Incentives for Spatially Coordinated Land Conservation: A Conditional Agglomeration Bonus

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Introduction

Land conservation is a tool extensively used by governments and environmental organizations to obtain a multitude of environmental benefits. The largest land conservation program in the U.S. is the USDA's Conservation Reserve Program (CRP). It pays farmers to retire land in crop production in favor of conservation measures that will achieve environmental objectives such as reducing soil erosion, improving air and water quality, and providing wildlife habitat. Over 33 million acres were enrolled in CRP programs as of September of 2009. The efficient allocation of funds is a subject of interest to economists in that annual expenditures for land conservation range in the billions of dollars. An extensive economic literature has emerged analyzing the cost-effectiveness of conservation programs in achieving environmental objectives. See Claassen et al. (2008) for a review of U.S. conservation programs and previous research.

The marginal benefit of a conservation effort is often small until some threshold level of conservation has been reached. For example, the population of a species may not be viable when contiguous habitat is below some minimum acreage H_T. Conservation efforts resulting in the creation contiguous habitat of a size below H_T would provide no environmental benefits in terms of improving the viability of the species (see Figure 1).

Examples of such "threshold effects" considered in the economic literature include the effect of habitat fragmentation on bird and mammal species (Lewis and Plantinga, 2007; Parkhurst and Shogren, 2007; Parkhurst et al., 2002), and the effect of water quality on fish populations (Wu, et al., 2000). The marginal benefit of conserving a parcel of land may depend not only upon the parcel's characteristics, but on the spatial pattern of conservation among neighboring parcels given the presence of threshold effects. The concern is that ignoring threshold effects will result in an allocation of conservation funding that is spatially overly dispersed, as demonstrated by Wu and Boggess (1999).

Wu et al. (2000) consider a conservation issue prominent in the western United States: habitat enhancement for steelhead trout, a salmonid fish species. The authors identify a threshold effect in water temperature's impact on the steelhead abundance in the John Day River fishery in eastern Oregon: stream temperatures should not exceed 18° C. Measures that lower stream temperature one or two degrees when stream temperature is above 20° C have little effect on steelhead abundance. The authors find that the equal allocation of funds across sub-basins to improve stream habitat would tend to be inefficient because marginal benefits vary significantly depending on the condition of surrounding habitat. In the extreme case, benefits might even be zero if the allocation to each sub-basin fails to reduce temperatures below the threshold level.

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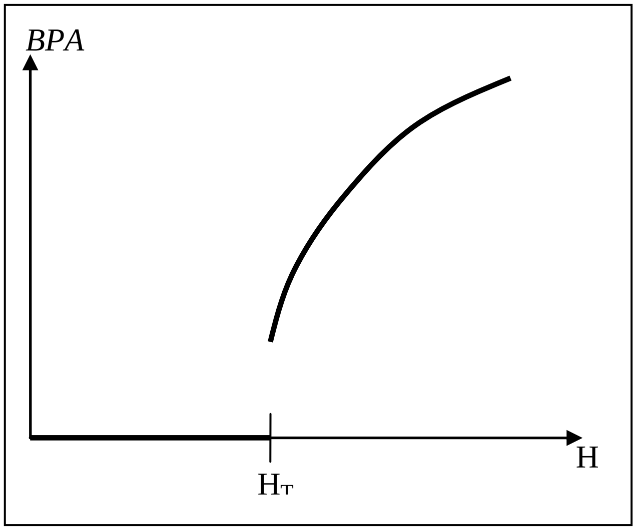
Figure 1. Benefit per Acre (BPA) of Contiguous Habitat Acreage (H)



An incentive mechanism proposed in the literature to encourage spatially coordinated conservation is the agglomeration bonus. It awards landowners bonus payments for the conservation of adjacent portions of land (Parkhurst and Shogren, 2008; Parkhurst and Shogren, 2007). In an experimental study, Parkhurst and Shogren (2007) found that groups of four players in a coordination game with an agglomeration bonus mechanism were able to achieve desired spatial configurations of land conservation (e.g., a wildlife corridor or core habitat) with over 90% efficiency. While these experimental results are encouraging, they were limited to the context of conserving endangered species habitat that overlapped several parcels of land. Furthermore, each player had exact knowledge of the other players' opportunity costs, and the total incentives paid to conserved land were disproportionately large.[19]

