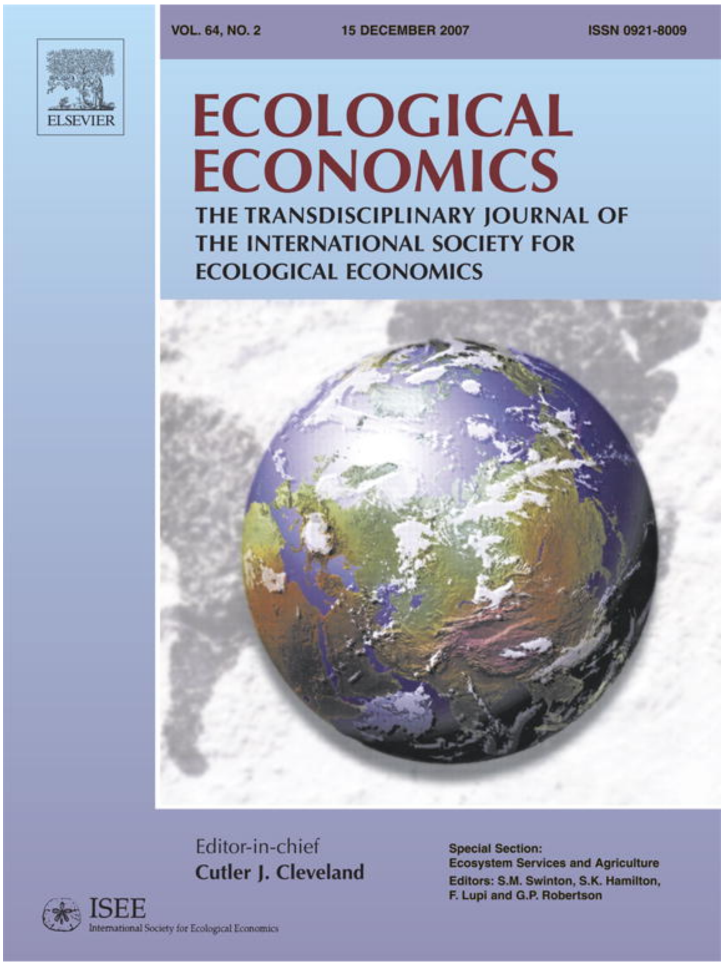
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An assessment of market-based approaches to providing ecosystem services on agricultural lands

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ABSTRACT

Market-based approaches are increasingly being advocated as tools for achieving the conservation of ecosystem services. We examine the reasons why markets so far appear to have failed to provide an efficient allocation of many ecosystem services, and identify the conditions under which markets deliver efficient resource allocation. We discuss different forms of market-based approaches to ecosystem services and identify the characteristics of services that make them better suited to one or another of these approaches. We find that lack of low-cost measurability and valuation currently precludes efficient allocation of many ecosystem services through market-based approaches. Still, some forms of market-based approaches hold promise for cost-effectively managing some ecosystem services provided by and to agricultural lands. In many cases some form of well-designed government involvement will be required to seek outcomes that protect the public interest.

1. Introduction

Rapid human population growth and increasing sub- and exurbanization have led to the loss of many ecosystem services in the United States (Burchell et al., 2002). It is now widely recognized that conserving ecosystem services often makes good economic sense. Some recent high-profile studies have documented the economic importance of these services to human societies (Balmford et al., 2002; Costanza et al., 1997; Daily et al., 1997), while others have shown that conservation often generates net benefits for society and can provide desired services cheaper than manmade alternatives (Logue, 2006; Ernst, 2004; Chichilnisky and Heal, 1998). Agriculture provides important ecosystem services in the form of food and fibers, which in turn use other ecosystem services as inputs. For example, a recent estimate puts the net value of services from wild insects to U.S. agriculture at US$ 8 billion per year (Losey and Vaughan, 2006). Water and fertile soils are other vital services to agriculture.

Because budget constraints limit the possibility of preserving ecosystem services through solely publicly financed payment mechanisms, serious attention is being given to the development of private markets for ecosystem services provision. One of the challenges such markets would need to confront is that in many cases these ecosystem services are public or quasi-public goods, delivering benefits such as reduced nitrogen loading of waterbodies or the restoration and conservation of native species and their habitats.

In this paper we critically assess the potential of markets to provide adequate incentives for agricultural landowners to produce ecosystem services. In doing so, we address the interrelated issues of measurement and valuation of ecosystem services and of using markets as a tool for organizing the supply of these services to and from agricultural landscapes. We begin by presenting an economically useful definition of ecosystem services. We then briefly review some general quantitative trends in the provision and appropriation of ecosystem services and the driving forces behind the widespread loss of many

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ecosystem services. Next, we briefly examine why market-based approaches to the provision of ecosystem services are gaining in popularity, and survey the different types of such approaches in existence today. We discuss the principal challenges and opportunities associated with using market-based approaches for ecosystem service management, and explore their potential in agricultural landscapes.

2. Defining ecosystem services

The ecological and economics literature provides several definitions of ecosystem services not all of which are compatible or equally useful from an economic perspective.

The term ecosystem services first was popularized by ecologists pointing out the wide range of natural processes and products that support human existence and enhance human well-being (Daily, 1997; Daily et al., 1997). This early work tended to define ecosystem services very broadly as the "biological underpinnings essential to economic prosperity and other aspects of our well-being" (Daily et al., 1997:2). The Millennium Ecosystem Assessment (2005a) followed this broad definition and distinguished between supportive services (leading to the maintenance of the conditions for life, such as nutrient cycling), provisioning services (providing direct inputs to human economy, such as food and water), regulating services (such as flood and disease control), and cultural services (such as provision of opportunities for recreation and spiritual or historical purposes).

