Effects of size of protected areas on ecological and economic effectiveness

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Abstract

This research analyzes how the size of protected areas influences the ecological and economic effectiveness through a return-on-investment in conservation (ROI) to help conservation organizations prioritize protected areas. Using the case study, we focus on whether the size variation has implications on ROI that is estimated by local richness (i.e., the total number of target species represented within a set of protected areas) divided by acquisition cost. We found that (i) local richness on a dollar invested to acquire a parcel is greater for smaller parcels than larger parcels and (ii) almost one half of the total effect of protected size on ROI is spillover effect. Our findings suggest that smaller land parcels should be prioritized for protection as part of an ecological and economic conservation strategy with understanding of spatial spillover effect of size of protected area on ROI.

Subjects keywords: Ecological and economic effectiveness, Return-on-investment, Size of protected area

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Introduction

Background

The academic literature has focused on a return-on-investment in conservation (ROI) to help conservation organizations prioritize protected areas (e.g., Ando et al. 1998; Possingham et al. 2000; Possingham et al. 2001; Sarkar et al. 2006; Wilson et al. 2006; Murdoch et al. 2007; Withey et al. 2012). ROI typically refers to *ex ante* study of investment portfolio intended to attain conservation outcome (Boyd et al. 2012). In developing a ROI analysis, protected areas are scored by dividing the quantitative measures of conservation outcome by the cost associated with protected areas for a given unit of area. The analysis focuses on priority decisions over large spatial extents and grains (e.g., global, transnational, ecoregional, landscape, and habitat scales) (Carwardine et al. 2008a; Murdoch et al. 2007; Naidoo and Iwamura 2007; Wilson et al. 2007) or at the finer spatial grain (e.g., parcel level) (Ferraro 2003; Messer 2006; Murdoch et al. 2010, Newburn et al. 2006). While the conservation ROI analyses over large spatial extents offer broader strategic choices that account both ecological and economic efficiencies, they do not help conservation action at the finer spatial grain (e.g., parcel level). The parcel-level analyses are critical in conservation decisions because much real decision-makings are made at the parcel level.

The parcel-level ROI varies in characteristics of different kinds (e.g., land use, politics and economic conditions, and climate change) (Armsworth et al. 2006). One essential feature is size variation of protected areas, which can vary widely both in the same conservation program and in across different programs. Size of protected areas has been the focus of strategies in land conservation. Both ecological consequences of size variations and cost of establishing protected areas have been the center of numerous researches. For example, single large or several small (SLOSS) debate has been the long-established question of conservation biology (Diamond, 1975; Simberloff and Abele, 1982), while cost implications of the size of protected areas have been studied in more recent years (James et al., 1999; Ausden and Hirons, 2002; Frazee et al., 2003; Balmford et al., 2003; Moore et al., 2004; Strange et al., 2006; Ausden, 2007; Armsworth et al., 2011; Kim et al. 2014). The SLOSS debate has addressed different ecosystem functions in larger versus smaller habitat areas. The studies about cost of establishing protected areas have dealt with the issues in terms of economies of scale with area. Despite the findings of important role of size of protected areas in conservation decisions, little, if any, research has explicitly focused on the role of size of protected areas on conservation ROI that combine cost and benefit measurements at the real decision-making units, the parcel level.

Objective and hypotheses

We seek to examine how the size of protected areas influences the ecological and economic effectiveness through ROI analysis. We examine how changes in size of protected area influence conservation ROI. We use protected areas acquired by The Nature Conservancy (TNC) in Central and Southern Appalachian forest ecosystems over 62 counties in 10 states as our case study (see Figure 1). Using the case study, we focus on whether the size variation has implications on ROI that is estimated by local richness (i.e., the total number of target species represented within a set of protected areas) divided by acquisition cost.

Recent literature find that acquisition costs for the protected areas show pronounced economies of scale, suggesting that it is economically more efficient to protect a larger protected area than establishing a smaller one, all else being equal (Kim et al. 2014). On the benefit side, on the other hand, early literature on SLOSS debate find that protected areas of various size are found to provide protection to various sets of species (Lomolino, 1994; Quinn and Harrison, 1988). For example, larger protected areas assist species requiring larger inhabitants (Caughley, 1994; Soule, 1987). More recent literature finds that the conservation organization's willingness to pay (WTP) is a function of substitutability of the parcel for attaining their conservation outcomes (Lennox and Armsworth 2013, Lennox, Dallimer, and Armsworth 2012). Hence, we expect that the conservation organization would have different WTP for different size of parcels with different conservation outcome, and thus we hypothesize the significant effects of size of protected areas on ROI.

