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Assessing economic and biological tradeoffs to target conservation easements in western rangelands

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Abstract
Conservation easements are a common tool for protecting important habitat and migration corridors from development across increasingly fragmented western rangelands. Spatially-explicit land market transaction data to evaluate and target easements, however, is sparse or non-existent in many western states. We demonstrate a propensity score matching (PSM) model using available assessment data to estimate unobservable future residential values and probability of habitat loss associated with agricultural parcels. Combined with available parcel-level biological benefits data, the PSM model's estimates of residential value and probability of loss can be used to target conservation easements cost-effectively.

Key words: Conservation, Easements, Propensity Score Matching, Cost-effective Targeting

Wildlife Conservation on Fragmented Rangelands in the Intermountain West
A patchwork of public and private rangelands across the U.S. Intermountain West make up contiguous habitats, which are critical for wildlife. Over 350 plants and animals associated with sagebrush ecosystems are identified as species of conservation concern (Rowland et al., 2010). Endangered Greater Sage Grouse depend on undisturbed buffers around breeding leks, sage grouse breeding sites (Connelly et al., 2004). Iconic big game species rely on their ability to move between seasonal ranges across both public and private lands (WMI, 2018). Despite the abundance of public lands in the

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West, substantial critical habitat and sensitive environmental areas still occur on private lands with little protection. In Wyoming, for example, 36% (>5 million acres) of crucial big game winter range, 87% of sensitive drinking water sources (>2.7 million acres), and 65% of blue ribbon fisheries occur on private lands (Korfanta et al., 2018). This critical habitat continues to be fragmented by extensive energy and amenity-driven residential development (Davies et al., 2011), which has negative impacts on wildlife and environmental amenities.

To preserve rangeland habitat, agencies and private partners often use conservation easements to purchase development rights as a tool for protecting habitat on private land. For example, in Wyoming, Colorado, and Montana, 2% to 6% of each state's private land area is currently protected by easements (approximately 5 million acres) (Korfanta et al., 2018). How should agencies best allocate limited conservation funds to achieve the most biological protection for the least cost? Despite much research on cost-effective conservation targeting (e.g., Duke et al., 2014; Polasky et al., 2008; Newburn et al., 2005), many on-the-ground conservation efforts still largely focus on targeting biological benefits alone. To make the best use of each conservation dollar, targeted spending on conservation easements must also consider cost and the risk of habitat loss from development. Quantifying and then balancing these three components—biological value, conservation cost, and the risk of loss—allows for the most efficient use of conservation funding (Newburn et al., 2005).

However, applying efficient conservation targeting approaches in Intermountain West rangelands faces a unique challenge. Efficient targeting approaches require an estimate of conservation costs—that is, the opportunity cost of foregone development values if a landowner enters into a conservation easement. This opportunity cost of future development cannot be observed directly since it is an option value capitalized into market prices. Common approaches for identifying this option value, such as the hedonic pricing method[5], require market data on land sale prices that are often unavailable in the Intermountain West for two reasons. First, sales of the typically large western ranches of interest for conservation easements are relatively infrequent. Thus, available sales data tends to be temporally and spatially thin. Second, and more importantly, many western states (Idaho, Montana, New Mexico, Utah, and Wyoming) have, or recently had, non-disclosure policies for land transactions. This means that actual sale prices for property transactions are not reported to the public for a substantial portion of the Intermountain West.

In the absence of readily available sales data, agencies and private partners need an alternative approach for estimating conservation value. We propose and demonstrate a propensity score matching method using readily available land assessor

[5] The hedonic pricing method is an approach that uses market prices to determine the value of specific product characteristics. It is used, for example, to disentangle how different non-market characteristics, such as scenic views or pollution, contribute to the price of real estate.

data. This approach allows us to simultaneously approximate unobserved development values (that is, conservation opportunity cost) for agricultural land parcels and parcel-level residential development risks (risk of loss). Combining these with measures of biological benefits provides more informed targeting for limited conservation funds. Next, we will discuss the propensity score matching method, and then demonstrate its use with an application to targeting conservation easements in Sublette County, Wyoming.

