Applying a Voluntary Incentive Mechanism to the Problem of Groundwater Conservation: An Experimental Approach

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Abstract

This paper uses experimental methods to examine how individuals react to a set of voluntary incentives related to the conservation of a resource. The goal was to determine whether conservation over a critical area, such as a deep portion of an aquifer, could be encouraged, and whether coordination between individuals could be induced. Participants were faced with a bidding process through which units were selected for conservation, and some participants were offered an agglomeration bonus for conserving units that shared a border. Examining how bids changed across rounds revealed the existence of a learning process; implying that a similar real-world program would need to provide a large amount of information up front in order to achieve the desired effect. Using a monetary selection constraint resulted in more units placed in conservation. The bonus did not necessarily encourage conservation at the critical area, but it did reduce participant's bid amounts.

Introduction

The questions of who owns a resource and who has a right to its use are critical to designing successful natural resource policy. For example, if the resource exists on private land, the owners may resent outside interference in the use of their property (and, in fact, interference may not be legal); however, this interference may be justified if the resource has value to others in the future. This is exactly the conflict facing policy makers and landowners on the High Plains of Texas regarding the right to use groundwater.

For most of the last century the right to groundwater in Texas has been defined by a modified rule of capture (Potter 2004), which states that property owners have the right to use any resource on their property as they sees fit, barring waste, subsidence, or harmful use. While the courts have upheld the property rights of landowners, the Texas Legislature asserts the right to manage groundwater through legislation such as Article 16, section 59 of the Texas Constitution, or the Conservation Amendment (Caroom and Maxwell 2004). To this end, the state has been separated into Groundwater Management Areas that are responsible for developing and enforcing conservation policies for the groundwater resources they represent; however, what kind of restrictions these areas can enforce is still being debated.

Recently, the Texas Supreme Court has limited the ability of water districts to restrict landowners' access to ground water. In *Edwards Aquifer Authority vs. Day*, the court ruled that water districts cannot restrict landowners' use of water on their property without compensation. This means that in the future, water districts may have to balance the need for conservation with the fiscal concerns related to compensating landowners to refrain from pumping water.

One method of controlling the costs associated with compensating landowners would be to focus conservation efforts in those areas where the greatest amount of water could be saved. Weinheimer (2008) evaluates the response of a farm to a water policy that restricts groundwater availability so that 50% of current saturated thickness[1] remains in the ground after 50 years. His results show that the greatest savings in water occur where the saturated thickness of the aquifer is higher. By targeting areas with high saturated thickness for conservation as opposed to blanket rules concerning water use, water districts could minimize the costs associated with compensating landowners. Of course, the targeted landowners will still resent limits placed on their water use and may resent being singled out by their water district. To avoid this, the water districts might consider employing policies that encourage landowners to conserve groundwater in target areas by choice.

Voluntary conservation programs allow landowners to choose the location and amount of land they wish to put into the program in return for compensation. Because landowners have the choice to participate, there is no reason for resentment toward the regulator. Landowners only restrict irrigation if they are compensated at a rate at least equal to the value of the land in production, so they are at least as well off as if they chose to produce on the land. As long as the regulator offers sufficient compensation, landowners should be willing to participate, but there is no guarantee that the land entered in to the program would overlie the deep sections of the aquifer where conservation is desired.

Landowners are assumed to participate in a voluntary conservation program with the goal to maximize their net returns. Assuming that land overlying deeper parts of the aquifer is more productive and delivers a higher payoff for agricultural production; landowners would choose to

[1] The saturated thickness of an aquifer can be defined as the vertical thickness of the underground area that is saturated with water.

place land where the aquifer is shallow into the program in order to take advantage of both the payments from the conservation program and the returns from production on high quality land. The result would be fragmented areas of water conservation and less water saved than is desired from the regulator's point of view.

Smith and Shogren (2001; 2002) addressed a similar problem in the wildlife habitat literature and, suggested an agglomeration bonus as a means to unite fragmented land parcels. Under this mechanism, landowners are offered a lump sum transfer payment for placing land in a conservation program. The agglomeration bonus is designed to reward landowners for retiring contiguous areas of land as opposed to fragmented areas by paying a bonus every time two units of retired land share a border, including borders shared between units of land owned by two different people. Because the bonus can exist across fence lines, landowners are encouraged to cooperate to create large areas for wildlife conservation. To test Smith and Shogren's claims, Parkhurst et al. (2002) use experimental methods to show that such an incentive mechanism can create contiguous wildlife habitats across fence lines.

Parkhurt et al.'s experiment supposes that two land owners share a border, and that the border and surrounding land is desirable for a wildlife habitat, such as a river. Figure 1 shows the actual scenario used in the experiment, taken from Parkhurst et al. (2002). From the landowner's perspective, the land bordering the river is the most valuable (worth $6 in the experiment), the land in the middle is the second most valuable (worth $4 in the experiment), and the land farthest from the river is the least valuable (worth $2 in the experiment). The authors argue that when offered a lump sum payment to place land in a conservation program, landowners will opt to accept the payment on their least valuable land regardless of the payment amount. Without some form of bonus payment to encourage landowners to accept payment for land in the center of the area, the conservation program would result in fragmented habitats away from the critical habitat area.

