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Final Report: Development of a Best Practices Framework for County Land Protection Programs in Maryland: Quantifying Benefits, Costs and Effectiveness of Land Parcel Selection

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Summary:
The final report summarizes the best practices recommendations for the Maryland Agricultural Lands Preservation Foundation and related research activities that have been supported by our grant from the Harry R. Hughes Center for Agro Ecology, Inc., affiliated with the University of Maryland. The project was funded by a Special Project Grant through USDA-NIFA.

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Section I. Executive Summary

State-of-the-art agricultural lands preservation involves careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. For agricultural preservation programs to deliver the greatest 'bang for the buck', it is critical to establish a robust decision support framework that can be used to reliably and consistently evaluate and select potential preservation opportunities.

Effective conservation efforts require both sound science and sound economics, yet the most common technique used to select conservation projects in conjunction with the MALPF program can be quite inefficient. This selection technique, a "rank-based model" (also referred to as benefit targeting), selects the projects with the highest benefit scores with little consideration of the relative project costs. In situations where numerous high quality projects go unfunded due to budget constraints, the rank-based approach ensures only that the available resources are spent on the highest ranked projects; however, the model frequently misses opportunities to spend the money in a cost-effective way by funding lower-cost, high-benefit alternatives that would extend limited financial resources and maximize overall conservation benefits.

In contrast, an optimization model identifies the set of cost-effective projects that maximizes aggregate benefits (Kaiser and Messer, 2011). The optimization model uses data describing the resource benefits of the potential projects and relative priority weights that an organization assigns to each benefit measure, as well as estimated project costs and budget constraints. An optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the aggregate conservation benefits given a specified budget.

Optimization offers a way for those engaged in agricultural land preservation to increase public confidence that taxpayer funds are being well managed and that scientific, objective, merit-based decision-making process is being used. In addition, optimization 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 "good value" projects that ensure that conservation benefits are maximized given the available budget.

The research evaluated MALPF administrators attitudes regarding optimization through two surveys: one administered before and one administered after an educational lecture on optimization. The survey instruments were pre-tested by a review panel consisting of key county MALPF administrators, state MALPF administrators, and prominent land preservation economists. Based on the concept of Dillman's total design survey method, a variety of follow-up attempts were made such that the overall response rate for the survey was 100% of the county administrators.

The primary survey results demonstrate that a better understanding of optimization increases administrators' willingness to adopt it. In addition, the required initial investment in technical resources has prevented program administrators from using this new approach. If there is no perceptible incentive to alter the current system, they surely will not be willing to put optimization to use. Administrators who have been the most successful in protecting land in terms of the percentage of farmland available are most willing to adopt more advanced approaches. Similarly, metro areas that are experiencing particularly strong development pressures are more willing than nonmetro areas to step up their efforts by adopting "sophisticated" but cost-effective preservation techniques. The knowledge model indicates that administrators' predictions about obstacles to adoption are related to how much they know about the new approach. The more people know about optimization, the less difficulty they perceive.

Based on the results from Baltimore County and the responses received from the survey, this report recommends the following best practices for the MALPF program:

A. Adopt Optimization at the County and State Levels.

B. Simultaneously Select Projects for Multiple Funding Sources.

C. Train Staff on Optimization and Provide Related Software.

D. Adopt Other Best Management Practices in Conservation Selection. These include:

- Reduce Parcel Costs with Landowner Discounts instead of Price Caps or Formula Pricing
- Do Not Count Price as an Element of Parcel's Benefits
- Be Cautious of Committing Future Government Resources
- Account for Development Threat
- Use Optimization for Other Conservation Programs
- Allow for Some Discretion in Selection

For counties engaged in agricultural preservation, optimization offers significantly higher benefits and greater cost efficiency – things that are particularly valuable with public expenditures constantly under scrutiny. A 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. Given Baltimore County's experience with optimization, they have an opportunity to gain further efficiency by integrating more sophisticated optimization tools that allow their selection of parcels for various programs simultaneously. Finally, at the state level, MALPF can support these efforts by creating incentives for counties to learn about optimization and to provide training and tools that would be helpful to county-level staff in making cost-effective funding recommendations.

