Land conservation for open space:

The impact of neighbors and the natural environment

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Land conservation for open space: The impact of neighbors and the natural environment*

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Abstract

This paper investigates the impact of neighbors and the natural environment on private land conservation for open space. A spatially-explicit panel dataset is constructed to illustrate the spatial patterns of private land conservation over time. In the empirical analysis, I identify the endogenous spatial interactions and employ a correlated random-effects model to correct for the endogeneity of time-varying covariates. In addition to the number of neighbors as a commonly used proxy for the impact of neighbors, I incorporate the nearest distance to neighbors to alternatively estimate such an influence. The results show that there exist positive impacts of neighbors on the likelihood of private landowners' conservation decision. I also extend the literature by showing that such effects diminish with distance and present a non-linear pattern as the number of neighbors increases. Land parcel characteristics and conservation easement properties are also found to influence landowners' decision to place an easement.

Keywords: conservation easements, private land conservation, spatial spillovers, open space, conservation planning

JEL Classification: Q15, Q24, Q57, R52

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1 Introduction

Land conservation has been widely used as a policy tool to contain urban sprawl, protect habitat, and provide ecosystem services through programs such as conservation easements. Numerous studies have shown that the public has substantial willingness-to-pay for programs that conserve open space for various environmental and ecological amenities (see McConnell and Walls, 2005). Meanwhile, prior research also found that conserved open space was associated with higher nearby property values (Yoo and Ready, 2016) and that conserved open space may reallocate development rather than altering the total amount of development (Zipp et al., 2017). To design policies that can effectively guide the conservation of open space, an understanding of what affects land conservation decision is essential.

In literature, the importance of the spatial arrangement of conservation activity (e.g., proximity to other protected areas) has been recognized by economists, ecologists, and conservation planners (e.g., Braid and Nielsen, 2015; Wang and Swallow, 2016). Consistent with this line of research, protecting spatially contiguous open space has become particularly popular when government and private conservation agencies face scarce conservation budgets (Costello and Polasky, 2004). The significance of protecting spatially contiguous open space comes from at least two factors. First, agglomeration effects appear when land parcels are conserved in contiguity (Duke et al., 2015; Fooks et al., 2016) since additional environmental and ecological benefits arise. Second, conserving large contiguous tracts of land generally requires lower average conservation costs such as acquisition and management costs (Lynch and Lovell, 2003; Margules and Pressey, 2000). Taking into account the spatial configuration of conservation activity, government and conservation agencies are more likely to achieve cost-effective budget allocations. However, recent studies pointed out challenges associated with conservation planning in regions dominated by privately-held land where government and private conservation agencies cannot effectively decide the location of conserved land parcels (Polasky et al., 2014). Such a situation can be especially problematic in areas where private landowners have little incentive to coordinate conservation activity.

This paper aims to explore the impact of neighbors and the natural environment on the spatial patterns of private land conservation for open space in Maryland. There are three objectives in this paper: (1) to construct a spatially-explicit panel dataset of conservation easements for open space and depict the spatial patterns of private land conservation; (2) to identify endogenous spatial interactions among conservation for open space, independent of spatially correlated landscape features that influence the conservation decision; and (3) to investigate the impact of neighbors on private landowners' conservation decision, controlling for the endogenous location of open space.

The spatial interactions of conservation activity stem from the proximity of one conserved open space to another, through which positive or negative spillovers might arise due to conservation agencies' preference for spatially contiguous protected areas or landowners' conservation preferences of neighboring landowners (Lawley and Yang, 2015). For example, previous studies examined the spatial attraction and repulsion between different types of land conservation and found both crowding-in and crowding-out effects of government protected land on private land trust activity (Albers et al., 2008; Parker and Thurman, 2011). Knowledge of these effects is of practical importance since government agencies are likely to allocate scarce conservation funds inefficiently across space without an understanding of how different conservation groups, private landowners included, will react to the choices the government agencies make. While there exist mixed effects of public land conservation programs on private conservation activity, whether or not such influences exist within private land conservation remains a question. From the policy perspective, an understanding of spatial spillovers within private land conservation can provide the government with more insights to design more effective programs, especially in regions where private landowners have little incentive to coordinate conservation activity.

This study differs from previous research and makes several distinct contributions to the literature. First, instead of examining crowding-in and crowding-out effects of government protected land on private conservation activity, I focus on the impact of neighbors on land conservation decision between private landowners. Second, I use a parcel-level dataset to estimate the spatial spillovers in more detail while prior studies investigating the impact of neighbors generally used spatially aggregated data at either township or county level (Albers et al., 2008; Parker and Thurman, 2011). This also allows me to directly examine endogenous spatial interactions between private landowners while prior studies were not able to separately identify such interactions from either conservation agencies or landowners (Lawley and Yang, 2015). Third, in addition to the number of neighbors as a commonly adopted metric (Graziano and Gillingham, 2015; Lawley and Yang, 2015), I incorporate the nearest distance to neighboring conserved land parcels to alternatively estimate the impact of neighbors. To identify spatial spillovers from conventional spatial econometric models that are designed for cross-sectional dataset, I adopt the correlated random-effects model to control for unobserved land parcel-level heterogeneity as a function of the average of time-varying covariates. Lastly, I estimate the marginal effects of the impact of neighbors and the predicted probability of conservation decision based on the number of neighbors, allowing for heterogeneous thresholds that define neighbors.

2 Background and Study Area

Maryland has been a national leader in land conservation for more than 40 years. There are four major state funded land conservation programs operated in Maryland to protect natural resources, farmland, and open space. As of June 2013, these conservation programs, combined with the effort of local and federal governments as well as private land conservation agencies, have preserved a total of approximately 1.5 million acres in Maryland (Maryland Department of Natural Resource, 2014). While some land is purchased and owned by the state for public recreation or specific resource management objectives, some programs conserve private land through easements, meaning that the land remains private but is protected from future development.

Research on land conservation programs has received growing attention in Maryland. One strand of literature focuses on farmland preservation programs that aim to preserve productive and contiguous farmland. For instance, Lynch and Musser (2001) evaluated the effectiveness of programs in preserving agricultural land and identified the efficiency of various programs in achieving particular goals (e.g., maximum number of acres, contiguous parcels). Lynch and Lovell (2003) further explored the factors influencing participation in farmland preservation programs and indicated that the likelihood of participation increases with farm size, growing crops, and the share of income from farming. Another line of study focuses on how the conservation of open space affects local development patterns and property values. For example, Goeghegen (2002) found that in Howard County, houses located near open space were sold for higher prices than similar houses not located near open space and that conserved open space was associated with a higher price premium than developable open space. However, mixed results were reported by Goeghegen et al. (2003) that permanent open space had positive significant impacts on housing values in Calvert County with high development pressure, but did not have significant price effects in Carroll County with lower development pressure.

This study focuses on three adjacent counties (i.e., Baltimore County, Carroll County, and Harford County) in Maryland (Figure 1). Located in the Baltimore metro area, these three counties represent a combination of urban, suburban, exurban and rural land uses, and several prior studies have been conducted with respect to different aspects of land-use patterns and policies in this region. For instance, Zhang et al. (2016) found evident leapfrog development in these three counties spanning 1960-2005 and that such a development pattern declines over time, especially after the downzoning policy. Newburn and Ferris (2016) analyzed the downzoning policy in Baltimore County, and indicated that the policy did not significantly alter the probability of development but strongly affected the density of development. Wrenn and Irwin (2015) examined the effects of regulatory delay on residential subdivision development in Carroll County. Their results suggested that regulation-induced implicit costs reduce the subdivision development probability.