During the experiment, the authors conduct two treatments. Players in the control group were only offered a lump sum payment of $3 for each conserved unit, and participants in the experimental group were offered both the lump sum and a bonus payment of $10. Participants were asked to choose five units to place in a program and were given a matrix that listed the payoffs both players earned for choosing different sets of five units. In the control treatment, the highest payoff came from both players choosing the five outer units and earning $15 from the program payment instead of $10 for using them. In the experimental treatment, the highest payoff came from both players choosing the five inner units and earning $15 from the program payment, plus $90 in bonus payments for borders shared between units. Based on the results of the two treatments, the authors concluded that an agglomeration bonus would, in fact, encourage landowners to retire land in less fragmented patterns.

The main point of Parkhurst et al. (2002) is that an agglomeration bonus payment can affect the behavior of individuals. To do this, the authors set the bonus high intentionally to ensure that participants would take it into consideration when making decisions. The experiment also places the bonus in a relatively simple context where the participants need only choose the set of units that maximize their payoffs. To add realism and complexity, a continuation of this line of research is necessary. In particular, the effects of a more realistic bonus (in terms of percent relative to the underlying payment) need to be investigated. Additionally, investigation of auction-based implementation mechanisms could provide insight on the probability of program success.

In an auction system, landowners compete to place land units into a conservation program by bidding how much they would be willing to accept to not use each unit. This is the mechanism by which programs such as the Conservation Reserve Program and Wetland Reserve Program work; and, in theory, such a system should create a competitive environment so that land is placed into the program at the lowest possible price (Smith 1995). Of course, an auction based on the absolute value of bids might not ensure that the land most desired for conservation efforts by the program is selected.

Depending on how the desired environmental qualities are distributed across a landowner's property relative to the land's private value, the least desirable land from the program's perspective could end up being targeted by landowners for acceptance. For example, in the case of groundwater, land that overlies areas where an aquifer's saturated thickness is greatest is the target of a program meant to conserve groundwater, and the most valuable land for irrigated agricultural production. Thus, the landowner's bid to not use this land will be higher than for land overlying shallow parts of the aquifer. To ensure the program results in the desired conservation benefits, the auction process would need to consider the environmental characteristics of the land associated with each bid as well as the bid amount itself.

To address this, the USDA developed an environmental benefits index (EBI) to select land for placement in the Conservation Reserve Program (CRP) in 1991 (Feather, Hellerstein, and Hansen 1999), and has since applied this index to the Wetland Reserve Program (WRP) land selection process as well. The EBI relates the environmental quality of a unit of land to a single number that can be used to rank units. Bids are weighted by the EBI so that if two units are bid into the program at the same amount but one has a higher EBI, then the unit with the higher EBI is accepted first (Buller and Hudson 2006). Using an EBI to rank bids allows landowners to bid higher on land that is more valuable to them, and for the program to accept land with the greatest environmental benefit at the same time.

The implementation of a bidding process that uses an EBI to select winning bids should increase the chances that the targeted area will be placed into the conservation program, but does not guarantee it. Buller and Hudson (2006) use such a process in an experiment to test the impacts of different bid selection criteria on the conservation of a riparian buffer. In the experiment, two different selection criteria were used. One treatment selected bids until a targeted number of units were reached, much like the selection process used by CRP. Another treatment selected bids until a targeted payout was reached, which is the way the WRP selects bids.

The authors find that the acreage constraint resulted in higher bids and program expenditures, and that about 55.9% - 60.4% of the buffer zone was conserved, on average, based on participants' choices. If this result is indicative of what can be expected from a bidding process, regardless of the selection criteria, then it would be interesting to study if some form of agglomeration bonus might increase the amount of targeted land that is accepted.

Offering an agglomeration bonus should make lower bids on high value land more attractive, thus making their acceptance by the program more likely. If the bonus is structured so that it targets areas where the environmental benefit of conservation is greatest, landowners may be willing to accept a smaller payment on this land to take advantage of the bonus payment, as in Parkhurst et al.'s experiment. To test whether this is true, this paper develops and implements a lab experiment where participants are paired and asked to make decisions regarding their use of a given good.

The purpose of this study is to extend Parkhurst et al.'s (2002) work by examining the effect of a bonus in an auction system in an experimental setting. The experiment will follow the same basic structure as Parkhurst et al. (2002), but instead of offering a lump sum payment, participants will have the chance to bid their willingness to accept to not use each of their units. Using an auction to select units as opposed to a system of lump sum payments reflect the interest of regulators to keep the costs related to a conservation program down. In addition, two different selection criteria will be used to pick winning bids. Theoretical and empirical evidence suggests that whether a specific number of land units or a specific total payment is targeted as the conservation's program's goal affect's the efficiency of the program in terms of environmental benefit per dollar spent (Babcock et al. 1996; Buller and Hudson 2006). Thus, this experiment will have four treatments. Two treatments will evaluate the addition of an agglomeration bonus to an auction mechanism using an acreage constraint to select bids, while the other two treatments do the same for a monetary constraint. The results from each treatment will be evaluated based on their ability to conserve the targeted area, the average bid amount for differing land values, and the total expenditures.

The Conservation Scenario

Figure 2 illustrates the conservation scenario that will be used in this experiment. Similar to Parkhurst et al. (2002), there are two landowners, with adjacent fields, who each own fifteen units of land; however, instead of the two properties meeting at a stream which is critical for a wildlife habitat, the properties overlie an aquifer that is used for irrigation. The area of the aquifer with the greatest saturated thickness, thus where both the financial benefits and conservation benefits are greatest, is situated under each landowner's five center units. As one moves away from the center, the saturated thickness of the aquifer decreases along with the productive and conservation value of the land.