These recommendations are based on Baltimore County's experience with using optimization, analysis of a survey completed by MALPF staff, and knowledge learned from other conservation efforts. In conclusion, to build a best practice framework for MALPF, education on optimization and/or training on the optimization decision tool must first be provided to program administrators and employees. Training should address the importance of a cost analysis and the value of being able to customize benefit factors in the analysis. Familiarity with the optimization tool will relieve concerns about implementing it, increase the incentive to reform existing processes, and increase willingness to employ a new tool.

Section II. The Report: Best Practices for Increasing the Cost Effectiveness of the Maryland Agricultural Lands Preservation Foundation

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Abstract

State-of-the-art agricultural lands preservation involves careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. This report outlines several "best practices" that can help the Maryland Agricultural Lands Preservation Foundation (MALPF) at both the county and state levels use its public funding efficiently with the goal of securing the highest public benefit from the program possible. Results from a survey of MALPF program administrators help identify staff's willingness to use more cost effective techniques and what obstacles may need to be overcome as part of this process.

A. Introduction

State-of-the-art agricultural lands preservation involves careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. For agricultural preservation programs to deliver the greatest 'bang for the buck', it is critical to establish a robust decision support framework that can be used to reliably and consistently evaluate and select potential preservation opportunities.

Integrating economic costs into conservation planning is a key to ensuring better conservation outcomes (Naidoo et al., 2006). When trying to select the most cost-effective mix of conservation projects, it is more efficient to determine overall quality based on benefit *and* costs rather than with an analysis strictly of either cost *or* benefit (Babcock et al., 1997; Hughey, Cullen, and Moran, 2003; Perhans et al., 2008). Optimization is a branch of economics and operations research studies that in recent years has shown conservation professionals how to get more land conserved within constrained budgets or achieve the same level of environmental benefits from land conservation projects with a smaller budget. Numerous academic studies have shown that using optimization in conservation programs yields significantly more acreage with higher overall conservation benefits than does applying more traditional project selection approaches.

Effective conservation efforts require both sound science and sound economics, yet the most common technique used to select conservation projects in conjunction with the MALPF program can be quite inefficient. This selection technique, a "rank-based model," selects the projects with the highest benefit scores with little consideration of the relative project costs. In situations where numerous high quality projects go unfunded due to budget constraints, the rank-based approach ensures only that the available resources are spent on the highest ranked projects; however, the model frequently misses opportunities to spend the money in a cost-effective way by funding lower-cost, high-benefit alternatives that would extend limited financial resources and maximize overall conservation benefits (Allen, Weber, and Hoellen, 2010).

In contrast, an optimization model identifies the set of cost-effective projects that maximizes aggregate benefits (Kaiser and Messer, 2011). The optimization model uses data describing the resource benefits of the potential projects and relative priority weights that an organization assigns to each benefit measure, as well as estimated project costs and budget constraints. An optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the aggregate conservation benefits given a specified budget.

Optimization offers a way for those engaged in agricultural land preservation to increase public confidence that taxpayer funds are being well managed and that a scientific, objective, merit-based decision-making process is being used. In addition, optimization 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 "good value" projects that ensure that conservation benefits are maximized given the available budget (Amundsen, Messer and Allen, 2010).

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.

In 2006, a team from The Conservation Fund 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 agricultural easement acres acquired through all sources, Baltimore County ranked among the top 12 local programs in 2003. Some $86.5 million had been invested in easements by 2003 and had put large, continuous blocks of agricultural land under protection (Sokolow and Zurbrugg, 2003, Sokolow, 2006). 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 MALPF. The state of Maryland established guidelines for agricultural preservation and relies on Land Evaluation / Site Assessment (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 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 protected 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.

The primary survey results demonstrate that the more administrators know about optimization, the less difficulty they perceive. Similarly, the results suggest that the higher the administrators' understanding of optimization the higher their willingness to adopt it. Additionally, administrators who have been the most successful in protecting land in terms of the percentage of farmland available are most willing to adopt more advanced approaches. Similarly, metro areas that are experiencing particularly strong development pressures are more willing than nonmetro areas to step up their efforts by adopting "sophisticated" but cost-effective preservation techniques.

The results also suggest that the initial investment in technical resources related to using optimization has prevented program administrators from using this new approach. Furthermore, many administrators report that the current system lacks incentives to use optimization and that the objective of cost effectiveness is relatively low priority. These factors reduce administrators' willingness to adopt this technique.

