Payments for Ecosystem Services and U.S. Farm Policy

John M. Antle

Widespread sentiment among both policy analysts and public interest groups that U.S. farm subsidy policy is flawed and in need of reform (Agriculture Task Force 2006) is not new. In his well-known book, *World Agriculture in Disarray*, published in 1973, D. Gale Johnson argued that agricultural subsidies by the United States and other industrialized countries distorted prices in domestic and international markets, and that policies in many developing countries further distorted markets by effectively taxing their agricultures. These ideas provided the intellectual foundations for efforts by the United States and other countries to bring agriculture into the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO). The outcome of the WTO case brought by Brazil in 2003 against U.S. cotton subsidies, in which the subsidies were declared to be in violation of international trade rules, indicates that American agricultural policies need to be reformed in the near future, either through U.S. initiative or in response to additional WTO cases that are likely to be brought against U.S. policies.

Economics tells us that policy has a positive role to play when markets fail to allocate resources efficiently and equitably. In the case of agricultural policy, producing equity between the incomes of farm and nonfarm households was a principal rationale for government intervention in agricultural markets. However, while public support for preserving the "family farm" seems to remain strong, existing subsidy policies cannot be justified on either equity or efficiency grounds. Subsidies based on acres produced of "program" crops not only distort domestic and international markets; they also disproportionately benefit large, commercial farms owned by corporations and individuals with above-average incomes and wealth (U.S. Department of Agriculture, Economic Research Service 2006c).

In this paper I build upon earlier work (Antle and Capalbo 2002) to argue in favor of a policy based on the provision of ecosystem services by agriculture.[1] A great deal of scientific data shows that agricultural land use and management affect a wide array of goods and services associated with ecosystem function that are not usually valued by or traded in markets. Economic theory tells us that, under these circumstances, markets based on private benefits and costs do not allocate resources efficiently. Left to their own devices, they will tend to overproduce market goods and underproduce ecosystem services. Thus, there is both a scientific and an economic basis for a policy that would provide incentives for farmers to supply the appropriate combination of market goods and ecosystem services.

I shall further argue that an efficient agricultural policy could be implemented using a mechanism that I call "payments for ecosystem services," or PES. I define a PES system as one that rewards farms for increasing the quantity of ecosystem services they supply above and beyond the amount that would have been provided without such rewards. A key feature of PES is that they are not subsidies, but financial incentives provided to farmers who bear costs to increase the supply of ecosystem services valued by society. Thus, PES differ in important legal and economic respects from existing commodity subsidies. A PES policy also differs in important ways from most existing

[1] Note that the discussion here focuses on existing commodity subsidy policies. As explained elsewhere (e.g., Agriculture Task Force 2006), similar arguments can be made for publicly funded provision of public goods such as infrastructure and research.

“conservation” or “environmental” programs, which prescribe conservation and environmental practices that farmers should use. Experience with environmental regulation as well as recent research show that this prescriptive approach is far less efficient than policies based on performance standards and incentives—one way in which a PES system could be implemented.

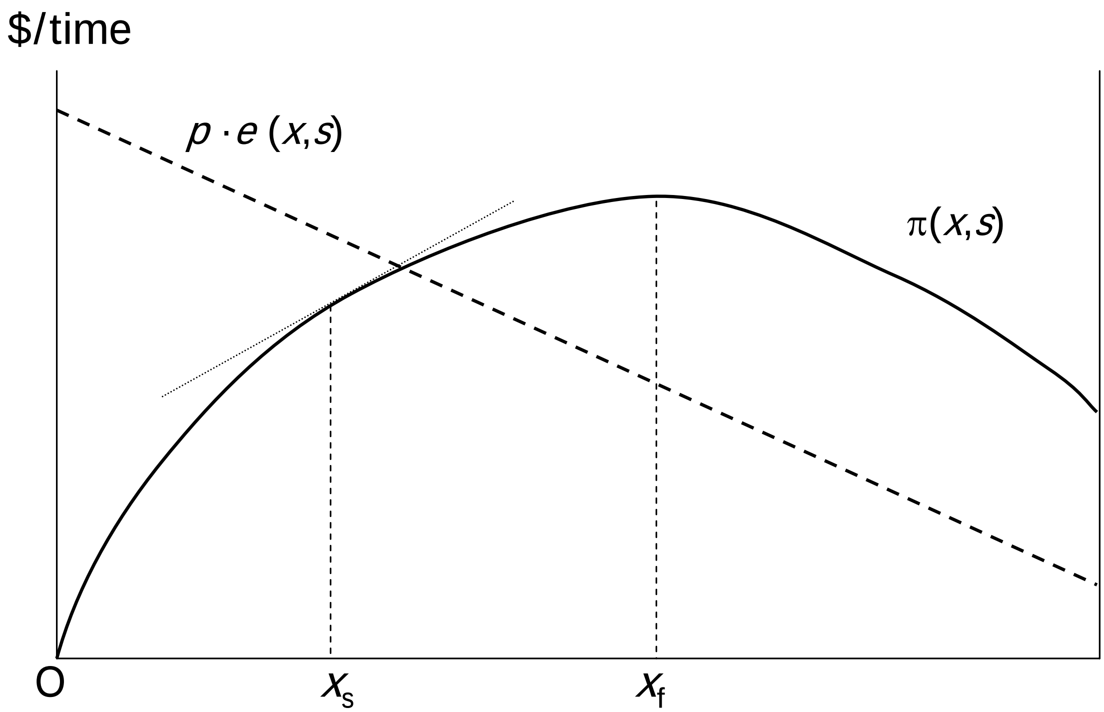
The first part of this paper discusses the scientific and economic basis for replacing existing commodity and conservation policies with a PES system. To support the transition from the current policy regime, policy decision-makers will need to know how to design efficient mechanisms for the provision of ecosystem services from agriculture, along with estimates of their environmental and economic effects. Accordingly, the second section of the paper discusses efficient mechanism design for PES, and the third discusses the current capability to quantify agricultural externalities and the effects of implementing a policy based on PES. The paper concludes with an assessment of the technical, economic, and political feasibilities of an agricultural policy based on PES.

Payments for Ecosystem Services as an Efficient Policy

A large and growing body of science—as presented, for example, in the journal *Agriculture, Ecosystems and Environment*—underpins the concept of ecosystem services and demonstrates that agricultural activities have impacts on ecosystem function and the provision of those services. Ecosystem services are services naturally provided by the environment that benefit human beings and other organisms. They are “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life” (Daily 1997) by “purifying air and water, detoxifying and decomposing waste, renewing soil fertility, regulating climate, mitigating droughts and floods, controlling pests, and pollinating plants” (Salzman et al. 2001). The scientific literature establishes that farmers’ land use and management decisions may affect biological and physical systems through a number of mechanisms. Some effects, such as changes in soil productivity, may be limited to the land owned by the farmer; others, such as chemical runoff into surface waters, may appear offsite.

