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Ecosystem services from agriculture: Steps for expanding markets ☆

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ABSTRACT

Farmers in the United States produce a wide variety of commodities for food and fiber. Farmers can also produce a variety of non-commodity ecosystem services for which markets do not exist or are imperfectly formed. Such services may be valued by society, but due to their nature or institutional arrangements, farmers often do not receive a price signal for them. This results in inefficient allocations of resources, in that farmers under-produce non-commodity ecosystem services. One possible way to increase private investment in ecosystem services is to create a market for them. We draw lessons from six different markets for providing ecosystem services from farms (water quality trading, wetland mitigation, carbon cap-and-trade, over-the-counter carbon, eco-labeling, and fee hunting) on what is required for a market to function, and the problems these markets might face.

1. Introduction

Farmers and ranchers produce a wide variety of ecosystem services that are valued by society. These include regulation functions, habitat functions, provisioning functions, and information functions (de Groot et al., 2002). Some outputs, such as food, fiber, and energy, are sold in well-established markets. Many, however, such as climate regulation, water supply, waste treatment, recreation, biodiversity, and cultural information, do not have established markets. Agricultural producers' actions can increase or decrease the provision of ecosystem services. Understanding how agricultural producers make their production and land management decisions is critical in designing strategies for enhancing the provision of those ecosystem services that society values.

Well functioning commodity and input markets use prices to signal farmers and ranchers what to produce with their land, and how to allocate resources most efficiently to maximize profits. In contrast, for a variety of reasons, markets for most ecosystem services have generally not developed. As a result, producers' responses to market signals lead them to produce agricultural commodities, but do not encourage production of non-commodity ecosystem services. These ecosystem services may therefore be under provided from society's point of view.

Yet, with growing population and incomes, society increasingly values the non-commodity ecosystem services agriculture can produce (Antle, 1999). Since markets typically undersupply non-commodity ecosystem services, Federal, State, and local governments have developed a range of approaches for increasing their production (Table 1). Most rely on policy tools such as financial and technical assistance, regulation, and education. Although these approaches may be relatively simple to implement, it is widely believed that such approaches are costly and inefficient (Freeman and Kolstad, 2007). Market-based approaches are seen as more efficient because they use prices to allocate resources, and they allow producers to use their own private information in the production of the service (Freeman and Kolstad, 2007; Murtough et al., 2002). The success of the sulfur dioxide allowance trading program in reducing the costs of meeting air quality standards demonstrates what a market can achieve (Stavins, 2005).

The U.S. Department of Agriculture (USDA) and other groups have expressed great interest in the use of market-based policy instruments as a more efficient way of providing environmental quality and other ecosystem services. In 2006 USDA outlined its role in supporting "market-based environmental stewardship." USDA is seeking to broaden the use of markets for environmental goods and services to "…encourage competition, spur innovation, and achieve environmental benefits…" (USDA, 2006a,b). Some of the approaches that can be used to promote markets include emissions trading, mitigation banking, and eco-labeling. To emphasize USDA's growing role, the Food, Conservation, and Energy Act of 2008 includes a provision directing USDA to facilitate farmer, rancher, and forest landowner participation in ecosystem services markets.[1]

☆ The views expressed in this paper are those of the authors and do not necessarily reflect those of the US Department of Agriculture or the Economic Research Service.

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[1] Other examples of government interest in markets for environmental services include the U.S. Environmental Protection Agency (EPA) promotion of emissions trading as a way of reducing the cost of meeting air and water quality goals (U.S. EPA, 2003). The Organisation for Economic Co-Operation and Development is also promoting the use of market mechanisms for the provision of ecosystem services (OECD, 2005), indicating a world-wide interest.

Table 1
Some environmental services and farm management options.

Environmental service	Farm-level management option
Carbon sequestration in soils	Manage soil organic matter
Carbon sequestration in perennial plants	Convert cropland to grassland or forest
Methane emission reduction	Capture and destroy methane from animal waste storage structures
Water quality maintenance	Reduce agrichemical use, establish vegetative buffers, and improve nutrient management
Erosion and sediment control	Manage soil conservation and runoff, and increase soil cover
Flood control	Create diversions, wetlands, and storage ponds
Salinization and water table regulation	Grow trees and manage water
Wildlife	Protect breeding areas and wild food sources, improve timing of cultivation, increase crop species/varietal diversity, and reduce use of toxic chemicals

The purpose of this paper is to explore the conditions under which markets for non-commodity ecosystem services from agriculture might arise. We draw lessons from six different markets for providing ecosystem services (water quality trading, wetland mitigation, carbon cap-and-trade, over-the-counter carbon, eco-labeling, and fee hunting), on what is required for a market to function, and the problems these markets might face. We also identify actions that government agencies might take to facilitate the development and function of markets, as well as farmer participation in markets.

