AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

The Agglomeration Vickrey Auction for the promotion of spatially contiguous habitat management: Theoretical foundations and numerical illustrations

Simanti Banerjee, James S Shortle
Department of Agricultural Economics & Rural Sociology

Anthony M Kwasnica
Department of Insurance & Real Estate

Pennsylvania State University
University Park
Pennsylvania

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009

Copyright 2009 by [Banerjee, Shortle, Kwasnica]. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Abstract

There is much interest among economists and policy makers in the use of reverse auctions to purchase habitat conservation on private lands as a mechanism for minimizing public expenditures to achieve desired conservation outcomes. Examples are the Conservation Reserve Program (US) and Environmental Stewardship Scheme (UK). An important limitation of these auctions as implemented to date is that there is no explicit consideration of the spatial pattern of participation in the evaluation of bids. In this study we present the structure of a simple auction – the Agglomeration Vickrey Auction that implements a Vickrey-Clarke-Groves mechanism. The auction is designed to attain conservation goals through specific spatial patterns of land management while minimizing the total budgetary cost. We present the theoretical structure of the AVA and provide simple numerical examples to illustrate the effectiveness of the mechanism. We conclude with a section documenting the experiments that are to be conducted as a part of the future research on this study.

Section 1: Introduction:

Habitat destruction is a major cause of species loss and the major threat to biodiversity (Knop et al., 2006, Millennium Ecosystem Assessment 2005). In consequence, protection and restoration of habitat is a high priority for policy makers. When endangered species are located on publicly owned lands, the protection measures are under the direct purview of the government. But it is often the case that essential habitats are located on private lands. The US General Accounting Office reported in 1995 that 90% of all species listed as endangered in the United States are located on private lands. One of the most widely used instruments to influence land use decisions to manage habitat located on such lands are reverse auctions. Conservation or land auctions as these reverse auctions are often called have been implemented through the operation of incentive schemes like the Conservation Reserve Program (CRP) in the US and Environmental Stewardship Scheme in the UK, to name a few. Since 1985 when the CRP was introduced, nearly 36.8 million acres of farmland has been enrolled, 1.8 million acres of wetlands have been restored and erosion of about 450 million tons of soil has been prevented annually. Kirwan et al. (2005) present that the CRP has disbursed about $26 billion in payments to landowners.

Yet a key limitation of these auctions is that they don't consider the issue of spatially contiguous land management. The ecological result of conservation actions that protect any particular patch of habitat in many cases however depends on which other areas are being protected, because of meta-population dynamics and community complementarity (Margules & Pressey 2000). Also the theory of bio-geography attaches considerable importance to the issue of spatial configuration of habitats (Wilson and Willis, 1975). For example large carnivores which have large home ranges are sensitive to fragmented habitats which include forests and the interface of forests and fields. These animals would thrive better in large and connected land areas. Fragmented reserves have considerable impacts on bird populations as most of them are either edge or interior species. Distances between forest fragments and smaller parcels of forest have also been shown to have a significant negative effect on number of species (Newark, 1991). Bockstael (1996) presents that it not just the total forested land in a region that matters for species abundance and diversity, but its size, shape and the conflicting land uses found along its edges. These factors indicate the importance of explicitly targeting spatially coordinated land management as a habitat management and biodiversity conservation policy.

Spatially explicit land auctions have been studied by Rolfe et al. (2005) and Reeson et al. (2008). The present research adds to this growing body of literature. Here, we first present an analysis of the performance of existing first-price sealed-bid scoring auctions in achieving spatially contiguous habitat management. We demonstrate that existing auctions will lead to desired outcomes when bids submitted are negatively correlated with total environmental benefits from parcel management and when land tracts generating high environmental benefits are situated adjacent to each other. In this situation existing auctions will choose the combination of parcels which provide high benefits at lower costs and will lead to desired spatial patterns. However when parcels generating high environmental benefits are not situated adjacent to each other and when greater environmental benefits can only come through management of high costs parcels, desired spatial configurations may not be attained. We present different numerical examples to support this claim. In order to solve the above problem, we present the structure of a new mechanism, the Agglomeration Vickrey Auction (AVA) that explicitly considers the ecological benefits from management of adjacent land tracts. The AVA implements a Vickrey-Clark-Groves (VCG) mechanism for spatially contiguous selection of bids. We then provide a simple numerical example to demonstrate the effectiveness of this new mechanism. This study is one of the very first to consider the application of a Vickrey auction to an environmental market setting and provides the theoretical foundation for an experimental study to establish the internal theoretical validity of the AVA. This is the subject of future research.

The paper is arranged as follows. In Section 2, we provide a survey of the literature on auctions for habitat conservation and highlight the issues that have been presented in the context of spatially explicit conservation auctions. In section 3, we present the general theoretical setup for the two mechanisms. In section 4 we present various scenarios and analyses of the performance of scoring auctions in these scenarios. In section 5, we provide the structure of the AVA. Section 6 focuses on the illustration of the performance of the AVA. Section 7 concludes with a description of the experimental research that is a part of future research.

Section 2: Auctions for environmental conservation and management – a review of the literature

In the presence of asymmetric information, reverse auctions have come to occupy a central position in economic literature on the allocation of land management contracts for habitat conservation (Latacz-Lohmann and Van der Hamsvoort 1997, Schilizzi and Latacz-Lohmann 2007, Glebe 2008). The seminal work by Latacz-Lohmann and Van der Hamsvoort (1997) was the first to develop the theoretical foundations of bidding for risk neutral and risk averse agents in a hypothetical soil conservation auction. This study analysed simulated data from auctions involving maximization of landowner enrolment, and environmental objectives to reveal the cost effectiveness of auctions vis-à-vis fixed payment schemes. The same result has been found in other studies that use both theory and experimental data (Schilizzi and Latacz-Lohmann, 2007), and data from field trials (Stoneham et al. 2003, Windle and Rolfe 2008).