Ample evidence shows that in the absence of policies that affect their incentives, most farmers make land use and management decisions based on maximizing economic returns and do not take into account society’s valuation of ecosystem services. To increase the supply of ecosystem services beyond this private equilibrium, farmers must be provided with incentives to change their management decisions. In most cases, ecosystem services are public goods, so some form of government intervention or assignment of property rights is called for. For example, a government program might pay farmers to promote the mitigation of greenhouse gases by adopting practices that sequester carbon. Alternatively, a government regulation that caps greenhouse gas emissions to create a market for carbon emissions reduction credits could also encourage carbon sequestration.

Figure 1. Economic analysis of payments for ecosystem services at the farm level



Note: (x = management activity, p = ecosystem service price, e = ecosystem service, π = economic returns, x_s = socially efficient management, x_f = profit maximizing management).

Economic theory has a well-established analytical framework to deal with external benefits and costs, wherein policy instruments are used to equate marginal "social" benefits to marginal "social" costs of an activity. Marginal social benefits and costs account for the "private" benefits and costs that are recognized in markets, as well as any "external" benefits and costs. While this principle is well established in theory, implementing it in practice with PES is the challenge addressed here.

This analytical framework can be explained using figure 1, which shows a graph measuring economic values on the vertical axis and the level of a management activity x on the horizontal axis (say, the use of an agricultural chemical, or a tillage practice that affects erosion). The curve $\pi(x,s)$ represents farm profits from growing a crop at site s, where this curve attains a maximum value at x_f. The function $e(x,s)$ represents the quantity of ecosystem services produced on the land under management; for simplicity it is drawn as a decreasing linear function of x with a maximum value attained when $x = 0$ (think of e as a measure of environmental quality such as water quality). The variable p represents the price paid for the ecosystem service (with units defined as \$ per unit of e). If the policy being used to implement the PES is efficient, p will be equal to the marginal social value of the ecosystem service. It is important to keep in mind that both economic returns, π, and ecosystem services, e, vary spatially, a key point we return to below.

To evaluate the implications for farmer behavior, observe that without a payment for the ecosystem service, the farmer would choose to produce with the quantity x_f where profit is maximized. However, if the farmer were paid p dollars per unit of ecosystem service, then the total value of the farm activity would be $\pi(x,s) + p\ e(x,s)$. Accordingly, the quantity of x that would be chosen to maximize economic returns to the production activity would be $x_e < x_f$ where the marginal private benefit of x is equated to the marginal benefit of producing more ecosystem service (the point where the slope of the profit curve equals minus the slope of the ecosystem service value curve).

The analysis in figure 1 has several important implications for agricultural policy design. First, it shows that the management strategy that maximizes the social value of the land (profit from the marketed good plus value of the ecosystem service) may involve the continued production of the marketed good with some change in management to increase the quantity of environmental service. Thus, the best use of the land from a social point of view does not necessarily involve dedicating it to a "conserving use" that precludes crop or livestock production, as is the case with existing conservation programs such as the Conservation Reserve. The elimination of productive activity maximizes value of the resource only in those situations where the marginal reduction in ecosystem service value is so large that it more than offsets the loss of market goods production. Figure 1 shows that as the price of the ecosystem service, p, increases, the efficient management x_e moves left toward zero, at a sufficiently high value, the socially efficient outcome would require that the farmer stop using the land for production of the marketed good. However, as this example shows, this "corner solution" need not be the way to maximize the sum of private and public value of the land.

Second, the analysis in figure 1 has important implications for the welfare effects of an efficient policy. Starting from the private equilibrium x_f, the move to the socially efficient point x_e results in a reduction in returns to crop production equal to $\pi(x_f) - \pi(x_e)$. This loss in value can be interpreted as the private opportunity cost to the farmer, in terms of forgone profits, for reducing production activity in order to increase ecosystem services from $e(x_f)$ to $e(x_e)$. Conversely, starting at the socially efficient point x_e, we could say that the social opportunity cost of agricultural production, in the form of a reduction in ecosystem services, increases if the farmer chooses to produce at the point that maximizes his private returns at point x_f. These observations imply that the efficient outcome x_e can be attained with either a positive or a negative incentive. The appropriate form of incentive depends on the allocation of property rights. On the one hand, if the farmer has the right to carry out the activity at point x_f , then society has to compensate the farmer in order to induce a reduction to point x_e. On the other hand, if society has the right to ecosystem services, the farmer can be penalized for actions that reduce them; for example, society can levy a tax per unit of reduced ecosystem services.

A third implication of this analysis is that an efficient policy must take heterogeneity into account. Crop returns as well as ecosystem services depend on site-specific characteristics, such as soils, climate, distance to market, and characteristics of the farm decision-maker. Thus, for given prices, the relationships in figure 1 differ from site to site, and a "one-size-fits-all" policy that treats every farm as if it were the same would not meet the goal of achieving the desired total quantity of ecosystem services at the lowest cost.

Current Policies and Their Limitations

A long history of government programs related to conservation and environmental management shows that, over time, U.S. policy has shifted from maintaining on-farm productivity toward rewarding farmers for resource conservation and provision of ecosystem services. Thus, the United States has already traveled some distance down the path toward policies that resemble a PES system, although they fall far short of what an efficient PES system would be.

Policies aimed at conserving and protecting soil and water resources grew out of the Dust Bowl crisis of the 1930s and have evolved significantly in recent decades (U.S. Department of Agriculture, Economic Research Service 2002). Early conservation programs focused mainly on maintaining cropland productivity through adoption of soil erosion control practices, with subsidies that paid part of the cost of adoption (cost-sharing). In addition, receipt of commodity subsidies was linked to adoption of soil conservation practices.

The 1985 Farm Bill introduced several new provisions that began a shift in focus from on-farm productivity to off-farm environmental benefits. It established the Conservation Reserve Program (CRP), which provided payments to producers to put environmentally sensitive cropland into conserving uses for ten to fifteen years. The bill also included the sodbuster, swampbuster, and highly erodible land provisions that tied eligibility for farm price and income support and other program benefits to adoption of soil and wetland conservation practices on fragile lands. The 1990 Farm Bill continued the CRP and created the Wetlands Reserve Program (WRP) to restore and place conservation easements on wetlands. It also authorized the Water Quality Incentives Program (WQIP).