Based on the results from Baltimore County and the responses received from the survey, this report recommends the following best practices for the MALPF program.

- **A.** Adopt Optimization at the County and State Levels.
- **B.** Simultaneously Select Projects for Multiple Funding Sources.
- **C.** Train Staff on Optimization and Provide Related Software.
- **D.** Adopt Other Best Management Practices in Conservation Selection. These include:
  - Reduce Parcel Costs with Landowner Discounts instead of Price Caps or Formula Pricing
  - Do Not Count Price as an Element of Parcel's Benefits
  - Be Cautious of Committing Future Government Resources
  - Account for Development Threat
  - Use Optimization for Other Conservation Programs
  - Allow for Some Discretion in Selection

B. Research Methods

The research approach is described including the survey construction, the pre-test of the survey, the revision process, the administration of the survey and the follow-up procedure. A critical series of questions in the survey were related to the concept of "optimization" of the project selection process. Borrowing the idea of optimization from operations research, this study uses the term in reference to a process "to provide a high level of aggregated benefits at the best possible price." The survey then asks for opinions about two different optimization approaches. One approach is called "Binary Linear Programming" that is the assured optimal algorithm common in the operations research literature (see Kaiser and Messer, 2011). The other approach is named "Cost Effectiveness Analysis", which is an approach commonly used in medicine to determine the treatments that yield the highest health benefits given the expenditure. The main objectives of the survey were to identify:

1. Preservation program selection criteria in each county and how these benefit factors and cost assessments are measured.

2. Administrator's willingness to adopt optimization as a selection process and compare the feasibility of optimization techniques.

3. Obstacles to adopting optimization and the severity of the obstacles.

Two survey instruments were used—a pre-survey and a post-survey (Appendix A). The five-part pre-survey was conducted before educational material about optimization was presented. The six-part post-survey was conducted after discussions with the administrators about optimization techniques, the results of its application in Baltimore County, and other related issues.

The survey instruments (both the pre-survey and post-survey questionnaires) were pre-tested on August 20, 2009, by a review panel consisting of key county MALPF administrators, state MALPF administrators, and two prominent land preservation economists (Dr. Lori Lynch – University of Maryland and Dr. Joshua Duke – University of Delaware). The panel was given the following tasks:

- Confirm the most appropriate method to define selection criteria and its calculation mechanism.
- Review the terms that county administrators could use to describe easement costs and select the best terms to provide a clear and understandable definition.
- Modify survey questions specifically related to county and state government contexts.
- Review the survey language and administration to ensure that it met current standards for academic research.

After the five-part pre-survey was completed, Dr. Kent Messer, University of Delaware, gave an educational presentation on optimization. He explained how the approach performs, how to implement it, and what had been achieved after its application. He also compared two optimization techniques this study defines: binary linear programming (BLP) and cost-effectiveness analysis (CEA).

After Dr. Messer's presentation, Wally Lippincott and Robert Hirsch, MALPF county administrator and GIS analyst from Baltimore County, Maryland, gave a presentation on improved results generated in Baltimore County after applying cost-effectiveness analysis to its county preservation program. During the presentation, Mr. Lippincott and Mr. Hirsch expressed very positive sentiments about Baltimore County's experience with optimization and its ability to work within the existing MALPF structure including the following statements:

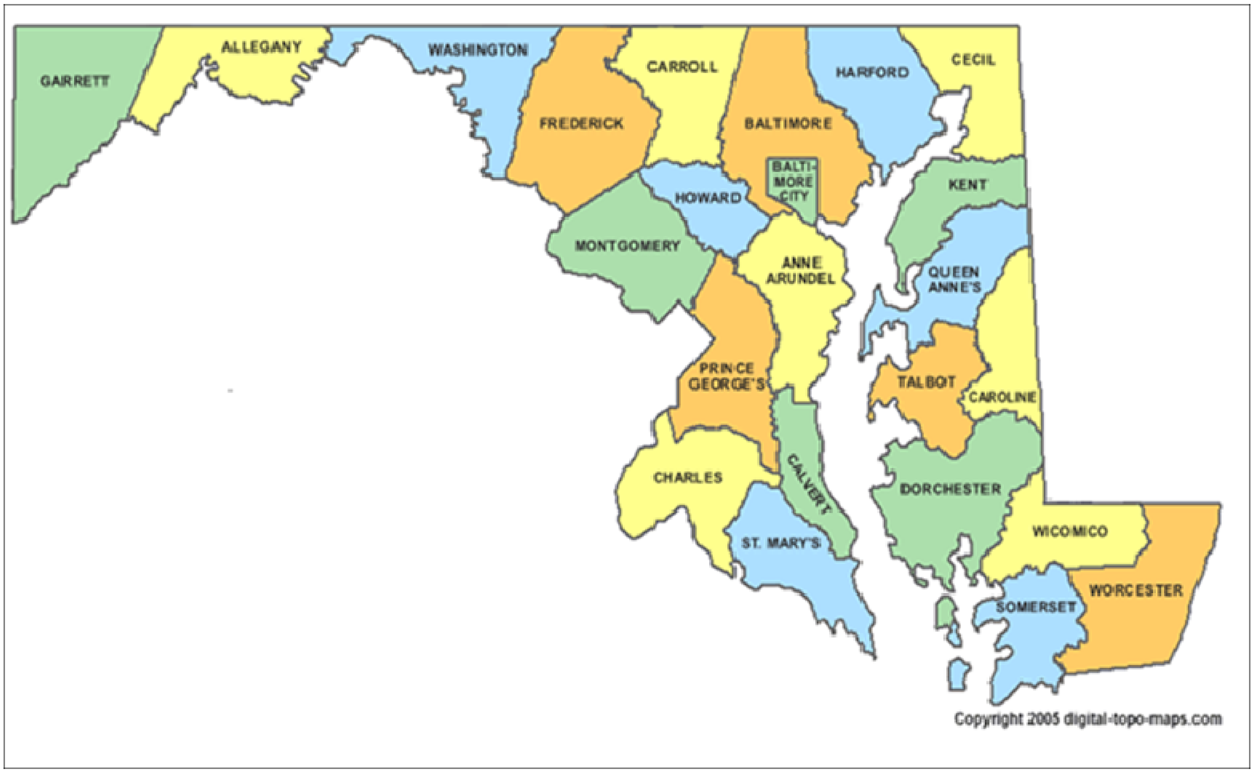
> "After trying for years to balance price with farm quality using rank based methods, we switched to optimization. In the first three years of using optimization, Baltimore County has been able to protect an additional 680 acres for the same amount of funds that would otherwise have been spent. This also translates into a savings of approximately $5.4 million." (Lippincott, 2010)

> **"**Optimization has proven easier to administer and run than our old methods. During our rank-based days, we performed extra administrative and mathematical work in order to solicit discounts and award extra LESA points for discounting. With optimization, this is no longer required." (Hirsch, 2010)

C. Survey Participation

Target participants in the survey were the program administrators in Maryland counties. Since there are 23 counties (see Figure 1), we used several different approaches to survey representative from all 23 counties. On November 19, 2009, MALPF held an annual conference in Annapolis, Maryland, for all county administrators. Representatives from 12 counties attended the meeting. Another five county representatives used the video conference software to participate. Pre-surveys and materials for the optimization presentation were prepared for each seat before the meeting. Twenty-three pre-survey questionnaires were collected: 18 from administrators and staff members of the 12 counties at the meeting, one from a county using video conference software, one from a MALPF board member, and three from MALPF staff members.

Figure 1: Maryland County Map[1]



Based on the concept of Dillman's (1978) total design survey method, a variety of follow-up attempts were made that included emails, written letters, telephone calls, prepaid return envelopes, and a mailing of the survey accompanied by a DVD with a Powerpoint file with Dr. Messer's presentation that he made at the meeting (Table 1). Finally, we abridged the survey for two counties (Appendix B). Overall, response rate for the survey is 100% of the MALPF County administrators.

D. Survey Results

Results from the pre-survey suggest that the surveyed participants have a high level of knowledge both with MALPF and more generally in the field of land preservation. For example, the average working experience of participants is 11.9 years with participants having spent an average of 8.3 years in the current job position. Participants also reported a high degree of knowledge of the MALPF program and their counties' agricultural preservation program as on a scale of 1 to 5, the 29

[1] Image is retrieved from www.digital-topo-maps.com/county-map/maryland.shtml.

county representatives reported an average score of 4.0 for MALPF's program and 4.4 for their county programs.

Table 1: Number of counties that responded to the survey over time.