Estimating Residential Development Values with Propensity Score Matching

Land value is a product of its current productive and future potential use. The latter is capitalized into current prices in competitive land markets. The current value of a parcel of agricultural rangeland is therefore comprised of net returns to agricultural production and potential returns to future development. Assuming conversion to residential use is irreversible, the current value of a parcel of agricultural parcel *i* in time *t* can be expressed as:

$$(1) \qquad P_i = \int_{t=0}^{t^*} \pi_{i,ag}\,(t,z_i)e^{-rt}dt + \int_{t^*}^{\infty} \pi_{i,res}\,(t,z_i)e^{-rt}dt - Ce^{-rt} \quad ,$$

$\pi_{i,ag}(t,z_i)$ is the net return to agriculture on parcel *i* with characteristics *z*; $\pi_{i,res}(t,z_i)$ is the net returns to residential use on parcel *i* with characteristics *z*; and *C* is the one-time cost of converting parcel *i* from agricultural to residential use (see Capozza and Helsley, 1989). Equation (1) is sufficiently generic and could be applied to model conversion to any irreversible non-agricultural land use.

The first term in (1) is the present value of returns from using the parcel for agricultural production, from the current time to the optimal conversion time, t^*. The second term is the present value of future returns from residential development less conversion costs, from t^* to infinity. To maximize profits, the landowners should convert land from agriculture to residential development at the optimal time, t^*, given market conditions. The opportunity cost of future development compensated by a conservation easement should therefore be equal to the difference between the net present value of foregone residential rents less conversion costs (the returns the landowner would receive if they converted to development) and the net present value of continuing agricultural production[6].

Assessed land values offer a readily available, spatially complete, regularly updated proxy for market values. However, assessed values of agricultural lands focus on use values (not option values) in order to provide preferential tax treatment for agriculture (Anderson, 2012). Thus, assessed values generally underestimate market

[6] $Easement\ Cost = \left(\int_{t=0}^{t^*} \pi_{i,ag}\,(t,z_i)e^{-rt}dt + \int_{t^*}^{\infty} \pi_{i,res}\,(t,z_i)e^{-rt}dt - Ce^{-rt}\right) - \int_{t=0}^{\infty} \pi_{i,ag}\,(t,z_i)e^{-rt}dt$
$= \int_{t^*}^{\infty} \pi_{i,res}\,(t,z_i)e^{-rt}dt - Ce^{-rt} - \int_{t^*}^{\infty} \pi_{i,ag}\,(t,z_i)e^{-rt}dt$

values. This is particularly true in areas where residential development option values are driven by amenities like recreational access, scenery, wildlife, and open space (Ma and Swinton, 2012; Spahr and Sunderman, 1998). In amenity-driven rural land markets, such as those observed in the Rocky Mountain region, amenity values could significantly drive land prices, accounting for as much as 50% of market values in some areas of Wyoming (Wasson et al., 2013). Because of the limits to acquiring meaningful market data, and because potential returns to future development are unobservable, we develop a spatially-explicit propensity score matching method to approximate residential development values from available county assessor data.

Given that assessors only consider a parcel's current use (e.g., agricultural or residential), the assessed value (AV) can be expressed as (2) for an agricultural parcel (*i, ag*) and (3) for a residential parcel (*j, res*):

(2) $$AV_{i|ag} = \int_{t=0}^{\infty} \pi_{i,ag}(t, z_i) e^{-rt} dt \quad ;$$

(3) $$AV_{j|res} = \int_{t=0}^{\infty} \pi_{j,res}(t, z_j) e^{-rt} dt \quad .$$

These assessed values are a function of profit or returns to each use, which are determined by the parcel's characteristics (z). Parcel characteristics can include attributes that affect agricultural use values (e.g., soil quality) or residential use values (e.g., scenic views).