To conserve water in the aquifer, a regulator offers these landowners the opportunity to participate in a voluntary conservation program. The mechanism allows the landowners to submit a bid which indicates the amount of incentive payment required for them take a unit out of irrigated production and place it in the program. According to Buller and Hudson (2006), if the landowners are risk-neutral, the bids offered will be at least equal to the productivity of the land.[2] Once the bids have been submitted, the regulator ranks bids based on an environmental benefits index (EBI) and accepts the best ranked units up to some constraint.

An EBI is used to translate the environmental characteristics of a land unit into a single number for the sake of comparison. In this case, only one variable is deemed important from a conservation standpoint; so, the EBI in this scenario is based solely on the saturated thickness of the aquifer under the land unit. Bids are weighted by their EBI such that $\frac{Bid}{EBI} = Score$. If the bid for two units is equal but one unit has a higher EBI value, the score for the unit with the higher EBI will always be lower. Thus, units are ranked so that units with lower scores are accepted first. The landowners should compete to have their units accepted by attempting to keep the score for each unit low, but at least as much as what they would earn through use of the unit.

The regulator can encourage bids that guarantee the center units are accepted by supplementing the returns gained from the auction with an agglomeration bonus. The bonus is paid to the landowner whenever two retired units share a border; therefore a unit can earn the

[2] The authors assume risk-neutrality in their analysis for the sake of simplicity. Allowing for risk-averse behavior would change this assumption. Risk-averse producers are assumed to lower their bids in order to ensure acceptability by the program, that is, a sure program payment is preferred to uncertain future returns by some amount. Because there is no risk or time dimension in this experiment, an assumption of risk neutrality is warranted.

bonus up to four times. Additionally, the bonus is paid when retired units owned by different landowners are adjacent. The landowners are therefore encouraged to move to the middle where the EBI is greatest and they can each benefit from the other's bids.[3]

Experimental Design

To translate the above scenario into an experiment, four treatments were constructed, with the treatments split up to represent two different selection criteria for bids. The first criterion was an acreage constraint where bids were accepted up to some maximum number of units. The second criterion was a monetary constraint where bids were selected up to some maximum payout for the program. For both of these criteria two treatments were performed; one treatment acted as a baseline with no bonus for shared borders, while the second treatment paid players an agglomeration bonus for the border of adjacent winning bids. All four treatments featured ten players matched into pairs over five rounds. One session was performed for each treatment. A summary of these treatments is shown in table 1.

Each player was given fifteen units of a good. Each unit was associated with a dollar value based on its productivity (use value) and an EBI value (non-use value). Five units were low productivity and low EBI land with a use value of $2 and a non-use value of $1, five units were medium productivity and medium EBI land with a use value of $4 and a non-use value of $3, and five units were high productivity and high EBI land with a use value of $6 and a non-use value of

[3] It could be argued that each landowner has an incentive to try and win all of the units and receive the entire bonus; however, doing so would require very low bids for land with a low or medium EBI. The landowner may be unwilling to bid low enough to make the units acceptable, and still runs the risk of being outbid by the other player's offer on high EBI land.

$5.[4] Both players' high productivity land bordered each other in the center of the area. A map of participants' units with use and non-use values is shown in figure 3 with the unit's number given in bold print in the upper left corner, the use value given in the upper right corner, and the non-use value given in the lower right corner.

During the experiment the total value of a participant's land was 60 dollars, so if a participant used every unit in every round they earned 300 experiment dollars. Players earned the use value for units whose bids were not accepted and earned the amount they bid for units that did win in the auction. In the agglomeration bonus treatments, players were paid one additional experiment dollar for every border shared by accepted units. Thus, every player's goal was to increase their earnings above 300 experiment dollars by winning bids to not use units. At the end of the experiment, players were paid $10 for participating, and earned another dollar for every 5 experiment dollars they earned over 300 during the five rounds of the experiment.

Participants were recruited for the experiment primarily from the graduate student population of the Department of Agriculture and Applied Economics (AAEC) at Texas Tech University and from students taking part in AAEC summer courses. To participate, students were asked to report to a computer lab on a specific date and time. Upon arriving, each student was asked to sign in and received a packet of materials which included a research study information sheet, experiment instructions, and a sheet on which to make bids in each round. Packets were numbered 1-10 and students were referred to by their packet number during the experiment.

Once all of the participants in a treatment had arrived, a proctor read through the instructions, randomly and anonymously paired participants, and led the group through a practice

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[4] The use values used are the same as those used by Parkhurst and Shogren while the non-use values were created for this experiment.

round. At the end of the practice round, participants were repaired and the experiment began following these steps:

1) The players reviewed the information on their bid sheet, which included the use value and non-use value for each of their units.
2) The players then entered the minimum value they would have to be paid to forgo production on each unit of land and submitted their bids to the experiment proctor.
3) Once bids were submitted from all players, the bids were scored and ranked by the proctor using their EBI, and the winning bids were chosen.
4) The proctors then returned the bid sheets to the players, and provided each player with a detailed summary of the round that included their own bids and scores, the other participant's bids and scores, which of their units were accepted, and their total payoff. In the treatments where a bonus was offered, the players were also given a map at the end of each round that showed which units from both participants had been selected and where the bonus was earned.
5) The players had five minutes to review this information and prepare bids for the next round. At the end of the final (5^{th}) round, the players were shown their final earnings from the experiment, and were paid according to their results.