Box 1. Agricultural Conservation and Environmental Programs

Land Retirement Programs

- The ***Conservation Reserve Program (CRP)*** and the ***Conservation Reserve Enhancement Program (CREP)*** offer annual payments and cost-sharing to establish long-term, resource-conserving cover, usually grass or trees, on environmentally sensitive land.
- The ***Wetlands Reserve Program (WRP)*** provides cost-sharing and/or long-term or permanent easements for restoration of wetlands on agricultural land.

Working-Land Payment Programs

- The ***Environmental Quality Incentives Program (EQIP)*** provides technical assistance and cost-sharing or incentive payments to assist livestock and crop producers with conservation and environmental improvements on working lands.
- The ***Conservation Reserve Program (CRP) Continuous Signup*** provides cost-sharing and annual payments to producers who establish "buffer" practices, such as riparian buffers, filter strips, grassed waterways, and contour grass strips to intercept sediment and nutrients before they leave the field.
- The ***Wildlife Habitat Incentives Program (WHIP)*** provides cost-sharing to landowners and producers to develop and improve wildlife habitat.
- The ***Conservation Security Program (CSP)*** will reward demonstrated land stewards for implementing appropriate land-based practices on working lands that address one or more resources of concern, such as soil, water, or wildlife habitat.

Agricultural Land Preservation Programs

- The ***Farm and Ranch Lands Protection Program (FRPP)*** provides funds to state, tribal, or local governments and private organizations to help purchase development rights and keep productive farmland in agricultural use.
- The ***Grassland Reserve Program (GRP)*** is designed to preserve and improve native-grass grazing lands through long-term contracts and easements. While normal haying and grazing activities will be allowed under GRP, producers and landowners cannot crop the land and will be required to restore and maintain native grass and shrub species.

Technical Assistance

- The ***Conservation Technical Assistance (CTA) program*** has been providing conservation technical assistance for planning and implementation of conservation systems since 1935.

Compliance Mechanisms

- ***Conservation Compliance, Sodbuster, and Swampbuster*** are provisions that tie the receipt of farm payments to management of highly erodible land and wetlands.

Source: U.S. Department of Agriculture, Economic Research Service (2005).

A number of important changes in the federal government's approach to agriculture and the environment occurred as the 1990s progressed. In 1994, Congress changed the name of the Soil Conservation Service—created in 1935 to combat the Dust Bowl—to the Natural Resources Conservation Service (Cox 2006). The 1996 Farm Bill took the trend toward agricultural-environmental policy further than previous legislation by consolidating the Agricultural Conservation Program, the WQIP, the Colorado Salinity Program, and the Great Plains Conservation Program into the Environmental Quality Incentives Program (EQIP). In addition, the 1996 bill authorized the Farm and

Ranch Land Protection Program (FRPP) and the Wildlife Habitat Incentives Program (WHIP).

Perhaps the largest advance occurred with the passage of the 2002 Farm Bill (formally, the Farm Security and Rural Investment Act of 2002). The 2002 Farm Bill authorized a historic increase in funding for private lands conservation programs. According to Congressional Budget Office estimates, the bill increased funding for conservation programs by over $17 billion during FY 2002–11 and increased annual spending to $4.7 billion in FY 2005, compared to $3 billion in FY 2001. It explicitly linked financial assistance programs to environmental objectives, and it shifted the emphasis significantly from conservation programs such as CRP toward "working lands" programs (U.S. Department of Agriculture, Economic Research Service 2005). EQIP was redesigned to help farmers institute conservation practices and integrate conservation structures into their farming operations. The Conservation Security Program (CSP) was created to reward producers for ongoing environmental stewardship on working lands and to provide them with financial incentives to adopt additional conservation practices on their farming operations. Under the program, producers agree to maintain and implement designated conservation practices for a period of five to ten years. In return, they receive payments that increase as they address additional resource concerns on larger portions of their farm operations.

Both the earlier soil conservation programs with their focus on farm productivity and the newer programs that focus more on off-farm environmental benefits have been viewed as successful in the sense that they have affected both areas as intended. Yet from the perspective of efficient policy design, these programs have left much room for improvement. As noted above, an efficient policy would aim to maximize the net benefits to both farmers and society, taking into account the value of marketed commodities and nonmarket goods and services. Most U.S. Department of Agriculture (USDA) soil conservation, conservation compliance, and conservation reserve programs fall short of this standard for several reasons.

First, conservation and environmental policies typically pay farmers for adopting certain practices, not for providing valued services. In addition, these policies often have multiple, conflicting goals and are implemented with politically determined budget constraints that do not reflect efficient regional resource allocation. For example, traditional soil conservation programs were designed to maintain on-farm productivity of soil without regard to off-farm impacts. Moreover, there is little connection between cost-share programs that are available to all farmers, regardless of site-specific conditions, and the level of investment in soil conservation practices that would be socially efficient.

Likewise, conservation compliance provisions for receipt of commodity subsidy payments encourage farmers to undertake soil conservation practices on land considered to have high erosion potential, but only for those receiving subsidies, and with little regard for potential benefits of reducing erosion. Other conservation programs, such as the Conservation Reserve, are also relatively inefficient at achieving environmental objectives and were particularly so when they were first implemented. For example, in the original CRP created in 1986, farmers could qualify land for participation if it met criteria that indicated potential for soil erosion, regardless of whether the erosion were likely to cause substantial damages off the farmer's field. Farmers of land located far from any surface water, and thus unlikely to have substantial impacts on water quality, would receive the same incentives to reduce erosion as those farming land near environmentally sensitive bodies of water. In response to this shortcoming, subsequent legislation attempted to improve the efficiency of the CRP by using various "targeting" criteria (Babcock et al. 1997; Wu, Zilberman and Babcock 2001; U.S. Department of Agriculture, Economic Research Service 2005; U.S. Department of Agriculture, Economic Research Service 2006b).

A second drawback to the CRP is that it requires farmers to take land out of production, even when it might be possible to continue using it productively with alternative management practices. Consequently, conservation reserve programs are often a relatively expensive way to achieve environmental benefits from agriculture. For example, Antle et al. (2001) showed that taking land out of production to sequester soil carbon would be almost an order of magnitude more expensive than paying farmers to change management practices while continuing to farm the land. Conservation reserve programs also may have negative impacts on rural communities by reducing the demand for agricultural inputs and services. Ranchers in drought-prone areas cannot utilize CRP lands for grazing unless USDA declares a drought emergency and gives special temporary exemptions from program rules.

