How to sell ecosystem services: a guide for designing new markets

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Payments for ecosystem services (PES) can improve environmental quality by aligning the incentives of individual landowners with societal interests in providing valuable ecosystem services such as carbon storage, water quality, flood control, and wildlife habitat. However, for this potential to be realized, many institutional details and technical challenges must be addressed. In this review, we discuss six critical issues for creating effective PES markets: using the appropriate type of market institution, defining suitable spatial and temporal scales for the market, promoting additionality (avoiding payments for services that would have been provided even in the absence of payments) so that payments result in increased services, offering incentives for projects that generate multiple ecosystem services, considering practice-based versus performance-based payments, and eliminating opportunities for strategic behavior aimed at “gaming the system”. We illustrate these issues with an example of how PES could be applied to floodplain restoration.

While generating much value for society, ecosystem services (ES; the benefits that humans derive from ecosystems) often fail to generate benefits for individual land managers who produce these benefits. Consequently, investments that would generate such societal benefits are often not made, and society does not realize many potential ES benefits. Payments for ecosystem services (PES) can be an effective way to provide incentives that align private and public interests. However, failure to correctly design markets for PES can make this approach ineffective or even counterproductive (Kinzig et al. 2011). A particular challenge in the design of PES is that many ecosystems provide multiple ES, thereby requiring market design that incentivizes the provision of multiple services.

In this paper, we address several institutional design issues critical to the successful implementation of payments for multiple ES and use floodplain restoration as an illustrative example. We synthesize relevant economic literature in a manner accessible for a general readership and provide practical recommendations for PES design.

PES: background and design considerations

The requirement for PES can be traced back to Pigou (1920), who introduced the notion of external costs and benefits, suggesting the need for a tax or subsidy to align private and public interests. Payments for ES are one way to achieve this. At a minimum, PES require appropriate conditions for market creation (eg exclusive, transferable, and enforceable property rights; Shogren 2005; Tietenberg and Lewis 2008), but effective PES also necessitate attention to multiple design and implementation issues. Researchers have raised a number of such issues, including whether to base payments on actions or outcomes, since actions are easier to monitor but outcomes are the real goals (Antle et al. 2003); asymmetric information, where sellers possess unique information about the costs of actions and so can overcharge (Ferraro 2008; Lewis et al. 2011); coordination among programs, because an ES may be directly or indirectly affected by various policies (Horan et al. 2004); funding responsibility, since ES often have multiple beneficiaries across jurisdictions (Wunder et al. 2008); distributional concerns, since successful programs need to be equitable and not disproportionately affect the poor (Bulte et al. 2008; Pascual et al. 2010); weak institutions, because institutional capacity is crucial for program integrity (Engel and Palmer 2008; Clements et al. 2010); adaptation to social and political contexts (Muradian et al. 2010); and specification of ES units over what geographic extent and for how long (Wunder 2005). Here we address six important issues in PES design: (1) choice of appropriate market type, (2) geographic and temporal scale of the market, (3) additionality (avoiding payments for services that would have

In a nutshell:

- Payments for ecosystem services (PES) can improve environmental quality by offering incentives for landowners or managers to carry out actions that will provide public environmental benefits
- To incentivise shifts in land management, PES must exceed the revenue from current land uses, which may often lead to payments for multiple ecosystem services
- Multiple services can be successfully delivered via separate markets and payments for each service (stacking) or by paying for activities that produce multiple services (bundling)
been provided even in the absence of payments), (4) stacking or bundling payments for multiple ES, (5) monitoring and practice-based versus performance-based approaches, and (6) strategic behavior. We address each issue in turn and then discuss their application to floodplain restoration.

**Market type**

Payments for ES schemes are implemented through mechanisms such as exchanges, clearinghouses, mitigation banks, and bilateral agreements (Panel 1; Woodward and Kaiser 2002). The appropriate mechanism depends on factors such as the number of interested buyers and sellers, the homogeneity of the ES, and transaction costs (Coase 1960; Stavins 1995).