2. Agriculture is a source of ecosystem services

Farmers and ranchers constitute the largest group of natural resource managers in the world (FAO, 2007). Farms exist to produce food, fuel, and fiber, and to sell them to consumers. However, farms also produce many other ecosystem services as externalities, in that markets for them do not exist, and those who are affected (positively or negatively) cannot use their purchasing power to influence their production. Farms can produce externalities as part of the production process (generally negative externalities such as nutrient runoff or air pollution), or from land on the farm that is not in crops (positive externalities such as wildlife, wetland services, and water quality) (Table 1).

Despite the fact that these non-commodity ecosystem services are valued by consumers, fully functioning markets for them rarely exist. This lack of markets is explained by a fundamental characteristic of ecosystem services: as products of complex ecosystem processes, that are delivered through a variety of landscape settings, they nearly always take on characteristics of social goods. That is, ecosystem services are often non-rival and/or non-excludable. Non-rival means that the consumption by one person does not reduce another person's consumption. Non-excludable means that no one can be excluded from benefiting from the provision of the good; it cannot be rationed by price.[2] These characteristics prevent the development of a market, primarily because ownership cannot be defined and enforced. And due to the absence of a market, for most ecosystem services the price that a producer can receives for producing them is zero. This zero price is in spite of the fact that if a market existed consumers would be willing to pay to obtain these services.

In short, since market prices inform market participants how valuable one good or input is relative to another, a zero price for ecosystem services (a price that under represents their true value) means fewer resources will be directed towards their production than is socially optimal.

[2] This is commonly known as the free-rider problem.

This has important consequences in the allocation of resources on farms. Without well-defined markets for ecosystem services, landowners are not rewarded financially for supplying them. For example, without a market for ecosystem services, a farmer with native vegetation on her land has no economic incentive to preserve the cover and the ecosystem services it provides. In contrast, if a portion of the value that society places on ecosystem services could be captured by the farmer, she would be more likely keep some or all of this land in a natural state.

It is important to note that agricultural producers' motivations are more complex than simply profit maximization. Many agricultural producers value ecosystem services, and may sacrifice some potential income to enjoy them on their farms. Without markets, however, agricultural producers' provisions of ecosystem services are based on their own personal preferences, rather than the value society places on them (Ribaudo and Horan, 1998; Abler and Shortle, 1991; Bohm and Russell, 1985). The result is likely to be an under provision of those services.

In the absence of markets, demand for ecosystem services is met in several ways. State and Federal governments have developed a number of programs to supply them. Environmental regulations are one approach used to provide ecosystem services. Regulations in the Clean Water Act, Clean Air Act, Federal Insecticide, Fungicide, and Rodenticide Act, and Endangered Species Act keep harmful chemicals from water and air, prevent wetland loss, and protect habitat for endangered species. These and other regulations arise because the public demands that ecosystem services be protected. However, it is important to note that agriculture is often exempt from these regulations. This leaves other mechanisms such as financial assistance to provide incentives for agriculture to maintain or to increase its production of ecosystem services.

Conservation programs such as the Conservation Reserve Program, Wetland Reserve Program, Environmental Quality Incentive Program, and Farm and Ranch Protection Program provide financial and technical incentives to agricultural producers to retire cropland, adopt management practices that protect and enhance environmental quality, or to preserve farmland. In recent years USDA has spent over $6 billion per year on such programs (USDA, ERS, 2009). However, payments are mostly based on practice costs, not on the value of the services these practices provide.

3. Markets for ecosystem services

Even though non-commodity ecosystem services from agriculture can be provided through conservation programs, regulations, or private actions, markets are often seen as a more desirable way of allocating resources. Market-based mechanisms are seen as more efficient than resource allocation decisions made by government, since those who benefit pay for the service, and the flow of services is not dependent on government budgets. The question is: how can the social-goods nature of ecosystem services be overcome so that market forces can be used to allocate resources?

Experience with six different markets for supplying ecosystem services from agriculture provide insights into how markets might be created, and the problems that must be overcome to keep them functioning. We examined water quality trading, greenhouse gas trading, wetland mitigation, fee hunting, eco-labeling, and retail carbon sales. These markets fall into three broad categories: emissions trading markets, linked markets, and over-the-counter markets.

