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INTEGRATING OPTIMIZATION AND STRATEGIC CONSERVATION TO ACHIEVE HIGHER EFFICIENCIES IN LAND PROTECTION

By

Ole M. Amundsen, Kent D. Messer, and William L. Allen, III

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Alfred Lerner College of Business & Economics

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Integrating Optimization and Strategic Conservation to Achieve Higher Efficiencies in Land Protection

Ole M. Amundsen[a], Kent D. Messer[b], and William L. Allen, III[a]

[a] *The Conservation Fund*
[b] *University of Delaware*

Abstract
Strategic land conservation seeks to select the highest quality lands given limited financial resources. Traditionally conservation officials implement strategic conservation by creating prioritization maps that attempt to identify the lands of highest ecological value or public value from a resource perspective. This paper describes the history of using optimization in strategic conservation and demonstrates how the combination of these approaches can significantly strengthen conservation efforts by making these programs more efficient with public monies.

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Introduction

Imagine that you are thinking about starting fly fishing, and are considering purchasing a new fly rod. There are many options on what type of fly rod you could purchase. For roughly $1,500 you could get a hand crafted bamboo rod. These rods connect the user with the tradition of fly fishing and are highly sensitive instruments. However, if the rod breaks, you will need to get your rod repaired with a new tip or buy a new rod. For $650, you could purchase a nice graphite rod that is well made, offers a range of casting options, can handle big fish and comes with a lifetime warranty. Finally, you could visit your local general sporting goods store and get a package with rod, reel, line and flies for $150 – without a warranty. In this scenario quality and cost are factors in the decision making process as well as the experience and skill level of the user.

As land conservationists, we have to make similar decisions regarding what land acquisitions projects to pursue. However, often the only factors considered in the decision making process involve the quality of the land. Now, acquiring high quality land – whether to provide habitat for rare species, protect rich agricultural soils or provide public access to a beautiful resource does represent decision-making in the public interest. Yet, not to include cost of the property at all, or to include it only in coarse ways, misses a major component in making a wise decision and being a good steward of public funds.

In these tough financial times of budget cuts and staff furloughs, state conservation officials are fortunate to have any funds for land acquisition. Even with potential Federal funding increases in

Land and Water Conservation Fund (LWCF), United States Department of Agriculture (USDA) Forest Legacy, and Farm Bill programs, state officials have limited funding for land conservation. While at the same time, the economic downturn has increased the opportunities for land conservation as landowners feeling the economic pinch seek buyers or as developers try to unload once-promising parcels. Fortunately, there are tools to help state officials address budget constraints while continuing with the conservation mission.

Optimization is a branch of economics and operations research studies that in recent years has shown land conservation managers how to get more land conserved under their budgets or achieve the same level of environmental benefits from land conservation projects with a smaller budget (Kaiser and Messer, 2010). Binary linear programming is a standard mathematical technique for optimization, while cost effective analysis is a computationally simpler technique that utilizes a ratio of benefits and costs for each project in the selection process. Both techniques offer significant benefits to conservation activities. This white paper will explore land conservation decision making, introduce optimization and provide examples of the use of this technique for a variety of land resource types. The use of optimization with strategic conservation plans will be highlighted as complementary approaches for prioritization. Finally, emerging issues in the application of optimization will be discussed.

Foundations of Optimization: Benefit Criteria

Most state agencies use benefit criteria for evaluating land acquisition opportunities. Benefit criteria are frequently utilized in a rank based selection process which refers to the practice of evaluating potential projects against a series of questions or desirable attributes, with each question offering a range of outcomes that are numerically scored. Based on the final score the state agency seeks to acquire the top ranked parcels until its budget is exhausted.

The origin of benefit criteria in conservation can be traced to a number of practitioners and was a response to try to balance many factors in public decision making. One of the earliest advocates for benefit criteria in evaluating public land decisions was noted landscape architect and leading figure of the park movement, Frederick Law Olmsted. In 1853, Frederick Law Olmsted went on a five month horseback journey through Texas and his travels influenced his professional practice of park design. Years later in an address to Prospect Park Scientific Association on the overall purpose of parks, Olmsted recalls his Texas trip and how he was studying the landscape, searching daily for the "ideal camping spot" and trying to define natural beauty. Olmsted used the following benefit criteria to evaluation camping locations:

1) Near good, clean water for drinking and bathing
2) Near good pasture for their cattle
3) Fire wood at a convenient distance
4) Seclusion; for greater safety from ruffians
5) Like to have game near at hand
6) We made it a point to secure as much beauty as possible from our tent door (Olmsted, 1868).