Exchanges are market institutions where numerous buyers and sellers trade a homogeneous, fungible (interchangeable) commodity in a single market (Tietenberg 2006). Examples of exchanges include stock markets and some commodity markets. With a large number of buyers and sellers, each buyer or seller is small relative to the size of the market and therefore cannot impact market price. In theory, such markets yield an efficient outcome where the commodity (in this case the ES) ends up in the hands of the market participants who value it most. Further, the presence of many potential trading partners and a standardized commodity result in minimal “transaction costs”, since the costs of running the market are spread across many similar trades (Wunder 2005). When working well, exchanges lead to an economically efficient outcome. However, in practice, incomplete information about market conditions, price manipulation by major participants, product heterogeneity, and other issues can distort exchange markets (Ferraro 2008).

Exchanges work best for homogeneous commodities. For example, carbon dioxide (CO₂) is a homogenous commodity because it mixes uniformly in the atmosphere such that each metric ton of CO₂ causes equivalent impact, independent of the location of its emission. In theory, this would allow a global exchange for carbon (C) trading. Examples of exchanges trading a homogenous commodity include the European Union Emissions Trading Scheme for greenhouse-gas emissions and the sulfur dioxide (SO₂) allowance program administered by the US Environmental Protection Agency (EPA; Stavins 1998, 2005; Tietenberg 2006). For most ES it is difficult to define homogeneous commodities because impacts vary over space or time. For instance, the floodwater storage services provided by a wetland depend on what is downstream from that wetland (eg a flood-prone city versus an ocean).

Clearinghouses and mitigation banks (Shabman et al. 1996) are designed to deal with more heterogeneous services. More than 600 mitigation banks have been approved or are under consideration for approval (Ruhl and Gregg 2001; Ribaudo et al. 2010). These institutions require identifying units that are similar enough to be traded within defined geographic areas. They may establish trading ratios when units are not identical. For example, wetlands of similar type in the same watershed may trade on a one-for-one basis while restoration in different watersheds may require several hectares to be restored for each hectare destroyed.

Some regulations allow or require PES to “offset” impacts from ongoing development or land use; the purchase of such offsets (eg from mitigation banks to offset impacts to wetlands) creates demand for certain types of ES and is a primary driver of ES markets (US EPA 2007; Ribaudo and Nickerson 2009). Trading ratios for offsets should be defined conservatively to ensure that overall impacts are reduced.

If sites are very heterogeneous, each proposed trade may need to be negotiated on an individual basis through bilateral agreements. Although such agreements often have high transaction costs relative to other market types, substantial savings can be achieved if there is a standard formula for calculating benefits and if contracts for an ES are auctioned (Latacz-Lohmann and Van der Hamsvoort 1997; Stoneham et al. 2003).

**Geographic and temporal scale of the market**

Most ES provision occurs at local or regional scales, constraining the location within which services can be traded (Wunder 2005; Wunder et al. 2008). For instance, pollination services occur only within the distance that pollinators can travel, and flood-control and water-quality services occur within watersheds (Cherry et al. 2007).
There are trade-offs when considering the appropriate size of an ES market (Engel et al. 2008). A small-scale market may not include an adequate number of buyers and sellers (termed a “thin market”), making it difficult to match buyers and sellers. Thin markets tend to have few trades, volatile prices, and the potential for price manipulation. Expanding the geographic scope may add potential buyers and sellers, reducing these problems. However, buyers of ES will often not want to pay for services that do not directly benefit them, constraining the geography within which they will be willing to pay for services. This suggests that a market should service as large a geographic area as possible, to maximize participation, while still providing services within the geographic area relevant to their buyers.

