# DESIGNING EFFECTIVE CONSERVATION AUCTIONS

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## I. Introduction

Financial incentives are commonly used as policy instruments to promote voluntary conservation and improve environmental outcomes. Incentives such as payments for environmental services (PES) are typically offered to landowners in exchange for some conservation action (e.g. planting riparian buffers) or inaction (e.g. not harvesting a forest). Determining how to cost-effectively allocate these incentives constitutes an important challenge to research and environmental program design. Efficient incentives are set at payment levels that are high enough to motivate land owners to participate in a conservation program without exceeding the amount required to achieve participation. In other words, efficient incentives should align with the full cost of participating in a conservation program, meaning the sum of direct costs of implementation plus the opportunity cost of foregone income, adjusted for the participant's conservation preferences. This payment level is known as the individual's minimum willingness-to-accept (WTA). Since the costs and benefits landowners incur from a conservation decision vary widely, offering a uniform incentive in exchange for an environmental service is not cost-effective. For some landowners, the payment could far exceed their costs thus providing excess rents. The same payment may be insufficient for others, resulting in less conservation.

Procurement auctions are an increasingly popular tool used to select cost-effective conservation projects because of their ability to reveal privately held information about landowner costs. Sometimes called "reverse" auctions because the low bidder wins, procurement auctions can be used to identify incentives that effectively motivate voluntary adoption of agricultural best management practices (BMPs), the focus of this research. BMPs can reduce the negative impacts of agricultural production on surrounding ecosystems while maintaining productivity. But BMPs are effective only if farmers adopt them. A host of factors affect farmer choices about adopting new practices, including costs, benefits, personal preferences, and risk. Some BMPs offer environmental benefits but reduce farm profitability. Often in these cases, farmers will only adopt the BMP when incentives are offered in return. The relative importance to individual farmers of the factors influencing adoption is often unknown to agencies trying to enhance environmental outcomes, thus it is difficult to identify incentives that will cost-effectively promote BMP adoption.

When designed appropriately, procurement auctions provide a mechanism to reduce information asymmetries, allowing more efficient allocation of funds to promote conservation. Incentive compatible auction designs promote efficiency through a bidding mechanism in which it is in each bidder's best interest to make bids that reflect their true valuation. Although some procurement auctions are not considered to be incentive compatible, the competitive nature of the mechanism supports efficiency relative to fixed-price conservation payments that have been traditionally used to improve environmental outcomes.

This review draws on a variety of sources to introduce the role that reverse auctions can play in conservation initiatives. A growing body of economic literature provides insight into how auctions can be conducted most effectively. Furthermore, applications of conservation auctions provide case studies from which we can draw insight about appropriate auction design and administration. The following section will define procurement auctions and describe the advantages of using this mechanism to allocate incentives. Section III focuses on auction design by identifying eight distinctive elements of a reverse auction and highlighting how these design issues have been handled in conservation auctions over the last decade. Section IV describes how auctions might be used to motivate group decision-making regarding conservation and promote collective action across a watershed or subwatershed. Throughout the review, examples of conservation procurement auctions are used to illustrate different features of auction design and implementation. A summary of these case studies is provided in Table A.1 in the Appendix.

## II. What is a Procurement Auction?

A procurement auction, also known as a reverse auction, involves multiple sellers competing to sell a good to a single buyer. In the context of conservation, a procurement auction involves multiple sellers of environmental services (ES) (e.g. landowners) selling to one buyer (e.g. government or private organization). Landowner bids implicitly reveal private information about the costs of providing these ES. Bid acceptance, in turn, provides a mechanism to "purchase" ES. By aligning ES supply and demand, auctions serve as a "quasi-market institution" to arrange the provision of public, environmental goods by private landowners (Latacz-Lohmann and Van der Hamsvoort, 1998).

*(i) Cost-effectiveness relative to other programs*

In the United States, both private and public organizations commonly use payments to promote conservation on privately owned land (Selman et al., 2008). One example is the USDA Environmental Quality Incentives Program (EQIP), which pays farmers a cost-share that covers between 50 and 75 percent of conservation project costs. Costs of various projects, such as the implementation of an agricultural BMP, are estimated based on a standard price list developed by each state. Cost-shares are not allocated based on a competitive process that makes payments to the most cost-effective applicants. Instead, each participate receives a uniform payment that is based on the direct cost of implementing the practice. The payment is not designed to capture the additional opportunity costs of any lost revenue due to the changed practices. Hence, a cost share payment to install a buffer strip would pay for a share of the planting cost, but it would not compensate the farmer for crop income foregone by converting that land to conservation use.

