land retirement or crop selection. By contrast, ecosystem services such as groundwater recharge, water quality control, and sediment capture are most valuable to local populations. Farmers should be paid in such cases to provide local services, but only based on local demand, meaning local government programs are more likely to calibrate compensation for local services efficiently. Indeed, as the economic values of ecosystem services become better appreciated, local land trusts and other nongovernmental organizations are also likely to play an expanding role in providing payments and other incentives for farm multifunctionality.

The point is to ensure that incentives for ecosystem services, as opposed to general environmental and ecological performance, are demand driven, not supply driven. In this sense policies designed to promote farm production of regulating services may give multifunctionality a renewed purpose and goal at local scales, connecting farms to their urban and suburban surroundings in ways that make all interests recognize the advantages of maintaining working agricultural landscapes.

A New Direction?

The concept of ecosystem services is no panacea for agricultural policy, but agricultural policy must awaken to its message. For decades, social, political, and economic forces have driven farms to manage ecological resources toward production of food, fiber, and energy commodities. They have done so well, but at the expense of maintaining the stock of natural capital necessary to provide a sustainable flow of ecosystem services of more general benefit to society, such as groundwater recharge, water purification, and flood control. Natural disasters and the effects of climate change are focusing society on the value of those services. While it may be a long time before we think of buying units of services from farms the way we do ears of corn at the grocery store, it is not too soon to think of ways to change the economic incentives farmers face to induce production of a more balanced portfolio of commodities and services. Doing so through Farm Bill reform, reorienting "green" subsidy programs toward a more multifunctional agricultural suite of outputs, will be an important component of the effort. But the goal of balanced, sustainable flows of ecosystem services from agricultural lands presents new opportunities for state and local programs to tap into and promote farm multifunctionality with true demand–driven market incentives. In the long run, such measures could reconnect agricultural lands and their surrounding communities in ways federal policy could never hope to achieve.

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Ecosystem Services and Western U.S. Rangelands

Rhonda Skaggs

JEL Classifications: Q24, Q28, Q57

Rangelands are expansive, unimproved lands located in arid or semi–arid regions, spanning a variety of landscapes including savannahs, high and low altitude deserts, mountain meadows, and tundra. Rangelands are generally unsuitable for crop production due to aridity, topography, and extreme temperatures. Rangelands support varying mixtures of native and nonnative grasses, grass–like plants, forbs, or shrubs which provide forage for free–ranging native and domestic animals (Stoddart, Smith and Box, 1975). There are more than 760 million acres of rangelands in the United States, including Alaska, comprising 33% of the nation's total land base (USDA–USFS, 1989a). While exact determinations are unavailable, it is estimated that more than 50% of U.S. rangelands are privately owned, 43% are owned by the federal government, with the remainder owned by state and local governments (National Research Council, 1994). Approximately 262 million acres of U.S. rangelands are controlled by the U.S. Forest Service (USFS) and the U.S. Bureau of Land Management (BLM) and leased to private individuals for the purpose of land–extensive livestock grazing (CAST, 1996). Many more acres of rangelands in the 11 western states1 are controlled by state or local government agencies and leased for livestock grazing, with all these states having a high degree of intermingled public and private ownership of rangelands.

Arid and semi–arid rangelands in the western United States are characterized by low and variable precipitation, high evaporative demand, nutrient poor soils, high spatial and temporal variability in plant production, and low net primary production (Havstad et al., 2007). These rangelands are often subject to desertification or invasion by shrubs and other woody plants as a result of drought, low resilience, and past management practices. Increased woody plant populations are strongly correlated with reduced forage availability for domestic livestock (primarily cow–calf, with some sheep and lambs) and wildlife grazing.

The public ownership of many western rangelands has led to ongoing, often contentious, policy debates regarding the ecological impacts of livestock grazing, and the types and levels of acceptable uses of the public lands. Given the nature of western rangeland ownership, it is often difficult to separate discussion of rangeland ecosystem services from discussion of public land policy. While western rangelands have been viewed primarily through the prism of livestock production, a broader awareness of the ecosystem services arising from rangelands has developed in recent years. This awareness has provided new grist for the public land policy debate, even though hard ecosystem services data for western rangelands remain elusive.