3.1. Emission trading markets

Emission trading is an artificial market organized around the creation of a private good related to the provision of an ecosystem service. Water quality trading and carbon cap-and-trade programs are examples of such markets. Simply, a regulatory agency creates a good

closely linked with the ecosystem service (generally a discharge allowance or an offset credit). This good has private good characteristics: it is rival and non-excludable. The government then stimulates demand for the good by requiring regulated firms to have enough allowances to meet a regulatory requirement (usually the discharge of a pollutant), and enforces property rights (for a complete description of trading, see Tietenberg, 2006). Regulated firms are allowed to trade discharge allowances amongst themselves, thus reducing the overall cost of achieving pollution control goals.

In the textbook case, all firms in the market are regulated and under a discharge cap. However, EPA allows unregulated sources to participate in a market by selling offsets to regulated sources. Offsets are interchangeable with discharge allowances as defined by program rules, and provide compliance flexibility to regulated sources. Both water quality trading markets and carbon cap and trade programs allow agricultural sources to produce and sell offsets.

To succeed, these markets must meet a number of conditions. Offsets should be real, verifiable, additional, and enforceable. In order for trades to occur, agricultural offsets should be cheaper than the emission reduction costs of regulated sources. The transactions costs of bringing buyers and sellers together, monitoring, and enforcement should be small.

In the case of water quality trading, the Total Maximum Daily Load provisions of the Clean Water Act provide the regulatory impetus for establishing a market for reduced pollution discharges. Firm-level discharge limits contained in National Pollutant Discharge Elimination System (NPDES) permits create demand for discharge allowances. Trading with agriculture is most often allowed when nutrients are the target pollutant. EPA is encouraging the development of water quality trading programs, and has developed guidelines to help States develop trading rules (EPA, 2007). However, of the hundreds of watersheds impaired by nutrients in the U.S., point–nonpoint trading programs have been established in only 15, and trades with farmers have occurred in only four (Ribaudo and Nickerson, 2009).

Several States have initiated cap-and-trade programs for reducing greenhouse gas emissions. The Oregon Standard and the Regional Greenhouse Gas Initiative (RGGI) are targeted at power plants, and allow regulated plants to seek offsets (Hamilton et al, 2008). Agricultural offsets are limited to methane destruction on animal feeding operations and conversion of cropland to forest. These markets are new and have yet to establish a trading history.

The Chicago Climate Exchange (CCX) is a legally binding, voluntary cap and trade program for reducing net greenhouse gas emissions. Members voluntarily join and agree to reduce their greenhouse gas emissions. Members can meet their obligations by purchasing offsets from qualifying emissions reductions projects, including carbon sequestration in agricultural soils, methane destruction, and conversion of cropland to permanent grass or trees (CCX, 2008). The CCX has traded about 35 million metric tons of CO_2 equivalents since 2003 (Hamilton et al., 2008). Soil sequestration projects have contributed 46% of these.

Besides emissions treading programs, a market that deals exclusively in offsets has developed for wetland mitigation. Mitigation markets also rely on regulation to define a marketable good, create demand, and enforce property rights. Under section 404 of the Clean Water Act, any loss of wetland services due to draining or filling must be offset by a new or improved wetland that offers similar services. Mitigation banks are created by private businesses to provide these services. The number of credits needed to mitigate lost wetland services is determined by a board chaired by the U.S. Army Corps of Engineers. An important consideration in the decision to create a mitigation bank is that marketable credits must be created before being sold. This can take many years.

Over 600 mitigation banks have been approved or are under consideration for approval in the U.S (Ribaudo et al., 2008). Nearly 60% of all mitigation counties contain agricultural lands that were once wetlands. Farmers located in these counties should be in a good position to supply mitigation. Wetland restoration tends to be less costly on cropland that is converted wetlands because soil type, topology, and other factors are favorable to wetland development (Ribaudo et al., 2008). However, to our knowledge, only one farmer has become a mitigation banker (Ribaudo et al., 2008).

3.2. Linked markets

A second approach for creating markets for ecosystem services is to link the provision of an ecosystem service (a social good) with the provision of a private good. Consumers who demand the ecosystem service and understand the link with the private good could choose those goods providing the ecosystem service, even if they are more expensive, benefiting the farmers who provide the ecosystem service. This provides an economic incentive to the farmer to continue to provide the ecosystem service. Linked markets do not rely on government regulation to create demand. Its success is based on consumers' willingness to pay for the ecosystem service, and not be free riders.