Compared to fixed-rate conservation payments, procurement auctions have several advantages that improve cost-effectiveness. First, auctions address issues of asymmetric information between landowners and the ES buyer by revealing the lowest incentive for which a bidder would be willing to adopt a certain conservation practice – i.e. her willingness-to-accept (WTA). Secondly, the competitive nature of bid selection creates incentives for landowners to offer bids closer to their true opportunity costs, thus reducing rent seeking behavior (Latacz-Lohmann and Van der Hamsvoort, 1998; Rolfe et al., 2009). Latacz-Lohmann and Van der Hamsvoort (1998) show that procurement auctions are more cost-effective than payment policies that don't base payments on *a priori* information regarding opportunity costs. One study, focused on phosphorus runoff, found that a procurement auction resulted in a seven-fold increase in the reduction of phosphorus runoff per dollar spent, compared to EQIP during the same period (Selman et al., 2008).

Maximizing conservation impact from limited funds requires two kinds of information. The first is a reliable prediction of ecosystem benefits from adopting the BMP on a specific farm. Well validated ecological simulation models are increasingly able to provide sound predictions.

The second kind of information is an understanding of the costs, benefits, and preferences that affect farmer willingness to accept payments for BMP adoption. An effective way to learn about both the farm and the farmer is to use procurement auctions in which farmers compete to win the low bid to offer conservation benefits from BMP adoption.

## III. Auction Design

To achieve cost-effective conservation outcomes, procurement auctions must be designed to elicit bids that reflect landowners' costs to provide an environmental service. Auctions are considered "incentive compatible" when designed so that it is in each bidder's best interest to make a truthful bid that reflects her true valuation. A conservation procurement auction would be incentive compatible, and thus efficient, if each bid equaled that landowner's total cost (equal to direct cost plus opportunity cost) of the conservation action. Five theoretical assumptions provide a foundation for the evaluation of auction efficiency: (i) bidders are risk-neutral; (ii) bidders have independent private values; (iii) bidders are symmetric, meaning that their values are independently and identically distributed, thus creating identical bidding functions; (iv) payment is a function of the bid alone; and (v) there are no costs associated with bid construction and implementation (Connor et al., 2008). Designing procurement auctions that are contextually robust and maintain the theoretical benefits attributed to auctions is important for successful field implementation. In this section, several design issues are discussed based on how each affects cost-effectiveness of procurement auctions.

### *(i) Training*

Before conducting the auction, participants need to be introduced to the auction mechanism and familiarized with the bidding process. The primary goal of an initial training period is to clear up and misperceptions that would prevent elicitation of true value or cause participants to engage in strategic behavior in an attempt to manipulate the game (Drichoutis et al., 2011). Training makes elicitation of accurate valuations more likely. Sometimes training involves practice bidding rounds so that bidders become acquainted with the auction process. Training may also include a verbal or written explanation of the bidding process, the goal of the auction, and the environmental outcomes sought by the buyer. The extent of training varies greatly depending on the organization conducting the auction, their budget and personnel constraints, and their goals.

*(ii) Number of bidding rounds*

Conservation auctions may have just one round or several. Single round auctions are suggested when bidders have independent private values (Latacz-Lohmann and Van der Hamsvoort, 1998). Variation between farms for characteristics like soil quality, slope, and production systems suggest that each landholder would base bids on private costs, rather than common values (Stoneham et al., 2003). Single round auctions force bidders to formulate bids based on their true private valuation and opportunity costs because they lack multiple rounds to engage in strategic behavior (Rolfe et al., 2009). In other words, if bidders must commit to a bid without an opportunity for adjustment, they are less likely to inflate their bid in an attempt to extract rents or bid low in an attempt to win. With only one round of bidding, a person who inflates their bid then has a lower probability of winning the auction, and a person who underbids might win the auction but receive an auction payment that is insufficient to cover their costs. Neither strategy would be in the individual's best interest. Single round auctions also reduce transactions costs and administrative costs. The majority of recent conservation auctions have used the single round format (Ajayi et al., 2012; Selman et al., 2008; Smith et al., 2009; Stoneham et al., 2003).