A key feature of most studies on conservation auctions is their reliance on experimental economics methods to analyse the performance of both the auction institutions and the behaviour of participants. This is largely to assess how these instruments could potentially perform in an actual setting with real stakeholders. Key issues highlighted in these experimental studies include the design and performance of auctions in the presence of complementarities between different conservation projects (Said and Thoyer 2007), variation in auction performance on the basis of difference in the pricing rule employed in the auctions – uniform price or discriminatory price auctions (Cason and Gangadharan 2004, 2005), the extent to which information about policy objectives is to be revealed to the bidders (Cason et al. 2003, 2004) and the effectiveness of multiple auction rounds in improving auction efficiency (Hailu & Schilizzi 2004 and Schilizzi & Latacz-Lohmann 2007).

Auctions for spatially coordinated land management:

Of all the above studies, none of them have explicitly considered the issue of spatially contiguous habitat management. Research on this topic is limited to Rolfe et al. (2005) and Reeson et al. (2008). Both these studies, present experimental analyses of performance and bidding behavior in simple first price scoring auctions targeting creation of landscape corridors and linkages between core areas of habitat. The chief objective of these studies is to identify the different factors that encourage coordination and improve auction performance. In Rolfe et al. (2005) coordination is promoted by informing players about the corridor formation objective and permitting them to communicate. In Reeson et al. (2008) no communication is allowed but bidders are informed about the regulator's spatial objective. Coordination is also facilitated by allowing players to interact in multiple rounds providing them the chance of revising the value or the location of the bids in the event of a mistake.[1]

[1] Such multi-round auctions have been considered in the context of reductions in non-point source pollution by Cason et al. (2003).

Analyses of bids from both these studies reveal that an auction is successful in revealing private cost information and incentivizing the creation of habitat corridors. However rent seeking is an issue. In Rolfe et al. (2005) rent seeking is mitigated in experimental sessions where bidders are not allowed to communicate. In Reeson et al. (2008) presence of unknown number of rounds and the inability to revise bids between rounds puts a check on rent seeking. However while the experimental research agenda provides valuable insight into the implementation of the auctions some theoretical issues still remain. First, none of these studies explicitly consider the impact of the relationship between the cost of management and environmental benefit of the parcel on the performance of the auction. Secondly, since these studies implement first-price sealed-bid auctions, truth telling is not a dominant strategy.

Section 3: The general theoretical model

In this section we provide the outline of the theoretical model and the assumptions that we make while analysing the performance of the conservation auctions.

There are two kinds of agents in the economy – the social planner and the landowners. The set of landowners is denoted by $F = 1, 2, ...f$ and indexed by i. Each landowner has private information represented by type θ_i which is an element of the set Θ_i. Let $\theta = (\theta_1, \theta_2, ...\theta_f)$ and $\Theta = \times_i \Theta_i$. The opportunity cost of land management for each property owner is determined by θ.

Let $x \in X$ be a vector of length f. X is the set of all possible combinations of f parcels which might be managed in the winning allocation. The i^{th} element of vector x takes a value of 1 or 0, depending upon whether the i^{th} owner is accepted into the management program or not. The set X consists of a total of $(2^f - 1)$ elements. The social planner has a net benefit function represented by $B : X \rightarrow R$. This is a function of total environmental value generated from management $V(x)$ – the sum of benefits from individual parcels in the allocation determined by x and sum of individual transfers $t(\theta_i)$ made to landowners.

$$B(x) = V(x) - \sum_{i \in x} t(\theta_i) \tag{1}$$

Equation (1) however does not consider the environmental benefits from spatial contiguity. In order to quantify these spatial benefits we define a $f \times f$ matrix Ñ – the Contiguity Welfare Matrix. Each off-diagonal element of this matrix represents half the environmental benefit from shared borders across parcels. All diagonal elements n_{ii} = 0 and all off-diagonal elements $n_{ij} = n_{ji}$ $\forall$ *i, j*. Diagonal elements of Ñ are zero as a parcel cannot be contiguous to itself so that there are no contiguity benefits from such. The situations where off-diagonal elements n_{ij} = 0 are when the i^{th} and j^{th} properties are not contiguous to each other.

The total environmental benefit from land management is a function both of the benefits from the parcels accepted into the program, represented by *V (x)* and the benefits from spatially contiguous habitat management that is represented in this study by the number of shared borders between management parcels and mathematically by the off diagonal elements of matrix Ñ. This is presented in a general form in (2) below.

$$\hat{V}(x) = V(x) + x'\tilde{N}x \qquad (2)$$

The expression $x'\tilde{N}x$ represents the environmental benefits from a particular spatial combination of parcels, *x*. In the case of the conventional scoring auctions, $\tilde{N} \equiv \text{O}$, the null matrix. The total environmental benefit under the general theoretical set-up is given by

$$B(x) = \hat{V}(x) - \sum_{i \in x} t(\theta_i) \qquad (3)$$

On the side of the landowners, we assume that they have a utility function that is of the quasi-linear form and represented by $u_i : \theta_i \rightarrow R$. Let $\Pi_0(\theta_i)$ represent the returns from commercial activities on the land prior to program participation – $\Pi_0(\theta_i)$ is the reservation profit and *b* represents the submitted bid. Let $\Pi_c(\theta_i)$ represent the profit from commercial land use activities on private properties after accounting for the costs of habitat management on these properties. In order for the model to be tractable, $\Pi_0(\theta_i) > \Pi_c(\theta_i)$. This implies that private participation in habitat conservation can only be incentivized through payments for the opportunity cost of change in land use given by

$$c(\theta_i) = \Pi_0(\theta_i) - \Pi_c(\theta_i) \quad \forall i \in F \qquad (4)$$

The private benefits from land management for a landowner in the winning allocation is then represented by

$$u_i(\theta_i) = t(\theta_i) - c(\theta_i) \quad \forall i \in F \tag{5}$$

The net social welfare from the mechanism $W : X, \theta \rightarrow R$ is

$$W(x) = B(x) + \sum_{i \in x} u(\theta_i)$$

$$\Rightarrow W(x) = \hat{V}(x) - \sum_{i \in x} t(\theta_i) + \sum_{i \in x} u(\theta_i) \text{ which reduces to}$$

$$W(x) = \hat{V}(x) - \sum_{i \in x} \left[\Pi_0(\theta_i) - \Pi_c(\theta_i) \right] \tag{6}$$

We now represent the theoretical framework for bidding in a first price sealed bid scoring auction. For this we follow the optimization framework presented in Latacz-Lohmann and Van der Hamsvoort (1997). The presence of asymmetric information indicates that submitted bids are typically greater than the opportunity costs of land management by some amount dictated by the nature of expectations that landowners have about the bid caps as well as their opportunity costs of shifting to conservation land management. As in Latacz-Lohmann and Van der Hamsvoort (1997), we will assume that bidders' expectations are uniformly distributed in the range $\left[\underline{\beta}, \overline{\beta}\right]$ where $\overline{\beta}$ represents the bid cap. In order to set up the theoretical background, we make a few other assumptions.