Third, existing conservation and environmental programs often involve arbitrary limitations on land use or on the budgets allocated, regardless of the potential benefits of increasing the size of the program. The CRP limits the amount of land that can be included in the program to 25 percent of cropland in each county, regardless of how much erosion is being generated by agricultural land use there. The CSP rewards farmers for adopting environmentally beneficial practices, but participation is limited by politically determined allocation of funding across states.

Finally, some of the relatively new programs reward farmers for "good stewardship." Some argue that farmers who manage land in a manner that sustains productivity and contributes to other positive environmental outcomes should be rewarded for doing so. This idea has political appeal, but no efficiency is gained from rewarding farmers for doing what they would do anyway, whether motivated by their private interest or by their desire to serve the public interest. Rather, a gain in resource allocation efficiency is achieved by providing incentives for actions in the public interest that farmers would not otherwise have taken.

Toward an Efficient PES Policy

We have seen that some U.S. policies—most notably CRP, EQIP, and CSP—already have features similar to a PES system. The Economic Research Service of USDA has published several studies providing a comprehensive discussion of the details of these programs, and how they might be made more efficient (U.S. Department of Agriculture, Economic Research Service 2006a). Still, these programs fall short of what a PES policy would be.

In this section my goal is to outline some key components that are needed for implementation of a PES-based policy. Rather than discuss the politics of the transition—about which I will say a few words in the concluding section—I intend to address two sets of issues that arise in constructing an efficient PES system once the decision to pursue such a policy has been made. First, we need to be able to quantify the environmental and economic effects of agricultural activities. Second, we need to determine how the system can be designed to overcome the shortcomings of the existing policies identified above.

Information to Support Policy Design and Implementation. To facilitate the transition from commodity-based subsidy policies to policies based on provision of ES, decision-makers will need accurate estimates of benefits and costs. Recent experience with the Conservation Security Program provides a good illustration of what can go wrong without this information. The ten-year costs of implementing the CSP were estimated to be $2.1 billion in 2002, but rose to $8.9 billion in 2004—an unanticipated overrun due, in part, to inaccurate estimates of farmer participation (U.S. Government Accountability Office 2006).

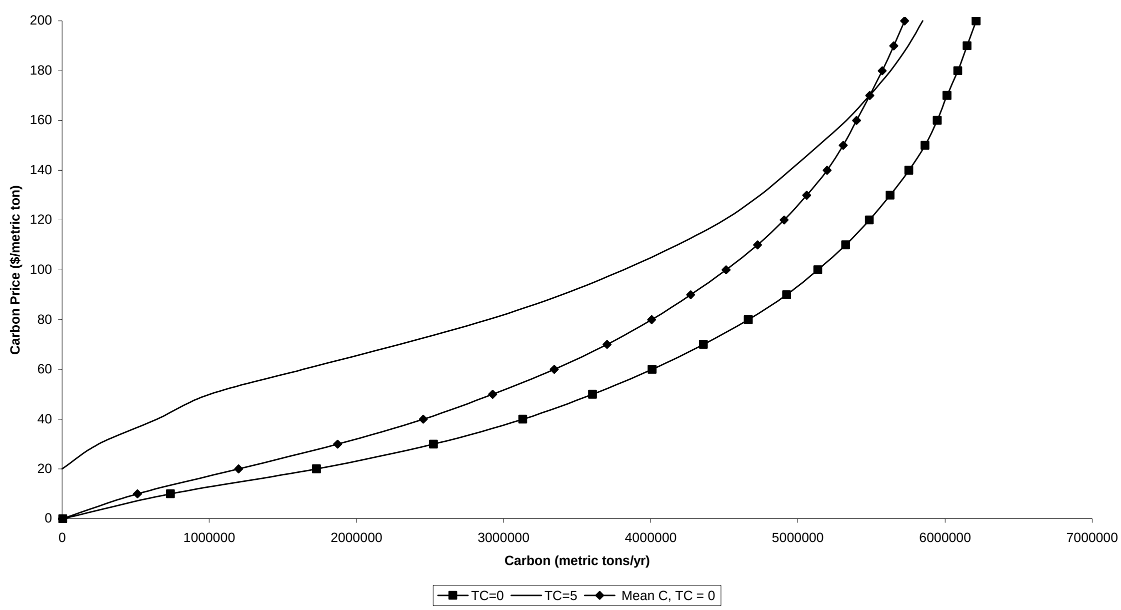
I stated above that an efficient policy involves equating marginal social cost to marginal social benefit. But designing policies to achieve that goal is a significant challenge because of the difficulty of determining social values for nonmarket goods and services. Despite a great deal of research on the part of the environmental economics profession, a solution remains elusive for a number of reasons, both theoretical and practical. Suffice it to say that governments, unable to ascertain society's willingness to pay for environmental protection or for provision of ecosystem services, have resorted to setting their policy objectives in terms of quantities rather than prices. Given that government policy often operates by allocating budgets and then operating within them, a PES policy is likely to be implemented by setting such quantitative goals and then determining the price that can be paid by a governmental agency to achieve them.

To cite one example, the 1990 Clean Air Act could have instructed the Environmental Protection Agency to establish the appropriate marginal social value of clean air, and then imposed a corresponding tax on sulphur dioxide emissions. Instead, air quality standards were set, a cap on emissions was set to meet these standards, and a trading system was created for emissions allowances. As has been discussed extensively in the environmental economics literature, an emissions trading system results in an efficient allocation of resources to emissions reductions by setting a price for reductions credits that equates supply and demand. If the quantitative emissions cap accurately reflects society's desire for cleaner air, then we can interpret this price as the marginal social value for emissions reductions.

The identical logic can be applied to the design of a PES system for agriculture. Rather than attempting to estimate the price that reflects the social value of ecosystem services, the government can determine the quantities of services desired by the public and how much it will cost to obtain those services by offering farmers incentives to change land use and management practices. Given the competition for government funds, it is likely that the desired level of ecosystem services will be constrained by the budget allocated for their provision.

Estimating Ecosystem Service Supply Curves. The ecosystem supply curve is a basic tool for determining the quantity of services farmers are willing to provide for a given economic incentive. Figure 2 illustrates several features of the ecosystem service supply curve. The slope of the curve is positive, showing that as the price increases, an increasing number of farmers would be willing to participate in contracts for ecosystem services, depending on the technical potential for increasing services on their land and on the opportunity cost they incur (Antle and Stoorvogel 2006). In addition, behavioral factors such as farmers' perception of risk and socioeconomic characteristics such as age and education can be expected to influence participation in ecosystem service contracts, much as these factors influence adoption of other conservation and environmental practices (Fuglie and Kascak 2001; Sunding and Zilberman 2001; Paustian et al. 2006). Prediction of farmers' willingness to participate must further take into account variations in the ecosystem services and in the returns of alternative practices over space and time.