As Boyd and Banzhaf (2006) point out, such broad definitions of ecosystem services are not very useful from an economic perspective, because they lump together ecosystem products (such as food, fiber, or water), ecosystem functions or processes (such as nutrient cycling or habitat provision), and benefits (the economic value of a service, such as flood control or aesthetic beauty). They emphasize, as have others (De Groot et al., 2002; Brown et al., 2006; National Research Council, 2005; Chan et al., 2006) that for valuation purposes one needs to distinguish clearly between ecosystem functions and services, the crucial distinction being that services require the explicit involvement of human beneficiaries. While ecosystem functions constitute the biogeochemical flows that connect the different constituent parts of ecosystems (Odum, 1962; Banzhaf and Boyd, 2005), ecosystem services are "flows from an ecosystem that are of relatively immediate benefit to humans" (Brown et al., 2006:4). To ensure that services can be quantified, (Boyd and Banzhaf (2006):8) suggest narrowing the definition of ecosystem services further to include only end-products — "components of nature, directly enjoyed, consumed, or used to yield human well-being". By defining ecosystem services as things or characteristics of nature directly valued by humans, ecosystem functions and processes like nutrient cycling are not considered services because they are intermediate to the production of the final services or ecosystem components, such as surface water, oceans, vegetation types, and species. This definition of services as end-products avoids the problem of double-counting that would result from counting both intermediate inputs, such as hydrological cycling and water filtration by soils, and end-products, such as drinking water. From a human welfare perspective, it is only the end-products that matter — humans do not care about hydrological cycling or water filtration per se, but about the resulting end-product — the amount of available water of a certain quality.

Defining ecosystem services as discrete and identifiable end-products is necessary for quantification, which in turn is a prerequisite for the establishment of ecosystem service markets. It is not surprising that all such markets or market-like arrangements that have developed are for what Boyd and Banzhaf refer to as services, that is, for end such as water, forests, or species. Not counting ecosystem functions as services does not imply that the former do not have value — they certainly do. However, this value is reflected in the value of the resulting services. These services are benefits-specific, that is, they are tied to particular human activities or desires, and are spatially and temporally explicit (Salzman and Ruhl, 2000; Boyd and Banzhaf, 2006). By focusing on end-products only, some services commonly identified in the literature are not considered services under Boyd and Banzhaf's definition. For example, carbon sequestration is not an end-product and hence not a service; rather, it is an intermediate input into services such as beaches, wetlands, or forests directly used by humans, and its value is already accounted for through the benefits provided by those services, such as avoided health and property damages, recreation, or provision of timber, among others. Table 1 lists selected ecosystem services provided to and by agricultural lands and selected benefits those services provide to humans.

3. Recent trends in ecosystem services

Humans have brought about massive changes in the structure and functioning of the Earth's ecosystems, significantly altering many biogeochemical flows on scales ranging from local to global (Vitousek et al., 1997a; 1997b). These changes have affected the volume of ecosystem service flows in every region of the globe (Millennium Ecosystem Assessment, 2005b). Removal or modification of "natural" ecosystems for purposes of agricultural production and application of new technologies have been the principal drivers of humanity's impacts on ecosystems and biochemical cycles (Millennium Ecosystem Assessment, 2005a). Overall, human appropriation of most services has increased substantially during the past 50 years. The Millennium Ecosystem Assessment (2005b) concluded that a large number of provisioning services (the supply of biotic matter) have been degraded, with the notable exception of crop and livestock production. Regulating services have fared even worse, with marked degradations in crucial services such as erosion regulation, water purification, pest regulation, pollination, and natural hazard regulation. The degradation of ecosystems and the resulting impacts on the quantity and quality of the services they provide to humans are expected to continue over the next several decades (Millennium Ecosystem Assessment, 2005b). This is of concern to the extent that many of the services undergoing decline are essential for sustaining the long-term well-being of societies (Foley et al., 2005).

Why has such a profound degradation of ecosystems occurred? First, trade-offs between the preservation of "nature" and the satisfaction of human needs and desires make unavoidable the conversion of some lands to accommodate

Table 1 – Selected ecosystem services provided by agricultural lands and associated benefits to humans

Benefit	Ecosystem service
Harvests	
Managed commercial	Pollinator populations, soil quality, shade and shelter, water availability
Subsistence	Target fish, animal, and plant populations
Pharmaceutical	Biodiversity
Amenities and fulfillment	
Aesthetic	Natural land cover in viewsheds; rural landscapes
Bequest, stewardship, spiritual, emotional	Wilderness, biodiversity, varied natural land cover and rural agri-landscapes
Existence	Relevant species populations; relevant rural agri-landscapes
Damage avoidance	
Health	Air quality, drinking water quality, land uses or species populations hostile to disease transmission
Property	Wetlands, forests, natural land cover
Waste assimilation	
Avoided disposal cost	Surface and groundwater, open land
Drinking water provision	
Avoided treatment cost	Aquifer, surface water quality
Avoided pumping/ transport cost	Aquifer availability
Recreation	
Birding/wildlife watching	Relevant species populations
Hiking, biking, pleasure driving	Natural land cover, rural agri-landscapes, vistas, surface waters
Angling	Surface waters, target species populations, natural land cover
Hunting	Natural land cover, target species populations
Swimming	Surface waters, river banks, lake shores

Source: Based on Boyd and Banzhaf (2006).

the production of food and fiber, the location of residential, production, transport, and energy infrastructure, the extraction of abiotic resources, and the disposal of waste. However, the lack of effective incorporation of ecosystem service values into resource allocation decisions has led to inefficient use of many unpriced resources and unnecessarily large ecosystem losses. Second, the diagnostic abilities needed to adequately quantify many ecosystem services, and, third, the approaches needed to assign reasonably accurate economic values to most ecosystem services, have only become available fairly recently, increasing the awareness of the value of these services. Fourth, some ecosystem services are what economists refer to as public goods, that is, they are non-rival and non-exclusive (Eatwell et al., 1987). Others are quasi-public goods that may be rival but non-exclusive. Lack of excludability prevents their owners from reaping the full benefits of these services because of free-riding behavior of those who cannot be excluded from consuming those services, and thus results in incomplete or missing markets. Consequently, owners of lands producing such services have no financial incentive to take the services' value into account in their decision making. Fifth, the large human population increase during the last 50 years, coupled with increasing average per-capita resource consumption, has dramatically increased the scale of ecosystem transformation (Millennium Ecosystem Assessment, 2005b). Sixth, accounting systems that predate the recent period of increasing scarcity of many services and widespread awareness thereof have prevented the incorporation of environmental considerations into decision making at both macro (Hecht, 2005; Hamilton and Lutz, 1996; Repetto et al., 1989) and micro scales (Bennett and James, 1998). Finally, perverse incentives actively encourage environmentally degrading behaviors (Myers and Kent, 2001).