Multiple rounds provide opportunities for participants to learn about the auction process. In practice, while most conservation auctions are conducted as single round affairs, they are often repeated over the years, creating parallels with multiple round auctions. There is evidence that bidders learn over time (Latacz-Lohmann and Schilizzi, 2005) as they compare bids between auctions and discover common values for conservation practices. Valuations of other landowners may influence individual bids; therefore, studying multi-round procurement auctions may provide more insight regarding how auctions actually operate in the field.

Multiple rounds are valuable as a price discovery mechanism. They can increase efficiency for participants by allowing inexperienced bidders to learn and avoid costly mistakes (Cason and Gangadharan, 2004). Efficiency gains can be generated if participants lower their bids, but gains are likely limited to the first two rounds when participants are in the learning stage (Lusk et al., 2004; Rolfe et al., 2009). Later rounds are subject to risks of collusion and strategic bidding behavior that may lead to efficiency losses (Brown et al., 2011; Rolfe et al., 2009). Multiple rounds can also increase administrative costs of assessing offers and providing feedback to bidders.

Multiple round auctions require a stopping rule to determine how many rounds will take place. Sometimes this rule is simply a predetermined number of rounds, but other stopping rules are also possible. One option is to randomly select the number of rounds from a uniform distribution – this number could be revealed to participants ahead of time or concealed. If payments are made based on bid acceptance in the final round, then revealing the number of rounds ahead of time creates risk of strategic bidding behavior in the last round. Another stopping rule could be to continue bidding until participants' bids are constant between two rounds. Auctions are likely most cost-effective when the number of rounds is not known to participants *a priori*.

*(iii) Bid submission*

Rules for submitting bids vary depending on how much time is allowed for bid formulation and how offers are made. During the submission process bids can remain private by sealing the bid or can be made public by announcing them in an open auction setting. Sealed bids limit the possibilities for collusion (Stoneham et al., 2003) and thus represent the preferred method in procurement auctions (Rolfe and Windle, 2011).

Asking landowners to submit bids in a short time period may be impractical because participants likely require time to consider their full costs and formulate a reasonable bid. In conservation auctions with farmers, Hill and others (2011) found that farmers needed sufficient time prior to bidding to consider factors such as the costs per acre of land, labor and equipment needed to undertake a conservation practice, and their personal time constraints. Furthermore, farmers must consider the opportunity cost of foregone income from changing their production methods. In practice, the submission period for conservation auctions is commonly between one and two months[1] (Hill et al., 2011; Smith et al., 2011). Multiple round auctions require significantly more time because they require that the original bids be ranked, which usually

[1] Thomas Van Wagner. District Conservationist for Lenawee County, Michigan. NRCS. Personal communication via phone. 10/18/2012.

requires model simulation to predict environmental outcomes. Recent examples of multiple round auctions have allocated two to five months in-between rounds[1] (Hill et al., 2011).

*(iv) Pricing mechanism*

The payment that each successful bidder receives may be the same (uniform pricing) or may vary among sellers (discriminatory pricing). Discriminatory pricing schemes award payments according to each actual bid. Uniform pricing schemes set a single price based on a value that is independent of individual offers. For example, an $n^{th}$ price auction uses a specified rule to determine the bid for which the price will be set. A common pricing rule is to set the price to the value of the first bid rejected (Ajayi et al., 2012). In traditional ascending bid auctions, a common rule is to have the highest bidder win, but pay an amount equal to the second highest bid. This format is known as a Vickrey auction and can be adapted to procurement auctions by paying the lowest bidder (the winner) an amount equal to the second lowest bid.

Participants in uniform price auctions are expected to bid their true opportunity cost or willingness to accept because their bid impacts the bidder's likelihood of winning, but does not impact the payment that will be received (Brown et al., 2011). However, there has been evidence of over bidding in second price auctions, despite the claimed incentive compatibility of the mechanism (Cooper and Fang, 2008; Kagel and Levin, 1993). One drawback of uniform price auctions is that participation may be discouraged due to risk aversion under conditions of price uncertainty, perceptions of little chance of winning by high-cost landowners, and landowner confusion about the pricing mechanism (Brown et al., 2011; Latacz-Lohmann and Schilizzi, 2005). Furthermore, by paying farmers more than their bid amount, uniform price conservation auctions do not achieve the greatest environmental benefit for a given budget.