Figure 2. Example of a Supply Curve for Ecosystem Services.



Note: Carbon supply curves for adoption of conservation tillage in the corn-soy-feed system, central United States, using county-level carbon rate estimates and using a regional mean carbon rate estimate. TC=5 denotes supply curve estimated with county-level carbon rates and a $5/acre transaction cost. Source: Antle et al. (2007).

As the discussion of figure 1 showed, the two key elements determining the supply of ecosystem services are the quantity of services supplied, $e(x,s)$, and the returns of alternative management practices, $\pi(x,s)$. When the spatial heterogeneity in these relationships is very high, spatially explicit data and models may be needed to estimate them so that ecosystem service supply curves can be reliably estimated. A substantial body of research has emerged recently showing how spatially explicit analysis of agricultural systems can be implemented (for example, Pautsch et al. 2001; Antle et al. 2003; Wu et al. 2004; Lubowski, Plantinga, and Stavins 2005). However, site-specific biophysical and economic data with the geographic coverage needed for analysis of agriculture-environment interactions are exceptional. Consequently, although advances in disciplinary models and data acquisition methods are being made continuously, the ability of the scientific community to model agricultural systems as complex, dynamic, spatially explicit systems is limited. Researchers, therefore, need to devise data and model simplifications that provide sufficiently accurate estimates of ES supply curves for policy analysis.

The recently developed minimum-data (MD) approach is one such simplification (Antle and Valdivia 2006). Utilizing a simple representation of the spatial distribution of the opportunity cost of providing ecosystem services, together with estimates of ecosystem service supply based on biophysical data representing conditions in agro-ecozones, the MD approach is very similar in conception to the way that policies have been targeted to improve their efficiency. Observe that ecosystem services are a function of management at a site and of site-specific characteristics, such as soils and climate. While observing or measuring ecosystem services at a site can prove difficult, it may be feasible to use these land use and site characteristics as proxies. When Antle and Valdivia applied the approach to the analysis of soil carbon sequestration, they found that the MD approach provided a close approximation to the carbon supply curve derived from the more complicated model. These findings suggest that in the case of ecosystem service analysis, it may be possible to achieve predictions of farmers' participation in programs with relatively low-cost data that are currently available. Further research is needed to validate this type of practical approach for other ecosystem services.

Information to Support Farmer Participation in Ecosystem Service Contracts. The change in policy orientation from commodity-based subsidy programs, and from practice-based conservation programs, to a PES system will create a need for new kinds of information to support informed decision-making by farmers. Under the commodity-subsidy programs, farmers have sought advice from both public information and private sources regarding the value of program participation. Under a PES system, there will be a similar need for public information about the relevant data and science. The private sector will also play a role, analogous to the private information services that farmers now buy to support other kinds of management decision-making.

Farmers will need to have both biophysical and economic information to assess the current and future benefits and costs of adopting practices that increase ecosystem services. The economic information will be similar to that which they already use to make land use and management decisions. To estimate the quantity of ecosystem services they can produce when they adopt alternative land use and management practices and to assess how their operations affect ecosystem services, new data and expertise will be required. An important role will be played by public provision of information that has public-good attributes—for example, data and models that can be used to assess ecosystem service production, and decision tools that reduce the costs to farmers of using these resources.

Recent experience with providing information to support greenhouse gas mitigation sets an example for such activities, both public and private. In the public domain, data and models have been developed to quantify the sequestration of carbon in soils under alternative crop systems and management practices (Paustian et al. 2006). This information is being embodied in decision tools that farmers can use, such as the COMET software being developed by the Natural Resources Conservation Service of USDA. In the private domain, firms with experience in areas such as crop insurance are acting as intermediaries to facilitate carbon contracts, and institutions such as the Chicago Climate Exchange are creating markets where contracts for greenhouse gas emissions reductions can be standardized and traded. Organizations such as the Katoomba Group are facilitating information exchange about and development of markets for ecosystem services.

Policy Design and Implementation. In moving from existing programs toward a more efficient PES system, a number of issues will need to be addressed.

Payments for practices versus payments per unit of ecosystem service. Most conservation programs in the United States have been based on paying farmers to adopt certain practices deemed to reduce soil erosion, improve water quality, or have other environmental benefits. Until very recently, however, these programs were not designed to pay farmers in direct relation to the environmental benefits they produce. As with environmental regulation, wherein the EPA typically used "command-and-control" regulation to achieve improvements in air and water quality, experience has shown very clearly that such a system is a far less efficient way to achieve environmental quality improvements than one based on performance standards and incentives (Council of Economic Advisers 1990). Similarly, experience has shown that the typical approach to agricultural conservation policies based on adoption of government-prescribed "best-management practices" is an inefficient way to achieve environmental objectives. Fundamentally, "one-size-fits-all" solutions are not efficient when conditions vary greatly across the landscape, as we know they do in agriculture. Moreover, prescriptive policies are expensive because they fail to create incentives for participation by those farmers who can provide the ecosystem service at the lowest cost per unit.

There are several reasons for the use of practice-based programs. In the early days of soil conservation programs, providing farmers with information about soil conservation practices was an important objective. More recent programs needed to find ways to increase their efficiency and thus to approximate more closely what would be produced by a performance-based policy, but the cost of measuring outcomes was presumed to be prohibitive. A case in point was the Conservation Reserve Program, a goal of which was to reduce water pollution caused by soil erosion. To qualify for participation land had to meet certain erodibility criteria, but actual reductions in erosion were not measured. As a result, while practice-based criteria are still used, they are being increasingly linked to specific factors, such as proximity to surface water, that serve as proxies for the desired outcomes (Cox 2006).

Recent research suggests that the purported high costs of measuring performance may not be a good reason to use practice-based participation criteria. The relevant issue is not whether it is costly to measure performance, but rather whether the gain in efficiency from using a performance-based reward mechanism compensates more or less for the cost of implementing it. As far as I know, there has been only one study looking at this question. In their study of contracts for agricultural soil carbon sequestration, Antle et al. (2003) found the costs of implementing a performance-based incentive for soil carbon sequestration to range from $0.08 to $0.67 per metric ton of carbon, based on a sampling scheme that provided a 5 percent measurement error. In contrast, the efficiency gains from the performance-based incentive were two orders of magnitude higher, in the range of $3.00 to $44.00 per metric ton of carbon. Moreover, the study found that the gains from using performance-based contracts were higher the greater the spatial heterogeneity in economic and environmental conditions, confirming the hypothesis that the value of efficient performance-based policy mechanisms increases as heterogeneity increases. The Economic Research Service of USDA also showed that performance-based payments for working-lands programs would result in large gains in efficiency compared to practice-based payments, but this study did not attempt to compare those efficiency gains to the costs of implementing performance-based incentives (U.S. Department of Agriculture, Economic Research Service 2005).

