Tradable Set-Aside Requirements (TSARs): Conserving Spatially Dependent Environmental Amenities

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Abstract

In the lab, we examine the effectiveness of two land use conservation policies: a tradable set aside requirements (TSARs), and the TSARs combined with an agglomeration bonus. Evaluated by bioeconomic efficiency, our experimental results suggest: 1) TSARs is a cost-effective land conservation tool; and 2) combining TSARS with the agglomeration bonus increases habitat connectivity but at a price—lower economic efficiency.

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Introduction

Protecting biological diversity and ecosystem services remains a key element of 21st Century government regulation (see e.g., Barbier, 2011). Numerous government programs around the globe have been implemented to control or influence public and private land uses (Langpap and Wu, 2004; Crepin, 2005; Feng et al., 2006; Clement and Amezaga, 2009; Henger and Bizer, 2010; Bullock and King, 2011). In the United States, for instance, federal policies such as the National Environmental Policy Act, Farm Bills, the Endangered Species Act, and the Clean Water Act all place regulatory requirements on land use practices. The regulations imposed by these policies extend across both private and public lands as do the majority of the resources these federal policies are designed to protect. Not surprisingly, the political opposition against implementation of these policies differs, however, depending on whether the policy affects private and public lands—private landowners complain loudly when public policy restricts their land use decisions (see, e.g., Smith and Shogren, 2002).

While the costs of meeting regulatory constraints on public lands are incurred by society, private landowners pick up the tab to protect biodiversity and ecosystem services on private lands. These private landowners have incentive to avoid the costs of land use regulations; for example, they can alter land attributes to have less conservation value prior to the imposition of regulatory constraints (Innes et al., 1998). This can result in less conservation at greater cost to achieve regulatory goals (see Ando et al, 1998; Dreschler and Watzold, 2001; Hartig and Drechsler, 2009; Hamaide and Sheerin, 2010).

Economists and practitioners have long argued that positive incentives are needed to induce landowners to cooperate with regulatory protection of ecosystem services

(Bean, 1998; Shogren et al., 1999; Adler, 2008). Positive incentives take on many forms (e.g., taxes, subsidies; see Parkhurst and Shogren, 2003; Ferraro and Kiss, 2002). Tradable development rights (TDR) is a key incentive system proposed for efficiency properties (Innes et al., 1998; Thornes and Simons, 1998; Boyd et al., 2000). For a TDR policy, a regulator sets the maximum amount of allowed development, allocates TDRs to landowners, and then allows a market to exist so buyers and sellers can reallocate TDRs such that the property with the lowest opportunity cost remains undeveloped.

One of the initial tradable development scheme was implemented in New York City and allowed for neighboring landowners to trade building density (Renard, 2007). Adjoining landowners can combine their allowed floor area while maintaining separate property ownership, provided the aggregate floor area for both buildings does not exceed the zoned maximum amount of floor area of the two properties. A developer can increase the buildings allowed density by purchasing the unused floor area of an adjacent landowner.

The TDR program can work for economic efficiency by transferring development rights from low value areas to high value areas; but has two primary weaknesses when we consider *biological efficiency*: 1) low land development values are imperfectly correlated with high conservation values. The land conserved will be the lowest development valued land but it might not be the land desired for the valuable ecosystem services; and 2) conserved parcels may not be located spatially to create the contiguous habitat and land corridors that create positive biological network externalities. Networking conserved parcels may reduce the cost of conservation as fewer parcels are needed to meet the regulatory objective (Ando et al., 1998; Parkhurst and Shogren, 2008). To overcome these shortcomings, a regulator should design the TDR incentive mechanism to have two components: one focused on retiring land, and a second that creates the desired spatial configuration.

Two mechanisms have been proposed that combine TDRs and a spatial component. First, Mills (1980) proposed combining a TDR policy with zoning to deal with the imperfect spatial correlation between development values and conservation values. A government regulator first determines the area desired for conservation (the "sending zone"), severs the right to develop, and then allocates TDR to the landowners within the sending zone. TDRs are sold through a market instrument.[1] The problem with Mills' mechanism is it negates the least cost aspect of a TDR policy. Instead the method relegates TDRs to be just a compensatory tool in a landscape in which the regulator chooses winners and losers. In addition, implementing a TDR with zoning mechanism is expensive for local jurisdictions which may prove cost prohibitive given economic circumstances (see Henger and Bizer, 2010).