If we can observe characteristics that influence residential values on an agricultural parcel, then we can approximate its potential residential value by examining the assessed value of residential parcels that have similar characteristics. Thus, an approximation of the full market value of an agricultural parcel is given by:

(4) $$\tilde{P}_i = AV_{iag}(Z_i) + AV_{jres}(Z_i),$$

or the current assessed value of an agricultural parcel with characteristics z_i plus the current assessed value of a residential parcel with the same characteristics. The estimated value in (4) is a biased approximation of the true value, P_i, because it assumes that parcel i can receive both agricultural and residential rents in perpetuity, from t to infinity. In reality, the contribution to rents in perpetuity from agriculture and development depends on the optimal conversion time (t^*), which is unobservable. However, if parcels are matched well the magnitude of bias should be relatively small. If an agricultural parcel with low development pressure is matched with a similarly rural residential parcel, the assessed value of the residential parcel should reflect the low market demand for such properties. The assessed residential value will be close to the assessed agricultural value and the bias will be relatively small. Similarly, for parcels facing high development pressure, the assessed agricultural value will be small relative to the assessed residential value, making the bias of including agricultural rents relatively small.

Propensity score matching

The health sciences developed propensity score matching to reduce selection bias when comparing non-equivalent groups (Rosenbaum and Rubin, 1983). Propensity scores reduce systematic sampling bias by matching individuals or groups based on a set of observable characteristics. We use propensity scores to match agricultural and residential land parcels with similar observed physical and geographic characteristics. This matching process allows us to estimate both the probability of conversion (the propensity score), and to approximate the current value of an agricultural parcel if it were converted to a residential use. The matched residential value is used as a proxy for future development values, and thus conservation costs, of an agricultural parcel.

We propose the following steps to estimate propensity scores to match agricultural and residential parcels, and then to approximate development value using assessed land values:

1) Estimate propensity scores [$p(.)$] for all land parcels using a standard binary logit model to predict the probability of observing each agricultural and residential parcel in residential use:

(5) $$p(Y_i = 1|x) = \frac{e^{z'\beta}}{1 + e^{z'\beta}} \quad ,$$

Y_i is an indicator variable equal to 1 if parcel i is in residential use, and 0 otherwise; z is a vector of characteristics expected to influence the probability of residential use (physical and geographic characteristics); and β is a vector of parameters to be estimated.

2) Match agricultural and residential parcels with similar propensity scores (that is, their probability of being residential conditional on their characteristics).
3) Estimate residential value ($/acre) associated with agricultural parcels based on the assessed values of matched residential parcels:

(6) $$\tilde{P}_i = AV_{i,ag}(z_i) + f\left(AV_{k,res}(z_k)\right),$$

$f(AV_{k,res}(z_k))$ is a function of the assessed values of matched residential parcels. The function used depends on the matching strategy. For example, each agricultural parcel is matched with a group of residential parcels that have propensity scores within a pre-defined range and then the residential value can be approximated by the mean of the assessed values of matched parcels.

Application: Targeting Conservation Easements in Sublette County, Wyoming

Sublette County is located in Southwest Wyoming's Upper Green River Basin. The county has seen rapid energy and residential development. The Jonah Field and Pinedale Anticline are among Wyoming's largest natural gas fields, and their development (largely on public land) has fragmented habitat. In concert with oil and gas development, the county's rich natural amenities have spurred rapid population growth and amenity-driven residential development: Sublette County's growth rate between 2000 and 2010 was greater than 73%, and 25% of homes in the county are classified as second homes (USCB, 2010). The county is also home to critical wildlife habitat, including habitat for the Greater Sage Grouse, and migratory and wintering habitat for pronghorn and mule deer. Thus, Sublette County is an ideal case study for examining effective conservation targeting in the absence of land-market data.