Although the growing interest in the policy effects from different land-use regulations that include land conservation programs, little is known about the spatial patterns of conservation for open space, nor the factors that influence private landowners' conservation decision. However, knowledge of such information is essential for both the government and private conservation agencies to more efficiently allocate scarce conservation funds.

[Figure 1 is about here]

3 The Conceptual Framework

The conceptual model is adapted from Lynch and Lovell (2003) that land ownership can be considered a bundle of rights. One option is to develop the land up to the allowable zoning density, when a landowner can sell the land without relinquishing the ownership. It is also assumed that a landowner can extract the value of development rights by selling the rights to a conservation agency and receiving a net easement payment, E_i, to keep the land in its current status perpetually. Alternatively, a landowner can sell the land parcel on the open market at some optimal date, t^*, for a net payment of D_i.

Different landowners may attach different levels of utility from owning a land parcel, from the net returns from agriculture, from the net easement payment, and from the net returns from converting the land to development in the optimal period. Given the heterogeneous landowner's preferences and land parcel characteristics, X_i, the utility of landowner i, V_i, can be modeled as a function of the non-consumptive value of owning the land parcel at time t, $Z_i(X_i, t)$, of the net annual agricultural returns per acre, $A_i(X_i, t)$, of the net value per acre of converting the land from current status to development at the optimal time t^*, $D_i(X_i)$, and of the net value per acre from selling the development rights linked to the land parcel, $E_i(X_i)$. Given the discount rate r, landowner i's time preference ρ, and time t, the utility for landowner i over the planning horizon can be maximized by choosing δ given:

$$\begin{aligned} V_i = max \Bigg\{ (1-\delta)\Bigg[\int_{t=0}^{t^*} U_i(A_i(X_i,t), Z_i(X_i,t))e^{-\rho t}dt + \int_{t^*}^{\infty} U_i(rD_i(X_i))e^{-\rho t}dt\Bigg] \\ + \delta\Bigg[\int_{t=0}^{\infty} U_i(A_i(X_i,t), Z_i(X_i,t), rE_i(X_i))e^{-\rho t}dt\Bigg]\Bigg\} \end{aligned} \tag{1}$$

where $\delta = 1$ if the landowner places a conservation easement on the land parcel, and $\delta = 0$ if the landowner retains the right to sell the land at the optimal time in the future, t^*. If a landowner's behavior is rational, he or she will choose to conserve the land ($\delta = 1$) when

$$\begin{aligned} &\int_{t=0}^{t^*} U_i(A_i(X_i,t), Z_i(X_i,t))e^{-\rho t}dt + \int_{t^*}^{\infty} U_i(rD_i(X_i))e^{-\rho t}dt \\ &\quad < \int_{t=0}^{\infty} U_i(A_i(X_i,t), Z_i(X_i,t), rE_i(X_i))e^{-\rho t}dt \end{aligned} \tag{2}$$

That is, the utility from selling the development rights for the easement payment and keeping the land in its current status exceeds the utility from keeping its current status until the optimal sales time and then selling the land on the open market.

However, a large body of research has begun to consider the role of social interactions (e.g., the impact of neighbors) in economic behavior in the sense that an individual's utility from a given action also depends on the decisions of that individual's neighbors (Brock and Durlauf, 2001). This type of spillover can be exemplified as a form of a classical non-pecuniary externality (Arrow and Hahn, 1971). Bernheim (1994) further stated that even when the underlying intrinsic utility from the actions differs widely across individuals due to heterogeneity of individual characteristics, the presence of externalities may create either a tendency towards common behavior or towards a polarized behavior within an individual's reference group. Some previous efforts have been made in this regard. For example, Irwin and Bockstael (2002) built the social interactions literature on spatial spillovers in residential development. Lewis et al. (2011) examined farmers' decision to adopt organic dairy farming with a focus on the role of learning about organic production from neighbors. In the case of land conservation, interactions between neighboring landowners might also lead to spatial spillovers between conserved areas due to landowners' learning about easements from their neighbors and social norms within landowners' social networks (Lawley and Yang, 2015). To incorporate the impact of neighbors, Equation (1) can be modified as follows:

$$\begin{aligned} V_i = max \Bigg\{ &(1-\delta)\left[\int_{t=0}^{t^*} U_i(A_i(X_i,t), Z_i(X_i,t), S_i(X_i,t))e^{-\rho t}dt + \int_{t^*}^{\infty} U_i(rD_i(X_i))e^{-\rho t}dt\right] \\ &+ \delta\left[\int_{t=0}^{\infty} U_i(A_i(X_i,t), Z_i(X_i,t), S_i(X_i,t), rE_i(X_i))e^{-\rho t}dt\right]\Bigg\} \end{aligned} \tag{3}$$

where $S_i(X_i, t)$ is the net value per acre from landowner i's neighboring conserved land parcels. Similarly, if a landowner's behavior is rational, he or she will choose to conserve the land ($\delta = 1$) when

$$\begin{aligned} &\int_{t=0}^{t^*} U_i(A_i(X_i,t), Z_i(X_i,t), S_i(X_i,t))e^{-\rho t}dt + \int_{t^*}^{\infty} U_i(rD_i(X_i))e^{-\rho t}dt \\ &\quad < \int_{t=0}^{\infty} U_i(A_i(X_i,t), Z_i(X_i,t), S_i(X_i,t), rE_i(X_i))e^{-\rho t}dt \end{aligned} \tag{4}$$

4 The Empirical Strategy

4.1 Creation of spatiotemporal neighbor variables

One major methodology in the empirical approach is the creation of spatiotemporal neighbor variables to capture the impact of neighboring conserved land parcels on landowners' conservation decision. For each conserved land parcel in the database, I record how many land parcels had previously been conserved within a 0.5-, 1-, and 2-mile radius following the similar practice by Graziano and Gillingham (2015) and Lawley and Yang (2015).

In specific, for each land parcel i, I counted the number of neighboring conserved land parcels at time t, such that:

$$I_{ij,t} = \begin{cases} 1 & \text{if} \ \ d_{ij,t} \leq D \\ 0 & \text{if} \ \ d_{ij,t} > D \end{cases}$$

$$n_{i,t} = \sum_{j=1}^{J} I_{ij,t}$$

where $d_{ij,t}$ is the Euclidean distance (in mile) between land parcel i and previously conserved land parcel j at time t, D is the distance threshold (i.e., 0.5-, 1-, and 2-mile), $I_{ij,t}$ is an indicator to represent whether or not the conserved land parcel j is counted, and $n_{i,t}$ is the number of conserved neighbors for land parcel i at time t.

To more precisely examine the effect at each distance threshold, I subtracted the inner distances from the outer radii to see the effects from 0.5-1 mile and from 1-2 mile. Another reason that different distance thresholds are chosen to define neighbors is to test the distance-decay effect. This multiple-ring buffer method is illustrated in Figure 2, where the buffers are both spatial and temporal.