Each PES market is likely to have a unique ideal geographic scale (Figure 1). The benefits of actions taken in one location may accrue to different geographic areas, depending on the service (e.g., floodplain restoration may have global benefits for C sequestration but local benefits in terms of water quality or floodwater storage). In addition, actions taken in one location can have impacts at multiple locations (Sommerville et al. 2009). For example, fertilizer runoff in the upper Midwest of the US both reduces local water quality and contributes to the Gulf of Mexico hypoxic zone. One way to deal with this is to create separate markets, such as both a local water-quality market and an overall Mississippi River Basin market related to hypoxia issues. Local landowners who reduce nutrient pollution levels could sell this service in either market (Kroeger and Casey 2007).

The timing of impacts can also matter. Ozone from air emissions is of greater concern during the summer because heat is an important component in its formation. Temporal differences in the value of ES may require limiting trades over time (e.g., not allowing trades across seasons) or the establishment of trading ratios for emissions occurring at different times.

Trading ratios should also take into account time lags in ES provision. For instance, restoration through mitigation banks occurs upfront, through the creation of wetlands that can be used to offset future impacts of development. But restoration in response to damage from unanticipated impacts, such as oil spills, typically occurs after the fact. Restoration that occurs before any damage is done is preferable because there is no period of time with diminished ES flows. Delayed restoration should be given less credit (i.e., require higher trading ratios) than upfront restorations (Wunder et al. 2008; McKenney and Kiesecker 2010).

**Additionality**

It is desirable to link PES only with those ES that would not have occurred otherwise (i.e., to require additionality; Kollmuss et al. 2008). Given limited resources, paying for ES that are not additional will result in lower ES provision than could be achieved with payments only to additional projects.

An eligibility clause can help protect against non-additional projects by excluding landowners from getting paid for a practice that they have already implemented. For example, farmers already using no-till practices would be prohibited from getting paid to implement this practice. For floodplain restoration, only those landowners with newly restored lands would receive payments.

Evaluating additionality requires comparison with a “baseline” situation not actually observed: what would have happened without the PES scheme (Sohngen and Brown 2004). With inherent uncertainty about this baseline, our ability to know what is additional is imperfect. Consequently, restrictions to ensure additionality can exclude some truly additional ES, potentially eliminating cost-effective opportunities for additional ES. On the
other hand, paying for ES that would have occurred anyway can drain budgets and prevent funding other more beneficial ES investments. Thus, with limited budgets and imperfect knowledge of baselines, additionality requirements that are either too lenient or too stringent will result in the underprovision of ES.

This trade-off can be addressed with good knowledge of the baseline to discern what is additional, or with budget increases to allow payments for all beneficial ES. In this latter case, landowners will have proper incentive to provide ES, though some landowners may be paid for ES that they were willing to provide even without payments. Coupled with reasonable eligibility requirements, markets that allow competition among ES producers to deliver services at the lowest cost (eg with a reverse auction) may provide a reasonable approach to minimizing the risk of both overpayment and underpayment. In environmental reverse auctions, sellers bid for the amount of payment they would need to provide the ES in question, allowing auctioneers to preferentially purchase the cheapest ES (Greenhalgh et al. 2007). Indeed, because the actual costs for provision of additional services can never be perfectly known, this is likely to be as close to an optimal approach as can be achieved (Lutez-Lohmann and Van der Hamsvoort 1997; Polasky and Doremus 1998; Connor et al. 2008).

**Payments for multiple ES**

Conservation activities typically impact multiple ES simultaneously. For instance, floodplain forest restoration can improve C sequestration, nutrient retention, and wildlife habitat (Jenkins et al. 2010). To provide incentives for the provision of multiple services, payments could be made through separate markets for each service (stacking) or through payment for an activity that generates multiple benefits (bundling). Failure to pay for multiple services can result in insufficient incentive to provide even one service. For example, consider a farmer choosing between growing flood-intolerant row crops and flood-tolerant perennial biomass crops on a floodplain. The biomass crops could generate higher societal benefits because of the provision of several ES, but generate lower private agricultural market returns than row crops (Figure 2). In this hypothetical example, payment for any single ES is not sufficient to incentivize land-use change, but stacking ES payments would be sufficient.