Results

The following section reports the analysis of the results from each treatment. The treatments were analyzed with regard to the participant's bids, expenditures in the each treatment, and the area conserved in each treatment.

Average bids

Table 2 reports the average bid per round for each treatment by non-use value. As expected, bid amounts increased as the non-use value increased, and, on average, bids were greater than the use value for the unit. At the same time, average bid amounts for units with higher non-use values were relatively closer to the non-use value, which means that high non-use value units should have had a greater chance of being accepted into the program.

Viewing the table, it appears that player bids tended to decrease as the experiment advanced through the five rounds and that at least three of the four treatments resulted in different bid amounts, on average. A non-parametric Quade test and a Two-way ANOVA were performed comparing the average bids for each treatment by non-use value. The results for the Quade tests are reported in table 3. In each case the calculated F statistic is large enough to reject the null hypothesis at the $\alpha = 0.05$ level and conclude that at least one of the treatments yields larger bids than the others. Two-way ANOVA results, shown in table 4, indicate that while there is a statistically significant difference at least at the $\alpha = 0.1$ level in bids across treatments, there is no significant difference across the rounds after controlling for non-use value differences.

While player's bid may differ greatly in each treatment, *winning* bids, shown in table 5, do not appear to vary as much. As the table shows, there is very little difference in the average winning bid for a non-use value across treatments; however, results from Quade tests and 2-way ANOVAs (shown in tables 6 and 7) show that there is still a statistically significant difference between treatments. In most cases the average winning bid appears to be a little less than double the non-use value.

The above analysis is based on the average bids across all ten participants in a treatment. To further study the affect of treatment and non-use value on bid amount at the level of the individual, the data from all participants was analyzed using repeated measures ANOVA. This method allows for the examination of how players' bids change as they move from one round to the next, given that participants are responding multiple times in each round. In this analysis there were two between-subjects (grouping) factors, the bid selection constraint and the bonus payment, and one within-subjects factor, the experience the player gained from participating in the previous round. The non-use value associated with each bid was also included as a variable in the analysis as a control variable.

Table 8 reports the results from the GLM procedure used to estimate the repeated measures ANOVA. At the beginning of the experiment, the effect of the non-use value on bid amount is not significant; however, by the second round players were taking the non-use value into account, and by the last round this factor has a significant effect on the bid amount. The selection constraint and existence of a bonus payment both have statistically significant impact at least at the $\alpha = 0.1$ level for the first four rounds. In the fifth round the bonus payment continues to have a significant effect on bid amounts, but the selection criteria no longer has a significant impact.

Within-subject effects test whether or not individuals' bids change as the experiment is repeated. The results for multivariate tests for within-subject effects are shown in table 9. The first item in the table reports the result for the within-subject main effect, whether or not the experience gained from each round affects the bid amount. The final three items in the table report how the non-use value and the two between-subjects factors interact with experience. According to the table, experience does have a statistically significant effect on the bid amounts of individuals, at the α = 0.01 level, indicating that individual bids do change as the round changes, unlike the average bids discussed earlier. In addition, both the experience/selection and the experience/bonus interaction effects are statistically significant at any level, indicating that how experience changes bid amounts across rounds depends on which selection constraint a player is in and whether a bonus payment was offered or not.

Between-subject effects show whether there is a difference between individuals based on the factors included in the analysis. Results from the between-subjects analysis are listed in table 10. The non-use value has a statistically significant effect at the α = 0.01 level, the bonus payment has a statistically significant effect at the α = 0.05, and the selection criteria has a statistically significant effect at the α = 0.1 level. Players bid differently based both on which selection constraint they faced and whether a bonus payment was offered, and players reacted differently to the non-use value of units.

After analyzing the bids of individuals, two conclusions can be made. First, between-subjects results show that the difference in bids can be explained by the selection criteria an individual faces and whether or not a bonus is offered. In other words, individuals do react to the given incentives of the program. Second, within-subjects results show that individuals change their bids as they learn; indicating that the amount of knowledge a person has affects their bid. In the experiment, participants experienced the learning process over the course of an hour; however, producers participating in this type of bidding process would likely be tied into long term conservation contracts that don’t allow for adjustments in the short term. Thus, the program would need to provide producers with a large amount of information up front to account for this learning effect.

Expenditures

The total expenditures per round for each treatment, total expenditures for each treatment, and average expenditures over the five rounds for each treatment are reported in table 11. Of the four treatments, the two that use a monetary selection constraint result in the highest total expenditures. Recall that in these treatments bids were accepted until the payment amount of $80 was reached. In the other two treatments, where the number of accepted bids was constrained to 10 for each pair of players, the total bid amount for the ten selected units did not reach $80.

Bonus expenditures for the acreage and monetary treatments are reported in table 12, and show a similar trend as total expenditures. Players faced with a monetary constraint earned almost 2.5 times as much in bonus payments as players faced with the acreage constraint. Again, this is because the monetary constraint allowed for more units to be accepted, thus it was easier for players in this treatment to have accepted units share borders.

While a simple examination of expenditures reveals which treatment results in the greatest cost, the purpose of the experiment is to influence conservation in a specific area. Thus, it is important to consider the expenditure per critical unit conserved. Table 13 provides this information for each of the four treatments. To calculate these figures, the total program expenditure, or the value of all accepted bids, in each round were divided by the number of critical units accepted in the round. Examining the table shows that while each treatment's total expenditures may differ, the expenditures per critical units conserved are more similar.