Most importantly, Olmsted asserted that these benefit criteria were used by pioneers to select sites for early settlements and in a more urban context, are useful for evaluating potential lands for public parks. Olmsted's impact on the park movement was substantial and his use of benefit criteria illustrates the appeal, focus and application of a thoughtful selection process during the early years of park planning.

Benefit criteria were also used to ensure public trust and prevent corruption. Many state agencies and conservation organizations adopted a rank based selection process to demonstrate that land acquisition decisions were made based on objective merit instead of purely political motivations. Having benefit criteria that are communicated to the public increases transparency and hopefully improves public confidence. Interest in using benefit criteria to bolster public support and confidence can be seen most recently in the land trust community's approach to addressing increased public scrutiny on use of conservation easements. Land trusts are measuring their compliance with the public benefits requirements for federal tax deductions by placing a stronger emphasis on the use and value of benefit criteria in the decision making process (Amundsen, 2004). In some states, criteria are being used to help balance the regional distribution of funding or the social equity of land conservation dollars between urban and rural regions within a state. This too can increase the credibility of a state land acquisition program with the public and state legislative bodies.

An additional motivation for using a rank based selection process is that state agencies and conservation organizations have faced incredible demands for the use of their limited funding.

Many states have adopted acreage goals for land conservation, accelerating land acquisition activity but also increasing the pool of potential projects. State conservation personnel need decision support tools to separate worthy projects with many resource benefits from projects with few resource benefits. Finally, state agencies receive significant funding from the federal government and those funds frequently come with or use benefit criteria. By using similar benefit criteria state improve their chances for success in competing for federal funds.

For instance, conservation programs aimed at protecting farmland have long used rank based selection processes for evaluating applications to purchase development rights. At the federal level the Natural Resources Conservation Service (NRCS) began advocating use of a rank based approach in 1981 with a criteria system to evaluate parcels for both overall agricultural quality and site based factors in Orange County, New York (American Farmland Trust, 2006). Shortly after the New York application of the criteria system, NRCS launched a 12 county, six state pilot study of what would become known as the Land Evaluation and Site Assessment or LESA model (Pease and Coughlin, 1996). By evaluating both land attributes such as soil quality and other factors linked to viability of the parcel to support farming, such as zoning or distance to a grain elevator, it was hoped that a more complete understanding of a parcel's relative worth would be obtained. The application of LESA ranking systems by state and county offices of NRCS influenced state sponsored programs that sought to leverage state funds with federal funding. State and county conservation programs often mirror the LESA criteria as a strategy to stretch their budgets by submitting unfunded projects to the federal agencies, without having to conduct a new analysis. However, the LESA model does not take into account the proposed cost of acquiring the development rights in evaluating a collection of potential projects.

In general, benefit criteria have largely fulfilled their mission in keeping the public trust, preventing open corruption, targeting high quality lands, helping state staff sort projects and meet federal mandates. However, increasingly questions have been raised about the inefficiency of the rank based selection approach and what alternatives may exist that can use benefit criteria in a way that efficiency uses public funds to achieve conservation objectives.

The Growth Acceptance of Optimization

The introduction of optimization is the next stage in the evolution of the decision making process for state agencies building on the interest of state agency staff in making solid choices for land conservation. In fact, optimization relies on benefit criteria to articulate the overall conservation value of a project. Optimization offers the chance to improve the ability of state agencies to address the concerns that gave rise to a rank based selection process by increasing public confidence that taxpayer funds are being well managed, making objective, merit-based decisions and using a rigorous, scientific approach to comply with increasing guidelines on federal funding. In addition, optimization techniques can help decision makers distinguish between high-cost projects that can rapidly deplete available funds while making relatively small contributions to overall conservation goals and "value" projects that ensure that conservation benefits are maximized given the available budget.

Optimization models enable the user to select the set of projects that maximize the total conservation benefits. An important distinction must be underscored that the total benefits are all the projects selected *combined*. Optimization focuses on the total benefits of the pool of potential projects, whereas a rank based selection process examines projects and determines their *individual* worth in isolation without looking at the broader portfolio of potential projects.

Twenty years ago, it may have taken a super computer to run an optimization model. Today the average office computer has both the raw computation power and the software necessary to run these models. The models run on standard spreadsheet software. In the Microsoft program Excel™, optimization runs on an “Add in” that comes with the standard professional office package called “Solver” that can run models with roughly 200 parcels. However, if the model is at the edge of the 200 parcel limit the run time on the computer can be several hours. For models with more parcels more powerful software is recommended from Frontline Systems. Dr. Kent Messer and The Conservation Fund (TCF) have built a custom tool that uses state-of-art optimization processes in a user-friendly, click-and-point interface within Excel.