4. Importance of agricultural lands for ecosystem services

Agricultural systems are human-dominated ecosystems that, to varying degrees, are actively managed. The provision of ecosystem services *by* a particular agriculture site is affected by land management practices on that site. The provision of ecosystem services *to* a particular agriculture site is affected by activities on-site and off-site. Part of the ecosystem services provided by a site are captured on-site (such as pollination of crops grown on the site through pollinators living on the site) while others generate private or public benefits off-site. To the extent that landowners have not been compensated for such benefits to third parties, this is likely to be one of the factors contributing to the historically observed reduction in some ecosystem services provided by agricultural lands.

Because they account for a large share of total land use, agricultural lands constitute a prime target in any strategy aimed at slowing, halting, or reversing the loss of ecosystem services. In 2002, private crop (including the Conservation Reserve Program), pasture and rangelands together accounted for an estimated 49% of total surface area in the 48 contiguous states of the United States, with private forest lands accounting for another 21% (USDA, 2004). This makes it obvious why agricultural and private forest lands must form part of any large-scale efforts to maintain the provision of ecosystem services.

5. Why market-based approaches to ecosystem service provision?

A wide variety of policy approaches can influence the conservation or increased production of ecosystem services. These comprise legal and ethical tools such as liability laws, property rights, and moral suasion; institutional innovations; command-and-control approaches such as product, input, or technology standards; and economic incentive approaches, such as subsidies or tax reductions for adopting desired technology and production practices, or the levying of taxes and fees on sanctioned engagement in otherwise prohibited behaviors, such as the emission of pollutants. All of these approaches currently are employed to varying degrees to agricultural lands. However, there exists a belief that the expansion or creation of new market-based approaches to providing ecosystem services will better achieve conservation goals by making conservation financially attractive to the private sector. This seems to be based on the increasing evidence of the successful use of market-based approaches in conservation schemes around the world (Landell-Mills and Porras, 2002; Pagiola et al., 2002), as well as the popular view that markets by nature generally are superior allocation mechanisms. In fact, the issue of superior efficiency properties of market mechanisms for environmental management is not settled satisfactorily, due to a dearth of extensive empirical tests (Gustafsson, 1998).[1] This is certainly true also for the particular case of ecosystem services, and we know very little about the relative technical or cost effectiveness of many of the incentive mechanisms with regard to agriculture (Casey et al., 2006).

Private markets have been around for a long time for some ecosystem services provided by and to agricultural lands. Unsurprisingly, those services generally are private goods such as food and fiber or professional pollination services (Sumner and Boriss, 2006). The idea of deploying market-based approaches for environmental services more widely is attractive in part because some alternative approaches are of limited applicability or efficacy to the preservation or increased provision of ecosystem services on a meaningful scale. Private land use is subject to a variety of environmental regulations, but generally these are not designed to further the production of ecosystem services.[2] Liability laws impose sanctions for trespass and nuisance and have been quite effective in reducing water and air pollution. But where legally defensible links between cause and effect are difficult or costly to establish, or where services are difficult to measure, liability rules may be of not much help in preserving ecosystems. In addition, liability rules are intended to avoid the imposition of environmental "bads" to others — they do not prevent reductions in beneficial services to third parties, because no one is legally entitled to receive ecosystem services from someone else's lands. Property rights approaches to preserving ecosystem services also are likely to be infeasible in many cases because such rights are not well-defined for many ecosystem services.[3] Lack of well-defined property rights leads to socially suboptimal management of private lands that fails to maximize the total value of ecosystem services for society, because owners cannot capture the full value of public good ecosystem services. As a result, landowners often lack sufficient financial incentives for the socially efficient allocation of environmental resources and thus tend to manage for those services that are exclusive, such as food and fiber. In general, the difficulty of accurately measuring many ecosystem services hinders the application of liability and property rights approaches to these services.

Private markets also have failed to assign prices to many ecosystem services that reflect the benefits those services provide to society as a whole (Hamilton and Lutz, 1996; Salzman, 2005). This is not surprising, given that private markets require measurability of service flows, enforceable liability rules and property rights, and low transaction costs. Given the track record of missing markets and market failure for many ecosystem services, what needs to be examined is what has changed in the constraints that traditionally have led to these failures and that might improve the feasibility of market-based approaches.

6. Markets and payments for the provision of ecosystem services

Although today one constantly encounters references to "the market", there is of course, as Bromley (1997) reminds us, no such thing. Markets are socially constructed, ordered domains of exchange through which individuals can arrange the transaction of goods and services (Polanyi, 1944; Bromley, 1997), and the vast diversity of existing markets reflects the diversity in the underlying "prior collective notions and expressions of who counts, and what is valuable and useful" (Bromley, 1997:1391). An even more misleading notion is that of the "free market." Markets, especially efficient ones characterized by low transaction costs, require supporting institutions that facilitate information flows about exchange opportunities, reduce negotiating costs among market participants, and ensure the enforceability of contracts (Bromley, 1997). All of these require some form of community or government involvement. Markets are embedded in a larger institutional context that both enables and restricts the behavior of participants.

In many cases where ecosystem services are exchanged, the exchanges do not occur in what economists would consider a market. One important reason for this is that the economic value of many ecosystem services is highly location-specific (Salzman and Ruhl, 2000). The resulting spatial non-fungibility of ecosystem services restricts the geographic scale of the potential market and creates many small, discrete exchanges, all characterized by a small number of service suppliers and/or buyers. The resulting oligo- or monopolistic or -psonic exchange regimes still are markets in the basic sense that they involve voluntary exchanges, but they do not conform to what economists refer to as competitive markets. Importantly, a non-competitive market loses much or all of the theoretical efficiency advantage competitive markets might have over alternative resource allocation strategies. Because the structure of an ecosystem service market is a function of, among other things, the characteristics of the particular service — its temporal and spatial fungibility, its

[1] Experience in the U.S. with the control of some air pollutants indicates that market-based approaches may achieve environmental objectives cost-effectively, but the circumstances of those particular contexts (high-quality, continuous monitoring of emissions with strict oversight by public authorities, coupled with relatively small numbers of sources) differ from those found in the majority of cases in the ecosystem services context.