[Figure 2 is about here]

4.2 Econometric model

I model the impact of neighboring conserved land parcels on the likelihood that a previously unconserved land parcel transitions into conserved status via an easement. In specific, the probability that land parcel i is conserved through an easement at time t given it has not yet been conserved is written as:

$$Prob\ (e_{i,t} = 1 | e_{i,t-1} = 0) = Prob\ (v_{i,t} > 0 | v_{i,t-1} \leq 0) \tag{5}$$

where $e_{i,t}$ is a binary variable that takes a value of one if land parcel i is conserved through an easement in period t, and $v_{i,t}$ is a latent variable that is greater than zero if $e_{i,t} = 1$ and less than or equal to zero if $e_{i,t} = 0$. The latent variable $v_{i,t}$ is specified as a linear function of the following form:

$$v_{i,t} = \alpha x_i + \beta y_{i,t} + \gamma z_t + \delta n_{i,t} + \phi d_{i,t} + \mu_i + \epsilon_{i,t} \quad (6)$$

where α, β, γ, δ, and ϕ are vectors of parameters to be estimated; x_i denotes observed time-invariant land parcel characteristics and spatial fixed effects (e.g., parcel size, soil quality, distance to major roads, rails, rivers, streams, and forested areas); $y_{i,t}$ denotes observed time-varying land parcel characteristics (e.g., local land values); z_t denotes a set of year fixed effects that capture time-varying factors common to all land parcels such as interest rates, exchange rates, and agricultural commodity prices; $n_{i,t}$ denotes the cumulative number of neighboring conserved land parcels of land parcel i at time t; $d_{i,t}$ denotes the nearest distance of land parcel i to the neighboring conserved land parcels at time t, where $d_{i,t} = min\{d_{ij,t}\}$ as defined in Section 4.1; μ_i is a time-invariant random effect that accounts for land parcel-specific unobserved characteristics; and $\epsilon_{i,t}$ is a zero-mean error term.

The data used in the analysis includes repeated observations of the land parcel-level decision to conserve, $e_{i,t}$, where $e_{i,t} = 1$ if $v_{i,t} > 0$, as defined in Equation (5). The use of the term repeated is not meant to imply that land parcels move back and forth between being conserved and unconserved. Rather, the implicit conservation decision for all unconserved land parcels is observed repeatedly over time (e.g., whether land parcels are conserved in 2000, conserved in 2001, etc.). Letting $\Phi(\cdot)$ denote the standard normal cumulative distribution function, the probability of placing a conservation easement, conditional on x_i, $y_{i,t}$, z_t, $n_{i,t}$, $d_{i,t}$, and μ_i is given by a probit model:

$$Prob\ (e_{i,t} = 1 | x_i, y_{i,t}, z_t, n_{i,t}, d_{i,t}, \mu_i) = \Phi(\alpha x_i + \beta y_{i,t} + \gamma z_t + \delta n_{i,t} + \phi d_{i,t} + \mu_i) \quad (7)$$

An alternative to motivate the decision process is a survivor model estimated with a Cox partial likelihood approach (e.g., Lawley and Yang, 2015; Towe and Lawley, 2013). However, as noted by Cameron and Trivedi (2005) and following Lewis et al. (2011), the approach using a binary probit model of the probability of conservation in each period, with separate intercepts for each period, can be interpreted as a simple hazard model.

4.3 Identification strategy

4.3.1 Endogenous spatial interactions

In this paper, I am particularly interested in identifying the impact of neighbors, $n_{i,t}$, on the probability of conserving the unconserved land parcels at time t. However, the set of variables, $n_{i,t}$, are likely to be endogenous in the econometric model for at least two reasons.

First, since the dataset used for estimation includes repeated conservation decisions over time, $n_{i,t}$ is by construction a function of the past conservation decisions from all land parcels that neighbor land parcel i (Lewis et al., 2011). Formally, endogeneity bias arises in estimation due to the reason that $n_{i,t}$ is an explicit function of $\mu_{i'}$ and $\epsilon_{i',t'}$, where i' indicates the set of land parcels that are considered neighbors to parcel i when $t' < t$.

Second, $n_{i,t}$ may be endogenous if there are spatially correlated unobservable characteristics that influence the conservation decisions of neighboring land parcels. Specifically in the context of conservation easements, landscape features tend to be positively correlated due to spatial clustering (Lawley and Yang, 2015). For instance, we might observe easements on neighboring land parcels driven solely by the fact that these land parcels share similar land cover and soil quality. In addition, correlated effects might also appear due to local factors such as the same municipal infrastructure (e.g., major roads and highways), municipal tax rates, and local economic development. These influences expose neighboring land parcels to the similar economic environment, and lead to the endogeneity problem if unobserved.

Prior work on discrete-choice panel data models has exploited the repeated observations of individual choices to correct for the endogeneity of time-varying covariates, using a correlated random-effects estimation strategy (Chamberlain, 1982; Mundlak, 1978) as the most notable work in this area. More recent research has adopted this approach to addressing the endogeneity issue when exploring the impact of neighbors (Lewis et al., 2011; Zipp et al., 2017). In this paper, treating μ_i as a random effect induces endogeneity if it is correlated with $n_{i,t}$. A correlated random-effects model builds the correlation between μ_i and $n_{i,t}$ into the model by specifying the land parcel-specific unobserved characteristics as follows:

$$\mu_i = \overline{n_{i,t}}\psi + \omega_i \tag{8}$$

where $\overline{n_{i,t}} = \frac{1}{T}\sum_{t=1}^{T} n_{i,t}$, the average of $n_{i,t}$ over all T periods that land parcel i is observed in the data. Note that since the model is defined for the decision to conserve the land parcel, the panel is unbalanced as land parcels drop from the dataset once they are conserved (see similar practice by Lawley and Yang, 2015; Lewis et al., 2011). $\overline{n_{i,t}}$ in Equation (8) is commonly referred to as the Mundlak-Chamberlain device (Chamberlai, 1982; Mundlak, 1978), which in this paper decomposes the land parcel-specific effect into a zero-mean normally distributed random variable, $\omega_i \sim N(0, \sigma^2)$. More generally, the Mundlak-Chamberlain device includes the average of all time-varying covariates included in the econometric model. As a result, Equation (8) can be modified as follows:

$$\mu_i = \overline{n_{i,t}}\psi + \overline{d_{i,t}}\xi + \omega_i \tag{9}$$

where $\overline{d_{i,t}} = \frac{1}{T}\sum_{t=1}^{T} d_{i,t}$, the average of $d_{i,t}$ over all T periods that land parcel i is observed in the data.

Using a correlated random-effects model as the identification strategy provides at least two advantages in this paper. First, it is more applicable when the regression function is non-linear and fixed-effects estimation is not appropriate (Wooldridge, 2002). In specific, by including $\overline{n_{i,t}}$ and $\overline{d_{i,t}}$, I can identify the spatial spillovers by isolating the effects of the number of conserved neighbors at the time of conservation decision from simply being in areas where land parcels are conserved more densely (which would be measured by a high value of $\overline{n_{i,t}}$ and a low value of $\overline{d_{i,t}}$). Second, correlated random-effects estimation works particularly well to consistently estimate the effect of neighboring land-use changes on the land conversion decision when repeated land-use decisions are observed within a landscape that is changing over time, as indicated by Lewis et al. (2011). A changing landscape allows me to adequately control for time-invariant unobservables and time-specific shocks to all land parcels, where spatial spillovers arise from spatial and temporal variation in the time of conservation (e.g., Irwin and Bockstael, 2002; Towe et al., 2008).