In discriminatory price auctions, bidders do not receive a surplus on top of their bid amounts. In conservation auctions, this pricing scheme has been shown to generate significant savings compared to uniform pricing (Cason and Gangadharan, 2004). Pollution abatement is higher and seller profits are lower compared to a uniform price auction, so discriminatory price auctions can achieve environmental benefits at a lower cost. Discriminatory pricing may, however, create incentives for bidders to strategically inflate their bids about their true willingness-to-accept (Jack et al., 2008).

Discriminatory, first price auctions have been the preferred method in recent procurement auctions[2] because the bidders do not extract rents in excess of their bid, thus resulting in the most environmental benefit for a specified budget (Connor et al., 2008; Rolfe and Windle, 2011; Stoneham et al., 2003). Although less common, examples of uniform, $n^{th}$ price auctions also exist (Ajayi et al., 2012). $N^{th}$ price auctions are considered more incentive compatible by revealing the bidders' true WTA, but each bidder is paid more than their bid, which exhausts a conservation budget more rapidly than under a discriminatory, first price auction.

The organization conducting the conservation auction must decide which design criterion matters more: 1) truthful bids that reflect the minimum WTA or 2) obtaining the most environmental benefits within a limited budget. If truthful bidding is important, the $n^{th}$ price auction should be used. Agencies aiming to maximize environmental benefits should employ discriminatory price auctions.

*(v) Ranking bids*

There are numerous ways to rank bids in procurement auctions, depending on the goals of the buyer. Conservation auctions typically rank bids based on three different criteria: cost, benefits, or cost-effectiveness. Ranking bids based on cost alone would result in accepting the cheapest bids, but these bids may be associated with practices with little to no environmental benefit. Likewise, ranking bids based on ecological benefits alone may result in accepting a bid that is so costly that it completely exhausts the budget constraint. To procure the most environmental benefits within a limited budget, bids are frequently ranked based on cost-effectiveness. Cost-effectiveness is measured either in benefits per dollar or costs per unit of benefit. A benefit per dollar index is calculated by dividing the predicted benefits of each bid (e.g. reduction of soil erosion in tons) by the bid amount. A cost per benefit index would reflect the amount of money required to procure one unit of environmental improvement (e.g. one ton reduction in soil erosion).

Dividing benefit quantity by the cost (bid payment) is straight forward, but deciding which benefits to rank is more complex. The benefits selected will depend on the goals of the conservation project. Some may have one goal in mind, like reducing phosphorus runoff into

[2] Thomas Van Wagner. District Conservationist for Lenawee County, Michigan. NRCS. Personal communication via phone. 10/18/2012.

streams, whereas others may have multiple objectives. Single objective rankings can be constructed by simply calculating the units of environmental benefit (e.g. tons of sediment reduction) achieved per dollar spent for payments or, inversely, the cost per unit of environmental benefit. This strategy has been used in various watersheds to reduce sediment loads (Smith et al., 2009) and phosphorus runoff (Selman et al., 2008). To accommodate multiple objectives, auction regulators must design a weighting system to account for various benefits based on relative importance to the overall goal.

One way to accommodate multiple objectives is to develop an environmental benefits index (EBI). The USDA Conservation Reserve Program (CRP) has employed a competitive bidding mechanism to select parcels of agricultural land to conserve using a cost-effectiveness ranking based on a six factor EBI (wildlife, water quality, erosion, enduring benefits, air quality, conservation priority areas) (USDA-FSA, 2012a). The Australia Bush Tender combines two separate EBIs to construct a composite index that they call a biodiversity benefits index (BBI). Many other auctions have also constructed EBIs that cater to a particular goal or policy environment (Connor et al., 2008; Hill et al., 2011; Rolfe and Windle, 2011).

*(vi) Information revelation*

When and how information is revealed about the auction process and about individual bids can strongly influence auction outcomes. Such information can be revealed beforehand, between bidding rounds, or withheld altogether. Before starting the auction, researchers should decide how much information will be revealed and what will be the likely effects on auction outcomes. For example, if bids will be ranked by an EBI, the buyer should decide whether or not to reveal the EBI and the relative weights of its component factors. Withholding this information may result in bids that are more closely aligned with participants' costs, but it will also increase the uncertainty surrounding how the auction mechanism works.