The concept of ecosystem services provides a framework for organized thinking about the relationships between humans and nature (Swinton, Lupi, Robertson and Landis, 2006) and for relationships within nature. Daily (1997) defined ecosystem services as "…the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life." The Millennium Ecosystem Assessment (2005) further developed the concept by defining the various categories of services human receive from the natural environment. Supporting ecosystem services which benefit people include nutrient cycling, soil formation, and primary production. These services in turn make provisioning, regulating, and cultural ecosystem services possible. Provisioning is the ecosystem's generation of food, fiber, fuel, and fresh water supplies. Regulating services include the ecosystem's role in providing pollination services, climate mediation, watershed functions (including flood control, storage, and filtering), and waste absorption and processing. The ecosys-

1 *Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Utah, Colorado, Arizona, and New Mexico.*

tem also provides cultural services to humans, which include educational, aesthetic, spiritual, and recreational opportunities.

While forage production for domestic livestock has been a key ecosystem service of western U.S. rangelands, there is a broad array of ecosystem services forthcoming from rangelands. These services include wildlife habitat, recreation (including that associated with wildlife), watershed functions, carbon sequestration, and biodiversity conservation. As working lands, western U.S. rangelands have been managed primarily to generate provisioning (e.g., forage) ecosystem services now or in the future. Public policy controversies regarding western rangelands since the 1970s have been largely based on real or perceived trade–offs between provisioning (e.g., forage production and livestock products) and other ecosystem services (e.g., wildlife, recreation, biodiversity). Research has attempted to address these trade–offs; however, many questions remain unanswered even after decades of research. Thus, our ability to value and represent trade–offs through the use of traditional economic tools such as the production possibility frontier is limited. Furthermore, U.S. rangelands cover vast expanses of land, encompass numerous climatic, ecological, and vegetative types, and are extremely diverse. U.S. rangelands are located in remote areas distant from population centers, on the urban fringe, and everywhere between these two extremes throughout the West. Thus, the characteristics, quality, and quantity of ecosystem services arising from rangelands (as well as the value of the services) are highly variable. This diversity further complicates economic valuation efforts and the development of policies or programs designed to enhance the flow of ecosystem services from rangelands.

Valuation of Rangeland Ecosystem Services

About 20% of beef cattle in the United States, or six million head, are in the eleven western states (CAST, 1996). The USFS has estimated that less than 10% of total national forage consumption by domestic livestock is provided by public lands (USDA–USFS, 1989b). Torell, Fowler, Kincaid and Hawkes (1996) estimated that 15% of the nation's beef cows and 44% of the sheep and lambs were produced on public land ranches, that approximately 5% of the nation's grazing capacity comes from BLM and USFS lands, and that 4% of the forage for the nation's beef cow herd is supplied by these lands. While neither the overall national beef cow herd nor the national beef supply is greatly dependent upon public rangelands, many individual ranching operations in the inter–mountain West are almost 100% dependent upon total annual or seasonal forage provided by publicly–owned rangelands. Torell, Fowler, Kincaid and Hawkes (1996) also concluded that 41% of beef cows in the eleven western states grazed on federal lands for part of the year, and that 19% of the total annual forage demand in the region was met from federal land. From these numbers, aggregate estimates of the value of forage provided by public–domain rangelands can be made; although precipitation changes from year to year can greatly affect the values.

Rangelands represent a vast store of carbon, both in soils and vegetation (Havstad et al., 2007). The general conclusions of rangeland–related climate regulation research are that the carbon sequestration potential of rangelands depends greatly on appropriate management of the lands, minimizing degradation or desertification (including encroachment by undesirable species), and restoration or improvement of degraded rangelands (Follett, Kimble and Lal, 2001). Restoration of arid–region degraded rangelands is extremely difficult, and variability in precipitation throughout most U.S. rangelands adds additional uncertainty to the carbon sequestration regulating service provided by these lands. Although rangelands can contribute to carbon sequestration, the generally low productivity of arid rangelands also means that their sequestration potential is also lower than other types of land.

The first rangeland carbon credits pool was created in 2008, intended for sale on the Chicago Climate Exchange (CGX). According to AgraGate (2008), the company creating the pool, the number of carbon credits available from rangeland varies from 0.12 to 0.52 tons per acre, depending on soil types and precipitation. Ranchers wanting to sell carbon credits from rangelands must follow approved management plans designed to achieve targeted CO2 uptake levels. These management plans generally require reduced stocking rates, more dispersed livestock distribution, reduced forage utilization rates, and various rangeland improvements.