4.3.2 Space/time unobservables

There are some unobservables that likely affect a landowner's conservation decision and may be correlated with the location of open space, such as municipal taxation rates, local infrastructure, and community development, which can vary over both time and space (Lawley and Yang, 2015; Zipp et al., 2017). For example, communities that provide high levels of open space are also likely to provide high levels of other local infrastructure (e.g., small roads and bridges), which affect the conservation decision. On the other hand, conservation agencies may target areas that have lower levels of community development and thus cheaper land. To control for these time- and spatially-varying effects, I include in the model a full set of three counties and year dummies in this study. In addition, I include the county-specific land price (i.e., average market values of land and buildings) to control for time-varying spatially correlated factors that are substantial enough to be capitalized into land values.

As thoroughly discussed by Zipp et al. (2017), another potential source of bias comes from the omission of developable − as opposed to conserved − open space as an independent variable affecting the conservation decision. Omitting developable open space could bias the estimation if developable open space is correlated with conserved open space and further influences the probability of conservation. However, this may not be a concern in this study since the use of county/year fixed effects as well as land price likely controls for the most important variation in developable open space.

5 Data

Data for this study come from several sources. The conservation easements data is from the *National Conservation Easement Database* (NCED). The NCED team, together with its partner groups, developed the database by incorporating a list of organizations that could potentially hold conservation easements such as local land trust organizations, national or regional conservation organizations, state agencies, and federal agencies. The geo-referenced dataset includes land parcel information such as the enrollment year of the easement, the geographical location, the parcel size, the easement holder type (e.g., federal, state, non-governmental organization), the landowner type (e.g., federal, state, non-governmental organization, private) etc. Based on the landowner type, the geographical location, and the enrollment year, I assemble a land parcel-level spatial panel dataset that documents all private land conservation in three counties in Maryland (i.e., Baltimore County, Carroll County, and Harford County) from 2000 to 2009. Figure 3 illustrates the spatial distribution of private land parcels on conservation easements in the study area over 2000-2009.

[Figure 3 is about here]

The location data for major cities (i.e., Aberdeen, Baltimore City, and Westminster), major roads, rails, rivers, streams, and forested areas are from *MdProperty View* managed by the Maryland Department of Planning. The hydric soils data (e.g., drainage class, slope gradient, and whether or not the soil is hydric) is from the Maryland GIS Data Catalog. The data for local land values (i.e., estimated average market value of land and buildings per acre) is provided by the Maryland Department of Planning.

All the distance analysis, the identification of neighbors, and the calculation of neighbor numbers are conducted through *ArcGIS*. Table 1 presents summary statistics for the dependent and explanatory variables used in the empirical analysis.

[Table 1 is about here]

6 Results and Discussion

6.1 Primary results

Tables 2-5 present the regression results from four different model specifications that incorporate county dummies, year dummies, and/or correlated random-effects. The results generally conform to the theory and are consistent with previous studies in this field.

First, land parcel characteristics influence the likelihood of private landowners' conservation decision. For example, land parcels closer to major cities are less likely to have an easement. This is primarily due to the increased residential development pressure in proximity to urban areas (Lawley and Yang, 2015). However, being closer to the existing forested areas increases landowners' propensity to place an easement on their land. Such a result is intuitive given that private conservation is more likely to be established in places with existing high-value natural resources such as wetlands and forests (Albers et al., 2008). Parcel size is a significant factor in explaining landowners' conservation decision such that higher acreage increases the probability of land being conserved. This is consistent with Lynch and Lovell (2003) that landowners' participation in agricultural land preservation programs is positively correlated to the farm size. Another observation is that having hydric soils decreases the likelihood of land conservation. Considering that land containing hydric soils may be too wet for agricultural production and that hydric soils force out air, especially oxygen, from soil pores, landowners are expected to obtain lower returns from agriculture.

Second, some properties of conservation easements also influence the conservation decision. In specific, the probability of having an easement is higher if a land parcel is conserved for farming. As indicated by Cross et al. (2011), agricultural property holds unique meanings for landowners as a source of financial well-being and a place of work, based on which landowners develop a sense of place and attachment. Further, having non-governmental organizations (NGOs) as the easement holder encourages landowners to participate in conservation programs. This finding corresponds to a similar argument by Stroman and Kreuter (2014) that landowners whose easement is held by either a federal or state government are more likely to express dissatisfaction relative to landowners whose easement is held by an NGO.

Third, there exist positive impacts of neighbors on the likelihood of private landowners' conservation decision. Such a finding can be supported by two facets in this paper. For one thing, the coefficient estimate of nearest distance to neighbors is significantly negative. This indicates that being closer to previously conserved land parcels increases the likelihood of landowners' decision to place an easement. For the other, the parameters of number of neighbors within 0.5 mile, 0.5-1 mile, and 1-2 mile are all positive and significant. These results suggest that neighboring eased land parcels stimulate the odds of an additional easement. This outcome is consistent with a prior study on the prairie pothole easements (Lawley and Yang, 2015). Lynch and Lovell (2003) found similar results that that hearing from a neighbor about the preservation information increases the likelihood of joining the farmland preservation programs for landowners.

[Tables 2-5 are about here]

6.2 The impact of neighbors

Based on the coefficient estimates from Tables 3-5, I further report the average marginal effects that vary by the number of neighboring conserved land parcels when other explanatory variables evaluated at mean. Two notable findings can be drawn from Table 6.

First, it is evident that the impact of neighbors on the likelihood of landowners' conservation decision diminishes with distance. For example, the first easement within 0.5 mile, 0.5-1 mile, and 1-2 mile increases the likelihood of a new easement by 13.7%, 5%, and 1%, respectively. This is consistent with a previous argument that spatial spillovers among landowners become weaker when neighbors are more distant (Lawley and Yang, 2015). Such results are of significant practice and could provide important policy implications. On the one hand, landowners do learn about conservation easements from their neighbors, with possible reputation effects associated with easements. Prior studies on landowners' preferences for conservation easements indicated that a good relationship between landowners and land trusts improves the possibility of reaching an easement agreement (Bastian et al., 2017; Cross et al., 2011). To take the advantage of the positive impact of neighbors among landowners, conservation agencies may want to take more proactive actions to maintain the relationship with their previous clients (i.e., private landowners). On the other hand, since the influence from neighbors substantially declines with distance, conservation agencies will need to know how to more strategically target new clients given their limited conservation budgets.

Second, the marginal effects present a non-linear pattern as the number of neighbors increases. In specific, there exists a threshold such that the marginal effects start to drop when the cumulative number of neighboring easements reaches the threshold. Furthermore, the threshold differs when the distance to define the neighbors varies. In the case of neighbors within 0.5 mile, for instance, the marginal effect increases to a maximum of 15% when the number of neighbors is two. If we focus on neighbors within 0.5-1 mile, the marginal effect reaches the maximum 8.3% when the number of neighbors is five. Such an outcome also has some notable policy implications. For example, while incentives to advocate private conservation may work effectively in regions where there are few conserved land parcels, the same policy interventions may not live up to the same expectation if there are already many conserved land parcels in the area. In other words, the government entities and conservation agencies may want to take into consideration the density of existing conservation easements when providing monetary bonuses to encourage private land conservation.