To confirm whether or not the values from each treatment differ, a Mann-Whitney U test was performed for each pair of treatments. The Mann-Whitney U is a non-parametric test that evaluates whether one of two samples tends to have larger median values. In this case the total expenditures per round for each treatment were compared to the expenditures per round for every other treatment. The results of these tests are given in table 14. Each row in the table shows the results for one comparison. The Group A Median refers to the first treatment listed and the Group B Median refers to the second treatment. The results show that the expenditures per critical unit conserved differ significantly only between the acreage with bonus treatment and the money with bonus treatment, which are the two treatments with the highest and lowest expenditures per critical unit conserved respectively.

To determine the separate effects of the unit selection criteria and bonus payment on expenditures per critical unit conserved, a time series-cross section regression model was estimated. In the model, the selection variable was coded 1 for the acreage constraint and 0 for the monetary constraint. The bonus variable was coded 1 if the bonus was offered and 0 if it was not. The results from this regression are reported in table 15. While the selection criteria had no statistically significant effect on expenditure per critical unit conserved, the existence of a bonus payment reduces these expenditures compared to the no-bonus treatments by almost $3 per critical unit conserved. This result is significant at the $\alpha = 0.01$ level.

Area Conserved

It is also important to consider how well each treatment conserves the critical area. Table 16 reports the proportion of the critical area conserved in each round of all four treatments. Of the four treatments, the money constraint with bonus treatment conserves the greatest amount of the critical area by far; however, this does not necessarily mean this treatment is better at targeting the critical area than the other treatments. Table 17 shows the critical area conserved as a proportion of all conserved units. In both of the money treatments and the acreage with no bonus treatment, critical units conserved makes up about 60% of the total units conserved. In the acreage with bonus treatment, critical units conserved makes up about 50% of the total units conserved. Thus, the money constraint with bonus treatment is not necessarily better at targeting the critical area, but does result in a greater total area conserved.

A time series-cross section regression model similar to that used to analyze expenditures per critical unit conserved was estimated using the percent of the critical area captured as the dependent variable. The results from estimating this model are reported in table 18. The type of constraint has a statistically significant effect on the proportion of the critical area conserved, and according to the model the acreage constraint will conserve 25% less of the critical area than the monetary constraint, on average. The p-value for the bonus payment coefficient estimate indicates that offering a bonus does not have a statistically significant impact on how much of the critical area is conserved.

Discussion and Conclusion

If water districts choose to use a voluntary incentive mechanism to manage water use, two factors will be important for them to consider. First, the incentives must be correctly calibrated so that the desired area is placed into the conservation program. Second, the conservation program needs to influence conservation while remaining cost effective.

With respect to the first consideration, using a monetary constraint results in more units being placed into the program, which is similar to the findings of Babcock et al. (1996) and Buller and Hudson (2006). In addition, when the monetary constraint is paired with a bonus for conserving adjacent units, the proportion of critical units conserved is close to 1. However, with respect to the second consideration, the money constraint leads to greater total expenditures, and is no cheaper per critical unit than the acreage constraint.

The existence of a bonus payment did not necessarily influence greater conservation over the critical area. This result is interesting because it at least appears to run counter to the findings of Parkhurt et al. (2002); however, there are some key differences between these experiments that explain the difference in the results. First, in Parkhurst et al.'s experiment participants were paid a fixed lump sum for conserved units and could only retire 5 units total; thus, the only way to maximize the bonus was to move to the center. The addition of a bidding process in this study gives players more choice as to how much they are paid for conservation and allows for one player to retire more than five units. Second, the amount of bonus earned per shared border in this study is one tenth of the amount found in Parkhurst et al.'s study. The bonus simply may not have been large enough to affect player's choices.

What the bonus did do is reduce per unit bid amounts. It appears that the bonus influenced participants to capture the bonus payment by reducing their bids relative to the non-use value to guarantee their units were accepted. This result indicates that a bonus paired with a properly calibrated bid selection process could keep the total expense of such a conservation program from being prohibitive.

While these results shed some light on what types of incentives would influence the voluntary conservation of groundwater, they also suggest more questions to be answered in future studies. In the framework of this experiment, the monetary constraint appears to be no more cost effective than the acreage constraint, but this may be a result of the chosen cut off point for expenditures. It may be that a lower constraint on expenditures, say $40 or $60, would achieve the same amount of conservation over the critical area while reducing the total expenditure and the total number of conserved units. If so, the monetary constraint would likely be more cost effective than the acreage constraint as a mechanism for conservation.

A second consideration along these lines is that a more substantial bonus would likely do more to influence conservation over the critical area. Parkhurst et al. (2002) show that a bonus of $10, or about 2 – 5 times the value of the units, does in fact influence players to conserve units in the critical area when players are faced with a lump sum payment per unit conserved. A larger bonus payment in this experiment may have the same influence, but would also increase the expenditures the program would incur; however, a larger bonus paired with a smaller monetary constraint may still result in a high percentage of the critical area conserved and a smaller expenditure per critical unit conserved.

References

Babcock, B., P. Lakshminarayan, J. Wu, and D. Zilberman. 1996. "The Economics of a Public Fund for Environmental Amenities: A Study of CRP Contracts." *American Journal of Agricultural Economics*, 78:961-971.