Real-world applications of the agglomeration bonus are rare. One is Oregon's Conservation Reserve Enhancement Program (CREP), established in 1998 with the goal of assisting the recovery of salmon and trout species by creating riparian buffers along stream habitat. The program includes a provision that awards a one-time "Cumulative Impact Incentive Bonus" (CIIB) wherever at least 50 percent of any 5 mile section of streambed is enrolled in the CREP (USDA 1998). In a 1998 survey of potential CREP participants, approximately 76% indicated a willingness to work with neighbors toward enrolling contiguous stream miles (Kingsbury, 1999). One reason cited by landowners for not wishing to take advantage of the bonus program was the perception that it would require a large investment in time to coordinate with neighbors. During the past decade CIIB awards in Oregon have not been extensive. However, the incentive has proven successful in encouraging CREP participants who have enrolled without bonus compensation to promote the program to neighbors who can put them above the 50% threshold required for CIIB eligibility (Sundseth, 2009).

Incomplete information is a frequent impediment to the design of effective incentive mechanisms. Regarding the agglomeration bonus, its functionality is dependent on landowners' knowledge of their neighbors' willingness to participate in conservation. For example, consider

[19] In the 2007 study, incentives totaling $1,168 were paid to four players who conserved the desired configuration of core habitat, while the forgone rent (i.e. opportunity cost) on that portion of land totaled only $192. From a cost-benefit perspective, it would be preferable to simply make a take-it-or-leave-it offer of less than $1,168 for the desired core habitat.

a farmer for whom the bonus level of compensation (paid to contiguous conservation) exceeds rents from agriculture, and suppose his agricultural rents are higher than some base-level compensation (paid to non-contiguous conservation). His payoff from enrolling in the conservation program may be positive or negative depending on whether the pattern of his neighbors' enrollment is sufficient to warrant bonus compensation. Hence, the farmer's expected payoff is a function of each neighbor's probability of enrolling. The farmer takes on risk by enrolling because his payoff could be negative. If information about neighbors' willingness to participate is limited, he may forego participation even when he and his neighbors would mutually benefit from enrolling as a group.

The above example illustrates a significant limitation to the agglomeration bonus mechanism as it has been represented in the recent literature: the agreement to enroll is binding on both the landowner and regulator. The agglomeration bonus literature has not examined the potential for conditional agreements to overcome the informational requirements necessary to induce spatially coordinated land conservation. The real-world applicability of the agglomeration bonus has likely been constrained by its strong information requirements. The modification to the agglomeration bonus mechanism proposed in this paper improves its applicability by limiting landowners' information requirements to knowledge of their own opportunity costs and eliminating the need for landowners to coordinate their enrollment decisions.

Landowner Responses to Voluntary Incentives

Predicting a landowner's response to an incentive such as a subsidy from the USDA's Conservation Reserve Program can be complex. Underlying the landowner's decision to accept or reject such a subsidy is the quality (i.e. productivity) of his land, and by extension, the stream of rents he can earn from its highest and best use. Two factors that introduce complexity to predicting a landowner's response to an incentive are the long term commitment inherent to most conservation programs (the minimum CRP contract is 10 years) and the individual characteristics of the landowner.

A landowner's calculation of expected opportunity cost under a long-term commitment will incorporate his current rents as well as expectations of the levels and prices of future inputs and outputs. A group of landowners with similar parcels of land are likely to form variable expectations about the proceeding 10 to 15 years. A landowner's willingness to enroll in a conservation program is also likely to depend on his personal characteristics. Conservation payments provide a relatively predictable stream of rents compared to crop production and a landowner's calculation of expected opportunity cost depends on his risk profile.[20] Due to such human heterogeneity, a fragmented response to an incentive is possible even where land rents and characteristics exhibit little heterogeneity.