Eco-labeling and fee hunting are two examples. Labeling is a way of informing consumers of the process used to produce the private good, and concurrently, its impact on ecosystem services. Consumers who care about ecosystem services may be willing to pay a higher price for the labeled products, enabling those farmers to continue providing ecosystem services. Starting with the organic label in the 1950s, eco-labels have been used to advertise reduced pesticide use, wildlife protection, and other ecosystem services, for example.

The organic label is one of the more well-established eco-labels. Organic farming practices can provide a host of non-commodity ecosystem services, including biological pest control, gas regulation, water supply, soil formation, and wildlife habitat (Sandhu et al., 2008). While adoption of organic farming systems showed strong gains between 1992 and 2005 and the adoption rate remains high, the overall adoption level is still low. Only about 0.5% of all U.S. cropland was certified organic in 2005 (USDA, ERS, 2008). Verification and quality assurance is critical for this market, as the quality of ecosystem services provided cannot be observed by the consumer, and consumers who value ecosystem services from agriculture have the option of purchasing produce from conventional farms and making a donation to an organization such as The Nature Conservancy or Ducks Unlimited to support the provision of ecosystem services (Kotchen, 2006).

Fee hunting is another example of linking the provision of a social good with the provision of a private good. While wildlife residing on private land is a social good (non-excludable), access to hunting on private land is a private good (Benson et al., 1999; Butler et al., 2005). Selling access to private land so hunters can gain access to wildlife can be a source of income to farmers. This income is an incentive to maintain and improve wildlife habitat on farms, which benefits both game and non-game species.

Evidence suggests that there is a high level of demand for access to private lands for hunting (Larson, 2006; Bihrle, 2003). More than half of hunters indicate that they would be willing to pay for access (Benson et al., 1999). While some producers market hunting opportunities on their land, however, most do not. A 1993 survey indicated that while 77% of farmers allowed hunting on their land, only 5% charged a fee (Conover, 1998). Farm survey data from USDA indicate that only 1 to 2% received income from all recreation activities from 2000 to 2005, including hunting, fishing, and wildlife viewing (Brown and Reeder, 2007).

3.3. Over-the-counter retail markets

Over-the-counter (OTC) markets are purely voluntary. Government does not create demand through regulation, or play any role in

defining the good being sold. OTC markets are based on bilateral deals between producers and consumers, and operate outside of an exchange. The retail carbon market is the most visible OTC market where ecosystem services from agriculture can be sold. In this market, a consumer can offset their carbon footprint from a variety of activities, such as driving their car, taking an airline flight, and having a party. Since there is no regulatory cap to stimulate demand, demand is driven by buyers wanting to manage their greenhouse gas "footprint", interest in innovative philanthropy, public relations, or plans to resell credits at a profit (Hamilton et al., 2008).

The OTC carbon market consists of a wide range of voluntary transactions. Suppliers include retailers selling offsets online, conservation organizations hoping to benefit from sales of carbon credits, and developers hoping to sell carbon to aggregators, retailers, or final customers. The market is highly fragmented and operates without commonly accepted standards, either for how GHG "footprints" are calculated or for selecting eligible offsets (Trexler and Kosloff, 2006). In 2007 more than 148 retailers sold 42.1 million tons of CO_2 equivalents (CO_2e) on the international OTC market (more than on the CCX) (Hamilton et al., 2008). About 7% of the offsets were produced on farms (soil sequestration and methane destruction). Prices vary widely, from $5 to $25 per ton of CO_2e. This market has grown rapidly over the last few years.

4. Lessons learned

The six markets described above all have the potential for providing farmers the opportunity to sell ecosystem services. Overall, however, farmer participation in these markets has been limited. Impediments to supply and demand due to the nature of the good, market structure, or policy design all play a role in limiting agriculture's participation.

4.1. Issue: performance of management practices

One of the biggest issues facing producers wishing to participate in markets for ecosystem services is uncertainty about the environmental performance of management practices such as conservation tillage, riparian buffers, and nutrient management, when payments are based on the flow of services. Uncertainty arises from two sources. There is uncertainty associated with the performance of a management practice due to heterogeneity of field conditions that cannot be accounted for in field trials. There is also uncertainty associated with the actual implementation of a practice, related to its design, installation, and maintenance on a particular farm (EPA, 2007).