Date	Event	Cumulative survey response rate
November 2009	MALPF meeting	52.2%
December 2009	Initial reminder Duplicate packets	65.2%
January 2010	Initial phone calls Second round calls Follow-up reminder	91.3%
Feb.–Mar., 2010	Revised survey	100.0%

Several questions sought to measure how important various attributes of the selection process are to the administrators. Five attributes of the processes were considered: knowledge, fairness, transparency, cost-effectiveness and ease of administration. The importance of each attribute is measured on a scale of one to five with one standing for not important, three for somewhat important, five for very important, and two and four between. Statistical results from responses by the 23 senior representatives show that fairness of the selection process is valued most.[2]

As can be seen in Table 2, fairness was the attribute that received the highest average score (4.65) and the transparency of the process was also very important (4.48). While not statistically different from one another, these two factors were statistically more important than the other three attributes. Knowledge of the selection process, including understanding of the selection techniques used, received an average score of 4.26. Ease of administration of the process and the cost-effectiveness of the resulting selections were only moderately important, generating scores of 3.87 and 4.17 respectively.

[2] Unless stated otherwise, data from these 23 observations are used in the rest of the chapter.

Table 2: Assessment of preservation selection techniques from senior representatives

	Knowledge	Fairness	Transparency	Cost-effectiveness	Ease of administration
Importance of criteria	4.26 (0.62)	4.65** (0.65)	4.48** (0.79)	4.17 (0.65)	3.87 (0.76)
Current technique	4.10*,b,c (0.62)	4.05*,b,c (0.74)	4.00*,b,c (0.92)	3.16c (0.96)	3.74b,c (0.81)
BLP	2.26a,c (1.19)	3.11 a (0.83)	2.67 a (0.97)	3.56* (0.70)	2.78 a,c (0.94)
CEA	2.63 a,b (1.16)	3.33 a (0.84)	3.11 a (1.08)	3.78*,a (0.73)	3.17 a,b (0.92)

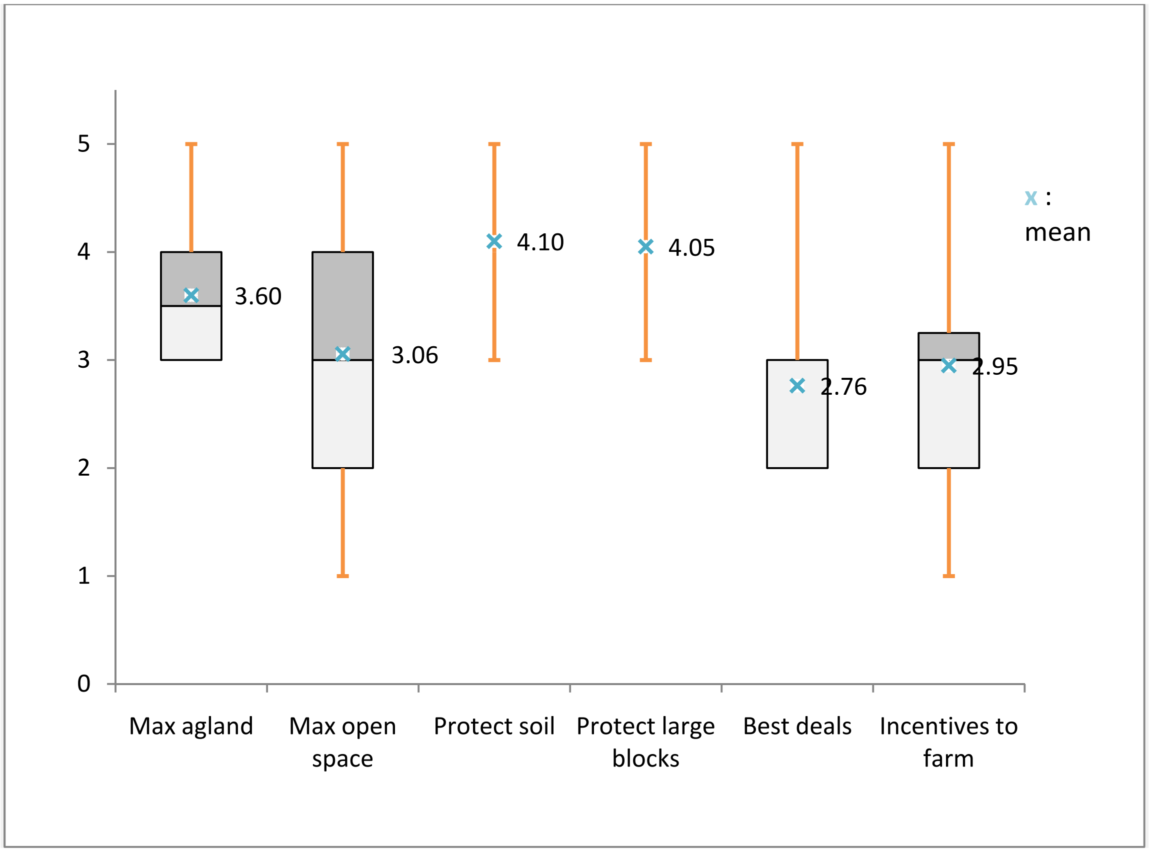
Notes:
1) * and ** denote numbers that are significantly different from the rest in the corresponding row at the 10% and 5% levels respectively.
2) a denotes number significantly different from that with current technique at 5% level.
3) b denotes number significantly different from that with BLP at 5% level.
4) c denotes number significantly different from that with CEA at 5% level.