A key implication is that, due to the spatial variability in ecosystem services and the opportunity costs of providing them, efficient measurement technologies are needed. Impacts often cannot be directly observed or measured (for example, nonpoint source pollution from chemicals, soil erosion, or changes in soil carbon) so we need both field measurements and models to predict outcomes reliably by combining site-specific biophysical data (such as on soils or climate) with management data. Recent research on carbon sequestration shows that this can be done sufficiently accurately at relatively low cost, and with those costs likely to decline once policies create an economic incentive to quantify ecosystem services (Antle et al. 2003).

Government programs versus assignment of property rights. Since most ecosystem services are public goods, markets for related private goods will not provide them in efficient quantities. There are several ways to achieve the socially efficient quantity of ecosystem services. Current agricultural policies are based mostly on direct government intervention, with the government defining practices that must be adopted for receipt of subsidies. As noted, strategies for implementation of PES include setting quantities of ecosystem services and auctioning contracts for their provision to the lowest bidders. An alternative strategy for some services would be to assign property rights and support the creation of markets for them, following the abovementioned emissions trading system model created for the regulation of air quality. This approach has already been taken in Europe to implement the carbon emissions reductions required by the Kyoto Protocol. Similarly, in the United States, the Chicago Climate Exchange has begun to create a market for voluntary reductions of greenhouse gas emissions, although it is not likely to function effectively as long as the United States does not have a policy to cap emissions.

Some ecosystem services remain difficult to quantify. Efforts are being made, for instance, to create markets for biodiversity preservation (for example, see the Katoomba Group 2006). Because biodiversity preservation is a pure public good, however, private individuals or nongovernmental organizations may not be willing to pay for the socially efficient quantity of it, assuming such a quantity can be determined in scientific terms. The only viable option may be direct government intervention.

Another challenge in providing some ecosystem services occurs when the amount of service provided on one unit of land depends on the amount provided on other land units. For example, migration routes may be needed for preservation of certain species of plants or animals that link together several differently owned and managed units of land. It remains to be seen whether simple assignment of property rights or other market mechanisms can be devised that effectively take these spatial dependencies into account. Such situations may require direct government intervention to coordinate land use, and management decisions to provide desired quantities of ecosystem services.

Yet another set of issues that must be addressed concerns the provision of local versus regional or global ecosystem services. Water-related services, for example, may be largely localized, whereas biodiversity or greenhouse gas mitigation have local and global benefits. Further research is needed to address how efficient incentive mechanisms can be designed when an agricultural activity affects both local and global services.

The importance of additionality in contract design. A key feature of PES—one that is essential to making PES a socially efficient policy mechanism—is that farmers be rewarded for supplying *additional* ecosystem services above and beyond what they would have supplied without the extra incentive. For a PES system effectively to result in additionality, a baseline must be established for past as well as future conditions.

Establishing a baseline for participation in ecosystem service contracts also avoids creating perverse incentives. For example, the Endangered Species Act effectively penalizes landowners who discover protected species on their land by restricting what they can do with the land, thus creating an incentive for landowners to remove habitat rather than protect it. Similarly, agricultural programs that provide soil conservation incentives only for farmers with degraded land may lead farmers to use practices that degrade land so that they can then participate in the programs. However, these perverse incentives can be avoided by requiring that farmers establish a baseline of land use and management in order to participate in contracts.

A related issue that has been raised concerns rewarding farmers for "good stewardship." Some suggest that policies should be designed to reward farmers who have managed their land so as to provide ecosystem services. The problem with this argument is that the goal of PES is to compensate farmers for increasing the amount of services above and beyond what they would have done based on their own interests. While some may see an element of fairness in rewarding actions that have social benefits, there is no basis for this practice in terms of resource allocation efficiency.

Leakage or slippage not likely to be an issue for PES. Another problem that has been discussed in relation to conservation programs such as the CRP that results in significant reductions in crop or livestock production is "leakage" or "slippage" (Wu 2000). The idea is that a reduction in acres in crop or livestock production may increase the prices of those commodities and cause farmers to increase production on other land, thus offsetting the environmental gains obtained through the program. While this may be a significant issue for conservation programs that reduce the amount of land in production, policies that maintain land in production are not likely to have substantial impacts on crop or livestock production, and therefore slippage is unlikely to be significant.

Multiple ecosystem services. There is likely to be more than one ecosystem service associated with changes from "conventional" to "sustainable" land use and management practices. For example, use of conservation tillage is likely to increase the recycling of nutrients, improve water quality, and sequester carbon. In principle we can say that there is a joint production of many ecosystem services. It is beyond the scope of this paper to address this issue in detail, but a few observations can be made here. In theory, the joint production of multiple services implies that the quantities of services can be "aggregated" if the nature of the "jointness" or interrelationships can be determined scientifically. The USDA has begun to address this question in the context of CRP by constructing an "environmental benefits index," which is based on weights given to different environmental service components (U.S. Department of Agriculture, Economic Research Service 2005). This procedure appears to be a step in the right direction, although the weights currently in use might be questioned. The different values placed on the environmental services by different groups (for instance, local, national, and international) complicates the task of assigning appropriate weights, which should reflect the relative marginal social value of the different services being provided. Following the earlier discussion of minimum-data methods for ecosystem service measurement, another solution to this problem might be to use indicators that correlate well with multiple services. For example, many agricultural scientists argue that organic soil carbon is a good indicator for the sustainability of a crop-based agricultural system.

Costs of contract implementation. An efficient policy design must take into account implementation costs (Antle et al. 2003; U.S. Department of Agriculture, Economic Research Service 2006d). With conservation programs implemented through required practices, it costs relatively little to observe practices and monitor compliance. Under a performance-based policy such as PES, however, farmers will enter into contracts that specify the quantity of ecosystem services to be supplied. Implementing these contracts will involve costs of measuring changes in services to verify contract compliance, as well as transaction costs similar to those associated with other kinds of financial contracts. These costs are borne by taxpayers under existing USDA programs. (Richards, Brown, and Sampson provide further discussion of costs of federal programs in their 2006 study.) Figure 2 illustrates the effects of transaction costs on an ecosystem service supply curve. At low prices, the costs create a participation threshold, but as the price increases their impact diminishes.