Significance of our analysis

Our literature contributes to the literature in two ways. First, we analyze the relationships of the effects of size of protected areas on ROI measurement that combine cost and benefit measurements for the understanding of ecological and economic effectiveness of land conservation. While the effects of size of protected areas on cost and benefit are interrelated, the previous literature has focused on each relation independently. Specifically, the literature related with the effect of size of protected areas on cost has focused on prioritizing areas for protection which account for cost variation (e.g., Ando et al., 1998; Kim et al., 2014; Murdoch et al., 2007, 2010; Naidoo et al., 2006; Polasky et al., 2001; Withey et al., 2012), while the literature dealing with SLOSS debate has been focusing on maximizing species number per area, by setting aside the cost issue (Lomolino, 1994; Quinn and Harrison, 1988). By analyzing these relationships in one model framework using ROI, we offer valuable information for the understanding the influence of protected area size on the ecological and economic effectiveness effects of these areas.

Second, we analyze the extent to which the effects of size of protected area on ROI at the parcel level. While much real decision making for the land conservation is made at the parcel level, past studies often focus on decisions over larger spatial extents (e.g., ecoregions) (Naidoo and Iwamura 2007; Carwardine et al. 2008a; Murdoch et al. 2007; Wilson et al. 2007). By analyzing conservation ROI at the finer spatial grain relevant to much real decision-making, the parcel level, we apply a spatial regression model, where ROI has spatial structure at the parcel level using land acquisition data for areas acquired by TNC. We predict changes in ROI that account for the spatial spillover of ROI, given increases in protected area. The finding would help conservation agencies prioritize parcel-level land conservation accounting for the spatial structures.

Empirical model

Model specifications

We apply a log-linear form of the ROI model to examine the effects of size of protected area on ROI for 87 recent transactions made between 2000 and 2009. The log-linear form has been applied frequently in the literature of cost effectiveness (Linna 1998; Greene 2005; Farsi and Filippini 2006) and cost-benefit analysis (Fuguitt and Wilcox, 1999). TNC acquired 41 out of 87 parcels with donative intent (i.e., acquired with no monetary compensation or at below than fair market value). Including the 41 transactions in developing the models may distort the measures of the effects of size of protected area on ROI whereas simply removing them may trigger selection bias that causes biased estimates. To avoid such problem, we adopt the

Heckman's two-step estimator for ROI model that is based on the conditional expectations of the observed ROI.

In the first stage of the Heckman's framework, we specify a probit model of the following form,

(1) $\text{Prob}(D = 1 | Z) = \Phi(Z\gamma)$

where *D* indicates donative intent by the original landowner (*D* = 1 if the transaction is made without donative intent and 0 otherwise), *Z* is a vector of variables that explain donative intent, γ is a vector of unknown parameter, Φ is the cumulative distribution function of the normal distribution.

The conditional expectation of the ROI given the transaction is made without donative intent is then,

(2) $E[y | X, D = 1] = X\beta + E[u | X, D = 1]$

where *y* denotes ROI, *X* is a vector of explanatory variables, *u* is unobserved determinants of ROI. Under the assumption that the *u* is determined jointly normal, we specify the following conditional expectation for the second stage estimation:

(3) $E[y | X, D = 1] = X\beta + \rho\sigma_u\lambda(Z\gamma)$

where ρ is the correlation between unobserved determinants of propensity of transactions without donative intent and unobserved determinants of ROI, σ_u is the standard deviation of *u*, and λ is the inverse Mills ration evaluated at $Z\gamma$.

Spatial dependences may occur in estimating the equation (3) for the ROI model because acquisition costs are highly dependent on land values which are highly spatially dependent (Anselin and Lozano-Gracia, 2009; Irwin and Bockstael, 2001; Irwin et al., 2003; Kim et al.,

2014) and local richness measuring species distributions are highly spatially dependent (Bahn, 2005; Carl and Kühn, 2007; Mattsson et al., 2013). Spatial dependences in regressions could yield biased estimates. To check for existence of such problems in estimates of the equation in the second step of the Heckman model, we conducted robust spatial Lagrange multiplier (LM) lag and error tests (Anselin, 1988) using 11 different row-standardized weight matrices. The different weight matrices were used as a sensitivity test for different spatial structures of the equation. The robust spatial LM-lag statistics and the robust spatial LM-error statistics based on 11 candidate weight matrices indicated that spatial lag (for 7 of 11 weight matrices) and spatial error models (for 9 of 11 weight matrices) are preferred to the aspatial model for the ROI model (see Table 1).

Following the spatial test results, the equation (3) for the conditional expectation in the second stage is rewritten as following:

(4) $$E[y \mid X, D=1] = \eta Wy + X\beta + \rho\sigma_u \lambda(Z\gamma) + e,\ e = \delta We + \varepsilon$$

where η and δ are parameter estimates of spatially lagged dependent variable and error terms, W is a spatial weight matrix, e is spatially autocorrelated disturbance, and ε is i.i.d. disturbance with zero mean and variance σ_ε. The equation (4) is estimated using log-linear form where natural log is taken for the dependent variable and all the continuous explanatory variables.