[2] Exceptions exist, such as the U.S. Endangered Species Act's injunctions against actions on private lands that jeopardize the continued existence of threatened or endangered species or adversely modify their habitat, if the actions in question are permitted, funded, or carried out by a federal agency; or state or local regulations that regulate forest practices, residential development in riparian zones, or pesticide application.

[3] Well-defined property rights are complete (i.e., the owner can capture all types of benefits derived from the services), exclusive (i.e., others can be prevented from enjoying them), transferable, and reliably and cheaply enforceable (Randall, 1987).

rivalness and exclusiveness, and its physical or economic quantifiability — efforts to establish service markets must be preceded by a careful analysis of these characteristics and their implications on supply and demand. The crucial question to consider is why are markets for many ecosystem services lacking? Answering this question will identify the obstacles to be overcome for ecosystem service markets to become a widespread reality.

The three main reasons for the widespread absence of ecosystem service markets are 1) the lack of widely available, easily applicable, and low-cost approaches to quantifying ecosystem service flows; 2) the difficulty of attaching to those flows reliable and low-cost estimates of their economic value (Boyd and Banzhaf, 2006; Boyd et al., 2001; Wainger et al., 2001; Troy and Wilson, 2006); and 3) the public goods nature of many of these service flows, or more specifically, their non-exclusiveness (Brown et al., 2006). While technical difficulties and limits to our scientific understanding may be the proximate causes for the first two reasons, the ultimate cause more likely is the fact that in most places, most ecosystem services have not become scarce until fairly recently (Millennium Ecosystem Assessment, 2005a). Since absence of scarcity by itself is a sufficient reason to prevent markets from developing, the increasing scarcity, present and projected, of many ecosystem services, and the increasing awareness of this scarcity, will by themselves favor the establishment of economic incentives for the provision of ecosystem services. However, measurability and exclusiveness remain necessary conditions for the development of private service markets. In fact, measurability remains a necessary condition for any kind of market-based approach, private or government created.

In any case, markets are not the only approach that allows the utilization of economic incentives. Rather, a variety of economic incentive approaches have been utilized to encourage the production of ecosystem services. These approaches can be distinguished into three principal types. Some payment systems have taken the form of business to business deals, where individual companies contract for the provision of services with landowners in what are essentially one-off, special arrangements driven by self-interest and worked out directly between the parties.[4] These arrangements are close to "real" markets in the sense that the only role for government is that of an enforcer of contracts. However, they are relatively rare due to the lack of excludability of many ecosystem services that prevents suppliers from reaping the full value of the services. A second type of payment system is direct government payments in the form of a competitive program, a subsidy, or hybrids.[5] A third approach is mitigation markets, which are based on compensatory mitigation requirements. These markets are entirely government created, since both demand and supply are the result only of environmental regulations coupled with monitoring and the credible threat of sanctions for non-compliance. In other words, they did not develop spontaneously from the profit motive of self-interested individuals. Rather, they are created through regulation and function well only to the extent that they are well-designed and implemented. In the U.S., mitigation markets for ecosystem services have been employed only in the case of wetlands and endangered species banking (Shabman and Scodari, 2004; Fox and Nino-Murcia, 2005). Even in those cases, however, markets are relatively new and often thin.

Of these three types of arrangements — business to business deals, government payment programs, and mitigation markets — the last is the only one that can be characterized as a market. By contrast, the business to business deals and government payment programs in existence so far all involve unique, tailor-made arrangements with products tailored to the buyer's needs, characterized by large requirements of highly specific information, resulting in intense negotiations and concomitant high transaction costs for buyers and sellers (Zilberman, 2005).

Because of their lower transaction costs, markets in theory are superior to payment schemes as a tool for achieving large-scale and broad-based private investment in ecosystem services. Of course, payment schemes and markets are not mutually exclusive. However, the presence of large-scale government payments for ecosystem services could crowd out some private investment in services. In general, which approach is preferable depends on the characteristics of the ecosystem service in question. Specifically, because of market failure, there is a role for public financing of service provision for services that have public good aspects and that cannot be bundled effectively with (i.e., that are not co-products of) private good type ecosystem services. For example, a given quantity of water of a given quality is a private good to the extent that its use is rivalrous and exclusive. Hence, the provision of this service (the water) is generally amenable to being marketed, and can be arranged through private interactions among self-interested individuals. In contrast, the

[4] Examples include Perrier-Vittel's payments to French farmers for changes in land use practices to improve water quality; Australia's Macquarie River Food and Fibre's payments to landowners for transpiration services achieved through afforestation (Salzman and Ruhl, 2000); payments by a hydropower plant in Costa Rica to upstream forest owners to reduce sediment loading through changed forest practices (Pagiola et al., 2004); or payments to landowners by an Oregon utility to achieve compliance with the U.S. Clean Water Act water quality standards through the planting of riparian shade trees (Logue, 2006).

[5] Examples of competitive programs are the U.S. Conservation Security Program's green payment type rewards for farmers and ranchers who engage in conservation and stewardship practices that go beyond addressing existing environmental problems and regulations, Costa Rica's biodiversity and water quality payments to forest owners, or Australia's BushTender and EcoTender programs that pay landowners for the provision of biodiversity services (Salzman, 2005; Brown et al., 2006). Examples of subsidies are several payment programs in Latin America for carbon sequestration and biodiversity conservation (Pagiola et al., 2004; Landell-Mills and Porras, 2002). Examples of hybrid programs are the New York City water agency's payments to farmers in the Catskills watershed, or payments by water utilities in Colombia, Ecuador and Mexico to farmers for conserving critical watershed forests (Pagiola et al., 2004).

biological resources found on that land to some extent may constitute public goods, and as such are not amenable to being marketed.[6] If water quality and quantity and biodiversity were perfect joint products, then biodiversity could be "bundled" with water, and the market-based conservation of water would also achieve biodiversity conservation. Evidence suggests that in many cases such bundling will be imperfect (Chan et al., 2006).