Second, Drechsler and Watzold (2009) introduced an algorithm for a TDR program that incorporates the spatial component within the biodiversity measurement mechanism. The mechanism accounts for the biodiversity network externalities created through the location of conserved land within the landscape and determine the amount of

[1] The most illustrative application of a TDR scheme is the Pinelands National Preserve in New Jersey which was established in 1978 to protect the environment. In 1980 a comprehensive management plan was approved. The plan delineated the 4,000 square kilometers of densely populated forested expanse into 10 categories with differing zoning ordinances. Some categories were designated as areas where development was not permitted but able to transfer development rights, while other categories allowed for varying degrees of development in conjunction with the purchase of a development right. The amount of developmental rights transferable from a development restricted area was dependent upon that areas environmental value. For example, one development credit was awarded for every 16 hectares of the core conservancy area, or for each 32 hectares of wetlands, or for each 8 hectares of agricultural land. A developer required 4 development credits to build a home in an area where development was permitted (See Renard, 2007).

development a landowner can trade contingent upon the location of the conserved parcels. They conclude that the TDR algorithm is effective provided the development values of the land maintain some correlation below a critical randomness measure. Two issues with their incentive mechanism stand out: 1) information and technical needs to understand the impact of spatial location of conserved land on a landowners available TDR are likely beyond landowners cognitive abilities and costly for the regulator to provide on a per landowner basis (an issue magnified in a dynamic setting); and 2) coordination across landowners is challenging due to different expectations and risk preferences. Their TDR policy is likely too complex to be implemented without significant and costly oversight.

Herein we propose a third incentive mechanism to combine tradable permits and spatial incentives. We create a system that combines a tradable set-aside requirement (TSARs) with an agglomeration bonus to meet spatial conservation objectives at least cost (see Parkhurst and Crocker, 2002; and Parkhurst et al., 2002). A regulator determines the number of land parcels necessary to meet spatial conservation objectives and then allocates set-aside requirements proportionally to the landowners. Each set aside obligates the possessing landowner to conserve one parcel of land. The regulator creates a market that facilitates trade that moves conservation to the low cost parcels. To induce the desired configuration the regulator pays the landowners an agglomeration bonus for each border shared between two conserved parcels (Parkhurst et al., 2002). The agglomeration bonus induces the landowners to coordinate their conserved parcels into contiguous habitat reserves. The agglomeration bonus can be structured to satisfy numerous spatial configurations (see Parkhurst and Shogren, 2007; 2008).

We design a lab experiment to testbed the two-part TSARs with agglomeration bonus mechanism; we compare our two-part mechanism to a TSARs-only policy and a benchmark command and control approach that forces each landowner to conserve an equal amount of land. Comparing the results over economic and biological measures of efficiency, we find that TSARs is a cost-effective land conservation tool. Additionally, combining TSARS with the agglomeration bonus increases biological efficiency (habitat connectivity) but at a price—lower economic efficiency.

Experimental Design

Our experimental design had six structural elements—1) treatments; 2) players, positioning, and the land grid; 3) subsidies, strategies, and calculator; 4) tradable set-aside requirements (TSARs) market and predictions; 5) communication, information and history, and 6) procedures. Consider each in turn.

Treatments. Three institutional structures were tested—no trade (NT), trade only (TO), and trade with an agglomeration bonus (TAB). In the NT treatment, each person was allocated 5 conservation set-aside requirements. People were forced to conserve one parcel of land to satisfy each conservation set-aside requirement. Similarly, in the TO treatment each landowner was allocated 5 set-aside requirements for which one cell must be conserved to satisfy the regulatory constraint. A market was now constructed in which people could trade their set-aside requirements. In this treatment, TSARs are seen as a liability—a landowner must forego productivity on one parcel of land to satisfy the TSAR, and as such requires the recipient of the TSAR to be compensated.