The agglomeration bonus attempts to overcome fragmented responses by creating a positive network externality among neighboring landowners (Parkhurst and Shogren, 2007). It requires each landowner to perform what can be a complex task: to incorporate expectations of neighbors' responses into his own enrollment decision. Each landowner's expected payoff from enrolling in a conservation program is a function of his expected opportunity cost and expectations about his neighbors' enrollment decisions (which are equally complex). For

[20] For example, Parks and Kramer (1995) found that older landowners were more likely to enroll land in the Wetlands Reserve Program.

reasons discussed in the above paragraph, predicting the response of any particular landowner to an incentive can be difficult even where land characteristics are observable.

Unless the agglomeration bonus is very large or small relative to opportunity costs, each landowner is likely to face some degree of uncertainty about his neighbors' willingness to enroll their lands. Where a large number of landowners are involved and/or communication among landowners is poor, the ability of an agglomeration bonus to induce coordinated land conservation is likely to be limited. The following section proposes a modification to the agglomeration bonus that eliminates the need for landowners to form expectations about others' willingness to enroll.

A Conditional Agglomeration Bonus

Asking landowners to predict neighbors' responses to an incentive is unnecessary when landowners' agreements to enroll are binding if and only if a desired pattern of enrollment is achieved (e.g., n contiguous acres). A conditional agglomeration bonus (CAB) program would pay compensation only where the desired pattern of enrollment occurs. As represented in Figure 2 below, a regulator would offer some level of compensation (S^{CAB}) to landowners and observe the spatial pattern conditional enrollment. Where the desired pattern of enrollment does not occur, the landowner is released from his obligation to enroll land and the regulator is released from his obligation to compensate the landowner. Assuming zero transaction costs, landowner i will conditionally enroll in the program whenever his opportunity cost is less than the CAB incentive because in that case his expected payoff π_i is always greater than or equal to zero:

(1) $E(\pi_i) = p * (S^{CAB} - OC_i) + (1 - p) * 0.$

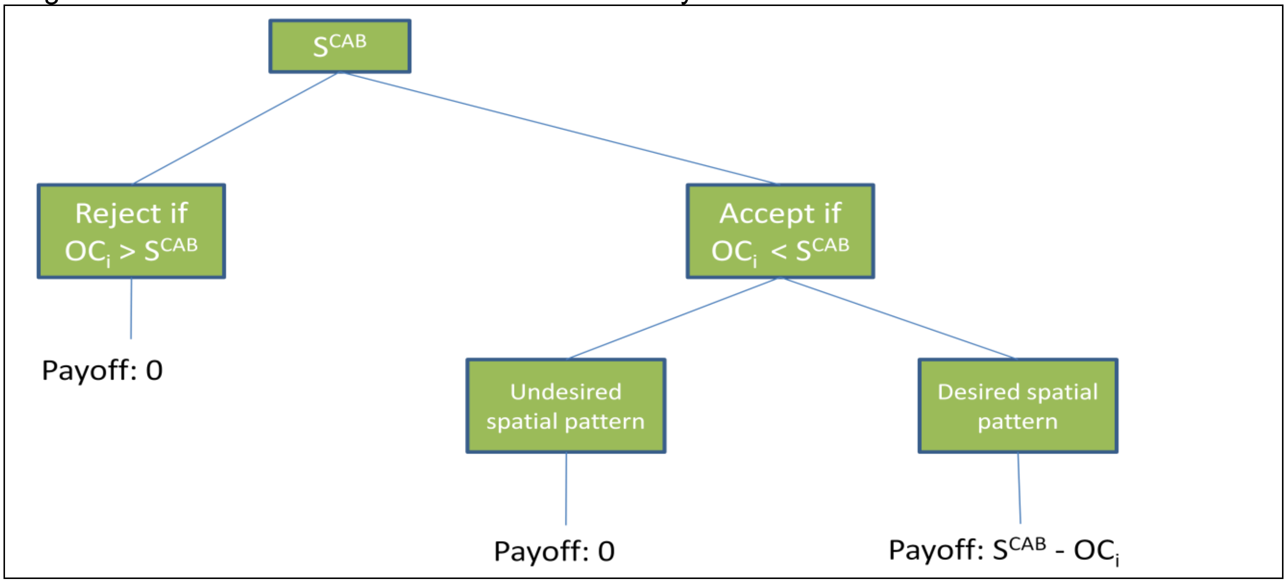
Where S^{CAB} denotes the CAB bonus payment, landowner i's opportunity cost of enrolling is OC_i, and p is the probability that his neighbors' enrollment will be sufficient to generate the regulator's desired pattern of conservation.