Assumption 1: We assume that all farmers are risk neutral.

Risk neutrality ensures that agents don't submit bids which are lower than their opportunity costs of management to ensure a steady income stream during the time period of the contract. Given that risk neutral landowners maximize expected income from land management and have expectations about the bid caps that are uniformly distributed; the bids submitted take the form b_i^* represented below.

$$b^*(\theta_i) = \max\left[\frac{\Pi_0(\theta_i) - \Pi_1(\theta_i) + \overline{\beta}}{2}, \underline{\beta} \right] \tag{7}$$

On the basis of the above bid function, we can evaluate the bidding behaviour and performance of a scoring auction for management of habitat on private properties. Since the scoring auctions are first price auctions, transfers obtained are equal to bid submitted. Thus (5) can also be written as

$$u_i(\theta_i) = b^*(\theta_i) - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] \;\; \forall i \in F \tag{8}$$

Assumption 2: All landowners submit a single bid for management of land rather than multiple bids for various parcels on their properties.

We make this simplifying assumption for two reasons. The first is that permitting multiple bid submissions may introduce combinatorial elements and complementarity into the auction. Conservation auctions with complementarities have been studied by Said and Thoyer (2007). However we don't consider this setting here in order to reduce the computational complexity in bid selection. This complexity arises owing to the use of the Vickrey-Clark-Groves (VCG) payment rule for allocation of multiple land management contracts under the AVA. The second and major reason for allowing single bid submission is to reduce the cognitive complexity of the AVA. Unlike in the case of the second price auction for the sale of a single contract, where the winning bidder would be paid the lowest rejected bid, truth telling is more easily motivated than in the present case (for sale of multiple contracts). Revelation of private information about costs of land management may be quite difficult for the bidders given the nature of the VCG payment scheme under the AVA. Complexity in turn may limit the applicability of the AVA in the field with actual landowners.

Assumption 3: There are three types of landowners on the landscape – those generating high, medium and low environmental benefits on their properties.

The above classification however does not consider benefits from spatial contiguity – the ecological externality that can only be captured if neighboring properties are managed together. For the present study, we consider a landscape with 16 properties of which 6 are high benefit properties, 4 are medium benefit and the remaining 6 are low benefit generating properties. The value and position of the properties on the grid can be changed to give rise to different scenarios under which the auctions may operate.

Assumption 4: The landscape has three types of properties with high, low and medium opportunity cost of management.

This assumption captures the fact that while the government may not have complete information about the costs of land management, some information is available on the basis of which the regulator can classify lands into different types.

While setting up the bidding model Latacz-Lohmann and Van der Hamsvoort (1997) assume that expectations about bid caps are distributed uniformly in the range between plus 40% and minus 40% of the average opportunity costs of participation. In this study we relax this assumption.

Assumption 5: Bidders' expectations about the bid caps vary within a range that is inversely dependent on the value of opportunity costs of management.

Thus lower the opportunity cost of management, wider is the range within which the expectations about the bid caps vary. This assumption is based on the fact that low type landowners will conjecture that they have a higher chance of acceptance (since their costs are low) and hence will expect the range within which the bids vary to be wider compared to landowners who are of the high cost type. For this study, let for all properties that have a low cost of management, the expectations are in the range between plus 60% and minus 60% of the opportunity costs and for medium costs parcels it is in the range between plus 50% and minus 50% of the program costs. For the high cost properties we retain the assumption of the expectations varying between plus 40% and minus 40% of the programme costs.

Given the above setup, we now consider the different scenarios and the performance of existing scoring auctions in selecting bids for spatially contiguous land management.

Section 4: Performance of conventional auctions in achieving spatial contiguity

A key feature of the present study that has not be emphasized in the past studies by Rolfe et al. (2005) and Resson et al. (2008) is the nature of the relationships between the environmental benefits from land management and the opportunity costs of managing the land tracts. In the present study, we look at this issue in considerable detail. We consider specific cases where the opportunity costs of land management are negatively associated with the environmental benefit from those lands and landscapes where the association is positive. The first scenario arises in situations where biodiversity and habitat protection involves retirement of large tracts of land which are not intensively cropped from production. This is common under the CRP where farmers receive payments for idling cropland. An example of low benefit generating high cost lands are those which are highly agriculturally arable and nearer to the transportation network. The second scenario of high costs high benefit properties arises in situations where lands with the potential to generate high environmental values are locked up in commercial land uses like agriculture and will require considerable expenses to return to their initial conditions as well as lead to a high loss in income for the property owner.

Given this scenario, we employ equations (7) and equation (2) to calculate the bid values and total environmental benefits generated from land management through the implementation of scoring auctions in various landscapes.

Scenario I: The opportunity costs of program participation and environmental benefits generated from land management on the properties are negatively correlated.

Under this scenario, we consider two types of landscapes – one where properties generating similar magnitudes of environmental benefits are situated adjacent to each other and the second case where they are geographically dispersed across the landscape so that same type of parcels may not be contiguous.