The TAB treatment was identical to the TO treatment except that people now could receive an additional payment—the agglomeration bonus—for each border shared between two of their own conserved parcels. This agglomeration bonus has three impacts:(i) it creates a network externality between own conserved parcels; (ii) by setting the agglomeration bonus to exceed the opportunity cost of conservation the agglomeration bonus changes participants perception of TSARs. TSARs are now seen as an asset as opposed to a liability; (iii) because TSARs with the agglomeration bonus is seen as an asset, participants will voluntary engage in the conservation program. We conducted two sessions of each institutional structure. Each session had 20 rounds.

Number of participants, positioning, and land grid. *Participants*. Eight subjects participated in each session. They were told they would be randomly assigned to a group of four subjects. The group of four participants and each participant's placement within the land grid would remain fixed for the remainder of the experiment. *Positioning*. We chose fixed groupings and fixed placements to provide participants consistency and they can apply past experience to present actions. *Grid*. In Figure 1 notice the 10X10 land grid and the positions of each participant within the land grid. Each participant knew they owned a 5x5 portion of the 10x10 grid, and could identify where their portion was located relative to the rest of the land grid. The values of each participant's 25 cells ranged from $20 to $50, with no two participants having identical grid values. The value in each cell represents the productive value of that cell. Grid values for all four positions were common knowledge and participants had a specification page that delineated grid holdings and showed the land values for the entire 10x10 grid.

Subsidies, Strategies, and Calculator. In the NT and TO treatments no subsidies existed—the costs of conservation were levied on the participants. In the TAB treatment, participants earned an additional $50 payment for each border shared between two of their own retired cells—shifting the costs of conservation from the participant to the experiment monitor (proxy regulator). *Strategies*. Participants were instructed that they could leave their cells *green*, in which case they earned the value in the cell, or they could *brown out* cells, which mean they earn the applicable subsidies but forego the value of the cell. Each subject was required (allowed for the TAB treatment) to "brown out" 5 cells. Note the large set of potential strategy set. By presenting participants with the land grid and requiring participation the participants have 53,130 potential strategies.[2] But in the TO and TAB treatments, the acquisition and remittance of TSARs changes the number of possible strategies. For the NT and TO treatments, each participant has a dominant strategy of conserving their 5 lowest valued cells. In the TAB treatment, the participant's dominant strategy is to conserve the lowest cost cells that maximize agglomeration dollars.

Calculator. To help in the subjects calculate profits a grid calculator was provided on the computer screen. The grid calculator was a 10x10 grid of cells with borders to differentiate each player's portion of the section. The participant's portion of the calculator was tied directly to his 5x5 grid and reflected the choices made on the 5x5 grid, meaning if a participant clicked on a cell in his grid, changing the color from green to brown, the same cell turned brown on the calculator. For the other participants portions of the calculator the subject clicked the cells directly. The participant's own potential profits, based on the configuration of brown cells on the calculator, were calculated and displayed on the computer screen.

[2] See Parkhurst and Shogren (2007) for an example of similar calculations of the potential strategy set when considering the agglomeration bonus incentive scheme.

Tradable Set-Aside Requirements (TSARs) Market and Predictions. Participants were provided with an auction window that facilitated trade in brown out cell requirements (or TSARs). They were informed they could be buyers or sellers and were allowed to submit both bids and asks. Further, they were informed that prices could be positive, negative, or zero and the implications of positive and negative prices were discussed. Participants were told all prices must be in whole integers and that they would have 7 minutes to make trades. The auction window allowed them to make bids or asks for individual units or for multiple units—a separate bid (ask) could be made for each quantity of TSARs up to the maximum individual holdings. This feature was important in the TAB treatment in which the agglomeration bonus created a sticky market when only single unit trading was allowed (purchase of the TSAR increases the bidders shared borders by one but diminishes the sellers shared borders by two).

Market Predictions. As an upper benchmark, our market predictions assume a best-case scenario—three transactions occur, one transaction between each participant and the position 2 participant, and of course the low cost land is conserved. The predicted quantity traded in the TSARs treatment is 14. Acquisition of TSARs was to the position 2 participant with the position 1 and position 3 participants each trading 5 brown out cell requirements (TSARs) and the position 4 participants packaging 4 TSARs. Predicted market price is all whole integers in the interval of -$28.00 to -$40.00 [-$28, -29,…, -39, -40].[3] For the TAB treatment, predicted quantity was 15, with the position 2 participant acquiring 5 TSARs from each of the other participants. Predicted market price is [$10, 11, 12,…, 56, 57, 58].