Rangelands continue to be largely natural systems; thus, all rangeland ecosystem services depend in some way on local biodiversity (Havstad et al., 2007). Given the diverse nature of rangelands and the traits of different species of flora and fauna present in rangeland ecosystems, it is not surprising that research has found both increases and decreases in biodiversity services as a result of livestock grazing and relative to varying grazing intensities. Endangered species and related biodiversity issues on rangelands are further complicated by situations where attempts to improve rangelands through shrub removal and restoration of natural grasslands reduces the preferred habitats of threatened or endangered species (e.g., the sage grouse).

As noted above, ecosystem services include cultural values. While broad–scale valuation of nonutilitarian or nonuse values of U.S. rangelands are not available, research by Torell, Rimbey, Ramirez and McCollum (2005) provides some insight into how individual ranch sales prices reflect the values of rangeland aesthetics. These authors found that ranch location, terrain, elevation, and scenic views have a greater influence on ranch value than livestock income earnings obtained from the land. Ranch buyers appear willing to pay for desirable quality–of–life ranch attributes—many of which are a function of the natural environment.

In recent years, efforts have been made to examine the impacts of shrub control treatments on ecosystem services other than provisioning. However, the growing appreciation of nonprovisioning rangeland ecosystem services has not been matched by rigorous long–term quantification or valuation of the services (Herrick, Schuman and Rango, 2006). As noted above, woody plant invasion of rangelands reduces livestock carrying capacity. Thus, rangeland managers generally have an interest in controlling or reducing shrub encroachment. However, the costs of shrub control treatments usually exceed the livestock producers' benefits attained from increased forage production (Lee, Conner, Mjelde, Richardson and Stuth, 2001). The response of federal and state governments has been publicly funded shrub control programs, which usually pay for 50–85% of the cost of the treatments.

Torell, McDaniel and Ochoa (2005) have noted that if brush control projects are to be profitable expenditures of public funds then the unmeasured benefits of ecosystem services to nonlivestock entities must exceed the state, county, or federal subsidies necessary to induce livestock producers' participation in brush control programs. Thus, if the programs and actions of the land management agencies accurately reflect social priorities, then public funds spent on the cost–share payments may provide some sense of the social value of nonprovisioning ecosystem services enhancement on rangelands. Skeptics, however, will counter that land management agencies' budgets and spending priorities most often reflect political and bureaucratic objectives. While the use of public expenditures on brush control as a surrogate measure of the value of ecosystem services is problematic, it does provide some insight into the value society (reflected in the political process and agency decisionmaking) places on rangelands. However, it is currently unknown whether these expenditures are reflections of society's willingness to pay for rangeland ecosystem services, indications of nonmarket valuation (e.g., rangeland option, preservation, or existence values, etc.), or the perceived benefits arising from recreational opportunities such as hunting or bird watching.

Government land management agencies are increasingly justifying brush control efforts on the basis of rangeland health and improved rangeland condition, with both concepts encompassing the broadest possible array of ecosystem services (Olson, Hansen, Whitson and Johnson, 1994). Perceived benefits of brush control include ecological restoration and stabilization, enhanced biodiversity, improved wildlife habitat, aesthetic improvements, increased carbon sequestration, reduced wind–caused soil erosion, and increased off–site water yields. The commonly heard argument regarding water yield on rangelands is that more water will be available for run off and/or deep drainage if there is more grass and fewer shrubs; however, potential increases in water yields resulting from brush control are highly variable, unpredictable, and may be unrealistic (Wilcox, 2002; Wilcox and Thurow, 2006). The value of wildlife habitat has been reflected in higher ranch values (Torell, Rimbey, Ramirez and McCollum, 2005), conservation easement values (Knight and Johnson–Nistler, 2004) and in fee–hunting opportunities (Sorg and Loomis, 1985). The research results likely reflect some combination of both intrinsic and market wildlife values in selected locations, although it is difficult to separate the two values.

While past research provides some insight into specific ecosystem services from specific rangelands, quantification and valuation of ecological restoration, stabilization, and biodiversity in the aggregate and at a broad–scale remain elusive. Furthermore, ecosystem and biodiversity trade–offs between woody species, grasses, and associated wildlife species can exist (Connelly, Schroeder, Sands and Braun, 2000), and both woody and grassland plants sequester carbon (Havstad et al., 2007)