Estimating Propensity Scores (Conversion Risk) and Residential Development Values

Using Sublette County assessment data (WDOR, 2017; 2012), we select all land parcels classified as "agricultural" and "residential vacant" uses outside of municipal boundaries (n = 2,939). Including only vacant residential parcels results in a more accurate estimate of future development value over possibly arbitrary additions to land assessed with a current residential use. Explanatory variables capture land characteristics expected to influence the desirability and cost of placing land in residential development (Table 1). The binary logit propensity score model fits the data well (LRtest < 0.001) and parameter estimates generally fit theoretical expectations (see marginal effects in Table 2). [7]

We next use the estimated binary logit model to predict propensity scores (that is, the probability of being residential) for each agricultural and residential vacant parcel. Residential vacant parcels have an average predicted propensity of 0.76; agricultural parcels have an average predicted propensity of 0.42, with scores ranging overall from 0.05 to 0.99.

Given the predicted propensity scores, we use a one-to-many caliper approach to match residential and agricultural parcels based on the similarity of their predicted propensity scores. The caliper approach matches each agricultural parcel to all residential parcels that have a predicted propensity score within a specified range or "caliper" of the agricultural parcel's score – thus matching parcels that are sufficiently similar (Guo and Fraser, 2010). We define the caliper as 0.25 standard deviations. In our data, this implies that agricultural parcels match with all residential vacant parcels that have a propensity score within +/- 0.068. Finally, we approximate the per-acre residential value of each agricultural parcel using the median assessed value per acre of

[7] The primary focus here is on the propensity score matching approach. For more details on the variables, data, and estimation results in the Sublette County application, see Mellinger (2012).

caliper-matched residential parcels. The resulting propensity score matches imply a residential development value for agricultural parcels ranging from $7,010 per acre to $31,972 per acre (average = $10,435/acre).

Using the Propensity Score Approach for Conservation Targeting

The propensity score-matching model generates estimates of conservation costs (residential development value) and risk of loss (the propensity score or the probability of being residential). To effectively target conservation, we also need a measure of the biological benefits from easements. We therefore construct a simple biological score to rank parcels for three species of interest in Sublette County: Greater Sage Grouse, pronghorn, and mule deer. For mule deer and pronghorn, we use available spatial data to identify crucial winter range, migratory corridors, and migratory stopover sites (Sawyer and Nielson, 2011; WGFD, 2011). Then, we create a simple weighted average of the area-weighted distance to crucial winter range, and the area of migration corridor and stop-over sites on the parcel. For sage grouse, we construct a biological score as the parcel area contained within a 5-kilometer buffer around occupied leks. We sum scores for each species to generate a total biological score associated with each agricultural parcel in the county (see Mellinger 2012 for details on the biological data and scores). While the values assigned to biological scores are arbitrary, they give a relative measure of the conservation value of private land parcels in Sublette County—easements on parcels with higher scores would preserve more critical habitat.

Additionally, to account for the risk of loss, we construct an expected biological score. The expected biological score for each agricultural parcel is equal to the parcel's biological score multiplied by its probability of being in agriculture (one minus the propensity score). This total expected biological score can be interpreted as what the landscape is likely to produce in the long-run as agricultural parcels convert to residential use according to predicted propensity scores (in the absence of conservation efforts).

With measures of conservation costs, risk of loss, and biological benefits, policy-makers can explore different approaches for most effectively targeting conservation easements or can assess the efficiency of conservation programs ex-post. Newburn, et al. (2005), for example, discuss four common methods for targeting conservation, each with different policy implications:

1) Benefits-Only Targeting: biological benefit value, measured by an index of biological characteristics, is ranked from highest to lowest then selected until the budget is fully expended.
2) Benefit-Cost Targeting: selects sites based on the highest ratio of biological benefit to conservation cost.

3) Benefit-Loss Targeting: selects sites for protection based on values of an expected benefit loss. Sites with the highest expected benefit loss are selected, constrained by a budget.
4) Benefit-Loss-Cost Targeting: parcels are selected to minimize the expected loss of biological benefits per dollar for a given budget.

Applying these targeting strategies to agricultural parcels in Sublette County for a fixed budget significantly affects which parcels are conserved and the efficiency of conservation targeting (Figure 1). Considering only biological benefits is not ideal because parcels with the highest biological scores are selected irrespective of cost, and thus budget is spent quickly. Accounting for costs (benefit-cost targeting) improves efficiency since limited budget dollars are spread more broadly; however, since risk of loss is not considered, dollars are expended to conserve parcels that would likely continue providing benefits in the absence of conservation efforts. When considering the relative risk of an agricultural parcel converting to residential use, benefit-loss targeting performs poorly because it includes expensive high-risk parcels even if their biological score is too low to be cost-effective. Thus, as demonstrated by others, benefit-loss-cost targeting produces the most efficient conservation outcome.