We used the variable of our interest (i.e., parcel size) for the test of our hypotheses and other control variables including take-out partner (i.e., whether TNC aims to retain the property or transfer it to another nonprofit organization or a state or federal agency), motivation for protection (i.e., presence of rare or imperiled species; presence of perceived threat of development), ecoregion information (i.e., whether transactions are inside of three of TNC's ecoregions: Cumberland & Southern Ridge and Valley, Southern Blue Ridge, and Central

Appalachian Forest), location information (i.e., distances to the nearest major cities with a population of 10,000 or more, local, state, or national park, and water body), socioeconomic information (i.e., population density and median household income), geophysical characteristics (i.e., slope and elevation). See Table 2 for variables used for the estimation of the model and descriptive statistics.

From the estimated equation (4), we estimated direct, indirect, and total elasticity of size of protected area on acquisition costs using the spatial dependence structure (LeSage and Pace, 2009). The total elasticity of the size was estimated as:

(5) $$n^{-1}\iota_n'\left[(\mathbf{I}_n - \eta\mathbf{W})^{-1}\mathbf{I}_n\beta_s\right]\iota_n = n^{-1}\left[\sum_{i=1}^{n}\sum_{j=1}^{n} v_{i,j}\beta_s\right],$$

where β_s is the coefficient of the size variable and $v_{i,j}$ is the (i, j) element of $(\mathbf{I}_n - \eta\mathbf{W})^{-1}$. Here, the direct elasticity was estimated as:

(6) $$n^{-1}tr\left[(\mathbf{I}_n - \eta\mathbf{W})^{-1}\mathbf{I}_n\beta_s\right] = n^{-1}\left[\sum_{i=1}^{n} v_{i,i}\beta_s\right].$$

The indirect elasticity is the total elasticity minus the direct elasticity.

Data

We use four data sets: TNC data, local richness data, census-block group data, landmark data, and geophysical data. The TNC data was obtained from the TNC documents that contain information regarding contract type, acquisition cost, size, grantor type, take-out partner, motivation for protection, and location information. We also obtained ecoregional portfolio information based on ecoregional assessment from TNC's website (TNC, 2014).

The local richness data was created based on element occurrences from Biodiversity Information Serving Our Nation database (USGS 2014). We downloaded 328 target species that were listed as high level conservation concern according to the ecoregional portfolios created by TNC (USGS 2013). We formed 5-kilometer (km) radius buffers around centroids of protected parcels to capture spatial variation in known element occurrences of target species (TNC 2010). The element occurrences of the target species within a 5-km buffer are used to create local richness of protected areas.

The census-block group data including population density and median household income were obtained from 2000 and 2007 US Census (US Census Bureau 2013). We assigned the census data of population density and median household income of the closest census year prior to the transaction within the boundaries of the census-block groups (i.e., the 2000 and 2007 census data were assigned to transactions made during the periods of 2000 – 2006 and 2007 – 2009, respectively).

Distance to nearest landmarks (i.e., major cities with a population of 10,000 or more and water body) represent the distance between parcel centroids and centroid of the nearest landmarks. Shape files of the major cities and water bodies were acquired from ESRI Data & Map 10 (ESRI 2011) and the distances were estimated using the “Near analysis” tool in ArcGIS (ESRI 2012). Geophyscial data of slope and elevation were obtained from the 30-meter Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) Version 2 (V2) (NASA JPL 2011). Using the data and the Zonal Statistics tool in ArcGIS 10.1 (ESRI 2012) based on raster grids, we calculated average slope and elevation of the 87 parcels.

Empirical Results

We estimated the second-step of the ROI model that is specified in equation (4) using a spatial general model incorporating spatial lag and error dependence and sample selection bias. Based on the goodness of fit in the Table 1, we report the parameter estimates of the ROI model and the direct, indirect, and total effect in Table 3. The parameter estimate for the inverse Mill's ratio (IMR) that controls for sample selection bias is significant at the 5% level (hereafter, "significant" means significance at the 5% level) and positive. The positive and significant parameter of IMR suggests that the selection of the transactions without donative intent is positively correlated with ROI. The positive and significant spatial lag parameter estimate (η) suggests that neighboring parcels are more similar in ROI than if parcels were distributed randomly—parcels with higher ROI are more likely to be neighbors while parcels with lower ROI are more likely to be neighbors. The finding affirms that acquisition costs representing cost associated with protected areas and/or local richness representing species distribution are positively spatially dependent. The negative and significant spatial error estimate (δ) suggests that error terms from the ROI model are more dissimilar than random error terms.