Few reliable data are available to estimate these costs for implementing ecosystem service contracts. Mooney et al. (2004) estimated the measurement and monitoring costs that are likely to be required to verify the amount of agricultural soil carbon sequestration achieved and therefore tradable. In a case study of the authors' prototype measurement scheme, the upper estimate of measurement costs was 3 percent of the value of a carbon credit. Although these estimates should be interpreted with caution—because they were not based on an actual contract implementation—they suggest that measurement costs are not likely to be large enough to prevent farmers from participating in a market for tradable emissions credits.

Compatibility with WTO rules. World Trade Organization rules are intended to support a transition from subsidies that distort production and trade to policies that are unrelated to production. On this basis, PES that are based on provision of ecosystem services, not market goods production, should be compatible with the WTO rules. However, Blandford

(2006) cautions that the rules do not allow producers to be compensated in excess of their private opportunity costs, thus possibly calling into question the acceptance of a PES system that rewards farmers based on social value in excess of opportunity cost. He suggests that to allow the development of cost-effective environmental programs that rely on incentives, some modification of the basic criteria for environmental payments in the WTO Agreement on Agriculture may be required.

Conclusions: Assessing the Political and Economic Feasibility of PES

In this paper I argue that there are sound scientific and economic reasons for an agricultural policy based on the provision of ecosystem services by agriculture. An abundance of scientific data and research show that agricultural production activities affect a wide array of goods and services associated with ecosystem function. Left to their own devices, markets will tend to overproduce market goods and underproduce ecosystem services. Thus, are both scientific and economic bases for an agricultural policy that would provide incentives for farmers to supply the appropriate combination of the two.

I further argue that an efficient agricultural policy could be implemented using a policy mechanism that I call payments for ecosystem services, or PES. I define a PES system as one that rewards farmers for increasing the quantity of ecosystem services they supply above and beyond the amount that would have been provided in the absence of such rewards. A key feature of PES is that they are not subsidies; they are financial incentives provided to farmers who bear costs to increase the supply of ecosystem services valued by society. Thus, PES differ in important legal and economic respects from existing commodity subsidies. A PES policy also differs in important ways from existing "conservation" or "environmental" programs. A key difference is that existing programs prescribe conservation and environmental practices that farmers should use. Experience with environmental regulation shows this prescriptive approach to be far less efficient than policies based on performance standards and incentives—one way in which a PES system could be implemented. Recent research has confirmed that performance-based policies will also be far more efficient in agriculture than existing practice-based policies.

Much of the data and science needed to implement an efficient PES currently exists, but there are gaps that need to be filled. To implement a PES policy successfully, data and models are needed to estimate farmers' willingness to participate in contracts, the quantity of services that would be supplied, and the budgetary costs of programs. Substantial progress has been made in developing this capability for some ecosystem services related to water quantity and quality and greenhouse gas mitigation, but less well-defined services, such as those related to biodiversity, need further work. Information is also needed to support farmers' contract participation decisions. Recent work on carbon sequestration provides a template for how information to support other ecosystem services could be made available to farmers. Existing USDA and land-grant university research and outreach organizations are well-positioned to provide the currently available information to policy decision-makers and to farmers, and to design and implement the research programs needed to supplement existing data and knowledge.

The proposal to change the basis for agricultural policy from commodity subsidies to PES might seem quite radical to some people, which raises the question, is it politically feasible? The starting point for assessing that is an understanding of the forces shaping agriculture and agricultural policy. Following established political economy theory, I take the view that policy formation is driven by the activities of competing interest groups. However, I differ with the conventional literature, which emphasizes competition among interest groups to redistribute income, in that I think some groups strive to achieve other objectives. For example, some advocate policies to achieve certain civic, moral, or ethical objectives, such as the American Farmland Trust's efforts to encourage agricultural policy reform.

Similarly, I observe that some interest groups pursue policies in the name of efficiency, with goals that could be described as aiming to correct market failures, rather than to redistribute income. Among them are groups dedicated to conserving natural resources. Many laws requiring federal and state agencies to implement policies and regulations to improve the efficiency of resource allocation exist because there is an element of the public policy process that represents the public good beyond simple income redistribution. Indeed, if this were not the case, there would be no role for science in the policy process. Yet Congress established the National Research Council to play this role, and various other nonpartisan organizations take a similar part.

These considerations lead me to believe that a fundamental redesign of agricultural policy will take place over time. As I noted earlier, there has already been substantial progress in making some of the conservation and environmental programs more efficient through better targeting and use of performance standards. The fact of interest-group competition also suggests that, to the extent these groups advocate increased provision of ecosystem services from agriculture, they have an interest in promoting the efficient provision of those services.

The shift in policy focus from income redistribution to efficient provision of ecosystem services is not only possible, but inevitable. But the road is likely to be rocky. Probably the biggest threat to the development of an efficient PES system will be the ongoing attempts by commodity interests to capture a share of the PES resources in place of their existing subsidies. The best way to prevent that, in my opinion, as well as to promote policy efficiency, is for advocates of policy change to insist that PES be based on quantifiable ecosystem services, not on past receipt of subsidies or production of certain commodities.

References

Agriculture Task Force. 2006. *Modernizing America's Food and Farm Policy: Vision for a New Direction*. Chicago Council on Global Affairs. http://www.agtradepolicy.org/output/resource/TaskForceReport.pdf (accessed March 21, 2007).

Antle, J. M., and S. M. Capalbo. 2002. Agriculture as a Managed Ecosystem: Policy Implications. *Journal of Agricultural and Resource Economics* 27 (1): 1–15.

Antle, J. M., and J. J. Stoorvogel. 2006. Predicting the Supply of Ecosystem Services from Agriculture. *American Journal of Agricultural Economics* 88 (5): 1174–80.

Antle, J. M., and R. Valdivia. 2006. Modeling the Supply of Ecosystem Services from Agriculture: A Minimum-Data Approach. *Australian Journal of Agricultural and Resource Economics* 50 (1):1–15.

Antle, J. M., S. M. Capalbo, S. Mooney, E. T. Elliott, and K. H. Paustian. 2001. Economic Analysis of Agricultural Soil Carbon Sequestration: An Integrated Assessment Approach. *Journal of Agricultural and Resource Economics* 26 (2): 344–67.

———. 2003. Spatial Heterogeneity, Contract Design, and the Efficiency of Carbon Sequestration Policies for Agriculture. *Journal of Environmental Economics and Management* 46 (2): 231–50.