Under the CAB program a landowner's expected payoff remains a function of his neighbors' opportunity costs; they affect the probability that the agreement to enroll will become binding. However, information about neighbors' willingness to enroll (i.e. p) is no longer relevant to a landowner's enrollment decision. The probability p affects only the magnitude of the expected payoff. The sign of the expected payoff, which determines whether or not landowner i will conditionally enroll, is determined entirely by the landowner's opportunity cost and the size of S^{CAB}.[21]

Figure 2 below demonstrates the landowner's enrollment decision and payoff structure under a CAB program. Initially, the incentive S^{CAB} is offered. If S^{CAB} is less than landowner i's opportunity cost, then the offer is rejected and the payoff is zero. If landowner i's opportunity cost is less than S^{CAB}, then the offer is conditionally accepted. Finally, if an accepting landowner is part of the desired spatial pattern of conservation he is enrolled in the program obtaining a payoff of $S^{CAB} - OC_i > 0$.

[21] For the purposes of this paper, I assume that the CAB program is offered once and only once. If the CAB were offered periodically, a landowner may find it optimal to delay his enrollment decision, even where, if his option value is positive.

Figure 2. Landowner's Enrollment Decision and Payoff Structure



Figures 3a and 3b represent the operation of a CAB program on a hypothetical landscape. Figure 3a shows parcels of land conditionally accepting the CAB offer. That is, all parcels for which $S^{CAB} > OC_i$. Figure 3b shows the parcels of land ultimately enrolled in the CAB program when the desired pattern of conservation is three or more contiguous units of land. Any landowner not contiguous to at least two other parcels of land is released from his conditional enrollment.

What should be clear is that the CAB program functions *without* the coordination of landowners. Each landowner's optimal strategy (accept if $S^{CAB} > OC_i$ and reject otherwise) is informed only by his own costs and S^{CAB}. Information about neighbors' willingness to enroll, represented by p, is irrelevant.[22] Hence, the CAB can achieve desired patterns of spatially coordinated conservation *without* making any assumptions about the level of information available to landowners and their ability to cooperate.

From the landowner's standpoint, the conditional agglomeration bonus improves upon the agglomeration bonus as it has been represented in the literature in two important ways. First, the CAB simplifies the landowner's decision process by eliminating the need to coordinate one's decision with others. Second, the possibility of coordination failure caused by uncertainty of neighbors' willingness to enroll is eliminated. Wherever a group of landowners is each better off enrolling, that group is ultimately enrolled (see Figures 3a and 3b).[23]

[22] Under a standard agglomeration bonus the size of p is relevant to the enrollment decision, and the functionality of the agglomeration bonus will depend on each landowner accurately determining p. The information contained in p is complex: it is the joint probability of each landowner enrolling and it is endogenous.

[23] It is possible for some landowners to be thwarted by an irrational neighbor who does not enroll, but they will be no worse off than the status quo.