Estimates from the propensity score matching approach are utilized to assess the efficiency of conservation programs ex-post. For example, we use estimated conservation costs (foregone residential values) and biological benefits to generate a theoretical production possibilities frontier for Sublette County, Wyoming (Figure 2). Points along the frontier represent conservation easements that would be most efficient. For any given biological score, the point on the frontier represents the minimum cost (or least foregone residential value) to achieve that biological score. The diamond represents the estimated conservation cost and biological score of all existing easements in the county. Thus, targeting existing easements could have been more efficient—for the same conservation costs, choosing alternative easement locations could have generated a significantly higher biological score (i.e., protected substantially more sage grouse, mule deer and pronghorn habitat for the same budget).

Conclusion

Limited budgets and ever-expanding conservation needs continue to emphasize the importance of targeting conservation efficiently. For land-based conservation efforts, such as conservation easements, the most efficient targeting requires estimates of conservation costs and risk of loss in addition to biological benefits. The propensity score matching method we describe using assessed land value data offers a relatively accessible, low-cost approach for estimating spatially-explicit conservation costs and risk of loss in areas where land market transaction data is sparse or non-existent (which is often the case in western rangelands). These estimates can be combined with available quantitative or qualitative data on parcel-level biological characteristics to improve conservation targeting. However, estimating a propensity score-matching model is challenging. Though spatially-explicit data on land characteristics that influence development propensity are widely available in the U.S., managing these data and estimating statistical models require some expertise. In the absence of sophisticated statistical approaches, land trust and other agencies can still improve conservation targeting by systematically considering cost, risk of loss, and biological benefits when selecting easements. As our approach demonstrates, risk of loss – often overlooked – closely relates to land characteristics that are attractive for residential development. Therefore, more efficient easement targeting could be as simple as selecting between similar cost parcels by weighing their combination of attractive development characteristics and high biological benefits.

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Tables

Table 1. Explanatory variables used in propensity score binary logit model

Variable	Description
DistTown	Distance from parcel boundary to nearest town.
DistRoad	Distance from parcel boundary to nearest road.
AvgStdD_Slope	Average standard deviation of slope measurements on parcel to measure roughness of terrain.
AgNearView	Share of agricultural lands, based on land cover data, within 1-mile viewshed of parcel.
ResNearView	Share of residential lands, based on cadastral data, within 1-mile viewshed of parcel.
CommNearView	Share of commercial lands, based on cadastral data, within 1-mile viewshed of parcel.
WetlandCover	Share of wetlands, based on land cover data, on parcel.
ForestCover	Share of forest, based on land cover data, on parcel.
UndevCover	Share of undevelopable lands – perennial ice/snow, open water, or barren land – based on land cover data, on parcel.
Mtn_Pks	Count of mountain peaks above 13,000 feet elevation visible from parcel.

Table 2. Marginal effects for propensity score binary logit model

Variable	Marginal Effect[1]
DistTown	-0.000001
DistRoad	-0.000203
AvgStdD_Slope	-0.105303
AgNearView	-3.482419
ResNearView	-3.673122
CommNearView	-9.265545
WetlandCover	-0.320029
ForestCover	0.535645
UndevCover	0.175655
Mtn_Pks	0.000192

[1] Marginal effects are calculated for each observation; the average across observations is reported.