In this study, all properties are arranged into a 4x4 grid with 16 cells where each cell represents one property on the landscape. Table 1 represent the environmental benefit from land management on that property and the opportunity cost of program participation.[2] All high benefit parcels have environmental benefits greater than 100. For medium benefit farms, the total benefit ranges between 50 and 100 and finally for the low benefit farms the same is under 50. Given assumption 4 and 5, all properties with costs between \$50 and \$80 are the low costs properties, those with costs in the range between \$80 and \$100 are the medium costs ones and the rest whose costs of land management exceed \$100 are the high costs farms. For the low type properties, expectations for the bids range between \$26 and \$104, for the medium cost farms it is between \$43.12 and \$129.37 and finally for high costs properties it ranges between \$67 and \$156.33.

---

[2] While all numerical examples are ad-hoc they are successful in demonstrating the differences in performance across landscapes and mechanisms.

Property ID	Environmental Benefit	Opportunity costs of program participation	Bid submitted	Score
HL1	170	50	77.00	**2.208(Selected)**
HL2	150	60	82.00	**1.829(Selected)**
HL3	140	65	84.50	**1.657(Selected)**
HL4	135	68	86.00	**1.570(Selected)**
HL5	130	70	87.00	1.494
HL6	110	77	90.50	1.215
MM7	95	81	105.19	0.903
MM8	80	85	107.19	0.746
MM9	75	89	109.19	0.687
MM10	65	90	109.69	0.593
LH11	50	100	128.17	0.390
LH12	45	100	128.17	0.351
LH13	40	110	133.17	0.300
LH14	35	115	135.67	0.258
LH15	30	120	138.17	0.217
LH16	25	125	140.67	0.178

Table 1: Summary of costs, benefits, bid and score values for Scenario I

M7	**L11**	**L12**	**L13**
M8	**H1**	**H2**	**H3**
M9	**H4**	**H5**	**H6**
M10	**L14**	**L15**	**L16**

Figure 1a: Spatially linked core habitat

L14	**M9**	**H4**	**L13**
M8	**H1**	**M7**	**H2**
H5	**L11**	**H6**	**L15**
M10	**H3**	**L12**	**L16**

Figure 1b: Fragmented habitat

For this example, the total budget is $350. On the basis of these figures and equation (7) the value of the bids that will be submitted are calculated. This is represented in Table 1 along with the corresponding environmental benefit-cost score on the basis of which decisions are made in these auctions. The benefit-cost score in this study is calculated as the ratio of environmental benefit and the bids submitted. It is similar to the Environmental Benefit Index that is used in the CRP auctions and the Biodiversity Benefit Index used in Stoneham et al. (2003). The property ID in the first column represents the benefit-cost type of a parcel. Thus HL3 implies the third property on the landscape that generates high environmental benefits and has low opportunity costs of land management.

In the present example, the auction leads to the selection of bids from landowners 1, 2, 3, and 4. The total disbursal under the program is $329.50 and total environmental benefit generated is 625 (as per Equation 2). Now if parcels of the same type are situated adjacent to each other, than the scoring auction leads to the creation of spatially linked habitat. This is represented by the green patches in Figure 1a. However if the configuration of parcels is like in Figure 1b, then the scoring auction leads to fragmented land management. This result leads to the following proposition.

Proposition: On landscapes where costs of land management and environmental benefits are negatively correlated and parcels generating similar magnitudes of environmental benefits share common borders, conventional scoring auctions can lead to spatially contiguous habitat management. However absence of common borders between similar types of parcels results in fragmented land management.

Scenario II: Costs of land management for habitat protection are positively correlated with the environmental benefits from land preservation and maintenance. We consider two scenarios here, one where similar parcels types are located adjacent to each other and another where they are not.

Scenario IIa: All properties are arranged on a 16 cell grid. Table 2 below considers the case where all parcels with costs of management $100 and above are high cost parcels, those with costs between $50 and $100 are of type medium and all the remaining parcels with costs less than $50 are low type parcels. Given the cost figures in the above table, the interval within which expectations for bid caps range is between $11 and $44 for low type parcels, between $31.87 and $95.62 for medium type parcels and between $76 and $177.33 for high cost properties. On the basis of these figures and equation (7), the corresponding bid values and the scores for each property is listed in table 2.

Property ID	Environmental Benefit	Opportunity costs of program participation	Bid submitted	Score
HH1	170	160	168.67	1.008
HH2	150	140	158.67	0.945
HH3	140	125	151.17	0.926
HH4	135	120	148.67	0.874
HH5	130	115	146.17	0.924
HH6	110	100	138.67	0.793
MM7	95	90	92.81	**1.024(Selected)**
MM8	80	60	77.81	**1.028(Selected)**
MM9	75	55	75.31	0.996
MM10	65	50	72.81	0.893
LL11	50	40	42.00	**1.429(Selected)**
LL12	45	35	39.50	**1.392(Selected)**
LL13	40	30	37.00	**1.351(Selected)**
LL14	35	25	34.50	**1.304(Selected)**
LL15	30	20	32.00	0.938
LL16	25	15	29.50	0.847

Table 2: Summary of costs, benefits, bid and score values for Scenario IIa

Scenario IIb: Table 3 below provides an example of a landscape where same type of environmental benefit generating properties are not be adjacent to each other except in the case of 3 low type parcels in the lower right hand corner of the grid. In this example, all properties with costs of management under \$50 are of the low cost type, all medium cost properties have costs ranging between \$50 and \$70 and finally all high costs properties have costs which are above \$70. Given the cost figures in the above table, the interval within which expectations for bid caps range is between \$13.06 and \$52.26 for low type parcels, between \$29.25 and \$87.75 for medium type parcels and between \$52 and \$121.33 for high cost properties.

Since existing conservation auctions lead to selection of bids for parcels that generate the highest benefit per unit of costs incurred parcels with the highest scores are accepted into the program. In the present situation, this leads to selection of parcel 7, 8 and 11 through 14 into the program under Scenario IIa and parcels 1, 3 and 5 under Scenario IIb. Total disbursal under Scenario IIa is

$323.63. In Scenario IIb, the total disbursal is higher at $317. In former case the auction gives rise to a fragmented landscape with a suboptimal spatial configuration where all the high benefit parcels are excluded from the winning allocation and only low and medium benefit lands are managed. In the case of Scenario IIb, bids for high benefit generating parcels are accepted into the program but no spatially contiguous management patterns can be obtained. Under the existing auction set up, total environmental benefits are higher under Scenario IIb (where parcels share no shared borders) than under Scenario IIa (where some shared borders do exist). This indicates the limitations of the auction in capturing the environmental benefits of spatial contiguity. This scenario gives rise to the following proposition.