Preservation of Agricultural Lands

In 2006, a team from TCF worked with Dr. Messer to create decision support tools to evaluate agricultural opportunities including optimization of the Baltimore County Agricultural Land Preservation Program (Messer and Allen, 2009). Baltimore County, Maryland has one of the most well established farmland preservation efforts in the country, dating back to 1979. In 2006, the county program had just reached a major milestone of preserving 40,000 acres – or the halfway point to its overall acreage goal of 80,000 acres of farmland. On reflecting on their achievement, county staff and the program advisory board wanted to apply optimization techniques to improve the use of their limited financial resources while maximizing the return on their investment by picking worthy projects.

A significant portion of the funding for projects comes from the Maryland Agricultural Land Preservation Program (MALPF). The state of Maryland established guidelines for agricultural preservation and relies on LESA models to help officials invest wisely in agricultural preservation. Baltimore County also had relied upon a LESA model for evaluating potential applicants and was seeking additional GIS refinement in their modeling of water quality and taking other factors such as forestland into account. County staff ran the optimization tool in 2006 on their applicant pool as a pilot project, learning how to apply the tool and make operational adjustments.

For the next three fiscal years, Baltimore County staff and advisory board evaluated applications for preservation using optimization. The county evaluated their applications over a series of grant cycles tied to different fund sources. The results of using optimization are for fiscal years 2007, 2008, and 2009 include both the state and county funding rounds.

In 2007, Baltimore County used the optimization technique of cost effective analysis in two different selection processes: (i) to select projects totaling 809 acres for protection given the $4.8 million of funding by MALPF and (ii) to select projects totaling 882 acres for protection given the $3 million of funding from Baltimore County. If the rank based LESA system that Baltimore County had previously used was employed, Baltimore County would have only protected 733 acres for the $4.8 million of MALPF funds and 651 acres for the $3 million of funding from Baltimore County. In other words, as a direct result of using conservation optimization, in 2007, Baltimore County protected 1,691 acres instead of just 1,384 acres that it would have protecting using its previous rank-based approach—a 22% increase worth an estimated $1.8 million.

Baltimore County has continued to apply optimization to its selection processes in 2008 and 2009. In total over the first three years of use, optimization has helped Baltimore County protect an additional 680 acres of high-quality agricultural land at a cost savings of approximately $5.4 million (average cost per acre of approximately $8,000). These estimates suggest that the return on investment during these three years is more than 60 to 1. In other words for every one dollar that Baltimore County spent to adopt optimization, it has returned more than 60 dollars in conservation benefits.

An important lesson learned from Baltimore County is that a change in attitudes and organizational culture may be required by both staff and advisory board members who are accustomed to appreciating the value of a project within certain parameters. Baltimore County staff and board members went through an adjustment period to recalibrate their perceptions of value to include cost and re-define their mental picture of an ideal project. For the adoption of a new technology or technique of evaluating projects, officials need to recognize that this change is significant and needs to be managed if the conservation organization is to succeed in actually using the new evaluation tools (Amundsen, 2009). Baltimore County still exercises discretion in the application of optimization within certain grant rounds and allows for compelling cases to made on a case-by-case basis reflecting the fact that are still factors or values that are not reflected in a model. It is this incremental approach to the adoption of optimization that makes Baltimore County's experience a model of how other conservation organizations can transition to the use of optimization.

Another point to underscore is that the Baltimore County's experience with the use of optimization over three years is a real on-the-ground application of optimization. When combined with the results from previous studies on the potential cost savings, efficiency gains and increased benefits and acreage, it makes for a compelling case for the expanded use of this tool.

Preservation of Working Forestlands

The USDA Forest Legacy program has started to explore optimization. This interest by Forest Legacy may lead many states agencies to consider cost to make their proposals more competitive. In 2008 the Forest Legacy program contacted Dr. Messer to undertake a pilot study comparing its current rank based model to optimization for a budget of $53 million with a pool of 82 potential projects ranging in size from 5 acres to over 100,000 acres (Messer 2009). The traditional rank based selection process recommended funding 17 projects that totaled 209,082 acres where as for the same budget, the optimization model that accounted for parcel size in the measuring of benefits recommended funding 20 projects totaling 300,703 acres (a 44% increase).