In multi-round procurement auctions, the buyer must decide whether to reveal bidding information to participants between rounds and, if so, how much information to reveal. Feedback can include several types of information. The buyer can reveal the preliminary bid acceptance cut-off level, the ranking of all bids, or the predicted environmental benefits from bids. Recent conservation auctions have taken various approaches. One approach is to use two rounds and provide feedback about provisional bid acceptance between the rounds before allowing participants to readjust their offers and bid again (Hill et al., 2011). This approach provides a price discovery mechanism for bidders, but still withholds information about the level of predicted benefits from each offer. The majority of multi-round conservation auctions, however, do not reveal information to participants in order both to avoid strategic bidding and to lower the administrative costs of conducting auctions (Connor et al., 2008; Rolfe and Windle, 2011).

In an experiment with undergraduate students, Cason and others (2003) designed an auction to test the effect of information revelation on bids for conservation practices. The treatment was to reveal the environmental benefits of conservation practices to some bidders, but not to others. Without information about value of output, the author predicted that bidders would base bids solely on their costs. Revealing benefit information tended to raise bids, thus providing bidders with information rents. Another study confirmed the finding that providing information about environmental benefits resulted in higher seller profits and lower efficiency for the buyer (Cason and Gangadharan, 2004). To limit information rents, other conservation auctions have withheld benefit information from farmers (Stoneham et al., 2003).

Revealing the prices of accepted bids provide another type of information feedback. Some studies suggest that people become more rational over repeated rounds with price feedback (Cox and Grether, 1996; Shogren et al., 2001). An individual's optimal bid level increases with the uncertainty surrounding the price that will be accepted (Connor et al., 2008), so reducing the uncertainty may lead to greater efficiency. However, experimental studies of ascending price Vickrey auctions have found that bidding becomes less consistent with price feedback due to bid affiliation (Corrigan et al., 2012). Bid affiliation occurs if bids contain components of both private and common values (Corrigan and Rousu, 2011). In other words, affiliated bids are correlated with market prices in the previous round.

Providing feedback about benefits and prices may lead to rent seeking behavior, which lowers the cost-effectiveness of a conservation auctions. However, if auctions have multiple rounds, some participants may share information about how much they bid, thus aquiring informal price feedback. Revealing information about provisional bid acceptance without providing specific feedback about ecological benefits or the values of the bids is one way to offer feedback with low risk of strategic behavior. Ultimately, the decision to provide participants with feedback depends on the goals of the buying agency. If transparency is the goal then multiple types of information can be provided, but many agencies may wish to simplify the auction and avoid strategic behavior by limiting the amount of information provided to bidders.

*(vii) Bid acceptance*

After bids are ranked the buyer must decide which bids will be accepted. Acceptance rules vary, but are primarily determined by setting a reserve price or accepting bids until the budget is exhausted. In practice, buyers of environmental services usually structure the auction to accept bids until a budget constraint is met (Stoneham et al., 2003). Some buyers establish reserve prices (i.e. payment ceilings) and will not accept bids that exceed this amount (Brown et al., 2011; Hill et al., 2011; Rolfe and Windle, 2011). For example, the USDA's Conservation Reserve Program sets a reserve price based on the rental value of land adjusted for it productivity, as a way to reflect differing opportunity costs (USDA-FSA, 2012b).

Setting a reserve price is not crucial if a budget constraint exists (Stoneham et al., 2003), but in some circumstances it may be necessary. If established, the existence of reserve prices should be announced to bidders, but the value of the reserve price should remain hidden to avoid anchoring bias that occurs when bids become correlated with the reserve price instead of reflecting the bidders true valuation (Latacz-Lohmann and Schilizzi, 2005; Reichelderfer and Boggess, 1988).

Bid adjustment and acceptance rules are important considerations for multiple round auctions. After first round bids are submitted, the auctioneer can accept some of the bids or allow everyone to adjust and bid again in a second round. If first round bids are accepted, only participants with rejected bids have the opportunity to adjust and bid again. This type of auction is a hybrid of the single round and multiple round formats. Bidders must commit to their bids in round one because, if selected, they would be expected to fulfill their agreement. But some participants will have the opportunity to adjust their bid amount if they aren't selected in the first round.