Proposition: When costs and the environmental benefit of land management are positively associated, conventional scoring auctions may not lead to spatially contiguous habitat management or lead to creation of fragmented and second best spatial patterns.

M7	**L11**	**L12**	**L13**
M8	**H1**	**H2**	**H3**
M9	**H4**	**H5**	**H6**
M10	**L14**	**L15**	**L16**

Figure 2a: Sub-optimal spatial patterns & fragmented land management

L14	**M9**	**H4**	**L13**
M8	**H1**	**M7**	**H2**
H5	**L11**	**H6**	**L15**
M10	**H3**	**L12**	**L16**

Figure 2b: Fragmented land management

Two conclusions can be drawn from the examples in this section. The first is that attainment of specific spatial patterns in land management will require the establishment of a new auction mechanism that explicitly considers the issue of spatial contiguity. The second issue that arises from observing the information rents that are earned by all winning landowners is that given limited program budgets, truthful bidding and reduction in information rents is an important consideration that the new mechanism will have to address. In the next section we present the theoretical structure of the new mechanism, the Agglomeration Vickrey Auction that addresses both these issues.

Property ID	Environmental Benefit	Opportunity costs of program participation	Bid submitted	Score
HH1	200	110	115.67	**1.729(Selected)**
HH2	150	100	110.67	1.355
HH3	140	85	103.17	**1.357(Selected)**
HH4	135	80	100.67	1.291
HH5	130	70	98.17	**1.375(Selected)**
HH6	110	66	95.67	1.150
MM7	88	63	76.88	1.145
MM8	80	55	75.38	1.061
MM9	75	50	71.38	1.051
MM10	65	45	68.88	0.944
LL11	50	40	48.63	1.028
LL12	45	36	46.13	0.975
LL13	40	36	44.13	0.906
LL14	35	30	41.13	0.851
LL15	30	25	38.63	0.777
LL16	25	20	36.13	0.692

Table 3: Summary of costs, benefits, bid and score values for Scenario 2b

Section 5: The Agglomeration Vickrey Auction (AVA)

The main objective of the AVA is to select the efficient allocation of bids from participating landowners that leads to the attainment of desired spatial patterns and maximization of environmental benefits given the budget M. Thus the AVA is both a target and a budget controlled auction.[3]

The optimization problem facing the social planner is given by

$$\max_{x \in X} W(x) = \hat{V}(x) - \sum_{i \in x} \left[\Pi_0(\theta_i) - \Pi_c(\theta_i) \right] \text{ subject to } \sum_{i \in x} t(\theta_i) \leq M$$

[3] The structure and performance of Target controlled and Budget controlled auctions have been separately studied in Schilizzi and Latacz-Lohmann (2007).

Let $x_{AVA} \in X$ be the combination of parcels which solves the planner's constrained efficiency problem given above. Then given the expression for net social welfare generated in the AVA we have

$$W(x_{AVA}) = B(x_{AVA}) + \sum_{i \in x_{AVA}} u(\theta_i)$$

which reduces to

$$W(x_{AVA}) = \hat{V}(x_{AVA}) - \sum_{i \in x_{AVA}} \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] \tag{9}$$

Now let $W(x_{AVA} \setminus i)$ be the net social welfare (the environmental benefit less the management cost) of the next best allocation that would be chosen without the i^{th} player where $i \in x_{AVA}$.

Given these value functions, the Vickrey payments or transfers $t(\theta_i)$ obtained by the i^{th} landowner under the AVA is given by

$$t(\theta_i) = b(\theta_i) + \left[W(x_{AVA}) - W(x_{AVA} \setminus i)\right] \tag{10}$$

The term in the square brackets indicates the social surplus that the i^{th} player generates by being a part of the winning allocation. Then using equation (5), the utility for each landowner in the winning allocation is given by

$$u(\theta_i) = b(\theta_i) + \left[W(x_{AVA}) - W(x_{AVA} \setminus i)\right] - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] \quad \forall i \in x_{AVA} \tag{11}$$

Given the above setup of the AVA[4], we present propositions to establish the AVA as an individually rational and dominant strategy incentive compatible mechanism.

Proposition 3: The AVA is strategy-proof where truthfully bidding ones own values is a weakly dominant strategy

[4] In order to set up the structure of the AVA, we closely follow Parkes and Kalagnanam (2002).

Proof: Let us consider the *i*th landowner who has been selected in the winning configuration. The utility of the landowner is given by (11). Here the value of the second term in the first set of square brackets is not affected by the bids of the *i*th agent. Equation (11) can be expanded as the following.

$$u(\theta_i) = b(\theta_i) + \left[\hat{V}(x_{AVA}) - \sum_{\substack{j \in x_{AVA} \\ j \neq i}} \left[\Pi_0(\theta_j) - \Pi_c(\theta_j)\right] - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] - W(x_{AVA} \setminus i)\right] - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right]$$

$$u(\theta_i) = b(\theta_i) - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] + \left[\hat{V}(x_{AVA}) - \sum_{\substack{j \in x_{AVA} \\ j \neq i}} \left[\Pi_0(\theta_j) - \Pi_c(\theta_j)\right] - W(x_{AVA} \setminus i)\right] - \left[\Pi_0(\theta_i) - \Pi_c(\theta_i)\right] \quad (12)$$

Then using equation (5) expression (12) can be simply written as

$$u(\theta_i) = b(\theta_i) - c(\theta_i) + G - c(\theta_i) \quad (13)$$

where $G = \left[\hat{V}(x_{AVA}) - \sum_{\substack{j \in x_{AVA} \\ j \neq i}} \left[\Pi_0(\theta_j) - \Pi_c(\theta_j)\right] - W(x_{AVA} \setminus i)\right]$ and $G \geq 0$

In equation (13), the *i*th landowner cannot influence the term in the square brackets. Now suppose that the agent bids an amount equal to their opportunity costs of management. In this case, $u(\theta_i) = G - c(\theta_i)$ and this expression is greater than the utility to the agent if they bid a value less than $c(\theta_i)$. Now if the agent bids above their actual costs of management, then the landowner has to weigh the possibilities of earning a higher VCG surplus owing to the submission of a higher bid or being left out of the winning outcome as the AVA chooses another spatial allocation that generates higher net social welfare than the present allocation to which the *i*th landowner belongs. Given these possibilities, it is a weakly dominant strategy for the landowner to bid their value and earn a non-negative surplus and be in the winning allocation x_{AVA} rather being left out of it.