The parameter of protected area size is negative and significant, suggesting that the smaller the size of protected area is, the bigger the conservation ROI is. The estimated direct, indirect, and total elasticities of protected size on ROI suggest that a 1% smaller protected parcel is associated 0.63% higher ROI in all the parcels as a whole, which combine a 0.33% higher ROI in the same parcel and 0.30% higher ROI in neighboring parcels. These findings suggest that (i) the overall efficiency of protected areas that sums up the ecological and economic efficiencies is higher in protecting smaller areas relative to larger areas and (ii) almost one half of the total effect of protected size on ROI is spillover effect. In relation to the finding (i), the conservation benefits measured by local richness of particular locations, given the same acquisition costs of protected areas, are greater for protecting smaller parcels. Concerning the finding (ii), the negative indirect elasticity of size of protected area on ROI suggests the spatial spillover of the greater local richness on a dollar invested to acquire a parcel for protecting smaller sizes than larger sizes.

Below, we briefly discuss other factors that affect ROI. The negative and significant parameter of the distance to the nearest city center suggests that the closer to the city center is, the greater the ROI is. The finding suggests that the conservation benefits measured by local richness of particular locations, given the same acquisition costs of protected areas, are greater for protected parcels closer to the city center than protected parcels farther away from the city center. The finding is interesting in a sense that the ROI is positively associated with urbanization. Given the positive correlation between urbanization and acquisition costs that depend heavily on the real estate market (Mueller and Loomis 2008; Ayan and Erkin 2014), the positive correlation between ROI and urbanization implies the positive correlation between local richness and urbanization. This finding reaffirms some of the findings that urbanization can increase species richness, depending on taxonomic group of species and the degree of urbanization (McKinney 2008).

The positive and significant parameter of the distance to the nearest water body suggests that the parcels farther away from the nearest water bodies are the ones with greater ROI. This finding suggests that the proportion of relatively greater species distribution for the parcels closer to water bodies than the parcels farther away from water bodies by providing suitable complementary habitats that are necessary for life-cycles of species (e.g., Amoros and Bornette 2002; Williams et al. 2003) does not exceed the proportion of relatively greater land values for the parcels closer to water bodies than the parcels farther away from water bodies due to water front and water view amenities (e.g., Doss and Taff 1996; Cho et al. 2006).

The positive and significant parameter of the household income suggests that the parcels with the greater household income are the ones with greater ROI. The finding suggests that conservation benefits of protected areas reflected in local richness are greater for the parcels with higher household income, given the positive correlation between household income and acquisition costs that depend heavily on land values (Troy and Grove 2008; Shimizu 2014). The positive correlation between conservation benefits of protected areas and household income reflects the species richness as a positive function of household income.

The positive and significant parameter of the elevation suggests that the parcels with the greater elevation are the ones with greater ROI. The finding implies that conservation benefits of protected area reflected in local richness are greater for the parcels with greater elevation, given a positive relationship between a land parcel's value and its elevation due to view amenities of higher elevation found in the previous literature (e.g. Cho and Newman 2005; Mukherjee and Caplan 2011; Walls, Kousky, and Chu 2013).

Conclusion

We summarize our empirical results with two key findings and their implications. First, we found that local richness on a dollar invested to acquire a parcel is greater for smaller parcels than larger parcels, indicating that smaller land parcels should be prioritized for protection as part of an ecological and economic conservation strategy. This is an interesting result for the comparison to what has been found in the previous literature, larger land parcels should be prioritized for (1) protection as part of a cost effective conservation strategy (e.g., Gjertsen et al.

2014; Kim et al, 2014) and (2) possible ecological benefits of protecting larger parcels of land (Maiorano, Falcucci, and Boitani 2007; 2008; Leverington et al. 2008; Smith et al. 2010; Worboys, Francis, and Lockwood 2010). Recognizing that protected areas of different sizes may protect different species, prioritization of protection for smaller parcels based on our finding does not mean that smaller parcels necessarily provide a better deal for conservation. However, quantifying the influence of size of protected area on the local richness on a dollar invested to acquire a parcel, as we have done, provides a benchmark for evaluating the ecological and economic effectiveness of protected areas.

Second, our finding of the spatial spillover effect of size of protected area on ROI implies that the greater ecological and economic efficiency for the smaller land parcels occur for the own parcel and neighbors' parcels. This implies that smaller land parcels should be prioritized for protection as part of an ecological and economic conservation strategy for both own and neighborhood effects. Although the highly spatially dependent species distribution is relatively well established in the literature (Bahn, 2005; Carl and Kühn, 2007; Mattsson et al., 2013), few, if any, studies explicitly consider the implication of the spatial dependence in species distribution in terms of the effect of size of protected area on ROI. Thus, our finding contributes to new dimension of literature dealing with ecological and economic effectiveness of size of protected areas.

Reference

Amoros, C., and G. Bornette, 2002. "Connectivity and biocomplexity in waterbodies of riverine floodplains." Freshwater Biology 47: 761–776.

Ando, A., Camm, J., Polasky, S., Solow, A., 1998. Species distributions, land values, and efficient conservation. Science 279, 2126–2128.