Interestingly, even in the survey participants were aware that the current MALPF programs did not secure the best deals available for land conservation. Given six different criteria by which to rate the effectiveness of the MALPF program, securing the best deals scored lowest with a score of just 2.76 (Figure 2). The six criteria were as follows:

1) Max agland — Maximize the number of agricultural acres protected.
2) Max open space — Maximize the open space quality of acres protected.
3) Protect soil — Protect the best agricultural land in terms of soil.
4) Protect large blocks — Preserve large blocks of contiguous agricultural land.
5) Best deals — Acquire the best deals on agricultural land.
6) Incentives to farm — Increase incentives for participants to remain in farming.

This finding is consistent with the results reported in Table 2, which showed that the current techniques scored lowest with regards to cost effectiveness (just 3.16 out of 5). Inspection of the results shown in Figure 2 also shows that administrators believe that their programs are doing reasonably well at protecting soil (4.10 out of 5) and protecting large blocks of agricultural lands (4.05 out of 5).

Figure 2: Assessments of the performance of current selection processes

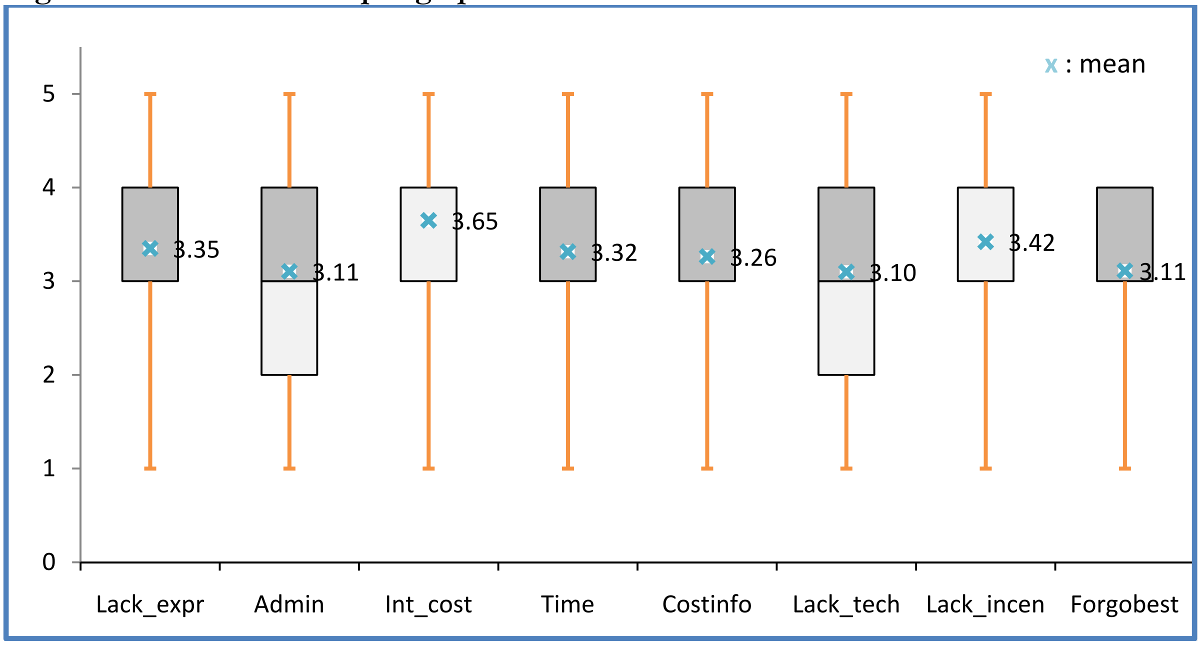