In emission trading and mitigation markets, uncertainty about the quantity and quality of credits that can be supplied reduces demand for ecosystem services from agriculture. Uncertainty is an implicit cost, and potential purchasers consider this when deciding if and where to purchase offsets. If a regulated point source is legally responsible for achieving a particular discharge goal, the uncertainty about credits generated by nonpoint sources over time may make them an unattractive option. To the extent that a point source's control strategy is over the long term, because of the decision's inherent irreversibility it may be unwilling to rely on an uncertain source of credits (McCann, 1996). These factors may push point sources towards providing their own internal emission controls or trading with other point sources, rather than relying on agricultural offsets. Measurement problems were cited as obstacles in several existing water quality trading programs (Breetz et al, 2004).

Regulators often try to account for this uncertainty by requiring that a lost unit of wetland services or a point source unit of pollution discharge be replaced or mitigated with two or more units of services (credits) from farms. While such uncertainty ratios may increase the likelihood that environmental quality expectations are met, they also increase the price of mitigation to buyers and can reduce overall demand for farmer-produced credits.

The success of wetland mitigation depends on regulators' and arbitrators' abilities to recognize the quantity of services lost through development and provided by a mitigation project. Uncertainty can also lead participants – mitigation bankers, developers, public agencies, local stakeholders – to negotiate an agreement on the value of services lost and gained (U.S. GAO, 2005) on a one-off basis. This process can be time consuming and costly. Regulators must also monitor and enforce compliance after implementation, which is another source of transactions costs.

Uncertainty about practice performance also affects the potential supply of ecosystem services. Uncertainty about the quality or quantity of the ecosystem services a farm can produce makes it difficult for a producer to decide the long term economic benefit of investing in a wetland mitigation bank, to make wildlife habitat improvements for a fee-hunting business, to enter an emission trading market, or to enter the organic market. One might argue that farmers are used to dealing with uncertainty from season to season. However, farmers are inexperienced in the production and sale of ecosystem services. And since services are mostly unobservable, the uncertainties surrounding their provisions would seem to be more difficult to cope with.

Government can play a role in reducing uncertainty by supporting research on the effectiveness of different conservation practices for producing ecosystem services. USDA already provides farmers and ranchers information on the general impact of conservation practices on air, water, and wildlife habitat through sources such as the NRCS Field Office Technical Guide. However, much more detailed information is needed to estimate the number of credits that might be produced for sale in emission trading markets, or the wetland services that can be sold by a mitigation bank.

USDA is currently supporting the development of tools and methods for quantifying how changes in farming practices affect ecosystem services (USDA, NRCS 2006a,b). For example, the Nitrogen Trading Tool (Delgado et al., 2008), GRACEnet (USDA, ARS, 2007), and Comet-VR (USDA, 2007) are recent developments for helping farmers estimate the environmental credits they can produce on their farms by adopting management practices. Such tools could help reduce uncertainty in markets, as long as the models are accepted as providing good information.

Another, broader, effort is the Conservation Effects Assessment Project (CEAP) (USDA, NRCS, 2006a). The goal of CEAP is to quantify the environmental benefits of conservation practices used by private landowners participating in USDA conservation programs. Field-level sampling, monitoring, and modeling are being used to estimate the impacts of conservation practices on water quality, wildlife, and soil quality. In addition, collaborative regional assessments are developing models for estimating ecosystem services from wetlands, including carbon storage, sediment and nutrient reduction, flood water storage, wildlife habitat, and biological sustainability (USDA, NRCS, 2006a). CEAP also includes watershed assessment studies that are to provide a framework for evaluating and improving the performance of water quality assessment models. Such models are critical for estimating the equivalency of water quality credits that are produced in different parts of a watershed. Models that can predict the movement of chemicals carried in runoff with a degree of certainty sufficient to allow agricultural credits to be traded would make it easier for producers to participate in trading programs. They would also allow uncertainty ratios (trading ratios that specifically reflect practice uncertainty) to be lowered, potentially reducing the cost of agricultural credits and making them more attractive to point sources.

Uncertainty over the economic performance of practices implemented to produce ecosystem services can also be addressed through risk-management instruments such as insurance (Zeuli and Skees, 2000). Private companies could provide such instruments, but

Government could also offer them if an active market for ecosystem services is an important conservation goal and private insurance is not available, due to the challenges of evaluating the risks associated with new markets and establishing premiums. As markets develop and mature, the private sector is likely to play a larger role in providing risk-management tools.