Buller, V., and D. Hudson. 2006. "The Impacts of Alternative Institutions on Distributional and Environmental Efficiency in Environmental Programs." *Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meetings Orlando, FL, February 5-8, 2006.*

Caroom, D., and S. Maxwell. 2004. "The Rule of Capture – 'If It Ain't Broke . . . .'" *100 Years of Rule of Capture: From East to Groundwater Management* (pp. 41-61). Texas Water Development Board.

Feather, P., D. Hellerstein, and L. Hansen. 1999. *Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP*. Washington D.C., ERS Agricultural Economics Report 778, April.

Parkhurst, G., J. Shogren, C. Bastian, P. Kivi, J. Donner, and R. Smith. 2002. "Agglomeration bonuses: an incentive mechanism to reunite fragmented habitat for biodiversity conservation." *Ecological Economics,* 41:305-328.

Potter, H. 2004. "History and Evolution of the Rule of Capture." *100 Years of Rule of Capture: From East to Groundwater Management* (pp. 1-9). Texas Water Development Board.

Smith, R. 1995. "The Conservation Reserve Program as a Least-Cost Land Retirement Mechanism." *American Journal of Agricultural Economics* 77:93-105.

Smith, R., and J. Shogren. 2001. Protecting species on private land. In: Shogren, J., and J. Tschirhart (Eds.), *Protecting Species in the United States: Biological Needs, Political Realities, Economic Choices*. Cambridge University Press, New York, pp. 326–342.

Smith, R., and J. Shogren. 2002. Voluntary incentive design for endangered species protection, J. Environ. Econ. Manag. 43, 169–187.

Weinheimer, J. 2008. Farm Level Financial Impacts of Water Policy on the Southern Ogallala Aquifer. *Unpublished doctoral dissertation* . Texas Tech University.

Figure 1. Picture of the experiment scenario from Parkhurst et al. (2002)

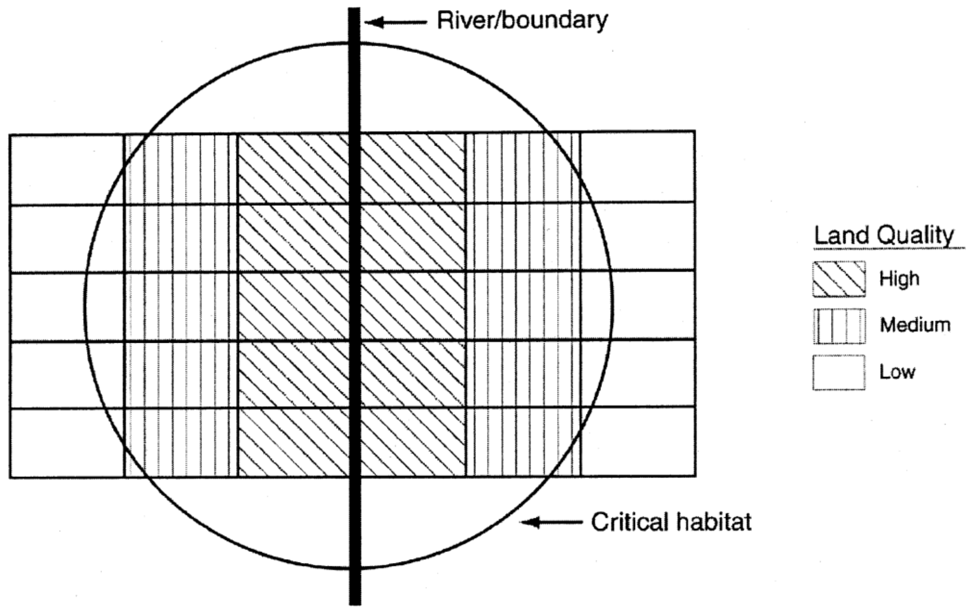

Figure 2. Map of the conservation scenario

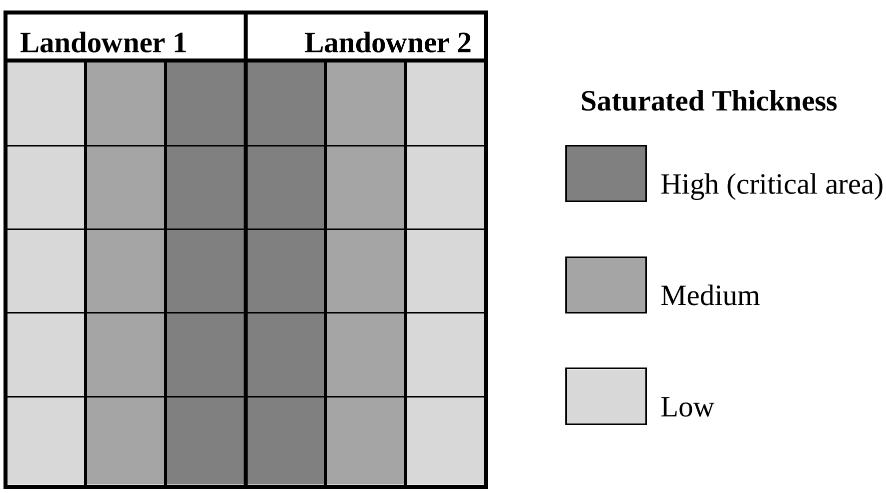

Figure 3. Map of participants' units with use and non-use values

Player's Units			Other Participant's Units		
1 2 1	**6** 4 3	**11** 6 5	**11** 6 5	**6** 4 3	**1** 2 1
2 2 1	**7** 4 3	**12** 6 5	**12** 6 5	**7** 4 3	**2** 2 1
3 2 1	**8** 4 3	**13** 6 5	**13** 6 5	**8** 4 3	**3** 2 1
4 2 1	**9** 4 3	**14** 6 5	**14** 6 5	**9** 4 3	**4** 2 1
5 2 1	**10** 4 3	**15** 6 5	**15** 6 5	**10** 4 3	**5** 2 1