Proposition 4: The AVA is Individually Rational.

Proof: The utility for the landowners in the winning combination is given by (11). From Proposition 3, it follows that landowners bid their true costs so that the utility to agents in expression (13) is given by $u(\theta_i) = G - c(\theta_i)$ which is always non-negative. Thus participation in the AVA is always a dominant strategy $\forall\, i \in F$.

Section 6: Spatially coordinated land management under the AVA

Given the above theoretical setup of the AVA, we now consider a numerical example to establish the effectiveness of the same in achieving specific spatial patterns in land management. In the first step, we present a brief description of the nature of the spatial patterns that we will consider for our example. It is to be noted that the configuration of parcel types on the landscape determines the type of spatial patterns that are to be created through selection of bids. In order to demonstrate the effectiveness of the AVA, we consider Scenario 2a where the nature of the landscape is such that similar types of parcels are situated adjacent to each other. The implementation of the scoring auction on this landscape leads to the selection of 2 medium benefit generating and 4 low benefit generating parcels. This gives rise to a sub-optimal spatial pattern where 3 low and 2 medium environmental benefit generating parcels are linked together. However fragmentation exists as the one remaining low type parcel that is selected does not share a common border with any of the other parcels.

Section 6.1: Types of spatial patterns

Different types of habitat reserves can be considered for the purpose of conservation. One of the most common ways in which such a goal can be achieved is through the creation of a habitat core reserve for species preservation. This involves management in and around large areas of land to create a zone that is relatively undisturbed by external anthropocentric and non-anthropocentric factors. Such reserves lead to easy proliferation and dispersal of different species improving their chances of survival. Examples of endangered species that thrive in core habitat reserves are red cockaded woodpecker, grizzly bear and northern spotted owl (Parkhurst and Shogren 2007). Another common spatial configuration involves the creation of corridors linking habitat cores (primary habitat patches) for improved movement of species across the landscape. Such corridors reduce the chances of isolation of reserves from each other especially for species which have very high mobility. Animals like wolves and elks survive well in such corridor reserves (Parkhurst and Shogren 2007).

For the purpose of illustration of the performance of the AVA, given the nature of configuration of high, medium and low type parcels on the landscape represented in Figure 2a, we consider 5 different possibilities for spatial patterns as represented in Figure 3 below. The objective of the AVA is to attain any of these specific spatial patterns.

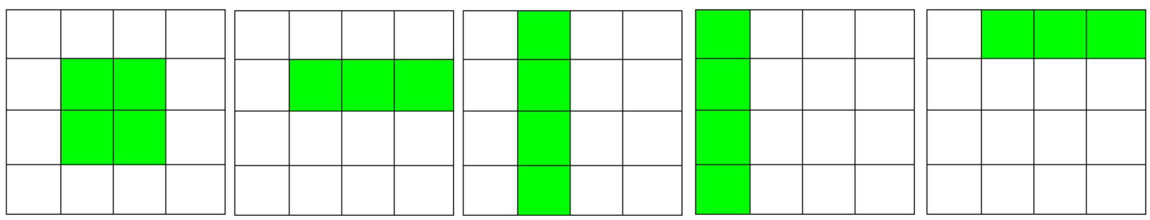

Figure 3a: Core

Figure 3b: East West (EW) Corridor-Type I

Figure 3c: North South (NS) Corridor-Type 1

Figure 3d: North South (NS) Corridor-Type 2

Figure 3e: East West (EW) Corridor-Type 2

Figure 3: Spatial patterns considered for landscape in Scenario 2a

Figure 3a represents the core area of habitat where four high benefit properties are selected into the program with the parcels sharing 4 borders. Figure 3b is an East West (EW) corridor – Type 1 project where three high benefit parcels are managed together, sharing 2 borders. In Figure 3c, we get a North-South (NS) Corridor – Type 1 where two low benefit parcels and two high benefit properties are accepted into the program. Here there is a common border between the two high type properties and one each between the low and high type parcel. In Figure 3d, NS corridor – Type 2 is considered that is created through management of all medium type parcels. Here there are 3 shared borders between all the three parcels. Finally in the East West Corridor – Type 2, three low type parcels are chosen with two shared borders existing between them.

Section 6.2: Performance of the Agglomeration Vickrey Auction

In order to demonstrate the effectiveness of the AVA, in achieving spatial patterns, we carry over the numerical example in Scenario IIa to this section. Since the AVA explicitly considers the environmental benefits from contiguous management, we need to assign values to the off-diagonal elements of matrix Ñ. Let the total environmental benefit from one shared border between two parcels of the high type be given by 60. For every border that a low type parcel shares with a high type parcel, the total benefit generated is 40 and for a shared border between the high and medium benefit generating parcels, the total benefit is 50.