4.2. Issue: quality assurance (standards and certification)

Many ecosystem services are either impossible or extremely costly to observe. For example, water quality and air quality services provided by a farm are largely invisible. Buyers of these services face a number of challenges in confirming the credibility of the services they purchase, including problems associated with measurement, additionality, and permanence. The failure to apply a well understood set of quality assurance mechanisms or standards limits market transparency, and harms market viability.

Steps to assure the validity and quality of an ecosystem service sold in a market have to take place at several places in the supply chain (U.S. GAO, 2008). Accounting and reporting methods define how to measure ecosystem services produced on a farm. Verification and monitoring standards can confirm that services are actually produced and measured correctly. Reporting registries can be used to track ownership and disposition of services, preventing double counting. Together, these mechanisms foster confidence that the services are real. To further instill confidence in the market, third parties can provide quality assurance services.

The use of quality assurance standards varies widely in existing markets for ecosystem services. Emissions markets created through regulation generally have strict standards that define the good to be traded and how it is measured, as well as strict reporting requirements. The Chicago Climate Exchange also has strict standards for measuring and recording transactions, and well-defined roles for third parties. Wetland mitigation banks have an established process for estimating wetland services that need to be replaced, and for tracking trades.

Some linked markets have well-established systems of standards and certification. Organic agriculture has benefited from a strong set of industry standards and certification that provide the assurance to consumers that the claims on the label are believable, and protect producers from dilution of price premiums due to less rigorous (and less costly) applications of organic standards (Ribaudo et al., 2008).

This is not the case for the OTC retail carbon market and some of the newer eco-labels, where there is widely varying use of quality assurance mechanisms (U.S. GAO, 2008). The fragmented nature of these markets makes it difficult to ascertain how many offsets being sold have been verified by third parties, and the methods used. It appears that there are many standards for measuring, verifying, monitoring, and tracking the distribution of carbon offsets, but few standards that cover the entire supply chain (U.S. GAO, 2008). GAO found that "The proliferation of standards has caused confusion in the market, and the existence of multiple quality assurance mechanisms with different requirements raises questions about the quality of offsets available on the voluntary market…" (p. 27).

The lack of standards makes it difficult for consumers to be certain of what they are actually buying, or how the ecosystem services provided by one supplier differ from another. For example, what does "wildlife-friendly" agriculture really mean? What does it really take to eliminate the carbon footprint of an airline flight or a wedding? As long as labels and advertising are the only ways consumers have of discriminating between the ability of producers to provide ecosystem services, consumers are likely to be skeptical of suppliers' claims. If consumers cannot judge the quality of the offset commodity, they may be inclined to select the lower price and often lower quality offsets (Trexler and Kosloff, 2006). If prices are too low, high-quality projects that can supply a stream of high-quality benefits may not get funded. The OTC retail carbon market is currently making increased use of third-party standards to increase consumer confidence (Hamilton et al., 2008).

Verification that ecosystem services are being produced is a tricky issue for agriculture. Monitoring practice performance through edge-of-field or ambient monitoring for ecosystem services is the most effective method for verifying that credits are being produced. However, due to the nonpoint nature of many ecosystem services from agriculture, monitoring may be extremely costly.

An alternative is on-site visits to determine whether the promised practices have been properly installed and maintained. Particularly in markets created through regulation, such as water quality trading and wetland mitigation, the prospects of on-site visits by representatives of EPA or other regulatory agencies has been a detriment to farmer participation (Breetz et al., 2004). In some markets, such as the Chicago Climate Exchange and some water quality trading programs, local conservation districts, aggregators or other third-party service providers verify that practices are in place, rather than a government agency. Experience with conservation compliance and Swampbuster (a compliance program to discourage the draining of wetlands) would seem to bear this out. The General Accountability Office found that almost half of all NRCS field offices were not properly verifying that producers were meeting the requirements of compliance and Swampbuster provisions (U.S. GAO, 2003). A reluctance to assume an enforcement role was cited as one of the reasons. Improved remote sensing technology might provide more acceptable (less intrusive) means of verification, although this may not be applicable for all types of management options.

Another aspect of quality assurance would be a system of liabilities or sanctions for failure to provide services for which producers have been paid. For example, EPA recommends for point–nonpoint water quality trading programs that clear, enforceable mechanisms be established to ensure the legal accountability for the generation of credits that are traded (U.S. EPA, 2007). Requirements could be included in trade agreements between point sources and farmers, or be enforced directly by the regulatory agency. In the case of fee hunting or OTC carbon markets, standard consumer protection laws could apply. In any case, a supplier with a reputation of being an unreliable provider in a market will likely lose customers and go out of business.