Some commentators have expressed concerns about paying for multiple services, primarily because of the risk of lack of additionality (Cooley and Olander 2012). In cases where landowners would have adopted practices that provide multiple services, even though they are only being paid for a single service, payment for a second service has been criticized as “double-dipping”. Yet, the additionality issue with regard to multiple ES is similar to that connected with a single service; there is the same trade-off between overpaying (ie paying for non-additional projects) and underpaying (ie stringent additionality requirements that exclude potential ES providers). This trade-off can be managed with the same approaches used to address the additionality concerns involved with payment for a single service: careful design of eligibility criteria, due diligence in estimating baselines, increased conservation budgets to allow for payment for all socially worthwhile projects, and price competition that reduces the cost of payments per unit of ES. If there is price competition (eg with reverse auctions, which minimize costs by enrolling lower-cost ES first), then the landowner who can earn payments for multiple ES would be able to charge less for each service, thus underbidding other landowners. Consequently, markets that select low-cost providers will favor projects that can provide the greatest benefit overall through multiple services, increasing public welfare and reducing the cost of each service.

It is doubtful that payments will cover all ES. PES design should therefore consider the unintended consequences caused by interactions between ES that are included in ES markets and those that are currently excluded from markets. For example, Jackson et al. (2005) found that increasing forest cover increases C sequestration but may reduce stream flows through increased transpiration. Paying for C sequestration but not water provision would result in a reduction in surface water flows that would be environmentally problematic in some locations (Jackson et al. 2005). One way to guard against such

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**Figure 2.** Shifting floodplain land use from flood-intolerant row-crop production to flood-tolerant biomass production incurs an opportunity cost, which could be overcome by payments for multiple ES. If landowners chose the profit-maximizing land use, then they would choose Scenario D if stacked PES are available, but would choose Scenario A if stacked PES are unavailable. In this hypothetical example, payment for any single ES is not sufficient to incentivize land-use change, but stacking ES payments would be sufficient.
unintended consequences of payments for one ES negatively impacting the provision of other ES is to expand coverage to multiple ES, thereby incentivizing provision of all important services.

We next consider the relative advantages of stacking versus bundling in providing payments for multiple ES. A fundamental finding from economic theory is that having a complete set of markets covering all goods and services can generate an efficient outcome where benefit to society is maximized (Debreu 1959; Hahn 1986). In the context of multiple ES, this implies a market for each ES. If landowners are paid for all ES, they will have the correct incentive to manage their land to maximize net benefits. While this theoretical argument for stacking is strong, this approach raises concerns about the added administrative burden associated with implementing multiple independent markets.

Management costs can be reduced through a bundled market that pays for practices that have multiple ES benefits (eg the US Department of Agriculture’s Conservation Reserve Program, which retires cropland to provide soil, water, and habitat benefits). Bundling will work well when a single practice achieves multiple desired benefits (Ribaudo et al. 1999). However, bundling is undesirable when service provision is not tightly coupled with practices, such as when the delivery of services is highly variable across locations or when multiple services are not tightly coupled (eg some practices are much better for C sequestration than for water quality, or vice versa).

New PES schemes are often driven by the identification of buyers willing to pay for specific ES in particular geographic locations. Consequently, the potential for bundling depends on what buyers are willing to pay for. In many instances, buyers are restricted to a single ES, based on regulation or institutional mandate, which would favor separate stacked markets for each service. This is the case for many existing PES markets such as municipal water utilities and water funds, water pollution trading schemes to meet regulatory targets (eg Total Maximum Daily Load [TMDL] limits), and the California Air Resources Board’s C market. Stacked markets may also be preferred when services produce benefits at different geographic scales (eg C sequestration with global climate change versus nutrient retention for local water quality).

Payments for multiple ES can be accomplished through either stacking or bundling. In practice, the most viable approach will likely be determined by what buyers are willing to pay for (if a single service, then stacked payments; if multiple services provided by one practice, then bundled payments).