Though the geographic scale and comprehensiveness of existing ecosystem service markets and payment schemes is still limited, the number of such schemes is rapidly increasing and large-scale, national-level payment schemes now exist in many countries. For example, in most European Union countries agri-environment schemes with a biodiversity component are in place (Kleijn and Sutherland, 2003). In the U.S., federal programs such as the Department of Agriculture's Conservation Security Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program or the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife and Landowner Incentive Programs provide incentives to farmers and ranchers to implement voluntary conservation measures (Casey et al., 2006), and the majority of states have public payment programs for the restoration or conservation of wildlife habitat (George, 2002).

Despite the rapid growth of markets and payment schemes aimed at ecosystem services to and from agricultural lands, substantial challenges remain to integrate the value of many ecosystem services into the broader economy. What needs to be explored is the suitability of the different approaches to the efficient allocation of various ecosystem services, their associated design requirements, and the feasibility of implementing these requirements given the current structure of resource conservation incentive programs in the agricultural sector. Importantly, the proposed 2007 Farm Bill legislation expressly calls for the increased application of market-based approaches for ecosystem services and the exploration of the above questions. We explore some of these questions in the next section.

7. Discussion: constructing markets and payment systems for agricultural ecosystem services: challenges and opportunities

Like all markets, markets for agricultural ecosystem services are constructed and require a set of institutions and rules that organize their structure and conduct. The quality of the rules governing ecosystem service markets will determine the quality of the outcomes. The crucial questions are: What is the objective of ecosystem service markets, and what kind of institutional arrangements are most likely to achieve this objective? If perfect, such markets would achieve the efficient provision and allocation of ecosystem services. More realistically, they could be used to provide a desired level of particular services at least social cost. What that service level should be by definition is a normative question that involves a number of value judgments based on the trade-offs between producing ecosystem services or using lands for the satisfaction of other human needs and wants. Minimum service levels could be identified on the basis of what would be considered safe minimum standards (Ciriacy-Wantrup, 1952; Bishop, 1978). The most appropriate type of market-based approach for achieving the production of desired ecosystem services is likely to vary among services, in accordance to the degree to which a particular service is affected by the constraints to its commodification — the complete specification of the property rights to the service, its measurability, and its valuation.

7.1. *Public good ecosystem services*

Market transactions occur when the participating individuals perceive an opportunity to realize net benefits. The quality of a good or service is one of the features that determine its utility (demand) and its production cost (supply). This immediately highlights the main challenge ecosystem service markets face: In many cases, private interest in the quality of ecosystem services is lacking or is weak due to a lack of the service's exclusiveness. For this reason, many ecosystem service markets currently operating are government constructed, existing only as a result of regulations backed by credible monitoring and enforcement. Examples are habitat and wetlands banking. Such public or quasi-public goods markets are intrinsically problematic because there is no inherent incentive to ensure service quality beyond what is required by regulation (Salzman and Ruhl, 2000):

> The problem with ecosystem service markets is that the market itself does not define the units of trade (whereas conventional markets do). Instead, units of trade and compensation have to be defined by governments, governments being the trustees of environmental quality. This is a point often missed by advocates of trade in ecosystem services. In a conventional market, the buyer is concerned selfishly about the quality of the 'unit' they buy. In an ecosystem market, the environmental good is a public good and the buyer is therefore indifferent to its quality. The buyer is concerned only about satisfying the regulator's definition of an adequate unit.[7] (Boyd and Banzhaf, 2006:3)

As a result, the appropriate institutional framework becomes the sine qua non for achieving the desired quality of the services in question. For the case of credit trading in mitigation banking, Salzman and Ruhl (2000) identify the requirements the framework must fulfill as *currency*, *exchange*, and *review adequacy*. A currency, or unit, is adequate if it does not lead to non-fungibilities, that is, if it captures the variations in environmental service values across time and space. Exchange adequacy is achieved if all trades in environmental goods and services are of equal total economic value. It is automatically achieved by an adequate currency; lacking such currency, exchange adequacy

[6] In particular instances, individual species or habitats may be exceptions to this general rule, to the extent that they are sufficiently well-known and appreciated to generate a willingness to pay among a segment of the public to support their protection. For example, conservation organizations may mobilize sufficient resources to take out biodiversity protecting easements or to purchase the respective land outright.

[7] This point is also emphasized by Eigenraam et al. (2006).

requires institutional constraints such as trading ratios or zones that guide market transactions such that only trades of equal value take place. Finally, review adequacy is achieved if, in the absence of currency and exchange adequacy, the mechanism for approval of trades is structured in such a way that it ensures that only trades of equal value are taking place. Given the absence of perfect service currencies, it is likely that institutional constraints needed to ensure exchange or review adequacy for public goods ecosystem services would lead to transaction costs for most services that would make such markets thin or unviable.

7.2. *Valuation and pricing of ecosystem services provided to and by agricultural lands*

Ecosystem services provided by agricultural lands generate both market and non-market benefits, comprising both use and passive use values. For example, natural land cover, an ecosystem service provided by certain agricultural lands, generates aesthetic and property damage avoidance benefits, both of which are direct use values reflected in markets through open space property value premiums (Earnhart, 2006; Krieger, 1999; Heimlich and Anderson, 2001; Kline and Wichelns, 1998) and avoided preventative or repair expenditures, respectively. It also generates passive use (bequest, stewardship, and existence) values which generally are not captured in markets but can be estimated through stated preference approaches (contingent valuation or conjoint analysis). For example, the value a farmer assigns to practicing good land stewardship and its contribution to public well-being and ecosystem health from clean water could potentially be estimated using the farmer's observed willingness to pay (WTP) to depart from profit-maximizing behavior (Provencher, 2005), something well-documented for example for non-industrial private forest owners (Raunikar and Buongiorno, 2006). Natural land cover in agricultural landscapes can also provide recreational benefits. These benefits represent direct use values that are reflected in markets (except for the consumer surplus) through recreationists' trip and equipment expenditures. The relative size of market and non-market value of particular agricultural lands varies depending on a variety of factors, but the non-market value of agricultural lands in many cases can be substantial (Loomis et al., 2000). It is therefore crucial that these values be included when analyzing the value of agricultural ecosystem services. Thus, it is necessary to determine clearly the types of values associated with particular ecosystem services in order to identify appropriate valuation methods.