*(viii) Contract payment*

Contracts and payment rules for conservation projects vary with the policy setting, goals, and project requirements. Contract lengths differ primarily based on the type of conservation practice being implemented (Stoneham et al., 2003). Land owners usually require longer-term contracts for actions such as land conservation/land retirement, tree planting, or installing riparian buffers. Practices for which adoption decisions are easily made each year are suitable for annual contracts that provide land owners with flexibility. However, the transactions costs of administering PES programs tend to be lower with multi-year contracts.

## IV. Incentivizing collective action in procurement auctions

Conservation procurement auctions are usually designed to elicit bids from landowners that are independent of the decisions of their neighbors. Most conservation programs for agricultural lands target individual actions with no incentives for cooperation across property lines. However, agricultural landscapes are managed by many individuals, and the actions of a single individual may have little environmental impact. Provision of environmental services has been focused at the farm level, but a growing body of literature recognizes the potential value of ES provision at greater scales by coordinating management across a landscape (Goldman et al., 2007; Hodge and McNally, 2000; Parkhurst and Shogren, 2007; Sarker et al., 2008; Stallman, 2011).

Coordinated behavior among landowners can have two primary benefits. First, increasing participation in conservation actions increases the level of environmental services provided. Second, coordination can promote certain ES that offer disproportionate benefits at larger scales. For example, enhancing species biodiversity necessitates a certain level of landscape connectivity, which requires coordination among multiple land managers. Without considering the location of project proposals, traditional conservation auctions may fail to reach a minimum threshold of ecosystem service acquisition required in a specific landscape. If the ranking mechanism does not consider the value of landscape level conservation actions, procurement auctions typically result in the acquisition of conservation projects that are scattered across a region. Although this type of auction may cost-effectively provide some ES, it may not be cost-effective for ES that are tied to landscape composition or configuration.

Using procurement auctions to promote large scale, coordinated conservation calls for a balance between cooperation among bidders and the competition necessary to achieve cost-effective allocation of funds (Reeson and Tisdell, 2008). Reeson and Tisdell (2008) identify two key issues to address when scaling up conservation goals. First, it is necessary to identify the combinatorial values of ES provision at different locations across the landscape so that an appropriate ranking mechanism can be implemented. Second, it must be possible for land managers to coordinate their actions to achieve the desired landscape characteristics, such as composition and spatial configuration. Calculating combinatorial values requires modeling capabilities that acknowledge spatial interactions across a landscape. Promoting coordination is a function of the incentive structure used in the auction mechanism.

Researchers have investigated several mechanisms to stimulate coordinated behavior by multiple land managers. One is the so-called "agglomeration bonus" (Parkhurst and Shogren, 2007). Originally designed for wildlife habitat conservation, "the agglomeration bonus is a spatial incentive system designed to create contiguous reserves across private landholdings voluntarily," (Parkhurst and Shogren, 2007, p. 1). By paying subsidies when land is conserved that borders another conserved parcel, Parkhurst and Shogren (2007) found that in a multiple round game, the agglomeration bonus could motivate participants to conserve contiguous land units. Agglomeration bonuses can be adapted to procurement auctions by offering additional payments when multiple land owners in the same region (e.g. subwatershed) agree to undertake a conservation practice or when a certain level of predicted environmental benefit is achieved.

Using experimental auctions, Reeson and others (2008) explored the effectiveness of iterated auctions designed to promote coordination. The auctions involved ten participants selecting parcels and prices at which they would rent land to a regulator. The directions indicated that the buyer preferred to rent land that was connected to other pieces that were rented. The number of rounds was known in some experiments, but not in others. In between rounds, feedback was provided about provisionally accepted bids. Provisional winners could adjust their bids only in specified auctions. The study found that iterated auctions could result in coordinated outcomes. Auctions were most efficient when the number of rounds was unknown to participants and when provisional winners could not raise their prices.