**Practice- versus performance-based schemes**

Payments for ES can be based on management activities (practice-based) or measured outcomes (performance-based). Since the goal of PES is to improve ES outcomes, it is appropriate to base payments on outcomes. However, measuring service output may be prohibitively expensive (eg measuring the export of nutrients from the edge of each restoration site), making performance-based PES impractical. Furthermore, management actions may have episodic benefits (eg flood control during large storm events), so that short-term measurements would not accurately assess performance. Because of these challenges, many payment schemes are based on the adoption of practices rather than on outcomes. The use of practices as a proxy for conservation outcomes is effective when supported by scientifically verified relationships between practices and outcomes (Ribaudo et al. 1999).

One criterion that can favor performance- over practice-based PES is high spatial heterogeneity. For example, for agricultural practices that increase soil C, performance-based measures become more efficient than practice-based measures as spatial heterogeneity of the ES increases (Antle et al. 2003). In such cases, efficiency gains from improved targeting of PES to those areas with the greatest ES provision can offset increased monitoring costs.

**Strategic behavior**

Poorly designed payment schemes can create perverse incentives for landowners to engage in strategic behavior to “game the system” (Cattaneo et al. 2006). For example, if farmers are paid to retire cropland to create perennial grassland, there is an incentive for farmers to convert grassland to crops in order to receive payments to restore cropland back to grassland. Program eligibility requirements can help address this issue. For instance, one could restrict payments for retiring cropland to lands that had been cropped before the program started. Such eligibility clauses can prevent strategic behaviors where individuals create environmental problems in order to get paid to fix them. If not properly designed, eligibility requirements can cause their own perverse incentives if landowners anticipate the institution of a program with eligibility requirements. Using eligibility criteria based on practices in place well before the initial date of the program (and before the program was anticipated) is one way to avoid this type of perverse incentive.

**Designing ES markets for floodplain reconnection**

Floodplain reconnection illustrates many of the issues that must be addressed if widespread adoption of PES schemes is to be successful (Tables 1 and 2). There are approximately 72 million hectares of floodplains in the US (Kusler and Larson 1993); these areas support numerous ES, including C sequestration, water quality, habitat, and flood control (Tockner and Stanford 2002; Zedler and Kercher 2005). In recent decades, floods and hurricanes have underscored the importance of floodplains for floodwater storage and conveyance (Pinter 2005; Opperman et al. 2009). Restoration of reconnected flood-
plains by replacing flood-intolerant annual crops with perennials would improve C storage, floodplain habitat, and water quality through reduced nutrient runoff (Jenkins et al. 2010). What type of markets, over what geographic and temporal scales, would be suitable for each of these ES, and what potential problems might occur as a result of a lack of additionality or strategic behavior (Table 2)?

Consider a farmer who is willing, given sufficient PES, to replace flood-prone row crops with a reconnected and restored floodplain. Levees would be breached, removed, or set back. Row crops would be replaced with native perennials. This would result in improved water quality through reductions in the amount of sediment, nutrients, and pesticides added to surface waters; C sequestration in soils and biomass; habitat creation for fish, waterfowl, and other wildlife; and potentially reduced flooding. However, this change would be expensive and would reduce farming income. How could PES be designed to provide sufficient payments to cover costs?

Carbon offsets could be traded on a national or global exchange and have been verified through both practice- and performance-based measures, mostly through empirically validated models that can be used to estimate performance following adoption of approved practices.

Water quality is a heterogeneous “product” with spatially restricted beneficiaries, and so is probably best suited to trading through a clearinghouse. Water-quality improvements associated with nonpoint-source pollution are expensive to measure, so water-quality trading is best suited to practice-based trading. To ensure ES outcomes, watershed-scale, performance-based monitoring should be used to evaluate the overall water-quality benefit.