Table 1. Summary of Experimental Treatments

Treatment Type	Bonus	Selection Criteria	# of pairs	# of students	# of rounds
Baseline	No	Acreage	5	10	5
Experiment	Yes	Acreage	5	10	5
Baseline	No	Monetary	5	10	5
Experiment	Yes	Monetary	5	10	5

Table 2. Average Bids by Non-Use Value

Non-use	Round						Compared
Value	**1**	**2**	**3**	**4**	**5**	**Ave.**	**to Non-use**
Acreage, no bonus							
1	9.58	9.42	7.39	6.70	4.93	7.60	7.60
3	13.38	12.98	8.14	8.47	6.97	9.99	3.33
5	18.15	15.71	10.16	10.46	9.57	12.81	2.56
Acreage, w/ bonus							
1	39.82	22.66	4.02	4.53	2.78	14.76	14.76
3	43.64	20.06	6.88	6.36	5.40	16.47	5.49
5	40.56	26.42	12.80	9.62	7.72	19.42	3.88
Money, no Bonus							
1	11.38	18.02	19.76	11.89	6.60	13.53	13.53
3	14.00	22.49	25.32	17.87	9.52	17.84	5.95
5	16.60	24.47	27.80	21.95	12.36	20.64	4.13
Money, w/ bonus							
1	2.95	2.24	2.20	1.95	1.95	2.26	2.26
3	4.93	4.62	4.42	4.16	3.72	4.37	1.46
5	6.85	6.52	6.67	6.47	5.67	6.44	1.29

Table 3. Results from Quade Tests, All Bids

	Quade F statistic	Num df	Den df	p-value
Non-use value = 1	3.1912	4	12	0.0530
Non-use value = 3	3.6914	4	12	0.0350
Non-use value = 5	3.5693	4	12	0.0386

Table 4. Results from 2-way ANOVA, All Bids

Source of variation	SS	df	MS	F statistic	p-value
Non-use value = 1					
Treatment	499.82	3	166.61	2.4931	0.1098
Round	382.20	4	95.55	1.4298	0.2833
Error	801.93	12	66.83		
Total	1683.96	19			
Non-use value = 3					
Treatment	581.11	3	193.70	2.6569	0.0959
Round	390.63	4	97.66	1.3395	0.3113
Error	874.87	12	72.91		
Total	1846.61	19			
Non-use value = 5					
Treatment	646.77	3	215.59	4.0819	0.0327
Round	352.19	4	88.05	1.6671	0.2217
Error	633.79	12	52.82		
Total	1632.74	19			

Table 5. Average Winning Bids by Non-Use Value

Non-use Value	**Round 1**	**2**	**3**	**4**	**5**	**Ave.**	**Compared to Non-use**
Acreage, no bonus							
1	1.75	2.30	2.17	1.00	n/a*	1.81	1.81
3	5.50	5.10	4.92	4.86	4.82	5.04	1.68
5	8.17	7.32	8.21	8.86	6.82	7.88	1.58
Acreage, w/ bonus							
1	1.70	2.00	1.00	1.00	1.00	1.34	1.34
3	3.61	5.00	4.67	3.39	3.39	4.01	1.34
5	6.59	7.35	7.40	6.64	6.52	6.90	1.38
Money, no Bonus							
1	2.11	2.49	2.00	2.00	1.72	2.06	2.06
3	4.84	5.75	4.99	5.74	4.39	5.14	1.71
5	8.52	9.02	9.80	10.50	9.52	9.47	1.89
Money, w/ bonus							
1	1.00	1.00	1.00	1.08	1.05	1.03	1.03
3	4.37	3.93	3.91	3.78	3.44	3.89	1.30
5	6.77	6.48	6.50	6.14	5.70	6.32	1.26

Note: There were no winning bids for units with a non-use value of 1 in round 5 of the acreage w/ no bonus treatment

Table 6. Results from Quade Tests, Winning Bids*

	Quade F statistic	**Num df**	**Den df**	**p-value**
Non-use value = 3	4.0931	4	12	0.0255
Non-use value = 5	2.1873	4	12	0.1321

Note: The Quade test statistic was not calculated for bids on units with a non-use value of 1 because of a missing value in round 5 of the acreage w/ no bonus treatment.

Table 7. Results from 2-way ANOVA, Winning Bids

Source of variation	**SS**	**df**	**MS**	**F statistic**	**p-value**
Non-use value = 3					
Treatment	6.59	3	2.20	9.8840	0.0015
Round	1.84	4	0.46	2.0747	0.1474
Error	2.67	12	0.22		
Total	11.10	19			
Non-use value = 5					
Treatment	28.54	3	9.51	27.6850	< 0.0001
Round	2.18	4	0.55	1.5882	0.2404
Error	4.12	12	0.34		
Total	34.84	19			

Note: 2-way ANOVA was not calculated for bids on units with a non-use value of 1 because of a missing value in round 5 of the acreage w/ no bonus treatment.