Interestingly, both models agreed on five of the top projects, however, the optimization model identified 14 other projects that were over-looked by the rank based selection process. On average, these 14 projects were larger in acreage than their counterparts from the rank based list, while still providing a high level of benefits when selected as part of a portfolio at a given budget constraint. The potential application of optimization to the Forest Legacy program would significantly change the types of projects selected, increase the pace of conservation and in turn influence state priorities in the conservation of forestlands.

Evaluation of both Fee Simple and Easement Options

One of the first major landscape scale applications of optimization was completed by Dr. Messer, with the application of the technique to the Catoctin Mountain region within Frederick County, Maryland (Messer 2006; Messer and Wolf 2004). The region was selected by the Maryland Department of Natural Resources (MD NDR) for a pilot application of optimization. Home to the presidential retreat Camp David, the Catoctin region is part of the Blue Ridge Mountains, and is ecologically significant. As the region is only 45 minutes drive from Washington D.C. and Baltimore Maryland, the area was under growth pressure from residential development. In 2001, the state of Maryland finished design a green infrastructure network green infrastructure network of large interconnected contiguous blocks of core resource lands connected with corridors (Weber, 2003). State officials wanted to examine how to improve the targeting of conservation with the combined use of their new statewide green infrastructure assessment and optimization.

The initial analysis of the optimization model was on a set of nearly 200 parcels, totaling over 10,000 acres highlighted by the state of Maryland green infrastructure network with a total estimated real estate value of over $14 million. The study examined outcomes with three sample budgets of $1 million, $2.5 million and $5 million. For each parcel, the conservation value was scored using MD DNR's benefit criteria and the optimization was run for each of the three sample budgets assuming the use of full fee acquisition. As a point of comparison, the MD DNR's rank based model was run using the same benefit criteria data on ecological benefits and acquisition costs without optimization. The results were striking. For each budget level optimization outperformed the rank based model by protecting high acreage totals as well as higher conservation value scores.

Next the analysis was re-run for each of the three budget scenarios using a mixture of fee acquisition and easement acquisition. Decision rules on when the agency would use fee acquisition were incorporated as well as estimates on the projected value of easements using the state property assessment data base. With the easement options added, the cost effective model again outperformed the rank based model, producing total conservation value scores several times higher and conserving roughly twice the acreage of the rank based selection process. Furthermore by including easements the optimization tool also had improved results over the full fee simple optimization model of by approximately 30 percent.

Why were the results so dramatic? The answer is that optimization consistently steered state acquisition strategies away from buying two very high-priced parcels that scored near the top of the rank based selection process. These two parcels, although very high quality, were absorbing most of the budget for land acquisition. What the optimization selection process demonstrated to decision makers was that by not purchasing these two “budget sponge” parcels, a collection of high quality and more affordable parcels could be put together that would exceed the aggregate conservation values and acreage of the other two parcels. Put another way, optimization showed decision-makers specifically what opportunities they were giving up by pursuing the two high ranked parcels. These two high ranked parcels may still be the best ones for the agency to move on for a number of reasons, but optimization at least makes all the decision makers aware of what they are trading for acquiring those lands. The message from the pilot application in the Blue Ridge Mountains of Maryland was clear - by systematically including cost in evaluating projects, state agencies can conserve more acreage of land and higher quality land at the same budget.

Meeting Acreage Goals

Many land conservation programs are focused on achieving an acreage goal that communicates success of a program or public policy by conserving a certain amount of acreage by a certain date. These goals galvanize political support, capture the public's imagination and motivate land acquisition staff. As the saying goes, "what gets measured gets managed". By providing acreage goals and deadlines, a series of incentives is offered to land protection professionals to achieve the state acreage goal. However, one of the unintended consequences of acreage goals can be an incentive for conservation officials is to simply buy as much cheap land as possible in order to achieve the acreage goal by the announced deadline. Optimization is still focused on protecting high quality land and guides officials on their exploration for high value projects, in terms of both cost and quality. Optimization can help conservation staff meet their acreage goals and protect high quality land and at a cost less than would be the case using a rank based selection process.

Optimization was used to help model the achievement of acreage goals in the state of Delaware. Dr. Messer and a team from TCF helped state and county officials consider funding levels to achieve the Kent County's (one of Delaware's three counties) portion of the state's Livable Delaware objective of conserving half of Delaware's remaining, unpreserved cropland by 2024 (Allen et al. 2006; Messer and Allen 2010). Using a green infrastructure method, 60,000 acres were identified as the acreage goal for Kent County to achieve the Livable Delaware objectives.