Figure 3a. Parcels Conditionally Accepting S^{CAB}

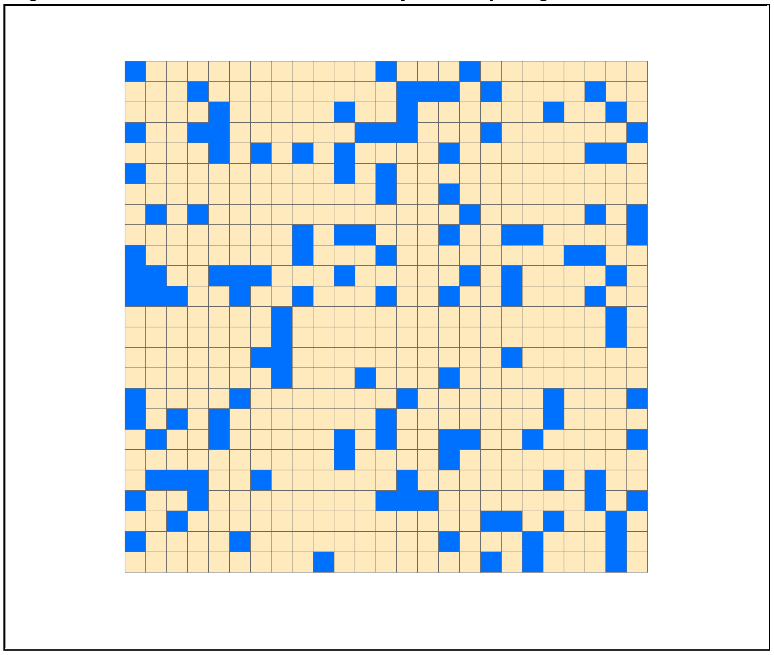
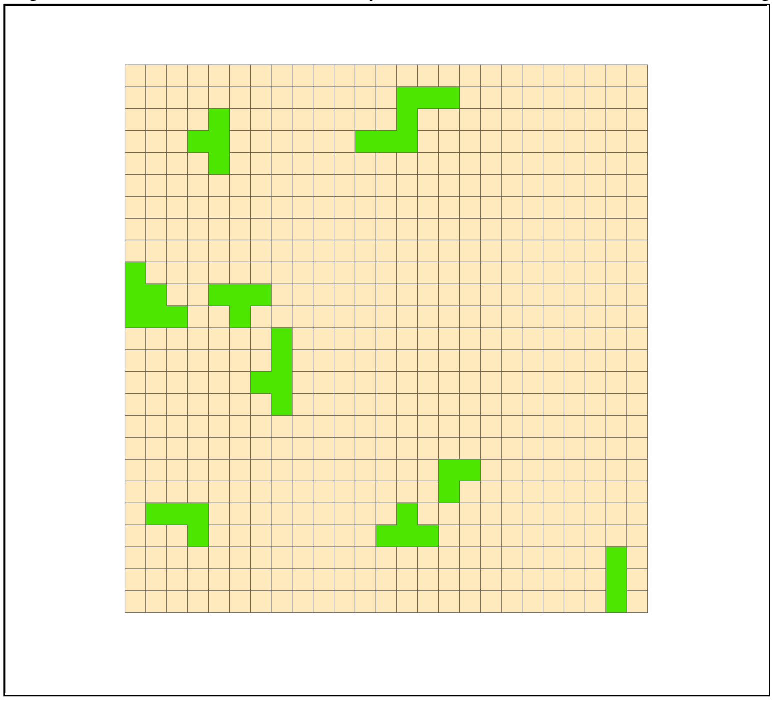


Figure 3b. Parcels Enrolled (criterion of at least three contiguous parcels)



Applications to Conservation

The ability of an incentive mechanism such as the agglomeration bonus to induce spatially coordinated land conservation does not alone recommend its application to conservation in the presence of threshold effects. The appeal of an agglomeration bonus incentive to a budget-constrained regulator will depend on how effectively it can be implemented. Factors affecting the efficiency of conservation incentive mechanisms that have been discussed in the literature include offsite environmental benefits, relationships between alternative environmental benefits, the correlation between land value and environmental benefits, threshold effects, and slippage caused by output price effects (Babcock, et al., 1997; Wu, 2000; Wu, et al., 2000).

Here the focus is on threshold effects and I assume that a single environmental benefit (e.g., habitat for a particular species) is being targeted. Suppose that the marginal benefit of conservation exhibits threshold effects such that the benefit per acre of conservation (BPA) is small until some threshold of contiguous acreage H_T has been conserved (see Figure 1). A cost effective allocation of conservation funds will target low opportunity cost parcels of land that form contiguous areas $H_j > H_T$.