Unlike commodities, which are reasonably fungible across space, most ecosystem services exhibit important non-fungibilities (Salzman and Ruhl, 2000). As a result of this strong context specificity, their value can vary greatly in different locations (Boyd and Banzhaf, 2006). It also varies over time. For example, the value of water availability for agricultural crops may vary substantially with the crop, the location of the service, and when the service is provided. This value, the marginal net profit forgone (Hanemann, 2005) without availability of the water from the local ecosystem, varies between different crops, depending on the production cost and the cost of substitutes for the ecosystem service. It also varies during the growing season, depending on the physiological water requirements of the crops at different points in time. Of course, the total value of the ecosystem service for crops also depends on the total quantity of the respective crops harvested in the location.

A great deal of experience has been accumulated in applying valuation approaches to ecosystem services. Nevertheless, the spatially specific nature of studies yields value estimates for individual, discrete locations. The high cost of high-quality valuation studies precludes closing the gap of site-specific studies by "simply" conducting more studies. Rather, a comprehensive mapping of ecosystem services values, across multiple services and over large areas or at a large number of individual locales, may be achievable through the application of cost-reducing techniques such as geographic information systems (GIS) analysis and benefit transfer.[8] For example, meta-analysis based transfers can be facilitated by WTP indicators (Boyd and Banzhaf, 2006), quantifiable characteristics that raise or lower WTP for particular ecosystem services (Boyd and Wainger, 2002, 2003; Wainger et al., 2001). Such an approach to full monetary quantification of ecosystem service values therefore would require GIS mapping of site-specific measures of ecosystem scarcity, substitutes, and complements (for example, irrigation water). The indicators can then be used to calibrate ecosystem service-specific WTP functions by relating measurable WTP indicators to existing WTP estimates of service values. Nevertheless, spatially explicit value transfers still are very challenging because of the lack of available spatial data and suitable primary valuation studies (Troy and Wilson, 2006).

Full monetary quantification clearly is not required if the goal is simply to prevent social-welfare reducing trades of regulated ecosystem services, as in the case of mitigation or conservation banking. In that case, relative value indices would be sufficient and full monetary quantification unnecessary (Wainger et al., 2001). Likewise, full monetization of service values is not needed when the goal is to provide given (but not necessarily efficient) levels of ecosystem services cost-effectively. This can be achieved through reverse auctions where landowners bid for contracts that stipulate the provision of certain service levels or associated management actions (Eigenraam et al., 2006; Greenhalgh et al., 2007).

The full monetary valuation approach of ecosystem services envisioned by Boyd and Banzhaf (2006) would satisfy Salzman and Ruhl's (2000) adequacy requirements. Full monetary valuation in fact would achieve the ultimate level of commodification of ecosystem services — their expression in market prices and therewith their seamless integration into the economy's market-based mechanism of allocation of resources. Importantly, this by itself does not ensure protection of these resources in the absence of regulatory constraints. First, even if the market value of ecosystem services on a given piece of land reflected the total economic value of those services, competing uses may have higher market

[8] For assessments of the performance and potential of benefit transfers and applications, see Brouwer (2000), Smith et al. (2002), Bergstrom and De Civita (1999), and Rosenberger and Loomis (2001).

values. Second, the ubiquitous phenomena of myopia, market power, imperfect information, uncertainty, and limits to scientific knowledge, and the drive to externalize costs and privatize benefits all make it unlikely that market prices will reflect the full value of ecosystem services and lead to optimal allocation of services.[9] Because of these concerns, we argue that it should not be left to markets to define the desired levels of those ecosystem services that are not pure private goods. Rather, well-designed markets can be used to provide desired service levels at least cost.

This leads us to the crucial point of price-setting in ecosystem service markets. In order for markets to achieve an efficient allocation of services, prices must reflect total service values, taking into account explicitly the variation in values across type, space and time. If service prices are to reflect total service values, prices of services with a public goods component cannot be based on production cost or the interplay of supply and demand, because of the problems of market failure and missing markets already discussed. Rather, they would be determined through an integrated scientific–economic analysis along the lines proposed by Boyd and Banzhaf (2006). This stands in sharp contrast to the price-setting in conventional markets, where prices are freely agreed upon by buyers and sellers. Thus, ensuring that service price reflects service value is a real challenge for services that are non-exclusive, non-rival, or that have passive use values. This will require some form of intervention to ensure socially desirable levels of production. For protected services (wetlands or endangered species habitat) this intervention takes the form of regulation, for others, that of government or third-party funded payment schemes that compensate landowners for service production. The treatment of passive use values presents a special challenge for market-based approaches to service provision — how can these values be broken down and assigned to individual properties? For wildlife habitat on agricultural lands, such a breakdown would require a science-based analysis of the relative importance of a property to individual species or communities that are objects of passive use values.