## V. Conclusion

Environmental organizations and government agencies have shown increasing interest in contracting with private landowners to provide environmental services. However, heterogeneity among land parcels and landowners makes it difficult to determine appropriate payment levels for various conservation actions. Procurement auctions offer a flexible tool to overcome these limitations and cost-effectively acquire environmental services from private landowners. The competitive mechanism encourages landowners to reveal the minimum amount they are willing to accept to adopt a conservation practice. By revealing this privately held information, procurement auctions can result in the cost-effective provision of ecosystem services by weighing both the payment requested and the expected environmental benefits.

The design of conservation procurement auctions varies greatly depending on the preferences and goals of the buyer. Each design feature has implications for the functionality of the auction, including how well the auction elicits bids that reflect landowners' true costs. The procurement auction mechanism is characterized by nine design elements:

1. Training prior to the auction
2. Number of bidding rounds
3. Protocol for bid submission
4. Pricing mechanism employed
5. Bid ranking
6. Information revealed to bidders
7. Bid acceptance rules
8. Contract structure and length
9. Incentives for landowner coordination

Identifying the appropriate format of a conservation procurement auction calls for adapting these elements to the goals of the auction.

Training is imperative and must be included in any auction design. Verbally explaining the auction mechanism and bidding strategy will help participants construct bids that are in line with their true willingness to accept payment for the conservation practice. A practice round before bidding begins is optional, but has been shown to improve auction outcomes because participants are more familiar with the auction process.

Single round auctions require participants to commit to their bids and may provide an incentive for truthful bidding. However, multiple round auctions allow inexperienced bidders to learn and increase the likelihood that their bids will be accepted. A hybrid model is to allow multiple rounds of bidding, but to accept winning bids in each round. Only participants with rejected bids can readjust their bid in subsequent rounds. This model provides the incentive for truthful bidding but also provides bidders with a chance to try again if they aren't accepted in the first round.

Sealed bid submission is preferred because it avoids participants making bids that are correlated with other offers. Thus sealed bids motivate bidders to make offers that are in line with their true willingness to accept. In an auction that allows coordinated bidding in order to obtain landscape level ES, submitted bids (e.g., from individual groups) should still be sealed.

The high complexity of conservation procurement auctions often requires days or weeks for participants to formulate bids, especially when bids involve multiple practices and/or land parcels. Landowners need adequate time between learning about the auction process and submitting their bids to consider their total costs, including opportunity costs, and the feasibility of implementing certain practices. Rather than formulate bids on the spot, farmers should be given a multiple week bidding window to submit bids electronically or by mail.

The pricing mechanism—uniform pricing versus discriminatory pricing—will affect how participants construct their bids and how well the bids reflect their true costs. If the buyer wants bids to reflect individual participants' true costs, a uniform $n^{th}$ price auction should be adopted. However, uniform pricing mechanisms result in each bidder being paid more than their actual offer, which reduces the cost-effectiveness of the auction. If cost-effective procurement of environmental benefits is the buyer's goal, a discriminatory, first price auction in which each winning bidder is paid the amount of their bid is preferred.

Bids should be ranked based on some measure of cost-effectiveness that considers both the payment requested and the predicted environmental benefits. The ranking can incorporate one or many environmental outcomes, depending on the goals of the buyer. The index of cost-effectiveness is then ordered so that the most cost-effective bids are accepted first.

Information about environmental benefits and/or bid amounts can be revealed to participants in multi-round auctions. However, revealing this information may encourage rent seeking behavior and strategic bidding. Withholding this information is likely to improve the cost-effectiveness of a multiple round auction. But if the auction is going to be held on a regular basis, participants will eventually be able to talk to one another to gain informal feedback about how they can improve their chances of winning in the future. Furthermore, low-cost bidders may discover that they can extract additional rents from the auction and still have their bid accepted.

For these reasons, information about prices and benefits should be withheld and feedback can be limited to notification of provisional acceptance (in the instance of a multiple round auction).

If cost-effective administration of a conservation budget is a primary goal, it makes sense to accept discriminatory pricing bids in the order of cost-effectiveness until the budget is exhausted. Another approach involves setting a reserve price so that bids that exceed this level will be immediately rejected. Reserve prices may be necessary for political reasons or when a budget is not specified, otherwise agencies should accept bids until all funds are allocated.

Contract requirements for the conservation practices in the auction must be explicitly stated prior to the auction. Landowners tend to prefer short-term contracts for practices that are annually adjustable (e.g., choosing crop, fertilizer, and tillage form), but they prefer long-term contracts for conservation practices that involve high upfront investment costs (e.g. installing riparian buffers). Buyers of conservation practices tend to prefer long-term contracts, due to the costs of conducting conservation auctions and monitoring outcomes.