Figures

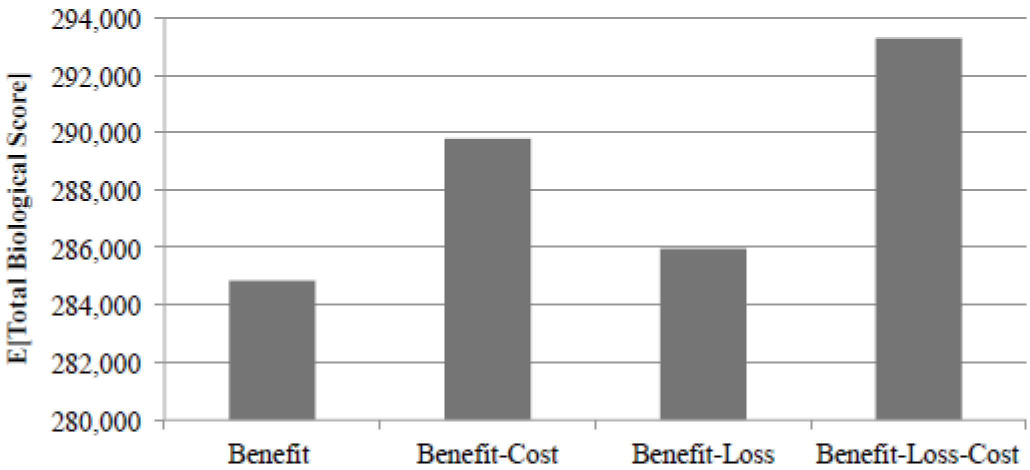

Figure 1. Landscape-level expected biological scores produced from alternative targeting strategies with a total budget of $36 million.

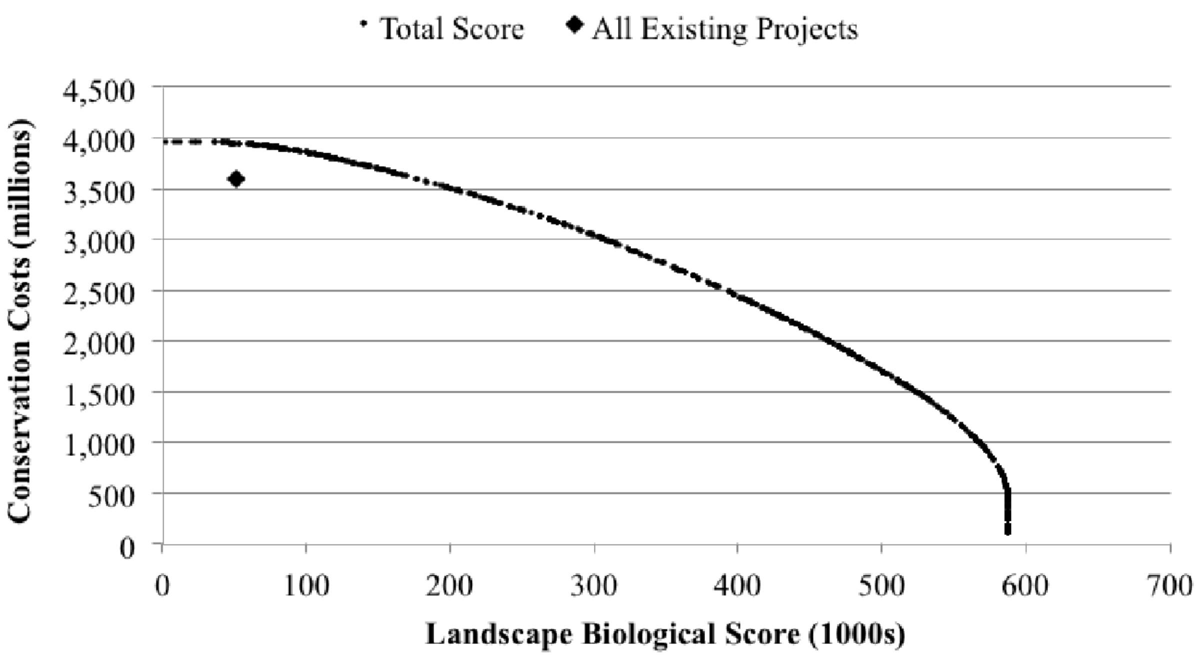

Figure 2. Comparison of conservation easements in Sublette County, WY to the theoretically most efficient production possibility frontier.