As noted above, cultural ecosystem values include educational, aesthetic, spiritual, and recreational opportunities. Western U.S. rangelands are the legendary wide–open spaces of American history and mythology (National Research Council, 1994); as a result they are settings for two–stage ecosystems services processes. First, rangelands provide forage; secondarily, the process of herding and managing the forage–consuming livestock appears to have high cultural and social value for many Americans. Placing a value on this "cattle culture" would be very difficult; however, it is possible that some sense of the magnitude of cultural values of western rangelands could be obtained through estimating the extent to which many ranching operations are subsidized by nonranch incomes. Gentner and Tanaka (2002) found that half of western public land ranchers earn less than 22% of their total income from ranching, that a ranch business "profit motivation" is a relatively low–ranked objective for all types of ranchers, and that public land ranchers are strongly motivated to be in ranching for tradition, family, and lifestyle reasons (i.e., cultural objectives). Pope (1987) concluded that “romance, recreation, the achievement of a desired social status, or simply the maintenance of a family tradition” are the primary motives for many western U.S. cattle producers.

The multiple roles of livestock in traditional societies have long been recognized by anthropologists, human ecologists, and other social scientists. In these societies, livestock are mobile stores of wealth and status. And even though the United States has a very advanced economy, livestock continue to be viewed as “banks–on–the–hoof” by many producers (Eastman, Raish and McSweeney, 2000). For many ranchers, cattle and the rangelands used to produce them are investments, savings, and financial safe–havens. Cattle provide emergency funds, and are also a stable supply of high quality meat for family consumption. Similar to their counterparts in traditional societies, western U.S. rangeland cattle production is a source of identity and a sociocultural touchstone. However, the fact that this source of identity often is derived from public domain rangelands continues to be a source of controversy and competing strong opinions. The middle–ground of western public rangeland use policy opinion holds that these lands can be sustainably managed for multiple uses (and multiple ecosystem services)—including livestock grazing (Brown and McDonald, 1995).

In Summary

Goods and services have value to humans because they provide utility and because they are scarce. Realistically, western U.S. rangelands are so expansive and so remote to the citizenry at large that attempting to infer broad–scale ecosystem values from small, localized studies will fall victim to the fallacy of composition. If broad–scale rangeland ecosystem services are valued at the margin, the values of those services are likely to be quite small.

Rangeland “restoration,” primarily through brush control, continues to be a priority for federal land management agencies in the West. For example, through Restore New Mexico, the BLM is seeking to enhance wildlife, allow reintroduction of native wildlife species, improve watersheds, reverse the expansion of invasive plant species, and protect outdoor values (USDA–BLM–NMSO, 2007). Previous research would lead to the tentative conclusion that the value of increased provisioning through forage production resulting from landscape restoration is very likely lower than the costs of restoration. While it is possible that the sociocultural and intrinsic ecosystem values of landscape restoration in the region are high enough to justify public expenditures on the federally–funded effort, these values have not been quantified. Thus, the sociocultural and intrinsic ecosystem values rationale appears to be the justification for an ecosystems management policy which is likely to defy rigorous economic analysis now and in the future.

For More Information

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

Stephen Polasky

JEL Classifications: Q57, Q20, Q51, Q15

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

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

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

Economists have much to contribute to research on ecosystem services. In fact, properly understood the research agenda on ecosystem services is a continuation of a long–standing set of research objectives in agricultural, resource and environmental economics. Agricultural economists know that soil and climate are necessary inputs to the production of agricultural crops and have studied production functions and agricultural profitability under a wide variety of circumstances. Resource economists know that natural resources (oil, minerals, timber, and fish) contribute to a wide range of intermediate and final products and have studied optimal harvesting and inefficiencies caused by open access. Environmental economists know that peo-

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

ple value the environment directly even where there is no market and have developed tools of nonmarket valuation to analyze such things as the value of a scenic vista or clean air. In fact, in the 1970s economists set out a research agenda to measure "the value of services that natural areas provide" (Krutilla and Fisher 1975, p. 12). The "new" topic of measuring the value of ecosystem services can build from a large existing base of prior research on the value of agricultural production (Beattie and Taylor 1985), bioeconomic modeling of fisheries and other renewable resources (Clark 1990), nonrenewable resources (Dasgupta and Heal 1979), and nonmarket valuation of environmental amenities (Freeman 1993).

A Research Agenda for Economists on Ecosystem Services

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

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

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

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

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

The Provision of Ecosystem Services: The Ecological Production Function

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

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

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

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

The Value of Ecosystem Services: Market and Nonmarket Valuation

The provision of ecosystem services yields outcomes in terms of physical units (e.g., bushels of crops, tons of carbon sequestered, concentrations of nitrate in water). But comparing outcomes of alternative management options is difficult when there are impacts on multiple ecosystem services and when each service is measured in its own physical units. Is a management option that increases crop yields but also results in increased carbon release and decreased water quality beneficial for society? The answer to this question depends on how one views the trade–offs between various services. In a standard economic problem, economists compare consumption bundles that might differ in many dimensions by converting the measures to a common metric of value measured in monetary terms. The same conversion to a common metric of value can be done with ecosystem services through the application of market and nonmarket valuation techniques.