Procurement auctions can also be adapted to motivate landscape scale conservation through coordinated actions of multiple landowners. One mechanism to promote cooperation is to offer agglomeration bonuses to groups of participants that all agree to specific management practices. The buyer can also make bid acceptance conditional on reaching a predefined environmental target or having a certain level of aggregate participation in a specified region.

## VI. Appendix

Table 1: Overview of conservation procurement auctions that have been conducted from 2000 – 2012.

| Auction Name | Reference | Goal | # of rounds | Bid Submission | Pricing Mechanism | Ranking | Information feedback | Bid acceptance | Contract length |
|---|---|---|---|---|---|---|---|---|---|
| ICRAF Pilot Auction for Erosion Mitigation (Indonesia) | Ajayi et al., 2012 | erosion mitigation | seven non-binding and one binding round | sealed bid | uniform, nth price that equaled the price of the lowest rejected | ranked on bid amount | price information withheld | no reserve | one year |
| Conservation Easement Auctions (Canada) | Brown et al., 2011 | land conservation using easements | single | mailed in a bid booklet | uniform, nth price that equaled the price of the lowest rejected bid | bids were converted to the percentage of assessed value of the land | reserve price withheld | hidden reserve price | multi-year conservation easement |
| Catchment Care (Australia) | Connor et al., 2008 | watercourse and riparian restoration | single | sealed bid | discriminatory, first price | bids ranked based on cost-effectiveness<br>i.e. EBI score divided by bid price | information withheld | no reserve, bids accepted until budget constraint | - |
| EcoTender | Eigenraam et al., 2005 | multiple objectives | single | sealed bid | discriminatory, first price | multiple outcome index of cost-effectiveness based on the Catchment Modeling Framework (CMF) | revealed information about ranking metrics | no reserve, bids accepted until budget constraint | five or ten years |

| Auction Name | Reference | Goal | # of rounds | Bid Submission | Pricing Mechanism | Ranking | Information feedback | Bid acceptance | Contract length |
|---|---|---|---|---|---|---|---|---|---|
| Assiniboine River Watershed (Saskatchewan, Canada) | Hill et al., 2011 | wetland restoration | two | sealed bid via phone | discriminatory, first price | bids ranked based on price and an EBI | benefits withheld, feedback about provisional bid acceptance after first round | bids rejected for exceeded the fair market value; bids accepted until budget constraint was met | 12 year |
| Conestoga Watershed Reverse Auction (Pennsylvania, USA) | Selman et al, 2008 | improved water quality in the Conestoga Watershed | single | sealed bid | discriminatory, first price | ranked based on price per pound of reduced phosphorus runoff | - | no reserve, bids accepted until budget constraint | varied |
| Pomona Lake Watershed (Kansas, USA) | Smith et al., 2009 | improved water quality in Pomona Lake | single | sealed bid | discriminatory, first price | ranked by the tons of predicted sediment reduction (at Pomona Lake) per dollar | no feedback provided | no reserve, bids accepted until budget constraint | varied |
| Victoria's BushTender Trial (Australia) | Stoneham et al., 2003 | increase biodiversity | single | sealed bid | discriminatory, first price | bids ranked based on Biodiversity Benefits Index (BBI) divided by bid | benefits score withheld | no reserve, bids accepted until budget constraint | multi-year |

| Auction Name | Reference | Goal | # of rounds | Bid Submission | Pricing Mechanism | Ranking | Information feedback | Bid acceptance | Contract length |
|---|---|---|---|---|---|---|---|---|---|
| Great Barrier Reef Auctions (Australia) | Rolfe and Windle, 2011 | water quality improvements in the Great Barrier Reef | multiple | sealed bid | discriminatory, first price | bids ranked on price and EBI | reserve price withheld | hidden reserve price | one year |
| Lenawee County Conservation Auctions (Michigan, USA) | Van Wagner, 2012 | reduced sediment flow and erosion | two - some bids accepted in first round | sealed bid | discriminatory, first price | bids ranked on tons of sediment reduction per dollar | no feedback provided | no reserve, bids accepted until budget constraint | one year |

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