Anselin, L., Lozano-Garcia, N., 2009. Spatial hedonic models. In: Mills, T.C., Patterson, K. (Eds.), Palgrave Handbook of EconometricsApplied Econometrics. 2. Palgrave MacMillan, Houndmills, UK, pp. 1213–1251.

ArcGIS Resource Center, 2013. Spatial Join. http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000000q000000 (Accessed in 03/12/2013).

Armsworth, P.R., 2014. Inclusion of Costs in Conservation Planning Depends on Limited Datasets and Hopeful Assumptions. Ann N. Y. Acad. Sci. 1322 (1), 61–76.

Ausden, M., 2007. Habitat Management for Conservation: A Handbook of Techniques. Oxford University Press, Oxford, UK.

Ausden, M., Hirons, G.J.M., 2002. Grassland nature reserves for breeding wading birds in England and the implications for the ESA agri-environment scheme. Biol. Conserv. 106, 279–291.

Ayan, E., and H.C. Erkin, 2014. "Hedonic Modeling for a Growing Housing Market: Valuation of Apartments in Complexes." International Journal of Economics and Finance 6 (3): 188–199.

Bahn, V. 2005. Implications of Spatial Autocorrelation and Dispersal for the Modeling of Species Distributions. Available at: http://works.bepress.com/volker_bahn/9.

Balmford, A., Gaston, K.J., Blyth, S., James, A., Kapos, V., 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proc. Natl. Acad. Sci. U. S. A. 100, 1046–1050.

Boyd, J., R. Epanchin-Niell, and J. Siikamäki. 2012. Conservation Return on Investment Analysis: A Review of Results, Methods, and New Directions. RFF DP 12-01. Available at http://www.rff.org/RFF/Documents/RFF-DP-12-01.pdf

Carl, G, and I. Kühn, 2007. Analyzing spatial autocorrelation in species distributions using Gaussian and logit models, Ecological Modelling 207 (2–4): 159-170, ISSN 0304-3800, http://dx.doi.org/10.1016/j.ecolmodel.2007.04.024.

Caughley, G., 1994. Directions in conservation biology. J. Anim. Ecol. 63, 215–244.

Cho, S., J.M. Bowker, and W.M. Park, 2006. "Measuring the Contribution of Water and Green Space Amenities to Housing Values: An Application and Comparison of Spatially Weighted Hedonic Models." Journal of Agricultural and Resource Economics 31 (3): 485-507.

Diamond, J.M., 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7, 129–146.

Doss, C.R., and S.J. Taff, 1996. "The Influence of Wetland Type and Wetland Proximity on Residential Property Values." Journal of Agricultural and Resource Economics 21 (1): 120-129.

ESRI, 2011. Data Maps For ArcGIS 10.

ESRI, 2012. ArcGIS Help 10.1: Spatial Analyst Toolsets, ArcGIS Resources. http://www.esri.com/ (Accessed in 04/03/2013).

Farsi, M., Filippini, M., 2006. An analysis of efficiency and productivity in Swiss hospitals. Swiss J. Econ Stat. 142 (1), 1–37.

Ferraro, P.J. 2003. Assigning priority to environmental policy interventions in a heterogeneous world. Journal of Policy Analysis and Management 22(1): 27–43.

Frazee, S.R., Cowling, R.M., Pressey, R.L., Turpie, J.K., Lindenberg, N., 2003. Estimating the costs of conserving a biodiversity hotspot: a case study of the Cape Floristic Region, South Africa. Biol. Conserv. 112, 275–290.

Fuguitt, D., and S.J. Wilcox, 1999. Cost-Benefit Analysis for Public Sector Decision Makers. Quorum Books, Westport, CT.

Fuller, R.A., E. McDonald-Madden, K.A. Wilson, J. Carwardine, C.J. Klein, and H.P. Possingham. 2010. “Replacing Underperforming Protected Areas Achieves Better Conservation Outcomes.” Nature 466, 365–367.

Gjersen, H., D. Squires, P.H. Dutton, and T. Eguchi, 2014. "Cost-Effectiveness of Alternative Conservation Strategies with Application to the Pacific Leatherback Turtle." Conservation Biology 28 (1): 140-149.

Greene, W., 2005. Reconsidering heterogeneity in panel data estimators of the stochastic frontier model. J. Econ. 126 (2), 269–303.

Irwin, E.G., Bockstael, N.E., 2001. The problem of identifying land use spillovers: measuring the effects of open space on residential property values. Am. J. Agric. Econ. 83, 698–704.

Irwin, E.G., Bell, K.P., Geoghegan, J., 2003. Modeling and managing urban growth at the rural–urban fringe: a parcel-levelmodel of residential land use change. Agric. Resour. Econ.Rev. 32, 83–102.