To achieve this goal, state and county officials would need to conserve an average of 3,333 acres per year for 18 years. Optimization was undertaken to provide decision makers with a range of annual budget options that would be required to achieve the acreage goal for Kent County.

Using the historical records of the Delaware Agricultural Lands Preservation Foundation (DALPF) future acquisition costs were estimated such that forecasts could be made regarding future budget scenarios. DALPF functions as an application program and uses an auction-type system for selecting projects based on the percentage discount for the easement value offered by the landowner. For each funding cycle, DALPF offers all landowners a free appraisal if they express an interest in selling their development rights. When the landowner receives the appraisal they decide whether to continue with the conservation transaction and if so, how much to discount the non-agricultural value of the easement to DALPF. Once the application deadline closes, DALPF evaluates all of the landowner offers and purchases the projects with the *highest percentage discount* until the budget is exhausted. An important point is that DALPF uses LESA scores as an initial screen on potential projects and once a project is deem eligible, DALPF only considers the discount percentage offered by the landowner in selecting projects for funding.

Using DALPF transaction records, over 500 parcels were evaluated and the data on these parcels was processed to enable an apples-to-apples comparison. At the time of the analysis DALPF had spent $44.6 million over nine grant cycles (roughly nine years) and acquired 37,000 acres in Kent County. As real estate markets are difficult to predict, low and high estimates were calculated. For the rank based selection process, it was forecasted that an annual budget of between $6.7 to $17.4 million would be needed to achieve the conservation goal. In contrast, if optimization was used, then an annual budget between $4.5 to $11.6 million would be required.

A comparison of projected total program efficiency was even more dramatic. Using the rank based selection process, the goal of 60,000 acres would be achieved for $121.9 million. In contrast, optimization would meet the acreage goal for $82.6 million, a savings of $39 million for Kent County alone. Importantly, the cost savings did not come with an impact on quality as the conservation values scores and scores for farming were all higher for the collection of parcels purchased with the guidance of optimization.

Current Use of Optimization

The prioritization of land conservation opportunities used as mitigation to offset impacts from infrastructure development projects is an emerging application of optimization. Over the past year, TCF has worked with the US Fish and Wildlife Service (US FWS) and state Natural Resource agencies across 14 states on drafting a green infrastructure network for strategically locating mitigation opportunities associated with a Multi-Species Habitat Conservation Plan (MSHCP) for the operation and maintenance activities along a 15,500 linear mile natural gas pipeline network managed by NiSource, Inc. Once qualified mitigation projects have been identified by state agencies, a decision support framework for evaluating and ranking submitted mitigation sites will be used by a mitigation panel to select projects using MSHCP mitigation funds. The decision support framework will utilize a customized optimization tool to help select a portfolio of projects that maximizes benefits at a given budget level or identify the minimum cost to achieve a defined benefit level based on compensatory mitigation requirements outlined by the mitigation panel.

The Maryland State Highway Administration (SHA) has been examining transportation improvement options for US 301 near the town of Waldorf, including the construction of a bypass or upgrading the existing road. SHA adopted environmental stewardship into its US 301 transportation planning, with the goal of creating a net benefit to the environment. This approach is innovative among transportation agencies in that it goes above and beyond compensatory mitigation required by the National Environmental Policy Act (NEPA) to offset impacts from construction and related activities. One of the methods by which SHA hope to achieve this ambitious goal is through the use of optimization to identify the set of stewardship projects that will maximize natural resource benefits within given budget constraints. Finally, the US Department of Defense, the US Army and US Marine Corps are exploring the use of optimization with their conservation planning efforts for protecting additional lands for buffers from military bases and in conjunction with their stewardship requirements for federally listed threatened and endangered species.

Conclusion

As these examples have demonstrated, optimization builds on the structure of benefit criteria and GIS capabilities that most state agencies have used for years to evaluate potential projects. Optimization will help conservation officials in the same way that the adoption of rank based selection process have helped in the past by improving credibility, transparency and ensuring the wise stewardship of public funds. When used as part of a strategic conservation plan, optimization can provide land acquisition program managers with added clarity, precision and direction. During these difficult economic times, optimization helps state agencies increase the quality and acreage of conservation land by using their limited resources more effectively. With the on-the-ground successes and demonstrated value of optimization, this technique will become increasingly common. Using incremental approach to the adoption of optimization can help with the cultural change that may be needed to facilitate full use of optimization. It is important to realize that the process conservation agency staff use to evaluated projects has evolved and changed over time, and that this natural process continues today.

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