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

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

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

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

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

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

Policies and Institutions for Efficient Provision of Ecosystem Services

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

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

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

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

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Ecosystem Services beyond Valuation, Regulation, and Philanthropy: Integrating Consumer Values into the Economy

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Ecosystem services have been identified as a central link between society, or human systems, and the structure and function of natural systems (e.g., U.S. LTER 2007, MEA 2005). A fundamental economic problem is that while almost everyone—environmental groups, policy makers, and broad segments of the general public—seems to believe ecosystem services are valuable, the available public policy tools and approaches for private action fall short, and often omit, a direct link to the real values of the people. If ecosystem services are of economic value, then a fundamental challenge concerns how to identify the link between ecosystem services and the quality of life of individual households, and how to use that link to integrate ecosystem service values into the decisions of businesses and individuals in society. Given current markets and policies decision–makers are unable to recognize the full value of services ecosystems provide. What can be done to integrate ecosystem service values into the economy? After reviewing a fundamental cause for why markets often overlook ecosystem services, and after considering some limitations of the often effective approaches of philanthropy and government, we consider the potential to leverage experimental economics to create and test approaches to integrate values at the individual level into markets addressing ecosystem services.

A Fundamental Problem

One daunting frontier for ecosystem services originates from the natural character of many services, which sharply restricts or prevents the ability of providers to capture a return from many, often most, beneficiaries. This is the nature of "public goods" and "fugitive resources." Both involve "nonexclusivity": providers cannot exclude beneficiaries from benefit without payment for the cost of provision. For public goods, many people may benefit simultaneously, so no one provider (or user–beneficiary) can exclude anyone else at any particular moment. An owner of undeveloped farm, forest or lake shore often cannot insist on payment from the sprawling, urban–fringe residents who value open space for aesthetic tranquility; therefore, the landowner has little incentive to consider his community's open space values in choices about current use of his land. For fugitive resources, Nature does not allow a provider to contain and control the resource she has provided or protected; rivers flow and wildlife migrate across boundaries. A farmer or lawn–owner whose fertilizer percolates to the Mississippi or Potomac cannot insist on a return from the fishermen who would gain from a smaller Gulf Coast dead–zone, or from the patrons of oyster bars who seek a Chesapeake culture of local shellfish. Moreover, the opportunity for every beneficiary to benefit without payment creates the incentive to "free ride" or hang back and wait for potential providers—or public–spirited philanthropists—to "do the right thing" at their own expense, despite their own opportunity to ride free on others' generosity.

As a result, the could–be bounty of ecosystem services, and the conditions of ecosystem structure and function, often arise as a residual, left–over after–thought of decisions that potential providers make to sustain their livelihoods. For example, even conservation–minded farmers must implement practices within the annual, weather–dependent, schedule of their business, and society receives fish, wildlife, open space and water quality that results (or doesn't result).

Current Solutions

To be sure, we have institutions, public policies and private actions underway that mitigate the nonexclusive nature of Nature's services. But most existing tools remain short on their ability to integrate ecosystem services into the economy in a manner that is fully commensurate with familiar, commercially viable products.

Government authority generates land–use and environmental regulations that place enforceable limits on the degree to which individuals and firms can impose consequences on a broader community, such as through pollution or use of resources held in the public trust, with impacts on public health or endangered species. Government can also implement incentive payments which directly or indirectly compensate providers for actions to provide for ecosystem services, such as through federally funded conservation reserve or wetland reserve programs. It should be noted that, as market–based approaches, government incentive payments primarily focus on the supply side opportunity costs of providers, such as compensating farmers who forego crop production on land enrolled in a conservation reserve. Centrally–guided incentive payments may reflect politically or bureaucratically attenuated demand–side, public values through a benefit–cost analysis, but, in this article, we discuss the potential to integrate demand–side values through more complete market mechanisms.

Philanthropy, such as through wildlife conservation organizations or land trusts, can provide complementary actions. Philanthropists can provide payments for ecosystem services by, for example, compensating ranchers for tolerating wolves or purchasing conservation easements on undeveloped farms or forests. Philanthropists can stimulate government action by offering matching funds for taxpayer–approved conservation bond–issues or providing some offsets for debts of developing countries that protect biodiversity. Of course philanthropy exists under the shadow of incentives for individuals to ride free–waiting for some other donor to step forward.