In the context of the previous section, the CAB successfully targets high-benefit/low-cost parcels by identifying all parcels for which $OC_i < S^{CAB}$ (see Figure 3a), and enrolling only those parcels that contribute to the formation of contiguous areas for which $H_j > H_T$ (see Figure 3b). From the standpoint of a regulator, the CAB improves upon a standard agglomeration bonus by eliminating the possibility of coordination failure, which could result in the enrollment of fragmented parcels of land with small benefits. Allowing the final enrollment decision to be made after the spatial distribution of lower opportunity cost parcels is revealed enables the regulator to allocate funds exclusively to high-benefit contiguous parcels.

A difficulty faced by the regulator is how to choose the size of the incentive S^{CAB}. If the regulator knows the distribution of opportunity costs he may predict how many landowners will conditionally accept his offer of S^{CAB}. However, the number of parcels that satisfy the desired pattern of enrollment, and are ultimately enrolled and compensated, is unknown without knowledge of the spatial distribution of low opportunity cost parcels. For a given S^{CAB}, a landscape with spatially correlated opportunity costs will tend to enroll a large number of parcels compared to a landscape with spatially fragmented opportunity costs. Such uncertainty is likely to be problematic for a regulator facing a budget constraint.

The use of auctions in conservation contracting has been proposed in the literature as a way to overcome information asymmetry between landowners and regulators (Latacz and Hamsvoort, 1997; Romstad and Polasky, 2008). An *n*-price auction could solve the regulator's information problem by inducing landowners to reveal information about their true opportunity costs prior to choosing S^{CAB}. In an *n*-price auction, the level of compensation is set equal to the highest accepted bid. Each bidder has an incentive to bid his true reservation price because the level of compensation is independent of the size of the bid, except for the highest accepted bidder (Romstad and Polasky, 2008).

An *n*-price auction applied to this hypothetical conservation problem would produce the same outcome as a CAB program whenever the highest accepted bid is equal to S^{CAB}. The advantage of the auction is that it allows the regulator to set the level of compensation in accordance with his budget constraint. With information about the level and location of landowner opportunity costs revealed by the bidding process, the regulator would be able determine the levels of enrollment and total compensation resulting from accepting progressively higher bids. A level of compensation could then be selected that would satisfy the budget constraint.

Concluding Remarks

The importance of considering threshold effects in the geographic allocation of funds to land conservation has been well demonstrated in the literature. The agglomeration bonus is a targeting mechanism that attempts to spatially coordinate the allocation of conservation funds using a voluntary incentive mechanism. The primary weakness of the agglomeration bonus as it has been represented in the literature is that it requires landowners to do the coordinating amongst each other. Landowners may be able to coordinate enrollment decisions well, or poorly, depending on any number of conditions (e.g., the number of landowners involved). However, the possibility of coordination failure is always present and limits the mechanism’s applicability to policy problems.

The primary contribution of this paper is to demonstrate that spatially coordinated land conservation can be achieved *without* landowners coordinating their enrollment decisions. Because a landowner’s enrollment decision under a CAB program is determined entirely by his private costs and benefits, the possibility of coordination failure caused by uncertainty about others’ willingness to enroll is eliminated. The elimination of coordination failure is attractive to both landowners and regulators. A group of landowners will want to participate in conservation whenever doing so results in each being better off. A regulator wants to enroll contiguous parcels of land while avoiding the enrollment of fragmented parcels.

In the limited context of targeting an environmental benefit exhibiting threshold effects, the cost-effectiveness of the CAB mechanism is attractive. A CAB identifies the spatial distribution of the parcels of land with lower opportunity cost and only enrolls those that satisfy the desired spatial pattern of conservation. That said, a host of other factors typically affect the cost-effectiveness of conservation strategies and a regulator must take those into account when considering a CAB. In some cases, it may be possible to incorporate a CAB into other incentive mechanisms such as competitive-bid auctions.

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