[Table 6 is about here]

6.3 Predicted probabilities estimation

Last but not the least, the predicted probabilities of conservation decision are calculated with varying numbers of neighboring conserved land parcels, when the rest of predictors set to their mean values, as shown in Table 7. In general, a rising number of neighbors increases the probability of having a new easement. This result makes sense given the positive marginal effects presented in Section 6.2. However, one can observe from Table 7 that in the case when 0.5 mile is chosen as the threshold to define neighbors, increasing the number of neighbors after six does not really improve the probability of having a new easement. In detail, the probability of conserving a new easement is higher than 90% given six neighbors and other explanatory variables with mean values. This result corresponds to the discussion in Section 6.2 that the marginal effects of the number of neighbors present a decreasing pattern after the threshold at which a maximal value is achieved.

[Table 7 is about here]

6.4 Robustness check

One unobservable factor that might be correlated with the number of neighbors, $n_{i,t}$, is exogenous easement holder (e.g., a government entity or conservation agency) preferences. As indicated by Lawley and Yang (2015), conservation easements may be placed on land parcels adjacent to previously protected areas if the government or conservation agencies attempt to capture additional ecological benefits or lower average conservation costs arising from contiguous conserved land parcels. This is especially true when easement holders face limited conservation budgets.

In a more basic sense, a government entity or conservation agency might target multiple neighboring land parcels for conservation. If these easement holders manage to place easements on different neighboring land parcels in different time periods (e.g., through advertisement or economic incentives), what might induce endogenous spatial interactions among conserved land parcels would also be due to unobserved characteristics or preferences of the easement holder.

Since I observe the type of easement holders in the NCED dataset, I conduct the following robustness check. I run four model specifications by type of easement holder, taking into account the space/time unobservables and/or correlated random-effects. The results of the robustness check are presented in Table 8. Similar to the findings in Tables 2-5, first, we can see that an increase in the number of neighboring easements increases the likelihood of an easement for all three distance thresholds. In addition, as expected, being closer to previously conserved land parcels increases the likelihood of landowners' decision to place an easement. Second, a comparison of the baseline model and the models specified by type of easement holder indicates shows quite similar and consistent coefficient estimates of nearest distance to neighbors and number of neighbors. These results suggest that unobserved characteristics or preferences of easement holders that might be correlated to the decision of conservation easements are not driving the baseline results in this study.

[Table 8 is about here]

7 Concluding Remarks

This study investigates the impact of neighbors and the natural environment on private landowners' conservation decision in three adjacent counties in Maryland. A spatially-explicit panel dataset is constructed to illustrate the spatial patterns of private land conservation spanning 2000-2009. Instead of examining the spatial interactions between public and private conservation, I contribute to the literature by directly working on the determinants of private land conservation and the potential spatial spillovers. In the empirical analysis, I identify the endogenous spatial interactions and employ a correlated random-effects model to correct for the endogeneity of time-varying covariates. Another contribution is that I incorporate the nearest distance to neighbors to estimate the impact of neighbors, in addition to the number of neighbors as a commonly used metric.

The results are generally consistent with the theory and previous studies. In detail, land parcel characteristics, such as parcel size and proximity to forested areas, are positively associated with the increased probability of private landowners' conservation decision. However, land parcels closer to major cities or with hydric soils are less likely to have an easement. In addition, some easement properties also affect the odds of conservation decision. I find that the probability of having an easement is higher if a land parcel is conserved for the purpose of farming and if the easement is held by non-governmental organizations.

The key finding from this study is the positive impact of neighbors on the likelihood of private landowners' conservation decision. The results from both the number of neighbors and the nearest distance to neighbors confirm such an influence from neighbors. However, the neighbor effect is found to diminish with distance and present a non-linear pattern as the number of neighbors increases. The robustness check further suggests that unobserved characteristics of easement holders that might be correlated to the placement of conservation easements are not a concern in this study. The findings from this paper shall provide significant and practical policy implications for the local government and other interested stakeholders. If private landowners' interactions are evident, economic incentives to enroll land in easements also serve as an investment in moral suasion such that neighboring landowners become more likely to subsequently enroll their land in an easement. Policy makers may want to take into account the positive impact of neighbors when designing voluntary environmental stewardship programs that aim to educate private land managers and to provide support for conservation.

However, some caveats exist in this paper. Although the inclusion of county and year dummies can possibly account for most spatially correlated unobservables in the model, it is important to note that this study can not account for all spatially correlated unobservables. For instance, some unobserved landowner preferences for conservation easements (e.g., social norm) might also be positively spatially correlated but are not captured in the model. In addition, the correlated random-effects strategy does not, however, provide a behavioral identification of why spatial spillovers arise in private landowners' conservation decision, as pointed out by Lewis et al. (2011). Therefore, future research may want to require further detailed survey data from private landowners to investigate the above issues. Consequently, a combination of spatial and survey data is imperative to thoroughly explain private landowners' enrollment of land conservation programs.

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Table 1: Summary Statistics of Variables (N=1396)

Variables	Mean	S.D.	Min.	Max.
Dependent variable				
conservation easement (1 or 0)	0.268	0.443	0	1
Explanatory variables				
number of neighbors within 0.5 mile	2.242	3.249	0	24
number of neighbors within 0.5-1 mile	6.431	6.634	0	33
number of neighbors within 1-2 mile	22.50	15.99	0	71
nearest distance to neighbors (mile)	0.521	0.397	0.010	4.911
nearest distance to major cities (mile)	8.316	4.241	0.011	22.15
nearest distance to major roads (mile)	0.761	0.568	0.001	3.039
nearest distance to forested areas (mile)	2.552	1.182	0.016	6.588
nearest distance to rivers (mile)	4.848	2.296	0.010	9.947
nearest distance to streams (mile)	0.162	0.165	0.001	2.203
NGO as the easement hold type (1 or 0)	0.612	0.488	0	1
farming as the easement purpose (1 or 0)	0.368	0.483	0	1
parcel size (acres)	45.36	49.30	0.696	307.6
well drained soil class (1 or 0)	0.742	0.438	0	1
hydric soil (1 or 0)	0.053	0.224	0	1
slope gradient	10.64	8.918	0	55
land price ($1,000 per acre)	6.419	1.142	4.570	9.721
Baltimore County (1 or 0)	0.581	0.494	0	1
Carroll County (1 or 0)	0.384	0.487	0	1
Harford County (1 or 0)	0.035	0.184	0	1

Table 2: Coefficient estimates with nearest distance to neighbors (N=1396)

Explanatory variables	Model I	Model II	Model III	Model IV
nearest distance to neighbors	-2.800***	-2.991***	-2.870***	-2.997***
	(0.408)	(0.422)	(0.428)	(0.441)
nearest distance to major cities	-0.034***	-0.052***	-0.034***	-0.054***
	(0.012)	(0.013)	(0.012)	(0.013)
nearest distance to major roads	0.124*	0.191**	0.113	0.217***
	(0.074)	(0.077)	(0.075)	(0.078)
nearest distance to forested areas	0.106***	0.134***	0.111***	0.140***
	(0.035)	(0.036)	(0.036)	(0.037)
nearest distance to rivers	-0.046**	-0.051***	-0.045**	-0.047**
	(0.019)	(0.019)	(0.019)	(0.019)
nearest distance to streams	-0.160	-0.190	-0.197	-0.324
	(0.244)	(0.248)	(0.252)	(0.261)
NGO as the easement hold type	0.476	0.184	1.374**	1.324*
	(0.406)	(0.431)	(0.627)	(0.708)
farming as the easement purpose	1.310***	1.300***	2.040***	2.433***
	(0.419)	(0.423)	(0.623)	(0.705)
parcel size	0.003***	0.002**	0.003***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
well drained soil class	-0.011	0.015	-0.013	0.018
	(0.104)	(0.106)	(0.106)	(0.108)
hydric soil	-0.333	-0.307	-0.359	-0.378
	(0.231)	(0.232)	(0.229)	(0.243)
slope gradient	0.008	0.008*	0.010**	0.009*
	(0.005)	(0.005)	(0.005)	(0.005)
land price	2.925***	0.450***	0.275**	-1.104***
	(0.389)	(0.049)	(0.115)	(0.382)
county dummies	No	Yes	No	Yes
year dummies	No	No	Yes	Yes
correlated random-effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.150	0.164	0.172	0.198

Standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 3: Coefficient estimates with the number of neighbors within 0.5 mile (N=1396)

Explanatory variables	Model I	Model II	Model III	Model IV
number of neighbors within 0.5 mile	0.589***	0.573***	0.612***	0.616***
	(0.086)	(0.086)	(0.089)	(0.089)
nearest distance to major cities	-0.033***	-0.048***	-0.033***	-0.049***
	(0.012)	(0.013)	(0.012)	(0.013)
nearest distance to major roads	0.126*	0.180**	0.119	0.214***
	(0.073)	(0.076)	(0.075)	(0.077)
nearest distance to forested areas	0.063*	0.082**	0.069*	0.089**
	(0.034)	(0.035)	(0.035)	(0.036)
nearest distance to rivers	-0.053***	-0.056***	-0.053***	-0.052***
	(0.019)	(0.019)	(0.019)	(0.019)
nearest distance to streams	-0.163	-0.204	-0.195	-0.349
	(0.241)	(0.245)	(0.249)	(0.259)
NGO as the easement hold type	0.305	0.051	1.221**	1.280*
	(0.379)	(0.402)	(0.614)	(0.717)
farming as the easement purpose	1.018***	0.997**	1.775***	2.226***
	(0.390)	(0.393)	(0.609)	(0.713)
parcel size	0.003***	0.002**	0.003***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
well drained soil class	-0.025	-0.001	-0.415	-0.002
	(0.104)	(0.104)	(0.105)	(0.107)
hydric soil	-0.379*	-0.368	-0.415*	-0.453*
	(0.228)	(0.228)	(0.236)	(0.241)
slope gradient	0.006	0.006	0.008	0.006
	(0.005)	(0.005)	(0.005)	(0.005)
land price	0.375***	0.388***	0.221*	-1.368***
	(0.049)	(0.051)	(0.115)	(0.400)
county dummies	No	Yes	No	Yes
year dummies	No	No	Yes	Yes
correlated random-effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.143	0.153	0.167	0.193

Standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 4: Coefficient estimates with the number of neighbors within 0.5-1 mile (N=1396)

Explanatory variables	Model I	Model II	Model III	Model IV
number of neighbors within 0.5-1 mile	0.462***	0.463***	0.466***	0.448***
	(0.053)	(0.054)	(0.056)	(0.056)
nearest distance to major cities	-0.026**	-0.042***	-0.029**	-0.044**
	(0.012)	(0.013)	(0.012)	(0.013)
nearest distance to major roads	0.105	0.168**	0.110	0.197**
	(0.074)	(0.077)	(0.076)	(0.078)
nearest distance to forested areas	0.074**	0.085**	0.073**	0.094**
	(0.035)	(0.036)	(0.036)	(0.037)
nearest distance to rivers	-0.043**	-0.047**	-0.045**	-0.044**
	(0.019)	(0.019)	(0.019)	(0.019)
nearest distance to streams	-0.084	-0.157	-0.151	-0.302
	(0.239)	(0.244)	(0.248)	(0.256)
NGO as the easement hold type	0.359	-0.031	1.184*	1.265*
	(0.375)	(0.398)	(0.621)	(0.718)
farming as the easement purpose	0.993**	0.936**	1.775***	2.236***
	(0.388)	(0.390)	(0.618)	(0.716)
parcel size	0.002***	0.002**	0.003***	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
well drained soil class	0.022	0.051	0.027	0.054
	(0.106)	(0.107)	(0.107)	(0.109)
hydric soil	-0.383	-0.359	-0.422*	-0.458*
	(0.235)	(0.236)	(0.243)	(0.248)
slope gradient	0.006	0.005	0.007	0.005
	(0.005)	(0.005)	(0.005)	(0.005)
land price	0.308***	0.301***	0.300***	-1.210***
	(0.053)	(0.056)	(0.116)	(0.400)
county dummies	No	Yes	No	Yes
year dummies	No	No	Yes	Yes
correlated random-effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.174	0.183	0.193	0.216

Standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 5: Coefficient estimates with the number of neighbors within 1-2 mile (N=1396)

Explanatory variables	Model I	Model II	Model III	Model IV
number of neighbors within 1-2 mile	0.447***	0.455***	0.507***	0.488***
	(0.033)	(0.033)	(0.037)	(0.037)
nearest distance to major cities	0.005	-0.016	-0.002	-0.017
	(0.013)	(0.014)	(0.014)	(0.014)
nearest distance to major roads	0.056	0.134	0.059	0.127
	(0.081)	(0.084)	(0.083)	(0.086)
nearest distance to forested areas	0.049	0.061	0.026	0.050
	(0.038)	(0.039)	(0.039)	(0.040)
nearest distance to rivers	-0.028	-0.028	-0.025	-0.026
	(0.020)	(0.020)	(0.020)	(0.021)
nearest distance to streams	-0.023	-0.095	-0.136	-0.254
	(0.252)	(0.260)	(0.268)	(0.276)
NGO as the easement hold type	0.459	-0.062	1.219*	1.224
	(0.394)	(0.417)	(0.699)	(0.798)
farming as the easement purpose	0.768*	0.708*	1.600**	1.939**
	(0.404)	(0.407)	(0.693)	(0.795)
parcel size	0.002*	0.001	0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
well drained soil class	0.004	0.057	0.016	0.054
	(0.115)	(0.117)	(0.119)	(0.120)
hydric soil	-0.385	-0.341	-0.372	-0.380
	(0.255)	(0.257)	(0.270)	(0.274)
slope gradient	0.004	0.002	0.004	0.003
	(0.005)	(0.006)	(0.006)	(0.006)
land price	-0.027	-0.041	0.150	-0.847**
	(0.053)	(0.067)	(0.128)	(0.423)
county dummies	No	Yes	No	Yes
year dummies	No	No	Yes	Yes
correlated random-effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.297	0.312	0.333	0.346

Standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 6: Average marginal effects of the number of neighbors

Number of neighbors	within 0.5 mile	within 0.5-1 mile	within 1-2 mile
0	0.099***	0.034***	0.007***
	(0.010)	(0.002)	(0.001)
1	0.137***	0.050***	0.010***
	(0.018)	(0.003)	(0.001)
2	0.150***	0.065***	0.014***
	(0.015)	(0.005)	(0.001)
3	0.133***	0.076***	0.017***
	(0.005)	(0.005)	(0.001)
4	0.101***	0.082***	0.020***
	(0.006)	(0.004)	(0.001)
5	0.071***	0.083***	0.021***
	(0.009)	(0.003)	(0.001)
6	0.050***	0.080***	0.021***
	(0.007)	(0.002)	(0.001)
7	0.038***	0.074***	0.022***
	(0.004)	(0.001)	(0.001)
8	0.031***	0.066***	0.023***
	(0.002)	(0.001)	(0.000)
9	0.026***	0.057***	0.025***
	(0.001)	(0.002)	(0.000)
10	0.021***	0.048***	0.028***
	(0.001)	(0.002)	(0.001)