Clearly, however, the limitations of government and philanthropic action may create additional expenses or opportunities lost. Philanthropists face their dependence on good will of donors, and costs to fight free–riding, and despite the effectiveness and nimbleness that can come from a carefully focused mission, philanthropic approaches can generate bureaucratic costs. Government may be better positioned to provide a broad approach, perhaps including equity considerations, casting a wide umbrella supported by more stable (if sometimes controversial) funding. But government's costs to obtain detailed (local–level) information, to safeguard public integrity, and to balance political tensions, can sometimes create the agility and efficiency of a bull at Tiffany's china shop. Both may find it difficult to focus their mission or goals in detailed alignment with the interests of a diverse public.

In contrast, decentralized market approaches to provision of valued goods and services are respected for agility, responsiveness to diverse preferences, and efficiency in directly aggregating consequences of individual values and choices into fairly universal signals of relative scarcity (called relative prices). Often supported by a coalition of nationally or internationally known, large, commercial firms and philanthropic organizations, we see nongovernmental organizations (NGOs) developing standards and practices for certification of ecosystem or natural resource–based products as "sustainably produced" through harvest and process chains that are environmentally friendly. The Marine Stewardship Council (MSC), concerning seafood, and the Forest Stewardship Council (FSC), concerning forest products, provide two examples, and we are witnessing a proliferation of green–marketing efforts—sometimes supported by third–party verification exemplified by MSC or FSC eco–labeling—whereby firms are recognizing a public demand for attention to environmental stewardship. While laudable, these efforts tie ecosystem services to the consumer's choices among familiar commercial products, rather than directly targeting the consumer's value for specified ecosystem services.

Approaches to ecosystem services based primarily on a natural–science perspective can overlook another significant challenge: identification of what people value, rather than simply what scientists currently measure. From the human household's perspective, what is the service? Physical measures of ecosystem output, such as for water quality and quantity, may often be salient and intuitive for, say, provisioning services like water for drinking or irrigation purposes. But what about measures linking water quality and services of interest for recreation? Egan, Herriges, Kling and Downing (forthcoming) show that individual households, pursuing a diverse set of activities, are responsive to a broad suite of water quality measures suggested by biologists, but careful modeling is needed to link biological measures through the process by which households seek ecosystem services and therefore value various dimensions of water quality.

Innovation Addressing Consumer Values

Private NGOs, government, and academia have stimulated innovative work on the valuation of ecosystem services. Society's representatives' need a better understanding of what it is that households actually value from ecosystems. We need, and are pursuing, better methods to measure value, and to link available actions to restore or sustain ecosystem structure and functions that yield desirable ecosystem services. Support for the social science of ecosystem services is critical to developing effective policies supporting the public welfare.

But what is substantially missing from the mission of economics relative to ecosystem services is work focused on integrating values directly into the economy, particularly demand–side values. Market–based approaches that integrate demand–side values give the people a direct and immediate voice—an economic voice—to indicate whether particular levels of or changes in ecosystem services are more or less valuable than particular levels of or changes in familiar, commercially produced goods.

How can society stimulate the integration of demand–side values in policies and market–based approaches addressing ecosystem services? This integration is already done for many provisioning services of ecosystems, through long established markets for food, fiber and natural resource–based commodities. How can we directly attack nonexcludability and give beneficiaries an economic voice upon which entrepreneurs can capture a return from enhancement of ecosystem services?

Experimental economists are increasingly investigating mechanisms that stimulate individuals to go beyond baseline donations and to transform a higher portion of their values into revenues in support of public goods. Experimental economists bring human subjects into a controlled laboratory setting to study how incentives and rules of exchange lead to individual or collective choices and outcomes. In public goods experiments, researchers design a set of monetary payoffs that individuals can earn through their choices, and these payoffs simulate the manner in which individuals benefit from real public goods. For example, working agricultural ecosystems might give rural residents aesthetic pleasure when farms provide grassland habitats for songbirds; every member of the community receives a "songbird benefit" whenever the habitat is provided, regardless of who bore the costs. In the laboratory, a group of individuals may be asked to pay for provision of a group–fund that provides a monetary return to everyone in the group, including those members who chose not to invest. Since the group–fund does not exclude noncontributors from benefiting, it comprises an abstract, monetized simulation of a public good.