7.3. *Measuring ecosystem service flows*

For markets to perform their allocative function efficiently or at least cost-effectively, the physical levels of ecosystem services provided by given agricultural lands must be measurable with a reasonable degree of accuracy and at a cost substantially below the services' market value. This is already achieved for most marketed agricultural ecosystem services, such as crops or livestock. For others, such as carbon sequestered in plants, "measurement" of service flows is becoming well-established using accepted procedures, and markets for these services have begun to develop (Diamant, 2006). However, even in these cases, service flows generally are estimated through models rather than measured. This in itself is not necessarily a problem for service commodification. Rather, the challenge lies in developing estimation techniques for the various services that allow the generation of service estimates that are seen as reasonably accurate by market participants. In the absence of this, uncertainty about the volume and hence the value of the services produced by a piece of land will decrease market volume or lower service prices, which in turn will lead to the provision of suboptimal levels of service flows. Recent research shows that it is certainly possible to develop model-based estimates for many ecosystem services provided by agricultural lands that can be considered reasonable (Chan et al., 2006; Troy and Wilson, 2006; Kremen et al., 2004; Casey and Boody, 2007). It is questionable however whether their associated uncertainty would be acceptable to private markets. Continuing research on service measurement is likely to reduce these uncertainties, but at this point it is too early to judge whether it will do sufficiently so to allow commodification of the associated services.

It follows from the foregoing discussion that achieving efficient or cost-effective ecosystem services provision from agricultural lands faces a number of challenges. None of the existing ecosystem service markets or payment schemes could be considered optimal in an economic sense. Very few of the requirements for optimal ecosystem service provision through markets are presently fulfilled. While some of the gaps could be closed with current knowledge, effective implementation of high-quality markets that capture the full economic value of traded services would most likely be very expensive and complex, and perhaps prohibitively so, because of the attendant measurement, valuation, and monitoring requirements. There is a fundamental difference between "optimal" markets that maximize social welfare, and "functioning" markets that achieve a high volume of transactions while sufficiently protecting service values. Optimal markets face technical challenges and high transaction costs, and consequently are likely to be unattainable or thin. "Functioning" markets on the other hand require high transaction volumes, which, given the current state of ecosystem service measurement and valuation, are likely to lead to substantial non-fungibilities and hence suboptimal outcomes. Moreover, even if most of the technical and financial challenges could be overcome, net loss of services may still result because of competing higher-valued uses that may neglect intertemporal welfare concerns. Hence, a regulatory framework is needed that addresses both the definition of service units and the monitoring of service provision to generate certainty over time by overcoming information asymmetry problems. That framework must also stipulate adequate provisions to ensure liability for services sold (Gardner, 2006).

Where does this leave us? Based on the preceding discussion, we can identify the characteristics of those ecosystem services that in principle are suitable to management using market-based approaches. These are services that are scarce, either because they are perceived as such by private actors or because their use is government regulated. They also are characterized by unattenuated property rights, that is, they can be defined clearly, their ownership is consistently and reliably enforced and transferable, others can be excluded from their use by the owner, and, importantly, all of these can be done relatively cheaply. However, if these services generate uncompensated third-party effects, either positive (use values such as off-site pollination, or passive use values) or negative (pollution), if there are only few buyers or sellers for a particular service, if buyers or sellers are not well-

[9] Market prices often fail to correctly indicate the relative scarcity of natural resources (Norgaard, 1990).

informed about the markets, or if the services are non-rival, then private markets will not be competitive, that is, they will lead to inefficient outcomes. In these cases, government-created markets or payment schemes may be better suited to managing these services. In general, the requirements for efficient private market allocation of ecosystem services to and from agricultural lands (Table 1) are fulfilled only for local soil quality, shade, shelter, and water availability provided by on-site vegetation (although measurement of service flows is likely to be imperfect for these), and domesticated and wild species that do not roam beyond the property boundaries. This does not mean that such services will never be traded in private transactions — take for example the case of Perrier-Vittel in France — but it makes it very unlikely for this to occur widespread or that the outcomes will be efficient. The requirements currently are not fulfilled for water quality and quantity (which are impacted by activities on larger scales), wild pollinator populations, air quality, natural landcover in viewsheds and rural landscapes, biodiversity, species or natural features that carry existence values, and mediation of weather extremes by ecosystems (the benefits of which extend beyond property boundaries). Government-created markets and payment schemes may work for those services that lack exclusivity, competitive market structure on the supply or demand side, or that cause uncompensated third-party effects. Efficient management of these services will still require measurement and monitoring and enforcement, and, importantly, only well-designed and implemented government programs can achieve desired outcomes. Nevertheless, even if government-created markets and payment schemes make efficient actions unlikely, they could still serve as a cost-effective means of achieving the desired levels of services through reverse auctions.

Importantly, these regulation-driven or government-created markets are very different from “free-market environmentalism”, which advocates the use of market-based approaches to achieve environmental protection, arguing that the latter are inherently superior to government regulation or ownership (Stroup and Shaw, 1989; Anderson and Leal, 2001). The central tenet underlying free-market environmentalism is that welfare-maximizing private actors will aim to preserve valuable environmental resources and avoid negative impacts on others because they benefit financially from such good stewardship. The problem in applying a “free” market approach to ecosystem services is that such an approach can only work for resources characterized by complete (clearly defined, easily defended against invasion, and transferable) property rights. However, many of those services not already marketed have public or quasi-public good character, thereby violating precisely the condition necessary for property rights based free-market approaches to be effective and to achieve efficient outcomes. For this reason, constructed rather than “free” markets seem to hold more promise for protecting public good ecosystem services. In these constructed markets, private property rights for some environmental services (e.g., habitat provision for endangered species) are created through regulation aimed at protecting the public interest in service provision.

Given the current structure of public, especially federal, conservation incentive mechanisms (cost-share, easements, land rentals, stewardship payments, institutional innovations) to maintain environmental services on agricultural lands, what is the feasibility of implementing markets for ecosystem services to and from agricultural lands? There are specific issues that will need to be addressed by public authorities in order to achieve effective and efficient market structures and conduct. These issues fall into the general categories of demand and supply. On the demand side, the major question is, “Who are the buyers?” With respect to resource conservation, the predominant “buyers” have been federal and state governments that have provided numerous types of environmental conservation incentive mechanisms. Only relatively recently have private market mechanisms such as conservation easements held by local land trusts, mitigation banking, eco-tourism, or eco-labeling engaged agricultural landowners in the preservation of ecosystem services. If the clientele for ecosystem services is going to expand beyond the public agency, then these agencies are going to have to play at least three roles: 1) to act as a repository of the services supplied (and their location); 2) to monitor that the marketplace is effective and equitable in meeting minimum product standards; and 3) to help facilitate the start-up of market-like approaches (e.g., eco-labeling, eco-tourism).