Table 8. Results from the GLM Procedure

	p-value				
Variable	**Rd 1 bid**	**Rd 2 bid**	**Rd 3 bid**	**Rd 4 bid**	**Rd 5 bid**
Non-use value	0.3244	0.0650	0.0058	< 0.0001	< 0.0001
Selection criteria	< 0.0001	0.0364	0.0006	0.0016	0.2130
Bonus payment	0.0153	0.1360	< 0.0001	< 0.0001	< 0.0001

Table 9. Results from Multivariate Within-Subjects Tests using Wilk's Lambda

Effect	**Value**	**F Statistic**	**p-value**
Experience	0.9772	3.45	0.0084
Experience*Non-use Value	0.9979	0.31	0.8703
Experience*Selection Criteria	0.9264	11.77	< 0.0001
Experience*Bonus Payment	0.9338	10.51	< 0.0001

Table 10. Results from Between-Subjects Tests

Variable	DF	Type III SS	Mean Square	F Value	p-value
Non-use value	1	13,985.60	13,985.60	8.66	0.0034
Selection criteria	1	5,326.62	5,326.62	3.30	0.0699
Bonus payment	1	7,275.80	7,275.80	4.50	0.0343
Error	596	963,035.93	1,615.83		

Table 11. Expenditures by Treatment across Rounds

	Round						
Treatment[a]	**1**	**2**	**3**	**4**	**5**	**Total**	**Ave.**
Acreage, nB	337.0	296.6	349.5	379.0	297.0	1659.1	331.8
Acreage, wB	249.0	352.0	339.0	292.0	293.0	1525.0	305.0
Money, nB	375.2	389.2	402.2	391.7	390.5	1948.7	389.7
Money, wB	509.9	516.4	523.6	540.3	563.0	2653.1	530.6

[a] The abbreviations "nB" and "wB" indicates whether or not a bonus was offered in the treatment. A treatment with no bonus is abbreviated as "nB" and a treatment with a bonus is abbreviated as "wB."

Table 12. Bonus Expenditures by Treatment across Rounds

	Round						
Treatment	**1**	**2**	**3**	**4**	**5**	**Total**	**Ave.**
Acreage	48.0	53.0	52.0	58.0	58.0	269.0	53.8
Money	110.0	120.0	125.0	139.0	163.0	657.0	131.4

Table 13. Expenditures per Critical Unit Conserved

	Round					
Treatment[a]	**1**	**2**	**3**	**4**	**5**	**Ave.**
Acreage, nB	12.96	11.86	11.27	10.83	10.61	11.51
Acreage, wB	14.65	13.54	11.68	11.68	11.27	12.56
Money, nB	12.10	13.42	10.27	13.99	12.20	12.40
Money, wB	11.08	10.99	11.38	11.75	11.26	11.29

[a] The abbreviations "nB" and "wB" indicates whether or not a bonus was offered in the treatment. A treatment with no bonus is abbreviated as "nB" and a treatment with a bonus is abbreviated as "wB."

Table 14. Results for Mann-Whitney U Tests

Treatment pairs[a]	Group A Median	Group B Median	W statistic	p-value
AnB/ AwB	11.51	12.56	6.5	0.2477
AnB/ Mnb	11.51	12.40	7.0	0.3095
AnB/ MwB	11.51	11.29	13.0	1.0000
AwB/ MnB	12.56	12.40	12.0	1.0000
AwB/ MwB	12.56	11.29	21.0	0.0937
MnB/ MwB	12.40	11.29	20.0	0.1508

[a] Treatments are abbreviated in the following manner: "A" or "M" refers to the selection criteria, either acreage or monetary. Whether the treatment offered a bonus payment is demnoted by "nB" for no bonus and "wB" for with bonus.

Table 15. Results from the Time Series-Cross Section Analysis of Expenditure per Critical Unit Conserved

Variable	Estimate	St. Error	p-value
Intercept	12.227	0.9044	< 0.0001
Selection criteria	0.807	1.0304	0.4345
Bonus payment	-2.856	1.0313	0.0063

Table 16. Proportion of Critical Units Conserved

	Round				
Treatment[a]	1	2	3	4	5
Acreage, nB	0.52	0.50	0.62	0.70	0.56
Acreage, wB	0.34	0.52	0.50	0.50	0.52
Money, nB	0.62	0.58	0.66	0.56	0.64
Money, wB	0.92	0.94	0.92	0.92	1.00

[a] The abbreviations "nB" and "wB" indicates whether or not a bonus was offered in the treatment. A treatment with no bonus is abbreviated as "nB" and a treatment with a bonus is abbreviated as "wB."

Table 17. Critical Units Conserved as a Proportion of Total Conservation

	Round					
Treatment[a]	**1**	**2**	**3**	**4**	**5**	**Ave.**
Acreage, nB	0.52	0.50	0.62	0.70	0.56	0.58
Acreage, wB	0.34	0.52	0.50	0.50	0.52	0.48
Money, nB	0.53	0.51	0.67	0.58	0.56	0.57
Money, wB	0.69	0.63	0.58	0.53	0.53	0.59

[a]The abbreviations "nB" and "wB" indicates whether or not a bonus was offered in the treatment. A treatment with no bonus is abbreviated as "nB" and a treatment with a bonus is abbreviated as "wB."

Table 18. Results from the Time Series-Cross Section Analysis of the Percent of the Critical Area Conserved

Variable	**Estimate**	**St. Error**	**p-value**
Intercept	0.72	0.0707	< 0.0001
Selection criteria	-0.248	0.0816	0.0027
Bonus payment	0.112	0.0816	0.1717