Such experiments have shown that changing the incentives for individuals to ride free on the contributions of others can increase the degree to which individuals voluntarily pay for the cost of a public good and can bring their payments into a closer correspondence with their own value for the good. While practical mechanisms reduce the incentives for individuals to free–ride, additional effort is needed to evaluate and improve the degree to which mechanisms balance the provision of benefits net of costs. Since many people benefit simultaneously, an efficient balance of costs and benefits occurs when a provider delivers increments of public good until the costs of delivering the last unit are just offset by the combined total amount that all beneficiaries would willingly pay for that increment rather than doing without it.

Since different people have different values, some may value the public good more or less highly than others, so a combined total amount may involve different people paying different prices. This issue is not surprising; obviously with familiar donations mechanisms, different people donate different amounts. But it means the nonexcludable character of some ecosystem services will require entrepreneurs to explain the rationale for market mechanisms to newcomers from the general public.

Real Markets for Ecosystem Services

The insights from economics experiment already offer potential to support markets for real ecosystem services. Through USDA funding, the authors have established an experimental market in Jamestown, R.I. This example shows both promising results and significant areas where progress requires additional work to design and test mechanisms by which entrepreneurs could develop ecosystem service markets.

Jamestown is widely regarded for supporting conservation of undeveloped farm, forest and open space and is in the process of completing transactions to purchase development rights on the last few operating farms. However, while setting aside development rights may prevent the construction of additional residential neighborhoods or other developed uses, it may still be challenging for farmers to maintain farm operations. Moreover, changes in the intensity of farming, along with rising costs for energy or other inputs, push more ecosystem services outside the margin that farmers can sustain while maintaining their business.

This applies, for example, to the cultural or aesthetic services provided by grassland wildlife to residents who seek to live in a rural community that supports a healthy ecosystem. The experimental market centered on selling, to Jamestown residents, an opportunity to protect grassland habitats during the nesting season. This product was presented as contracts with farmers who agreed to forego hay harvesting and restrict grazing on 10–acre fields during eight weeks from the beginning of May to the beginning of July.

Using insights from laboratory experiments, the research design allowed a comparative test of three market mechanisms, including one intended only to measure potential value and two intended to raise revenues sufficient to cover the costs of a contract. The study created an experimental (but nonprofit) business and advertised under the trade mark of the Nature Services Exchange of Jamestown, created as a partnership of the University of Rhode Island and EcoAsset Markets Inc., an independent business in Providence, R.I. Residents were randomly assigned to groups. Each household in a group was asked to make a monetary offer subject to rules of the market mechanism assigned to that group; offers were made by personal check or by credit–card authorization.

The rules for all mechanisms included a "provision point," which corresponds to the minimum amount of funding that a group must provide in order to cover the costs of a public good. In Jamestown, the provision point is linked to the cost of a contract with a farmer who agrees to omit any harvest of hay on a specified, 10–acre field during the late–spring nesting season for Bobolinks, a grassland–nesting bird. Contracts were negotiated to cover the farmer's cost to replace the loss of feed by foregoing a hay harvest and to compensate for additional risk and management inconvenience to manipulate herds around the protected field(s). However, the provision point is more than a simple fundraising goal; rather it also comprises an implicit (beneficent) threat that a specific, quantified increase in the services of a public good will not occur unless the group provides for its costs. Laboratory experiments have shown a money–back–guarantee reinforces the provision point and the tie between contributions and the specific service offered. The guarantee establishes the rule that if funding falls short of the provision point, so the good is not provided, the fundraiser (seller) will not simply redirect revenues to other purposes. The provision point and money–back–guarantee rules reduce the incentives to ride free because group members (should) realize that the responsibility lies with the defined group and no one outside the group, so there are limitations on the opportunity to wait for others to pay. These rules were used in the Jamestown experimental market.

Laboratory experiments have also demonstrated that rules to rebate excess funds to contributors increase the offers that individuals will make, given their values. Rebates reduce the free–riding incentive for individuals to hold–back in a strategic effort to offer just–the–right–amount rather than paying more than was necessary after the contributions of others. The rebate feature was varied across mechanisms tested in Jamestown.

Our "pivotal mechanism" (PM) established a full rebate to any individual whose offer was not needed to meet the provision point for their field after all other contributions from their group were taken into account. This PM creates an incentive for each person to view their own contribution as if it was the last one needed, and their decision would make–or–break the outcome for their group's hayfield. The PM provides incentives for individuals to reveal their full willingness to pay to protect a hayfield for grassland birds, but it's advantage in measuring value is off–set by the practical limitation that very few or no individuals will be pivotal in most situations, so the PM generally fails to raise actual revenues.