James, A.N., Green,M.J.B., Paine, J.R., 1999. A Global Review of Protected Area Budgets and Staff. WCMC—World Conservation Press, Cambridge, UK, (http://www.unep-wcmc. org/medialibrary/2010/09/10/93aac99d/Global_Review_Protected_Area_Budgets_Staff.pdf).

Kim, T., S. Cho, P.R. Armsworth, and E.R. Larson, 2014. Protected area acquisition costs show economies of scale with area. Ecological Economics 107: 122-132.

Linna, M., 1998. Measuring hospital cost efficiency with panel data models. Health Econ. 7, 415–427.

Lomolino, M.V., 1994. An evaluation of alternative strategies for building networks of nature reserves. Biol. Conserv. 69, 243–249.

Mattsson BJ, Zipkin EF, Gardner B, Blank PJ, Sauer JR, Royle, J.A., 2013. Explaining Local-Scale Species Distributions: Relative Contributions of Spatial Autocorrelation and Landscape Heterogeneity for an Avian Assemblage. PLoS ONE 8(2): e55097. doi:10.1371/journal.pone.0055097

Messer, K.D., 2006, The conservation benefits of cost-effective land acquisition: A case study in Maryland, Journal of Environmental Management 79 (3), 305–315.

Moore, J., Balmford, A., Allnutt, T., Burgess, N., 2004. Integrating costs into conservation planning across Africa. Biol. Conserv. 17, 343–350.

Mueller, J.M., and J.B. Loomis. 2008. “Spatial Dependence in Hedonic Property Models: Do Different Corrections for Spatial Dependence Result in Economically Significant Differences in Estimated Implicit Prices?” Journal of Agricultural and Resource Economics 33(2): 212–231.

Mukherjee and Caplan, 2011. "GIS-based estimation of housing amenities: the case of high grounds and stagnant streams." Letters in Spatial and Resource Sciences 4 (1): 49-61.

Murdoch, W., J Ranganathan, S. Polasky, and J. Regetz. 2010. Using return on investment to maximize conservation effectiveness in Argentine grasslands. PNAS 107 (49), 20855-20862.

Naidoo R. and T. Iwamura. (2007) Global-scale mapping of economic benefits from agricultural lands: Implications for conservation priorities. Biological Conservation. 140 (1-2): 40-49.

Naidoo, R., A. Balmford, P.J. Ferraro, S. Polasky, T.H. Ricketts, and M. Rouget. 2006. Integrating economic costs into conservation planning. TRENDS in Ecology and Evolution 21 (12): 681-687.

Newburn, D. A., P. Berck, and A.M. Merenlender. 2006. Habitat and open space at risk of landuse conversion: targeting strategies for land conservation. American Journal of Agricultural Economics 88 (1): 28–42.

Piha, M.M., J. Tiainen, J. Holopainen, V. Vepsäläinen, 2007. Effects of land-use and landscape characteristics on avian diversity and abundance in a boreal agricultural landscape with organic and conventional farms, Biological Conservation 140 (1–2), 50-61.

Polasky, S., J.D. Camm, B. Garber-Yonts, 2001. Selecting Biological Reserves Cost-effectively: An application to terrestrial vertebrate conservation in Oregon. Land Economics 77, 68–78.

Possingham, H., Ball, I., Andelman, S., 2000. Mathematical methods for identifying representative reserve networks. In: Ferson, S., Burgman, M. (Eds.), Quantitative Methods for Conservation Biology. Springer-Verlag, New York, pp. 291–305.

Possingham, H.P., Andelman, S.J., Noon, B.R., Trombulak, S., Pulliam, H.R., 2001. Making smart conservation decisions. In: Orians, G., Soule, M. (Eds.), Research Priorities for Conservation Biology. Island Press, Washington, DC, 225–234.

Quinn, J.F., Harrison, S.P., 1988. Effects of habitat fragmentation and isolation on species richness—evidence from biogeographic patterns. Oecologia 75, 132–140.

Sarkar, S., Pressey, R.L., Faith, D.P., Margules, C.R., Fuller, T., Stoms, D.M., Moffett, A., Wilson, K.A., Williams, K.J., Williams, P.H., Andelman, S., 2006. Biodiversity conservation planning tools: present status and challenges for the future. Annual Review of Environment and Resources 31, 123–159.

Shimizu, C., 2014. “Estimation of Hedonic Single-Family House Price Function Considering Neighborhood Effect Variables.” Sustainability 6: 2946-2960.

Simberloff, D.S., Abele, L.G., 1982. Refuge design and island biogeographic theory: effects of fragmentation. Am. Nat. 120, 41–50.

Soule, M.E., 1987. Viable populations for conservation. Cambridge Academic Press, Cambridge, UK.

Strange, N., Rahbek, C., Jepsen, J.K., Lund, M.P., 2006. Using farmland prices to evaluate cost–efficiency of national versus regional reserve selection in Denmark. Biol. Conserv. 128, 455–466.