[3] The range of market prices is determined as the average price per TSAR for the seller on the lower bound and the average price per TSAR for the buyer on the upper bound.

Communication, Information, and History. *Communication*. Participants were also provided the opportunity to communicate one message per round. Communication was non-binding, unstructured with no restrictions on timing or content, and in which a common language was implemented by allowing subjects to send messages in their natural language (Crawford, 1998). Participants had seven minutes to send messages, make trades and use the calculator, and send their choices.[4] *Information*. After all four participant's choices were submitted the resulting grid was presented to the group. They had common knowledge regarding payoffs and strategies. *History*. The entire 10x10 grid showing the configuration of brown cells and the payoffs for each subject within the group then appeared in the history box. They were also provided with record sheets to further help them keep track of their own and the other group members' choice of strategies and associated payoffs in previous rounds.

Procedures. All experiments were on computers. Participants were not told the objective of the experiment and all wording in the instructions and on the computer screens were context free. Following standard protocol, the participants were recruited campus wide and were told to report at a computer lab at a given time. Experimental instructions were provided to each participants and the monitor read them out loud. See Appendix A for the exact instructions. Participants were given an opportunity to ask questions concerning the experimental procedures, which were answered by the monitor. The monitor also walked the participants through two practice rounds to familiarize them with the experimental design. The monitor handed out the agglomeration bonus

[4] The seven-minute time period for sending messages and making decisions was timed manually. The experimenter used a clock and informed students when there were 90 seconds remaining, 60 seconds remaining, 30 seconds remaining, and then when 0 seconds remained. When the seven-minutes were up, participants who had not yet sent their actions were asked to do so at that time. Participants always complied.

specification page, which participants were allowed to review. The participants then entered their name and student identification number into the computer, and the computer randomly assigned them to groups of four.

Results

We examine the experimental results in two steps—1) we present an illustrative example for one group from each of the three treatments; and 2) we discuss the group outcomes based on several measures of bioeconomic efficiency: biological efficiency, economical efficiency, cost efficiency, and spatial efficiency. Consider each in turn.

Illustrative Example

Figures 2, 3, and 4 illustrate the actual outcomes for one group in each of the three compensation mechanisms. In Figure 1 the NT mechanism is presented. Here we see individuals conserved cells are distributed in random patterns. In early rounds the two players in the bottom part of the grid, positions 2 and 4, are not conserving their least expensive parcels, and are therefore playing dominated strategies. By round 6 and thereafter all four individuals are playing their dominant strategies. Note, conserved parcels are seldom connected across individuals, and, the group never obtains the maximum level of connectivity. Figure 3 illustrates a group outcome for the TO treatment. Here, the participant in position 2 plays a dominated strategy in rounds 1-7 and 9. The position 2 participant can increase earnings through a simple reallocation of his TSARs. In rounds 8 and 10-20 the position 2 participant plays his dominant strategy—no reallocation of TSARs can increase his earnings. The position 4 participant plays his dominant strategy in rounds 2-19, while positions 1 and 3 play their dominant strategies in every round. Also, as the experiment progresses, the position 2 participant is able to increase his inventory of TSARs through trade. In rounds 18 and 19 the group is able to achieve the group outcome that results in the greatest economic returns for the group. However, because TSARs, alone, does not create incentives to link conserved parcels, maximum payoffs do not imply maximum connectivity. Rather, for TSARs, maximum payoffs imply the minimum productive land is conserved.