Because we are addressing environmental resources such as soil and water quality or wildlife, there is a very strong public interest in the capacity of ecosystem service markets to provide long-term or permanent environmental benefits, especially those benefits provided by agricultural landscapes. The major questions to be answered include the following: Can markets be sustained over time to maintain ecosystem services? Does this mean a permanent role for public agencies in monitoring markets, which can be intensive and result in high transactions costs? The monitoring question is essential and sensitive. Problems associated with the collapse of some species mitigation banks (McClure, 2005), one form of ecosystem market, raise questions about the viability of markets to provide public ecological goods.

An interim step in operationalizing ecosystem service markets may be to encourage indirect market opportunities. Private landowner benefits derived from recreational activities, eco-tourism, or eco-labeling, consistent with restoring and maintaining valuable ecosystem services, can serve as an interim approach and maintain a public interest. Private markets already exist for these activities and they could continue to work with the provision that ecosystem services be maintained.

The supply of ecosystem services by private agricultural landowners will depend on prices received and the type of payment mechanisms, compared to alternative land uses. A crucial determinant of ecosystem service payments is the definition of what constitutes a “service”. Is it the actual increase in the flow of an ecological output, the land management practice adopted that will lead to an increase in that flow, or the actual performance-based outcome? The emphasis in policy discussions to date has been on developing ecosystem service markets based on performance outcomes, that is, measurable increases in the amount of an ecological benefit over a given baseline. A major constraint to date in implementing this approach has been in determining how performance for various ecological services will actually be measured. Will this entail intensive and expensive field monitoring techniques, or can an increase in services be predicted through resource models? If actual measurement is considered the most reliable approach, what will be the indicators employed? Woodward and McCarl (2006) call this the "verification quandary" and the "dark hole of management. " One initial approach to measuring outcomes would be to initiate a series of pilot projects that help to determine the physical cause-and-effect relationships. Although data and research intensive, such pilots could serve as a basis for defining and valuing ecosystem services that could be applied in other socio-physical contexts. Paying for the adoption of agricultural practices known to result in measurable environmental improvements could also be a proxy. But the relationship between practice and outcome needs to be a close one. In addition to the challenge of selecting indicators is that of defining a "unit" of ecosystem service. Along with value comes the quantity of the good at which that value is set. Is the unit, for example, pounds per acre of sequestered nitrogen? Is it the number of a particular species that re-colonizes an acre of land restored to habitat? These questions will need to be addressed before private ecosystem service markets will develop.

What is referred to as the "aggregation" problem is equally applicable to both the supply and demand side of ecosystem service markets. For particular ecosystem services that are provided in a defined agricultural area, both suppliers and buyers may experience thin markets. Subsidiary questions are where does the service exist and are units large in number or small? The usual approach to solving the aggregation problem is to enlarge the size of the trading area or the number of discrete environmental goods that can be traded in a more limited zone. An example of the former approach has been applied to water quality trading where a watershed-based approach is considered a more viable market compared to stream segments that may have a limited number of buyers and sellers.

The history of federal resource conservation incentive programs in the agricultural sector is one of allowing voluntary equal access to all landowners, based on achieving some minimal expected level of environmental benefit. In addition, conservation incentive funding is more or less distributed equally among states. It is only recently that a more targeted approach has been adopted. With the institution of ecosystem markets, there is likely to be a tension between allocating oversight resources efficiently according to environmental problems and the current emphasis on equity.

Lastly, we need to ask what the roles for public agencies are. These roles are very ill defined at present. Are public agencies serving in the role of market organizer, broker, or participant? These questions need to be resolved.

A concern on the part of the public at large is the uncertainty associated with the quality of agricultural ecosystem services that are bought and sold in a marketplace. Even within a private market structure there is a role for government to guarantee to consumers that a particular good or service is both what it says it is and that it meets certain minimum quality standards. This is certainly the case with agricultural food products and is one of the major objectives of the Food and Drug Administration. Given that traditional conservation incentive programs have not been based on market concepts, a wholesale transition to market-based payment mechanisms for ecosystem services could be problematic. Federal conservation programs designed to improve water and wildlife habitat quality and reduce soil erosion rates have been based on commercial land values that do not incorporate the value of ecosystem service flows. More work needs to be done in determining fair and efficient market structures, and developing the technical capacity to assist in their implementation and the monitoring of market outcomes. There will be an important role for public sector involvement and oversight. One example of this in the agricultural sector is the recent piloting of a reverse auction bidding process for wetland restoration (Greenhalgh et al., 2007).

8. Conclusion

Proponents of ecosystem service markets argue that ecosystem services need to be integrated into the broader economy in order to slow their continuing loss. If designed properly, ecosystem service markets can achieve this by giving landowners financial incentives to provide these services. However, many ecosystem services have public goods aspects and as such markets for them have not formed. Unless these services are co-products of marketable, private good type ecosystem services, markets will fail to generate incentives for their provision. Furthermore, creating markets that can capture at least the private value of ecosystem services currently is impossible for many services not already traded, due to the limits to accurate measurement or the associated high transaction costs. Where measurement is possible, markets that price ecosystem services solely on the basis of their private benefits could attract high transaction volumes, but this is likely to result in a loss of services that are non-exclusive, non-rival, or carry substantial passive use values. The challenge is to design markets that incentivate landowners to produce ecosystem services at socially efficient levels. We argue that this requires a carefully crafted regulatory framework to ensure that the likelihood of a net loss of ecosystem service values is minimized. At a minimum, such a framework would define the units for the various services as well as a reasonably accurate quantification mechanism, and it would entail public payments for landowners who provide scarce services that generate public benefits. It would also establish monitoring requirements and a chain of liability backed by sufficient securitization of service contracts. If these requirements are fulfilled, market-based approaches and the private awareness, initiative and capital they can mobilize may play an important part in overall ecosystem service conservation efforts. Contrariwise, given the large potential for market failure, commodification of ecosystem services by itself cannot be expected to yield outcomes that protect the public interest.

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