Flood-control PES could be implemented via a clearinghouse or a mitigation bank. Floodplain restoration can contribute to floodwater storage, reducing downstream flooding. Such restoration can also contribute to floodwater conveyance, speeding removal of floodwaters and reducing upstream flooding. Flood control is difficult to

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<th>Table 1. Questions, answers, and associated guidance for design of stacked ES markets</th>
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| Notes: For each issue, guidance depends on the answer to the associated question. |

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<th>Table 2. Possible configuration of a stacked market for floodplain ES</th>
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<td><strong>ES</strong></td>
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measure with performance-based monitoring, because floods occur intermittently and are the result of complex, landscape-scale hydrological interactions. Therefore, flood-control benefits should be modeled to predict the benefits of particular actions, and evaluated by testing model predictions against long-term datasets. Clearinghouses or mitigation banks would be responsible for monitoring, to ensure that flood risk-reducing activities are undertaken as promised.

Where purchasers of habitat credits require guarantees of permanence, the PES can work via mitigation banks (which own and monitor habitat or easements) or federal conservation programs (bilateral agreements). Typically, habitat credits are generated when a certain vegetation composition and habitat structure are obtained. This can be considered a performance-based measure or a proxy for the desired outcome of larger and more stable populations of targeted species.

Due to high capital costs and institutional barriers, it is unlikely that landowners would construct levees just to receive ES payments to remove them. Incentives promoting floodplain reconnection and restoration are therefore probably not susceptible to strategic behavior. Similarly, the high cost of floodplain restoration reduces additionality risks because landowners are unlikely to undertake restoration in the absence of payments. In fact, payments for multiple ES are likely to be required to provide sufficient incentives for restoration. It is estimated that floodplain restoration in the Mississippi Alluvial Valley (MAV) has a potential ES market value of US$396 ha⁻¹ yr⁻¹ for C, US$624 ha⁻¹ yr⁻¹ for nitrogen, and US$15 ha⁻¹ yr⁻¹ for waterfowl hunting, for a total of US$1035 ha⁻¹ yr⁻¹ (Jenkins et al. 2010). This total is comparable to the net returns from the most common row crops grown in the MAV, which have average projected profit margins ranging from US$450 ha⁻¹ yr⁻¹ for cotton to US$1190 ha⁻¹ yr⁻¹ for rice (USDA 2012). Consequently, payments for multiple ES may be necessary to make floodplain restoration competitive with row crops.

Although examples of markets that allow payments for multiple ES are rare, several do exist. In Oregon’s Willamette River Basin, for instance, a regulatory action – EPA setting a TMDL limit for thermal pollution in the Willamette River – spurred the creation of additional PES markets for nutrients and wetland banking (Willamette Partnership nd).

Payments for multiple ES could also be implemented via national policy. The foundation of such a policy in the US could come through expansion of conservation programs or could be spurred by changes in the Principles and Guidelines that govern the US Army Corps of Engineers. Indeed, a 2009 proposal would require incorporating ecosystem values and benefits in the Federal water resource management standards, using ecosystem- and watershed-based approaches (NRC 2012). This would encourage agencies to work with municipalities and levee districts to develop PES schemes (Chang 2008), as has been proposed following floods on the Cedar River (Baxter 2011) and Red River (DeVuyst et al. 2009).

Conclusions

Our recommendations for floodplain ES market structures illustrate how market design principles can be applied in ES markets. The four ES we consider here appear most likely to generate PES by stacking payments from different buyers willing to pay for services in different geographic locations and with different market types. Allowing payments for multiple ES may be necessary to overcome opportunity costs associated with land-use changes. Additionality risks from stacking payments for multiple services are similar to additionality issues with single services and can be addressed with appropriate eligibility criteria, due diligence in baseline determination, and competitive pricing (eg with reverse auctions). Prohibitive measurement costs associated with performance-based measures often necessitate practice-based measures as a basis for landowner participation in PES programs, but the overall program effectiveness should be evaluated with targeted monitoring of outcomes. There is minimal risk of strategic behavior in floodplain reconnection projects and, where a risk exists, strategic behavior by landowners can often be prevented by designating appropriate eligibility criteria. The framework and floodplain example presented here offer a starting point for the design of multiple ES markets in other systems and can be used to inform ongoing policy efforts.

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References