Type of spatial configuration	**Properties in configuration**	**Environmental Benefits -** $\hat{V}(x)$	**Management Cost**	**Net social welfare –** $W(x)$
Core-1	HH1, HH2, HH4, HH5	825	535	290
Core-2	HH2, HH3, HH5, HH6	775	480	295
NS Corridor-Type1-1	HH1, LL11, HH4, LL14	545	345	200
EW Corridor-Type2-1	LL14, LL15, LL16	160	60	100
NS Corridor-Type1-2	HH2, LL12, HH5, LL15	520	310	210
NS Corridor-Type1-3	HH3, LL13, HH6, LL16	475	270	205
EW Corridor-Type2-2	LL11, LL12, LL13	205	105	100
EW Corridor-Type1-1	HH1, HH2, HH3	580	425	155
EW Corridor-Type1-2	HH4, HH5, HH6	495	335	160
NS Corridor-Type2	MM7, MM8, MM9, MM10	450	255	195

Table 4: Outcomes of the AVA for Scenario IIa: Environmental benefits, costs & social welfare

Considering a shared border between two medium type properties, the total environmental benefit is 45. When two neighboring properties of type medium and low are managed, the benefit from the shared border is 32. The lowest benefit from land management is from the management of two low type parcels. This value is at 20. On the basis of these figures, the total environmental benefit from the various configurations listed in Section 6.1 is represented in Table 4 above. The number of shared borders for each configuration can be observed in Figure 3. We retain the same value of the budget at $350. The cost of supporting a particular allocation is obtained as the sum of the submitted bids that represent the actual opportunity costs of land management (as per Proposition 3).

Given, the net social welfare from every configuration that is represented in the last column of Table 4, the highest environmental benefit is generated from the achievement of Core-Type 1 habitat. This is followed by NS Type 1 corridors and NS Type 2 corridor. Now on the basis of Proposition 3 and equation (10), Table 5 represents the VCG transfers that are to be made to landowners in order to support the top three environmental benefit generating spatial configurations – those configurations that generate the highest net social welfare for both the social planner and the landowners. Table 5 indicates that while core habitat configurations generate very high benefits, they cannot be supported by the limited budget. As a result, bids for the combination of properties constituting the NS Corridor Type1-2 are selected under the AVA. The total value of transfers made to support this allocation is $330.

Spatial configuration	Net social welfare	Parcels in configuration	Transfers	Total
Core-2	295	HH2	230	670
		HH3	130	
		HH5	205	
		HH6	105	
Core-1	290	HH1	240	865
		HH2	225	
		HH4	200	
		HH5	200	
NS Corridor Type1-2	210	HH2	145	330
		HH5	120	
		LL12	40	
		LL15	25	

Table 5: Net social benefit & transfers for top 3 allocations

Section 6.3: The Agglomeration Vickrey Auction and Scoring Auctions: A comparative analysis

In this section we present a comparative analysis of the results of the AVA and the scoring auction. We demonstrate that for the landscape represented in Scenario IIa, implementation of the AVA leads to higher environmental benefits than when the scoring auction is implemented on the landscape. Figure 4 below represents the configurations of managed parcels under both the auctions.

Under the assumption that the environmental benefit function $\hat{V}(x)$ is additive in nature with the total benefit from a configuration equal to the sum of individual benefits, the total environmental benefit from the allocation in Figure 4a is 385[5]. The total disbursal is \$323.63 and the sum of opportunity costs of land management is 280. Thus the net social welfare is given by 105. For the allocation in Figure 4b, the total disbursal as given in Table 5 is 330 and the total environmental benefit generated is 520. The total opportunity cost of land management for this allocation is \$310 implying that the net social welfare is 210. Thus through the implementation of the AVA, the resultant allocation generates a higher environmental benefit. This higher benefit is owing to spatially contiguous habitat management. Also, the total environmental benefit generated from the allocation in Figure 4a when the spatial benefits of the shared borders (those between medium type parcels and between low type parcels) are considered is 502. Thus the total environmental benefit from NS Corridor Type1-2 is higher than the ad-hoc sub-optimal – semi fragmented configuration obtained under the scoring auction. Thus given a limited budget, for a landscape where both the AVA and scoring auctions maybe implemented, the AVA leads to higher environmental benefits as well as net social welfare than the scoring auctions.

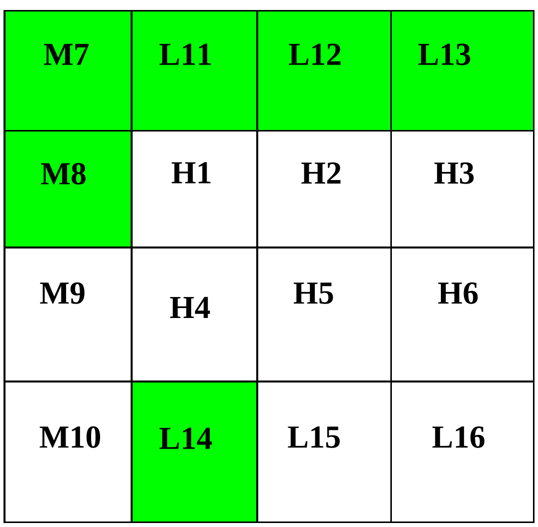

Figure 4a: Configuration under Scoring Auction

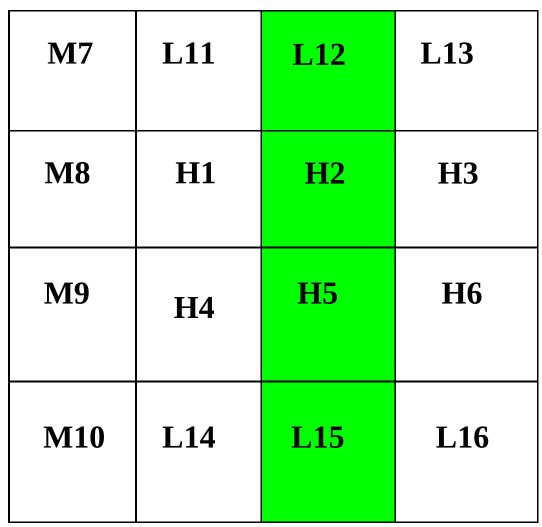

Figure 4b: Configuration under AVA

5 In this case, Ñ is the null matrix with all elements equal to zero as the auction does not explicitly consider benefits from spatial contiguity.

Section 7: Final remarks

The present study demonstrates that when ecological criteria like spatially contiguity between managed habitats are necessary to maximize the conservation potential of limited program budgets, existing scoring auctions like the CRP may not be efficient in many landscapes. Such landscapes are those where lands with similar features conducive to conservation are not situated adjacent to each other or where there exists a positive association between environmental benefits generated and the total private opportunity cost of generating these benefits. In these situations, a new mechanism, the AVA is to be employed to achieve the environmental value maximizing goals through creation of specific spatial patterns.