Finally, turning to group outcomes for TAB in Figure 3, we see the participant in position 2 played his dominant strategy in rounds 2-20. The participant in position 4 played dominated strategies whenever he failed to trade away his TSARs—rounds 1, 3-6, 9, 13, and 18. The participant in positions 1 played a dominated strategy in rounds 2-6, and 20 because he failed to capture the maximum number of agglomeration bonus dollars—a reallocation of conservation would yield an increase in own shared borders and associated subsidy dollars. The position 3 participant played his dominant strategy in every round. As expected, an increase in TSARs through trade tended towards the position 2 participant. In round 16, maximum economic earnings and connectivity are achieved. Adding the agglomeration bonus with TSARs provided the proper incentives for individuals to minimize the fragmentation of their joint conservation efforts.

Bioeconomic Efficiency

To better understand how our results relate to conservation targets, we evaluate the success of the compensation mechanisms by cost efficiency, economic efficiency, biological efficiency, and spatial efficiency. Cost efficiency (CE) is the ratio of actual foregone productivity to the minimum foregone productivity: CE = Group foregone productivity/540. Economic efficiency (EE) is the percentage of available program rents earned by the group: EE = (Group earnings – min earnings)/(max earnings – min earnings).[5] Biological efficiency (BE) is a gradient measure—the percentage of the shared borders between conserved parcels achieved by the group to the maximum number of shared borders.[6] Finally, spatial efficiency (SE) is the percentage of predicted cells that are actually conserved.

We use a Spearman's Rho rank correlation test to establish the independent set of observations within group. The Spearman Rho uses the combination of round and outcome to determine correlation (or lack thereof) across rounds (see Conover, 1999).[7] We use a Smirnov test of equal distributions to establish dependence between group outcomes within treatment. The Smirnov test is an appropriate test because the two samples are random, mutually exclusive, values are ordinal, and the random variables are continuous. The Smirnov test allows for the comparison of the distributions of values of two random samples.[8] Table 1 presents the descriptive statistics for the set of independent observations.

Cost Efficiency. From Table 1 observe CE averages 128% of the minimum possible cost ($540) in the NT treatment, 112% of $540 in the TO treatment, and for TAB, 113% of minimum cost. Using a two-tail Mann-Whitney test, we test if CE is invariant to treatment type. We reject the null hypotheses between the NT and TO treatments ($p < 0.001$), the TAB treatment and the NT treatment ($p < 0.001$), and we reject the null hypothesis at 11% significance for the TO and TAB treatments ($p = 0.11$).

[5] Maximum and minimum earnings depend on the institutional structure of the incentive mechanism, which differ across treatments. EE is an indicator of the ability of groups to earn the maximum available rents.
[6] We use Figure 3 to clarify the BE gradient. In round 1, 28 of a maximum 31 borders are shared between conserved parcels, implying BE = 90.3%. In round 3, BE = 71.0% (22 of 31 borders shared). In round 16, BE = 100% (31 of 31 borders shared).
[7] For independence within group observations, we limit the sample to the subset of consecutive rounds for which independence cannot be rejected at the 10% level or better. See Appendix B.
[8] We follow a rule: a group that has a different distribution from all three of the other group distributions cannot be an identical distribution and as such the data is omitted from the sample.

As expected, TSARs effectively reduces the cost of conservation. Adding the agglomeration bonus to TSARs increases the cost of foregone productivity relative to a TSARs only policy, because, now to create a contiguous habitat patch some more expensive land must be placed in conservation. Result 1 summarizes our findings.

Result 1. *Allowing individuals to trade in the requirements of conserving land reduces the opportunity cost of conservation. However, the addition of incentives to achieve a secondary objective—an agglomeration bonus to induce the creation of a contiguous conservation reserve—to a TSARs Policy increases the private cost of foregone productivity over tradable permits only, but is still less costly than the No TSARs policy.*

Biological Efficiency. For BE, Table 1 shows the NT treatment achieves 38%, the TO treatment 72%, and 84% for the TAB treatment. The null hypotheses of equal means are rejected at the 1% level for comparisons between NT and TAB and TO and TAB, and rejected at the 5% significance level for NT and TO. The introduction of a TSARs policy and the subsequent market in conservation improves BE. Adding an additional incentive mechanism, the agglomeration bonus, designed to coordinate conservation efforts within the landscape and create contiguous habitat reserve further improves BE. Note, the improvement in BE between NT and TO treatments is largely a result of the experimental construct. If the spatial allocation of low development valued land was less correlated, so that trade results in an offset in connectivity, it is conceivable that no differences in BE would be evident between the NT and TO treatments. Result 2 summarizes our findings.