Our "proportional rebate" (PR) mechanism is one of two we designed to raise revenues. Under the PR rules, any funds collected above the amount needed to cover the cost of a farm contract would be rebated to each contributor in proportion to their own contribution to the total of all contributions from their group. In our 2007 market, the second revenue–raising mechanism used the set of offers from a group to calculate the lowest possible "uniform price" (UP) such that everyone who paid would receive a rebate of the excess of their offer above the UP; anyone who offered to pay less than the UP would receive a full refund. Under the UP, everyone who pays will pay the same price (after their rebate).

The market generated total offers of around $9700, across all three mechanisms, with substantial variation across groups depending upon the rules by which excess funds would be rebated. Based on laboratory experiments, we expected the PR mechanism to come closest to the "full value" estimated under the pivotal mechanism (PM), and Jamestown's preliminary results support this prediction. While the UP approach was expected to, and did, elicit lower offers (and lower revenues) from groups, in on–going research we are investigating the possibility that similar mechanisms may produce more stable revenues year–after–year, as compared to PR. In the 2007 market, of six hayfields available for bird conservation, revenues met the provision points for three. Initial analysis suggests, however, that for about 400 homes participating there is potential value–as revealed under the various mechanisms– ranging from $8800 to $28,000 to protect a field for grassland birds. The on–going challenge will be finding better ways to align revenues with this potential value.

The Jamestown experience shows that, even in the case of a cultural or aesthetic ecosystem service, experimental economic markets might prove successful. In Jamestown, all three of the fields that were ultimately protected would have been harvested during the 2007 nesting season had the farmers been unable to obtain support to offset costs to their operation. Moreover, other data from this study suggests that not only did residents value contracts focused on Bobolinks, but they may also value contracts that help farmers to restore previously idled hayfields to a state that provides additional habitat and also eliminates invasive plants that may be harmful to other aesthetically–valued wildlife (like the monarch butterfly). The ecosystem service market may eventually enable farmers to expand their operations with services that Jamestown's exurban residents' value.

Concluding Observations

Developing mechanisms to enable entrepreneurs to leverage consumer values may substantially expand the potential for market approaches to lead to valuable impacts for ecosystem services. Consider for a moment the cap–and–trade approaches used for air and water pollutants, and currently under discussion for carbon emissions. If market mechanisms create a closer alignment between individual and collective values and incentives to support the public good, then markets may create an avenue by which communities can directly influence the key choice of the overall cap on emissions; individuals and groups who value a further reduction in emissions could buy and retire a quantity of permits in a manner that effectively lowers the overall cap. Markets enable private action that can complement or improve upon the government, or philanthropic, actions already underway for ecosystem services.

Here again the Jamestown Bobolink market provides an example. After seeing a summary of the experimental market in Audubon magazine in November 2007, a community–garden club in Grant, Minnesota, contacted the authors and developed their own entrepreneurial approach to protect a hayfield next to their community garden. This year their club members have rented the hayfield in consideration of grassland birds, illustrating that once enabled, entrepreneurship can expand to enhance the provision of ecosystem services in a nimble fashion.

Furthermore, research on the implementation of ecosystem service markets may benefit from interdisciplinary teams and inclusion of outreach. In Jamestown, farmers' independent experimentation is likely to yield modifications to contracts, such as to plan for early–season grazing, that both enhance farmers' ability to deliver ecosystem services and lower the costs (or provision points) implied. At this writing, Jamestown farmers are weighing options to alter grass species in their hayfields, to better manage joint production of grassland birds and feed for livestock (G. Neale, personal communication). Moreover, ecological research on bird behavior may enable the design of methods that allow environmental managers to guide birds toward fields that are likely to be protected in the next season. Such considerations may be critical to establishing hayfield harvest rotations through a series of years that sustain the quality of hayfields for both feed production and habitat. The field experience also has raised a number of questions that were not apparent from a review of experimental economics literature alone, including questions about which mechanisms would produce stable revenues over time or be adaptable to situations where many increments to ecosystem services might be possible.

The challenge of ecosystem services is as complex as the complexity of human and ecological systems combined. Ecosystem services link us with Nature and progress will often require a comprehensive approach with disciplinary, interdisciplinary and integrated teams on the frontier.

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