Delta-method standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 7: Predicted probabilities with varying number of neighbors

Number of neighbors	within 0.5 mile	within 0.5-1 mile	within 1-2 mile
0	0.020**	0.000	0.000
	(0.010)	(0.000)	(0.000)
1	0.070***	0.001	0.000
	(0.016)	(0.001)	(0.000)
2	0.188***	0.002	0.000
	(0.013)	(0.002)	(0.000)
3	0.384***	0.134	0.000
	(0.027)	(0.084)	(0.000)
4	0.616***	0.029***	0.000
	(0.057)	(0.010)	(0.000)
5	0.812***	0.075***	0.000
	(0.063)	(0.014)	(0.000)
6	0.930**	0.164***	0.000
	(0.043)	(0.013)	(0.000)
7	0.980***	0.302***	0.000
	(0.019)	(0.016)	(0.000)
8	0.996***	0.478***	0.000
	(0.006)	(0.033)	(0.000)
9	0.999***	0.658***	0.000
	(0.001)	(0.049)	(0.000)
10	0.999***	0.807***	0.000
	(0.000)	(0.051)	(0.000)

Delta-method standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

Table 8: Coefficient estimates by type of easement holder

Selected explanatory variables	Model I	Model II	Model III	Model IV
type of easement holder: NGO (N=854)				
nearest distance to neighbors	-2.563***	-2.703***	-2.870***	-3.081***
	(0.546)	(0.565)	(0.578)	(0.599)
number of neighbors within 0.5 mile	0.564***	0.558***	0.620***	0.626***
	(0.095)	(0.095)	(0.099)	(0.099)
number of neighbors within 0.5-1 mile	0.441***	0.442***	0.451***	0.444***
	(0.063)	(0.063)	(0.066)	(0.067)
number of neighbors within 1-2 mile	0.417***	0.425***	0.508***	0.504***
	(0.040)	(0.041)	(0.047)	(0.048)
type of easement holder: state government (N=514)				
nearest distance to neighbors	-2.804***	-2.367***	-2.720***	-2.557***
	(0.693)	(0.688)	(0.701)	(0.713)
number of neighbors within 0.5 mile	0.977***	0.796***	0.848***	0.769***
	(0.257)	(0.258)	(0.253)	(0.259)
number of neighbors within 0.5-1 mile	0.599***	0.532***	0.578***	0.579***
	(0.110)	(0.115)	(0.117)	(0.118)
number of neighbors within 1-2 mile	0.529***	0.520**	0.580***	0.542***
	(0.063)	(0.067)	(0.071)	(0.070)
county dummies	No	Yes	No	Yes
year dummies	No	No	Yes	Yes
correlated random-effects	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, and * p<0.10.