Result 2. *In a landscape similar to the grid representation—low valued land is spatially correlated, allowing trade in conservation set-aside requirements results in net gains in Biological Efficiency. Combining TSARs with an Agglomeration Bonus improves Biological Efficiency; with the impact being greatest as low development value land is less spatially correlated.*

Economic Efficiency. Our measure of economic efficiency is best characterized as a measure of the ability of participants to comprehend the institution. Turning to Table 1 we see EE is 100% for the NT treatment, 67% EE in the TO treatment, and 84% in the TAB treatment. Pairwise comparisons using the Mann-Whitney test indicates the null hypotheses of equal means can be rejected at the 1% significance level for comparisons between the NT and TO treatments and the NT and TAB treatments, and at the 5% significance level between the TO and TAB treatments. EE is greatest in the NT treatment in which economic efficiency requires people to conserve their low cost land. Once trade was introduced, where potential gains from trade increases the size of the pie, EE decreased. Though some gains were realized as evidenced by the decrease in CE, individuals were unable to extract all of the rents from the market. EE improved with the introduction of the agglomeration bonus to the TSARs policy, because now the portion of earnings that are attributed to gains from trade are less than half of the total gains resulting from this two part incentive scheme (59% of gains can be earned prior to trade with the efficient spatial allocation of TSARs). We summarize in the following result.

Result 3. *The addition of a market, which requires people to interact effectively to extract maximum earnings, results in net social gains; however, the market also increases the money left on the table. The percent of rents not captured decreases when the agglomeration bonus is added to a TSARs policy.*

Spatial Efficiency. From Table 1 we see SE is 71% for TO and 63% for TAB. Using a Mann Whitney test we fail to reject the null hypothesis of equal means. The probability of allocating conserved parcels (and TSARs) to the spatial area that provides the lowest cost is not statistically different. Note, on average two more TSARs are traded to the low cost land.[9]

Result 4. *The final after trade distribution of TSARs to the low cost landowner is not different regardless if people see TSARs as a liability or an asset.*

Concluding comment

The success of tradable pollution permit programs at meeting air quality standards for regional air pollutants at minimum cost has encourage policy makers and academics to find ways of creating marketable instruments that can be readily applied to land uses (see e.g., Stavins, 1998). Limits do exist, however, in transferring the idea of the standard tradable air pollution permit policy to control land uses. Marketable instruments need to address explicitly two challenges: spatial heterogeneity in habitat quality and the poor correlation between land valued low for development but high for conservation.

Herein we examined two institutions that address these challenges—tradable set-aside requirements (TSARs), and TSARs combined with an agglomeration bonus, relative to the benchmark case of command and control. Compared across cost efficiency, biological efficiency, economic efficiency, and spatial efficiency, the results suggest TSARs can work given asymmetric landowners, habitat quality connectivity, high correlation between low cost land, and an opportunity set for conservation that includes millions of possible combinations of 20 conserved parcels. Combining TSARs with an agglomeration bonus improves habitat connectivity but at a greater cost.

[9] The spatial correlation of low cost land is primarily responsible for this result. It remains an open question as to whether a more dispersed spatial distribution of low production valued parcels would maintain the no difference result in hitting the spatial target.

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Table 1. Descriptive Statistics for Independent Samples

	NT	TO	TAB
CE	1.28 (0.00) 55	1.12 (0.096) 23	1.13 (0.073) 24
BE	0.38 (0.102) 58	0.72 (0.149) 32	0.84 (0.073) 39
EE	1 (0.00) 55	0.67 (0.224) 38	0.84 (0.086) 25
SE		0.71 (0.227) 13	0.63 (0.199) 28

Figure 1. The 10x10 Experimental Land Grid

Position 1 (top left) — Position 3 (top right)

40	40	40	40	40	50	50	50	50	50
40	40	40	40	40	40	50	50	50	50
40	40	40	40	40	40	40	50	50	50
40	40	40	40	40	40	40	40	50	50
40	40	40	40	40	40	40	40	40	50
30	30	40	40	40	40	40	40	40	40
30	30	30	40	40	40	40	40	40	40
20	30	30	30	40	40	40	40	40	40
20	20	30	30	30	40	40	40	40	40
20	20	20	30	30	30	40	40	40	40