4.3. Issue: cost of information

An important aspect of a market for ecosystem services is that participants have access to the information they need to make informed decisions. Producers need to know which markets they can participate in, how to produce the services demanded at least cost, what the potential income might be, and what the total cost to the farm business will be. Producers are not likely to have the time to research all the questions that need to be answered, given the time needed for managing the farm.

Government and other groups can reduce the costs of participating in a market by providing the necessary information. The USDA department regulation calls for USDA to conduct research, outreach, education, technology transfer, and partnership building activities with producers, using established institutional arrangements, to provide producers with the information they need to successfully participate in markets for ecosystem services. Many State cooperative extension offices have developed publications to help producers set up a fee-hunting business, with checklists to help identify business goals, the type of lease to offer (daily, long term lease, lease to a hunt club), other services to offer (bed and breakfast, guides, and game cleaning), how to advertise, and how to manage risk (Chopak, 1992; Porter et al., 2007). Non-government organizations and private businesses that benefit from farmer participation in markets also have an incentive to reduce producers' information costs. NutrientNet

and the Nitrogen Trading Tool are examples of tools that can reduce information costs, as well as uncertainty.

Educating the public presents an important step in increasing the demand for ecosystem services. Raising the public's awareness of the potential threats from GHG emissions could increase their willingness to pay for GHG reductions in the over-the-counter carbon retail markets (Trexler et al., 2006). Similarly, educating hunters on improved habitat on a particular farm could increase income for a fee-hunting enterprise.

4.4. Issue: bringing together buyers and sellers

Ecosystem services are produced across a wide and diverse landscape. It may be costly for individual demanders to find all potential suppliers and to discover what each is selling, especially when the demand from a single source is much greater than the supply from a single farm. For example, a single sewage treatment plant may require nutrient credits from multiple farms to meet its permit requirements. Similarly, it can be costly for producers to find potential buyers, many of which may be located some distance away.

One way that markets have addressed this issue is through formal clearinghouses that assemble information from both buyers and sellers, making it easier for potential trading partners to find each other and to gauge supply and demand. The internet is an obvious tool that could be used to facilitate trades. For example, NutrientNet, World Resources Institute's online nutrient trading tool, can play a clearinghouse role in water quality trading programs (Kramer, 2003).

Government is playing a clearinghouse role in some markets. State-operated clearinghouses make it easier for point sources and nonpoint sources to find each other in some water quality trading programs (Breetz et al., 2004). The Voluntary Greenhouse Gas Reporting Registry can help agriculture and forest entities take advantage of State and private-sector generated opportunities to trade emission reductions and sequestered carbon.

Third-party brokers and aggregators also play a more direct role in bringing buyers and sellers together, by purchasing credits from producers and selling them to buyers. Aggregators play a critical role in the Chicago Climate Exchange, and are present in some water quality trading programs. In some cases, government plays an aggregator role by purchasing credits from producers and selling them on the market (such as what North Carolina does in its Tar-Pamlico water quality trading program) (Breetz et al., 2004). State agencies serve as third-party brokers in some wetland mitigation markets to reduce uncertainty and arbitration costs. A number of State programs purchase hunting access rights from landowners, and make these available to the hunting public. Hunters can consult State provided atlases to find hunter accessible land, with no need to seek out the individual landowner. As markets mature, the private sector is likely to play a greater role in reducing the cost of bringing buyers and sellers together.

4.5. Issue: coordinating conservation programs with markets

If a goal of policy is to stimulate the development and use of markets for ecosystem services, an important consideration is how Federally-funded conservation programs and markets interact. A major goal of conservation programs is to provide ecosystem services, primarily through financial assistance for the adoption of more environmentally-friendly management practices, and for retiring environmentally sensitive cropland from production. In a real sense, markets for ecosystem services and conservation programs may be competing with each other for the same natural capital, driving up costs to the possible detriment of market development (King and Kuch, 2003). This occurs if one assumes that agriculture faces increasing marginal costs as production of ecosystem service increases. Evidence suggests that this is the case (Ribaudo et al., 2001; Horan et al., 2004). For example, if farmers adopt nutrient management practices with support from conservation programs, any credits subsequently produced for a point/nonpoint water quality trading program will be more expensive than otherwise. This will reduce the volume of trades in the market compared to a situation where conservation programs were not present. If a goal of policy is to stimulate farmer participation in markets, then a hard look needs to be taken at how conservation programs and markets are coordinated.