The theoretical structure of the AVA is simple in order to make it easily understandable when employed with actual stakeholders. However complexity – cognitive and computational is a concern. Collusive bidding is another problem that may be encountered in the implementation of these auctions (Reeson et al. 2008) in general. Collusive tendencies arise when landowners situated at strategic positions on the landscape submit bids in excess of their costs of land management. Collusion will reduce the cost efficiency of auction. This might be problem in the present setting given that the second price auction has been proven to be more susceptible to collusion than the first-price auction both in a single round and repeated settings (Robinson 1985, Milgrom 1987).

On the basis of the above scenario, the theoretical structure of AVA has to be supported by experimental research to test various hypotheses about the proposed mechanism. The AVA will be tested in laboratory settings to determine whether the cognitive complexity of the auction for bidders reduces the performance and efficiency of the mechanism, and whether collusion occurs and results in suboptimal allocations reduction of cost efficiency. We also intend to conduct experiments to analyze bidder behavior under specific situations. These involve sessions where the bidders are informed about the spatial objective and others where they are not, and second sessions where the subjects participate in multi-round auctions that allow revision of bids submitted vis-à-vis sessions where this is not allowed. The first treatment is necessary to assess the trade-offs between revealing information to abet coordinated land management as opposed to suppressing the same to reduce collusive bidding. Results of these sessions will have bearing on the ultimate cost-efficiency of the AVA. The second treatment is necessary in order to assess whether revision of bids and the option to correct past mistakes improves auction performance. This is the subject of future research that will follow this theoretical paper.

Reference:

1. Bockstael, N.E. (1996). Modeling Economics and Ecology: The Importance of a Spatial Perspective *American Journal of Agricultural Economics*, Vol. 78, No. 5, Proceedings Issue, pp. 116

2. Cason, T, L. Gangadharan and C. Duke. (2003). A laboratory study of auctions for reducing non-point source pollution. *Journal of Environmental Economics and Management*. Vol: 46(3), pp. 446.

3. Cason, T and L. Gangadharan. (2004). Auction design for voluntary conservation programmes. *American Journal of Agricultural Economics.* Vol: 86, pp-1211.

4. Cason, T and L. Gangadharan. (2005). A laboratory comparison of uniform and discriminative price auctions for reducing non-point source pollution. Land Economics. Vol: 81(1), pp. 51.

5. Conservation Reserve Program. http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp

6. Environmental Stewardship Scheme. http://www.defra.gov.uk/erdp/schemes/hls/handbook/default.htm

7. Glebe, T.W. (2008). Scoring two-dimensional bids: how cost effective are agri-environmental auctions? *European Review of Agricultural Economics.* Vol 35(2), pp.143

8. Hailu, A and S. Schilizzi. (2004). Are auctions more efficient that fixed price schemes when bidders learn? Australian Journal of Management. Vol: 29(2).

9. Kirwan, B, R. N. Lubowski and M. J Roberts. (2005). How cost effective are land retirement auctions? Estimating the difference between payment and willingness to accept in the Conservation Reserve Programme. *American Journal of Agricultural Economics.* Vol. 87, pp. 1239

10. Knop, E, D. Kleijn, F. Herzog and B. Schmid. (2006). *Journal of Applied Ecology*. Vol. 43, pp. 120

11. Latacz-Lohmann, U and C. V. Hamsvoort. (1997) Auctioning Conservation Contracts: A theoretical Analysis and an application. *American Journal of Agricultural Economics*, Vol. 79(2). pp. 407

12. Margules, C.R and Rl L. Pressey. (2000). Systematic Conservation Planning. *Nature*, Vol: 405.

13. Milgrom, P.R and R.J. Weber. (1982) A Theory of Auctions and Competitive Bidding**.** *Econometrica*. Vol. 50(5), pp.1089

14. Millennium Ecosystem Assessment. http://www.millenniumassessment.org/en/About.aspx

15. Newark, W.D., (1991). Tropical forest fragmentation and the local extinction of understory birds in the Eastern Usambara Mountains, Tanzania. *Conservation Biology*. Vol.5, pp. 67. (as cited in Warziniack 2007)

16. Parkes, D.C and J. Kalagnanam. (2002). Iterative Multi-attribute Vickrey auctions. http://www.eecs.harvard.edu/~parkes/pubs/map.pdf

17. Parkhurst, G, J.F. Shogren, C. Bastian, P. Kivi, J. Donner and R. B. W. Smith (2002). Agglomeration Bonus: an incentive mechanism to reunite fragmented habitat for biodiversity conservation. *Ecological Economics*. Vol: 41, pp. 305

18. Pullin, A.S. (2002). Conservation Biology. Cambridge University Press. Cambridge, UK

19. Reeson, A, S Whitten, K Nolles, J Windle, J Rolfe. (2008). Designing Auctions for Conservation Corridors: An Experimental Approach. Paper presented to the 10th Annual BIOECON Conference on "The Effectiveness and Efficiency of Biodiversity Conservation Instruments"

20. Rolfe, J, J McCosker and J Windle. (2005). Establishing East-West Landscape Linkage In The Southern Desert Uplands Research Reports. FINAL REPORT FOR MBI PROJECT 18, RESEARCH REPORT No. 6.

21. Said, S and S. Thoyer. (2007). Agri-environmental auctions with synergies. http://www.lameta.univ-montp1.fr/Fr/Productions/Documents/DR2007-07.pdf

22. Schilizzi, S and Uwe Latacz-Lohmann. (2007). *Land Economics*. Vol. 83(4), pp. 497.

23. Stoneham, G, A. Ha, and L. Strappazzon. (2003). Auctions for conservation contracts: an empirical examination of Victoria's Bush Tender Trial, *The Australian Journal of Agricultural and Resource Economics*., Vol. 47(1), pp. 1

24. Wilson, E. O. & Willis, E. O. in *Ecology and Evolution of Communities* (eds Cody, M. L. & Diamond, J. M.) pp. 522 (Belknap, Cambridge, MA, 1975).