Position 2 (bottom left) — Position 4 (bottom right)

Figure 2. Illustrative Example—No Subsidy

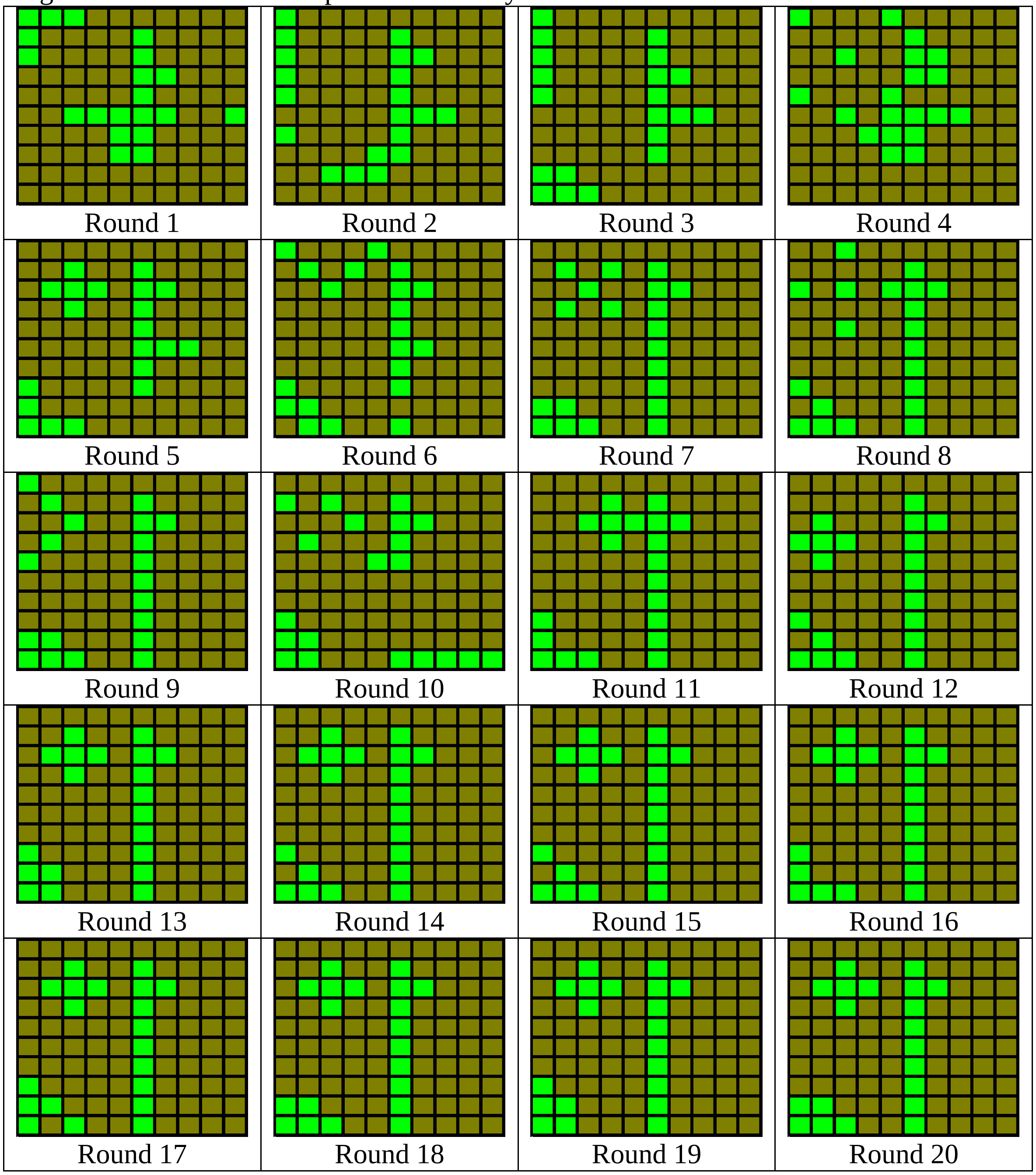