The coordination of conservation programs and ecosystem service markets can enhance the performance of both (Horan et al., 2004). A rising issue in water quality trading programs is a requirement that farmers may not enter a market until they meet some minimal threshold of practice performance, such as installing vegetative buffers or implementing a nutrient management plan, even though there is no legal requirement to do so. The cost of making these investments may keep farmers who have not adopted these practices from participating in the market. Assuming an increasing marginal cost of pollution reduction, this requirement keeps the lowest-priced credits off the market, reducing the volume of trades. Targeting conservation programs such as the Environmental Quality Incentive Program or the Conservation Stewardship Program to those producers with the most serious environmental problems would not only increase the performance of the conservation programs, but could also increase the number of producers that are able to enter a market, which would be expected to benefit market performance. In another example, research has indicated that coordinating the CRP with fee-hunting opportunities could benefit the program as well as producers and wildlife, by reducing the rental rates landowners are willing to accept to enroll (Ribaudo et al., 2008).

USDA has developed a Partnership Agreement with EPA to coordinate agency policies and activities that promote the effective use of water quality credit trading. To this end, USDA agrees to identify and remove program barriers that might impede the development of water quality trading markets. What these are, however, will depend on the rules adopted in each market. Similar agreements could be developed for other markets as well.

5. Conclusions

Because of their social-good characteristics, markets for ecosystem services do not develop without some type of outside intervention. Impediments to supply and demand can be addressed through regulation, market design, program coordination, education, verification, certification, and research (Table 2). Resulting markets are imperfect, in that they still face issues of free-riding, large transaction costs, few buyers and sellers, and asymmetric information. However, the allocation of resources through markets may still be more efficient than through regulation, subsidy, or other policy mechanism. Careful consideration of the benefits and costs of markets relative to other policy approaches, such as regulation and government incentive payments, is warranted whenever markets for environmental services are considered.

What the ultimate scale of markets for ecosystem services from agriculture might be is difficult to say. For fee hunting, which is not a new concept, attitudes of both landowners and hunters may prevent much expansion. However, there may be opportunities for expanding wildlife viewing for fee on private lands. Experience with water quality trading and wetland mitigation indicate that the combination of factors required for farmers to successfully participate in such markets may be limited by program rules, limited geographic scope of markets, and the costs of handling uncertainty and verification. On the other hand, the market for greenhouse gas reductions could be greatly expanded if a national discharge cap is implemented, soil sequestration of carbon is recognized as an offset, and all the necessary steps to ensure that offsets are real are taken. Organic agriculture and other eco-labels are relatively new, and increased concerns over the

Table 2
Summary of existing markets for non-commodity ecosystem services and some important market characteristics.

Market	Water quality trading	Chicago climate exchange	Retail carbon market	Wetland mitigation banking	Organic labeling	Fee hunting
Environmental service	Water quality	Reductions in net greenhouse gas emissions	Reductions in net greenhouse gas emissions	Wetland services	Various (water quality, biodiversity, and air quality)	Wildlife
Good traded	Discharge allowance	Carbon credit	Carbon credit	Qualified wetland acreage	Agricultural food, fiber, and other products	Access to land
Source of property right	Regulatory agency	CCX rules	Retail carbon provider	Regulatory agency	Private good	Private good
Source of demand	Regulatory discharge cap on point sources	Legally binding discharge cap on member firms	Private sentiment	Legally binding no-net loss rules	Private sentiment	Private sentiment
Standards?	Yes	Yes	No	Yes	Partial	No
Steps being taken to reduce uncertainty	Research on performance of conservation practices, flexible rules for point sources, verification, and enforcement	Research on performance of conservation practices and verification	None	Research on measuring and verifying wetland services	Uniform national standards, mandatory certification, and Federal enforcement	Research on improving habitat and outreach
Steps being taken to reduce transactions costs	Third-party aggregator, clearinghouse, and outreach, models	Third-party aggregator, models, Voluntary Greenhouse Gas Reporting Registry	Online decision aids	Third-party arbitrators	Reduction in multi-ingredient certification disputes	Outreach, clearinghouse operated by state, and liability coverage
Remaining impediments or issues	Producer reluctance, lack of binding caps, and interactions with conservation programs	Lack of national binding cap and interactions with conservation programs	Lack of standards and verification	Up-front costs and market uncertainty and interactions with conservation programs	Information overload and free-riding on environmental benefits	Public sentiment, free-riding on wildlife services

environment could raise demand for foods produced in ways that also provide ecosystem services, so long as consumers are confident that the label means what it says.

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