The Nature Conservancy (TNC). 2010. EAST: Ecoregional Status Assessment Tool. Available from http:www.conservationgateway.org (accessed December 2014).

Troy, A., and J.M. Grove, 2008. "Property values, parks, and crime: A hedonic analysis in Baltimore, MD." Landscape and Urban Planning 87: 233–245.

US Census Bureau, 2013, Geography – Maps & Data. http://www.census.gov/geo/maps-data/.

Vincent DD, L. Godet, R. Julliard, D. Couvet, F Jiguet, 2006. Can common species benefit from protected areas?, Biological Conservation 139 (1–2), 29–36.

Walls M., C. Kousky, and Z. Cho, 2013. "The Value of Natural Landscape Views." Resources for the Future RFF DP 13-15: 1-28.

Williams, P., M. Whitfield, J. Biggs, S. Bray, G. Fox, P. Nicolet, and D. Sear, 2003. "Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England." Biological Comservation 115: 329–341.

Wilson, K.A., McBride, M.F., Bode, M., Possingham, H.P., 2006. Prioritising global conservation efforts. Nature 440, 337–340.

Wilson, K.A., Underwood, E.C., Morrison, S.A., Klausmeyer, K.R., Murdoch, W.W., Reyers, B., Wardell-Johnson, G., Marquet, P.A., Rundel, P.W., McBride, M.F., Pressey, R.L., Bode, M., Hoekstra, J.M., Andelman, S.J., Looker, M., Rondinini, C., Kareiva, P., Shaw, M.R., Possingham, H.P., 2007. Maximising the conservation of the world's biodiversity: What to do, where and when. PLoS Biology 5, e223.

Withey, J.C., J.J. Lawler, S. Polasky, A.J. Plantinga, E. J. Nelson, P. Kareiva, C.B. Wilsey, C.A. Schloss, T.M. Nogeire, A. Ruesch, J. Ramos, W. Reid. 2012. Maximising return on conservation investment in the conterminous USA. Ecology Letters 15 (11), 1249-1256.

Table 1. Spatial LM test results and goodness of fits

W matrices	Spatial LM Lag		Spatial LM Error		R^2
	$\chi^2(1)$	p-value	$\chi^2(1)$	p-value	
Inverse Distance	20.648*	0.000	15.497*	0.000	0.701
K nearest neighbor (KNN)					
K=2	7.515*	0.006	3.807*	0.051	0.704
K=3	7.769*	0.005	3.273	0.070	0.745
K=5	12.835*	0.000	6.703*	0.010	0.769
K=10	10.830*	0.001	7.687*	0.006	0.741
Thiessen polygon	5.339*	0.021	0.906	0.341	0.758
KNN Inverse distance					
K=2	3.523	0.061	1.975	0.160	0.712
K=3	3.475	0.062	2.036	0.154	0.722
K=5	7.219*	0.007	4.596*	0.032	0.707
K=10	16.151*	0.000	11.740*	0.001	0.702
Thiessen polygon × Inverse distance	12.279*	0.001	8.421*	0.004	0.709

* represents the significance level at 5%.

Table 2. Variable definitions and descriptive statistics (n=87)

Variables	Definition	Mean	Std. Dev.
Return-on-investment in conservation (ROI)	Local richness (i.e., the total number of target species represented within a set of protected areas) divided by acquisition cost of protected area in 1,000 US dollar)	0.06	0.09
Size	Size of protected area (hectare)	103.69	226.61
Take-out partner	Dichotomous variable for take-out partners (1 if TNC, 0 otherwise)	0.83	0.38
Motivation by species protection	Dichotomous variable for transactions with the motivation in part by the protection of rare or imperiled species (1 if the motivation includes rare or imperiled species, 0 otherwise)	0.20	0.40
Motivation by threat of development	Dichotomous variable for the transactions with the motivation in part by the threat of development pressure (1 if under development pressure, 0 otherwise)	0.78	0.42
Cumberlands and Southern Ridge and Valley	Dichotomous variable for protected site in Cumberlands and Southern Ridge and Valley Ecoregion (1 if yes, 0 otherwise)	0.43	0.50
Central Appalachian Forest	Dichotomous variable for Protected site in Central Appalachian Forest Ecoregion (1 if yes, 0 otherwise)	0.36	0.48
Distance to city	Distance to the nearest major city with 10,000 or more population (kilometer)	34.83	16.69
Distance to water body	Distance to the nearest water body (kilometer)	20.35	15.30
Distance to Park	Distance to the nearest state, or national park (kilometer)	9.33	10.85
Population	Population within census block-group	47.98	50.36
Household income	Household income within census block-group	34941.80	7518.94
Elevation	Average elevation (meters)	538.20	300.76
Slope	Average slope (degrees)	13.86	7.29