Figure 3. Illustrative Example—TSARs

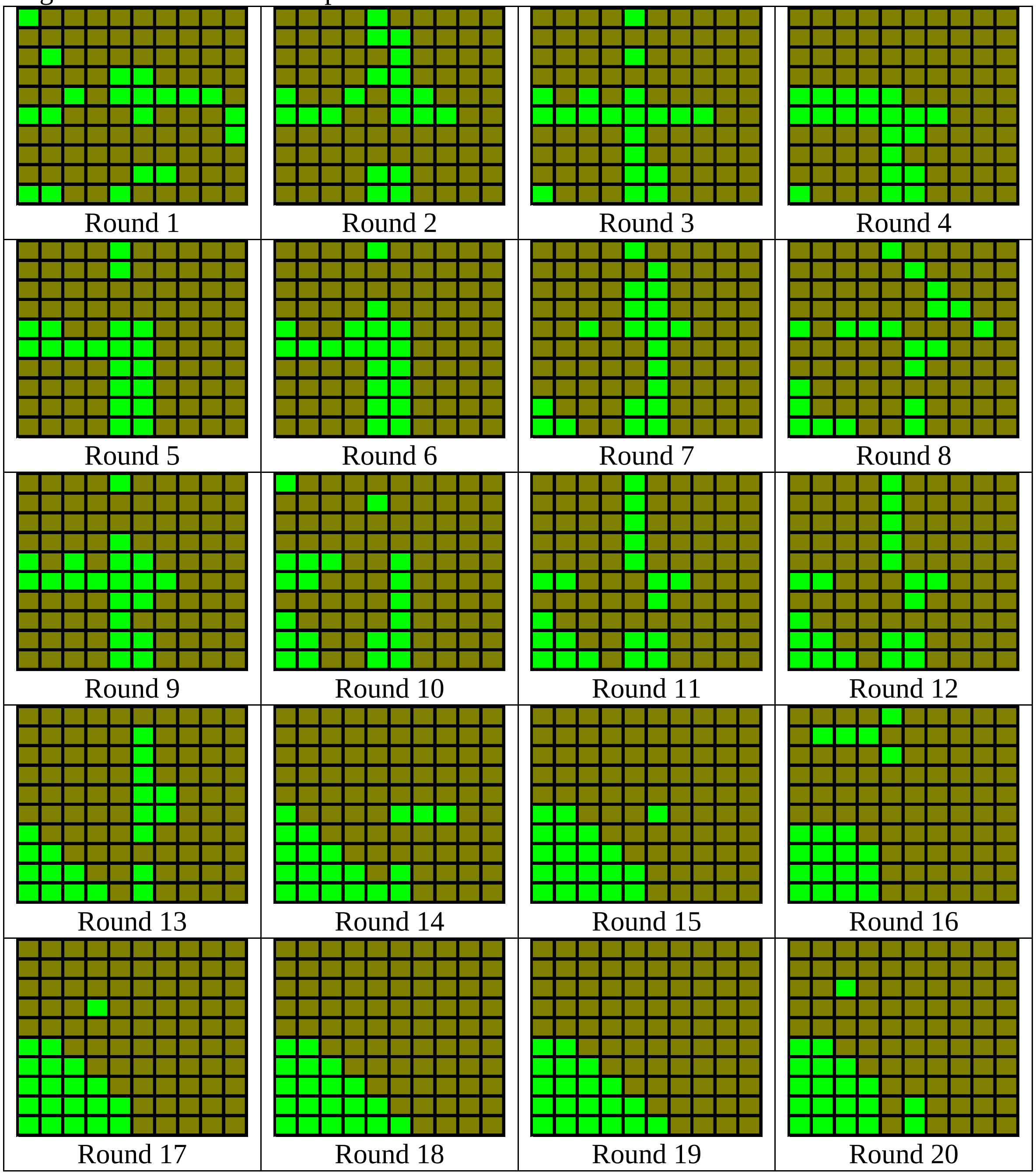

Figure 4. Illustrative Example—TSARs w/Agglomeration Bonus