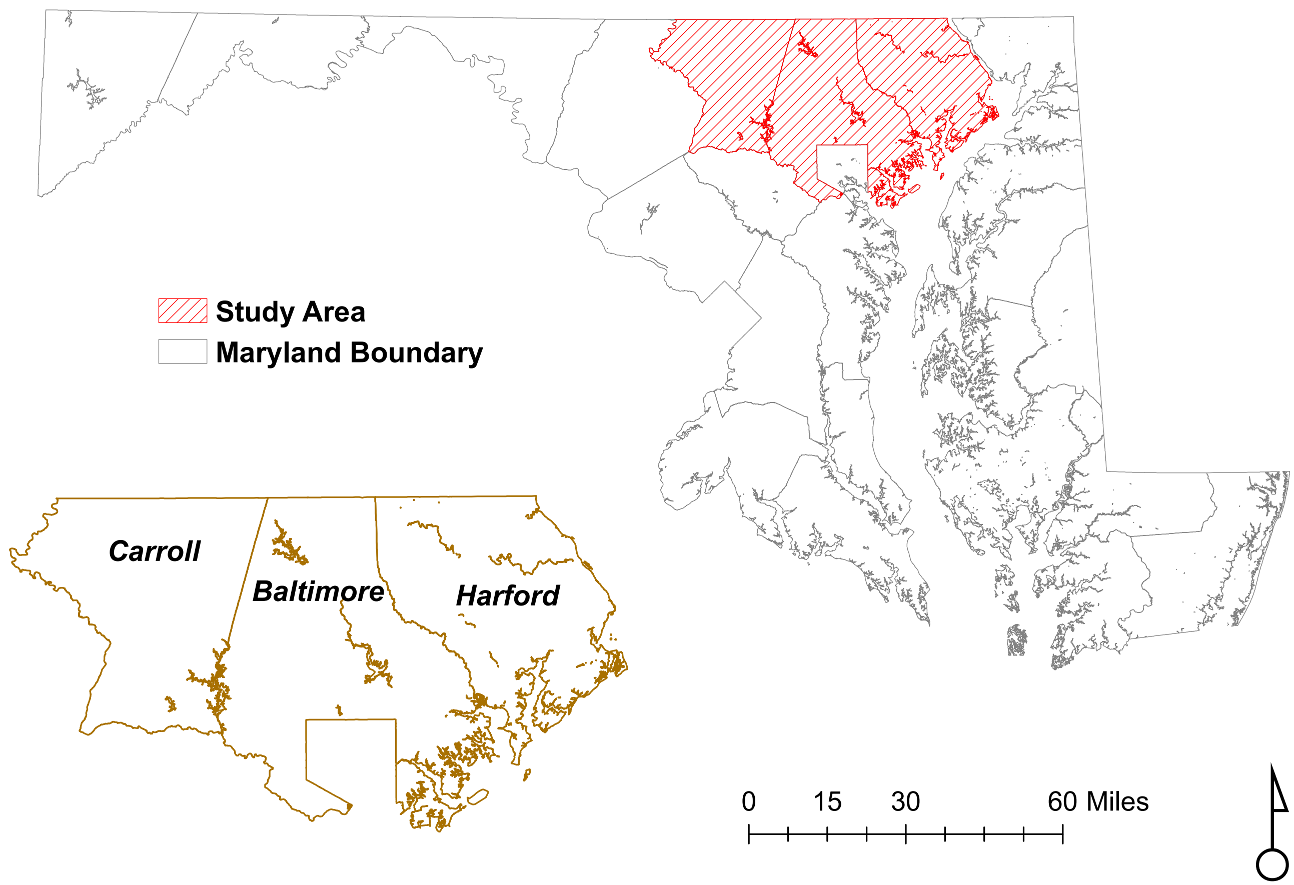

Figure 1: Study Area

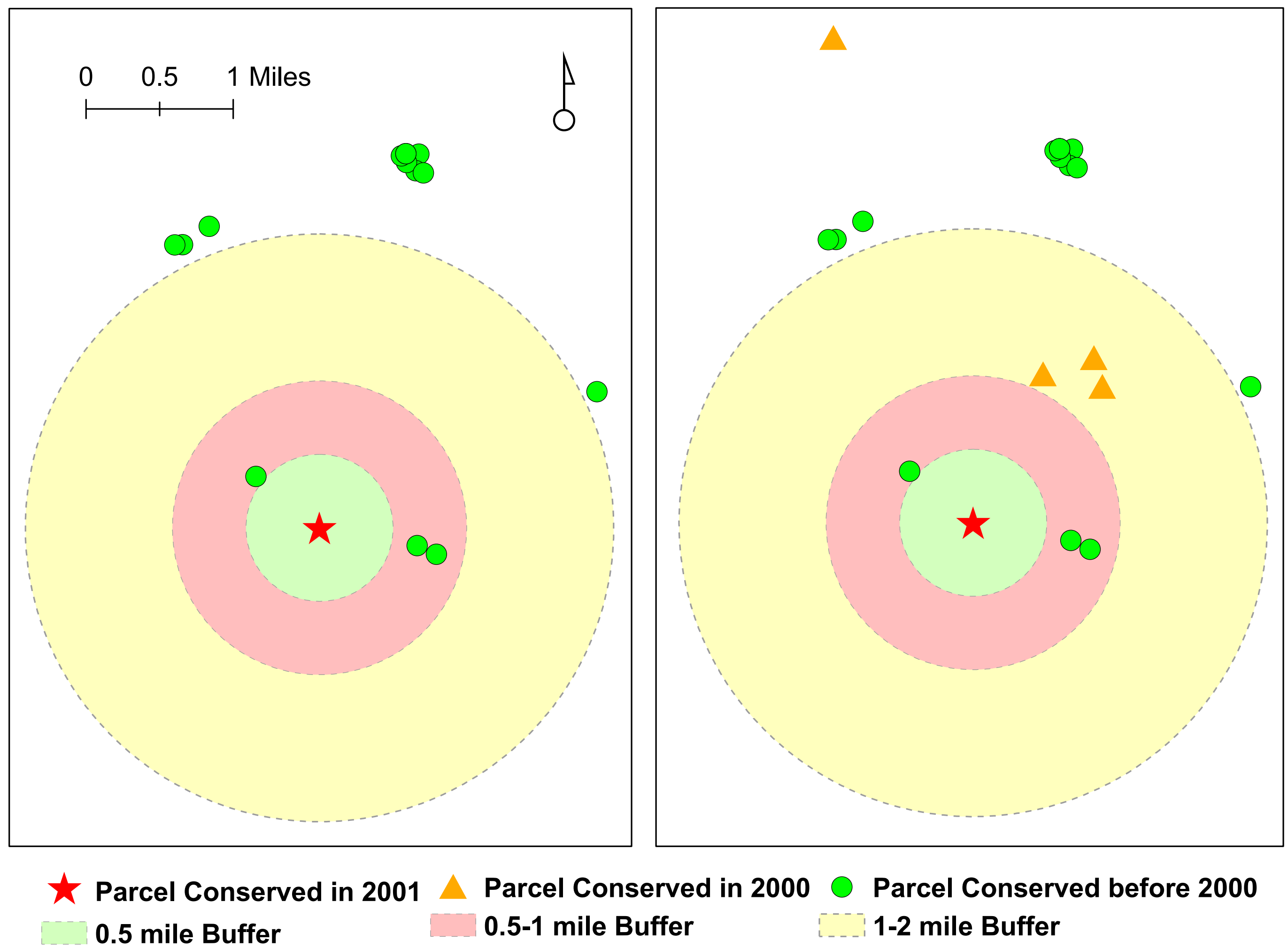

Figure 2: Demonstration of neighbors

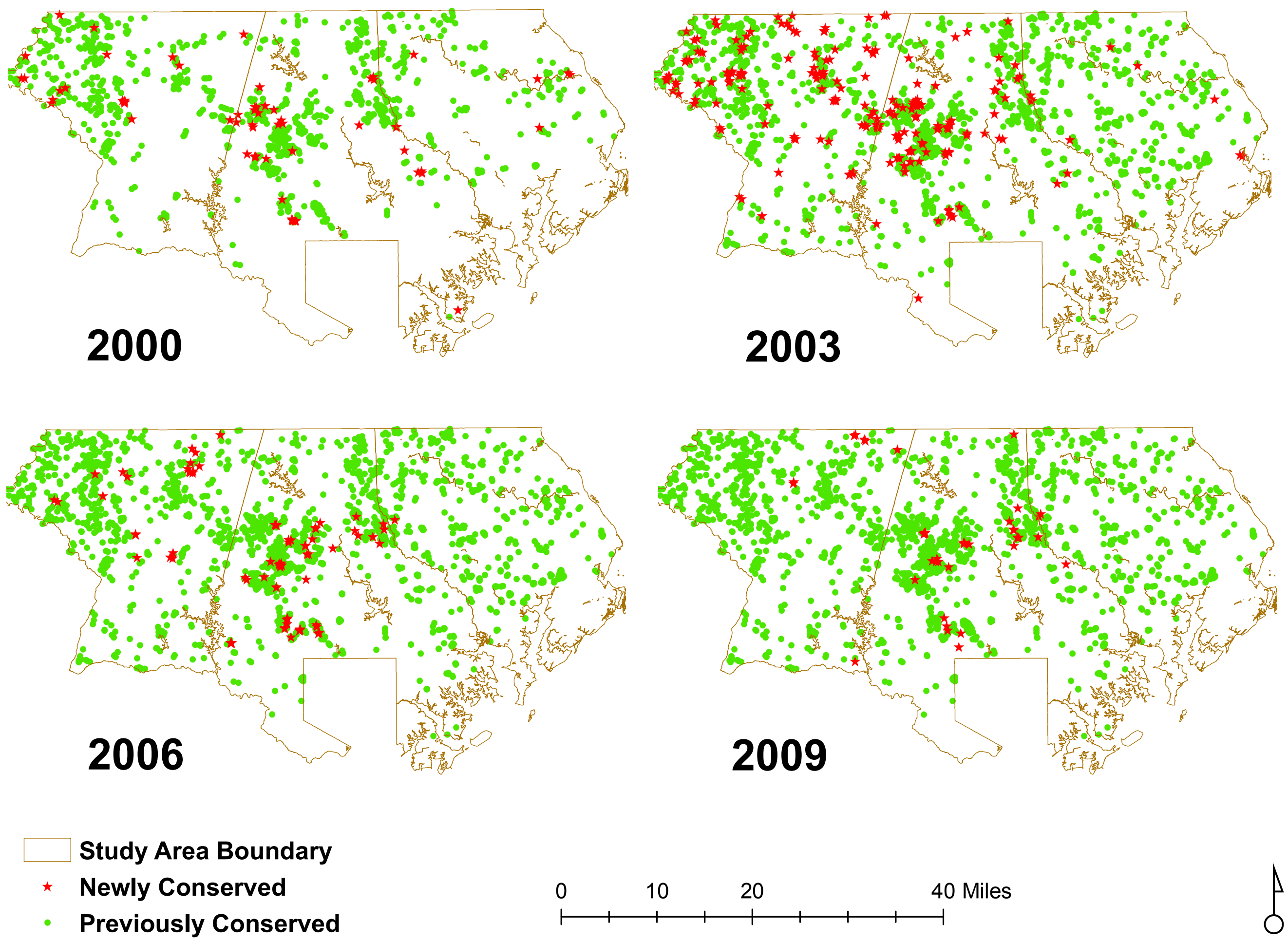

Figure 3: Spatial patterns of private conservation easements in the study area