Antle, J. M., S. M. Capalbo, K. H. Paustian, and M. K. Ali. 2007. Estimating the Economic Potential for Agricultural Soil Carbon Sequestration in the Central United States Using an Aggregate Econometric-Process Simulation Model. *Climatic Change* 80 (2): 145-171.

Babcock, B. A., P. G. Lakshminarayan, J. J. Wu, and D. Zilberman. 1997. Targeting Tools for the Purchase of Environmental Amenities. *Land Economics* 73 (3): 325–39.

Blandford, D. 2006. U.S. Environmental Programs and Green Box Provisions under the WTO Agreement on Agriculture. Paper presented at the workshop on Conservation and U.S. Agricultural Policy: Scope for and Application of Green Box Measures to Conserve the Ecological Integrity of American Farmlands, Stanford University, February 23–25.

Council of Economic Advisers. 1990. *Economic Report of the President*. April. Federal Reserve Archival System for Economic Research (accessed March 21, 2007). http://fraser.stlouisfed.org/publications/ERP/issue/1512/

Cox, C. 2006. U.S. Agriculture Conservation Policy & Programs History, Trends and Implications. Paper presented at the workshop on Conservation and U.S. Agricultural Policy: Scope for and Application of Green Box Measures to Conserve the Ecological Integrity of American Farmlands, Stanford University, February 23–25.

Daily, G. 1997. What Are Ecosystem Services? In *Nature's Services—Societal Dependence on Natural Ecosystems*, ed. G. Daily. Washington, D.C.: Island Press, 392.

Fuglie, K. O., and C. A. Kascak. 2001. Adoption and Diffusion of Natural-Resource-Conserving Agricultural Technology. *Review of Agricultural Economics* 23 (2): 386–403.

Johnson, D. G. 1991. *World Agriculture in Disarray*. 2d ed. London: Macmillan.

Katoomba Group. 2006. The Katoomba Group: International Experts' Working Group Promoting Conservation and Advancing Community Livelihoods through Markets for Ecosystems Services. http://www.katoombagroup.org/contact.htm (accessed March 21, 2007).

Lubowski, R. N., A. J. Plantinga, and R. N. Stavins. 2005. Land-Use Change and Carbon Sinks: Econometric Estimation of the Carbon Sequestration Supply Function. Faculty Research Working Paper Series RWP05-001, John F. Kennedy School of Government, Regulatory Policy Program, Harvard University, Cambridge, Mass., January.

Mooney, S., J. M. Antle, S. M. Capalbo, and K. Paustian. 2004. Design and Costs of a Measurement Protocol for Trades in Soil Carbon Credits. *Canadian Journal of Agricultural Economics* 52 (3): 257–87.

Paustian, K., J. Antle, J. Sheehan, and E. Paul. 2006. *Agriculture's Role in Greenhouse Gas Mitigation*. Arlington, Va.: Pew Center on Global Climate Change.

Pautsch, G. R., L. A. Kurkalova, B. A. Babcock, and C. L. Kling. 2001. The Efficiency of Sequestering Carbon in Agricultural Soils. *Contemporary Economic Policy* 19 (2): 123–34.

Richards, K., S. Brown, and N. Sampson. 2006. *Agricultural and Forest Lands: Policy Strategies for the United States*. Arlington, Va.: Pew Center on Global Climate Change.

Salzman, J., B. Thompson, and G. Daily. 2001. Protecting Ecosystem Services: Science, Economics, and Law. *Stanford Environmental Law Journal* 20 (2): 309–32.

Sunding, D., and D. Zilberman. 2001. The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector. In *Agricultural Production*. Volume 1A of *Handbook of Agricultural Economics*, ed. B. L. Gardner and G. C. Rausser. Amsterdam: Elsevier, 207–61.

U.S. Department of Agriculture. Economic Research Service. 2002. *The 2002 Farm Act: Provisions and Implications for Commodity Markets*, by P. C. Westcott, C. E. Young, and J. M. Price. Agriculture Information Bulletin No. 778. Washington, D.C.: Government Printing Office.

———. 2005. *Flexible Conservation Measures on Working Land: What Challenges Lie Ahead?* by A. Cattaneo, R. Claassen, R. Johansson, and M. Weinberg. Economic Research Report No. 5, June. http://www.ers.usda.gov/publications/ERR5 (accessed March 21, 2007).

———. 2006a. Agriculture and the Environment. *Amber Waves*, special issue, July. http://www.ers.usda.gov/AmberWaves/July06SpecialIssue/pdf/FullIssueJuly06.pdf (accessed March 21, 2007).

———. 2006b. *Better Targeting, Better Outcomes*, by L. Hansen and D. Hellerstein. Economic Brief No. 2, March. http://www.ers.usda.gov/publications/EB2/EB2.pdf (accessed March 21, 2007).

———. 2006c. *Growing Farm Size and the Distribution of Farm Payments*, by J. MacDonald, R. Hoppe, and D. Banker. Economic Brief Number 6. March. http://www.ers.usda.gov/Publications/EB6 (accessed March 21, 2007).

———. 2006d. *Rewarding Farm Practices versus Environmental Performance*, by M. Weinberg and R. Claassen. Economic Brief No. 5. March. http://www.ers.usda.gov/publications/EB5/EB5.pdf (accessed March 21, 2007).

U.S. Government Accountability Office. 2006. *Conservation Security Program: Despite Cost Controls, Improved USDA Management Is Needed to Ensure Proper Payments and Reduce Duplication with Other Programs*. report no. GAO-06-312, April. http://www.gao.gov/new.items/d06312.pdf (accessed March 21, 2007).

Van Kooten, G. C., S. L. Shaikh, and P. Suchanek. 2002. Mitigation Climate Change by Planting Trees: The Transaction Costs Trap. *Land Economics* 78 (4): 559–72.

Wu, J. 2000. Slippage Effects of the Conservation Reserve Programs. *American Journal of Agricultural Economics* 82 (4): 979–92.

Wu, J., R. M. Adams, C. L. Kling, and K. Tanaka. 2004. From Microlevel Decisions to Landscape Changes: An Assessment of Agricultural Conservation Policies. *American Journal of Agricultural Economics* 86 (1): 26–41.

Wu, J. J., D. Zilberman, and B. A. Babcock. 2001. Environmental and Distributional Impacts of Conservation Targeting Strategies. *Journal of Environmental Economics and Management* 41 (3): 333–50.

About the Author

John M. Antle is a professor in the Department of Agricultural Economics and Economics at Montana State University. The author thanks reviewers J. Horowitz and M. Roberts for their thoughtful comments.