Table 3. Estimation results

Variables	Coefficients		Total effects	Direct effects	Indirect effects
Size	-0.668*	(0.061)	-0.628	-0.329	-0.299
Take-out partner	-0.549	(0.398)	-0.516	-0.270	-0.246
Motivation by species protection	0.378	(0.383)	0.356	0.186	0.170
Motivation by threat of development	-0.460	(0.281)	-0.433	-0.227	-0.206
Cumberlands and Southern Ridge & Valley	0.957	(0.537)	0.900	0.471	0.429
Central Appalachian Forest	0.276	(0.579)	0.259	0.136	0.124
Distance to city	-0.660*	(0.198)	-0.621	-0.325	-0.296
Distance to waterbody	0.599*	(0.204)	0.564	0.295	0.269
Distance to park	0.043	(0.022)	0.040	0.021	0.019
Population	0.044	(0.303)	0.042	0.022	0.020
Household income	2.622*	(0.455)	2.465	1.291	1.175
Elevation	0.002*	(0.001)	0.002	0.001	0.001
Slope	0.052	(0.027)	0.049	0.026	0.023
IMR	3.767*	(1.166)	3.542	1.854	1.688
Constant	-26.581*	(5.830)			
ρ	0.508*	(0.149)			
λ	-2.891*	(0.385)			
R^2	0.769				
Log-likelihood	-37.479				

* represents the significance level at 5%.

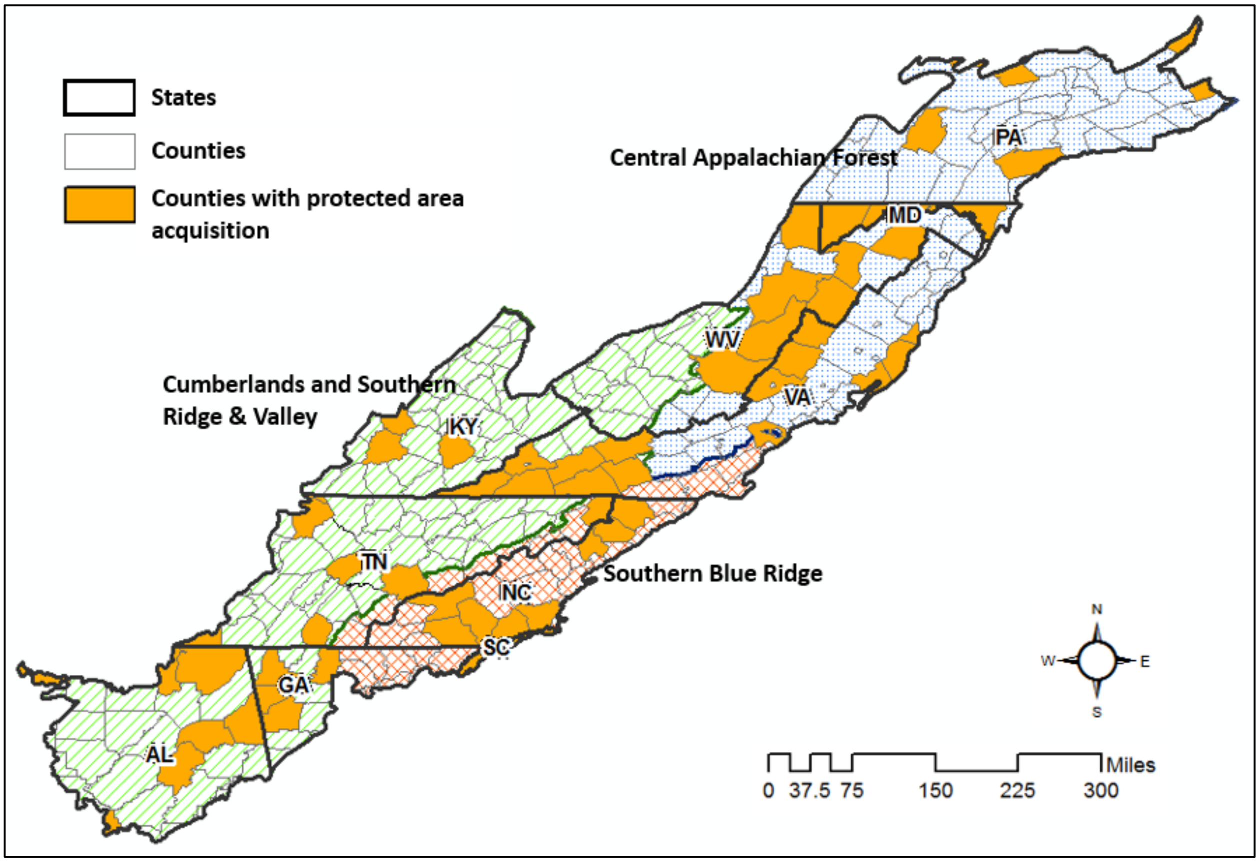

Figure 1. Counties with Protected areas acquired by TNC in Central and Southern Appalachian forest ecosystems over 62 counties in 10 states