Several of the survey questions evaluated the potential obstacles to adopting optimization as the selection process. The survey listed eight obstacles and asked participants to assess the difficulty each one presented on a scale of one to five in which one signified "not difficult at all", three signified "somewhat difficult", and five signified "very difficult". The eight obstacles were as follows:

1)	Lack_expr	Lack of previous experience.
2)	Admin	Administration of the process.
3)	Int_cost	Initial technical cost.
4)	Time	Time to implement the process.
5)	Costinfo	Need for cost information at the time of selection.
6)	Lack_tech	Lack of availability of technical resources.
7)	Lack_incen	Lack of incentives to justify a change in process.
8)	Forgobest	Possibly forgoing the "best" land regardless of cost.

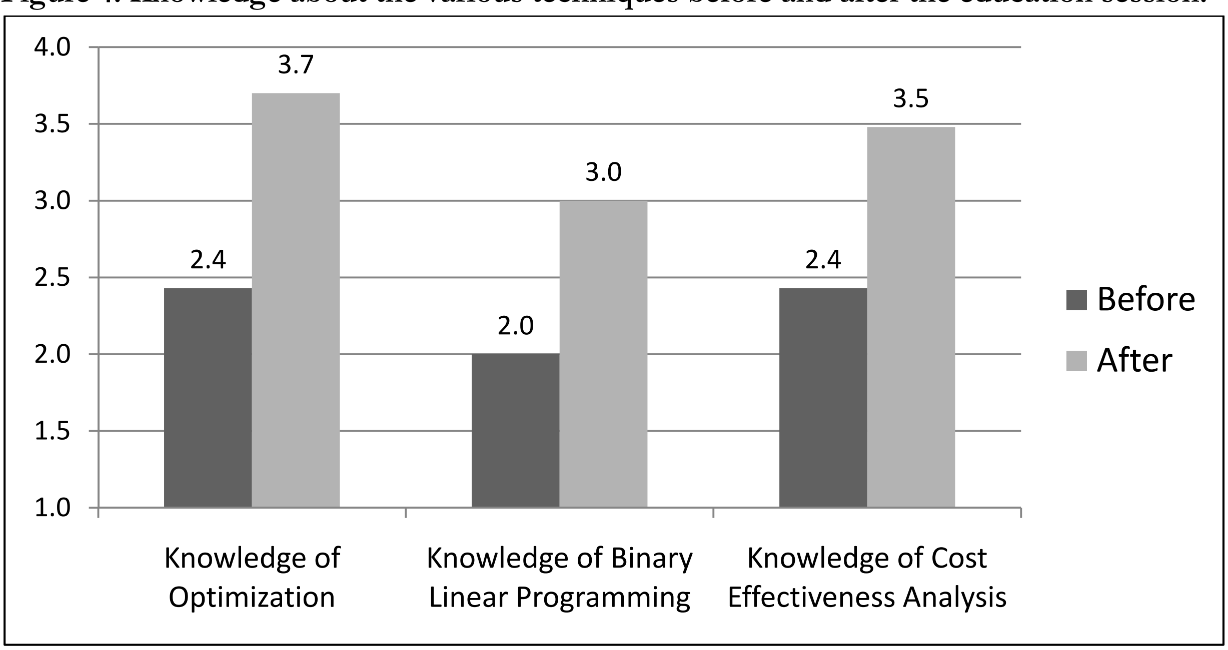
As can been seen in Figure 3 where the averages are represented by the "x" and the corresponding label, the standard deviations are shown in boxes, and the ranges are shown by the thin lines, all eight obstacles received a mean score of approximately three, suggesting that that no single problem was seen as impossible to overcome and that no single obstacle was seen as more important to overcome than others.

Figure 3: Obstacles to adopting optimization



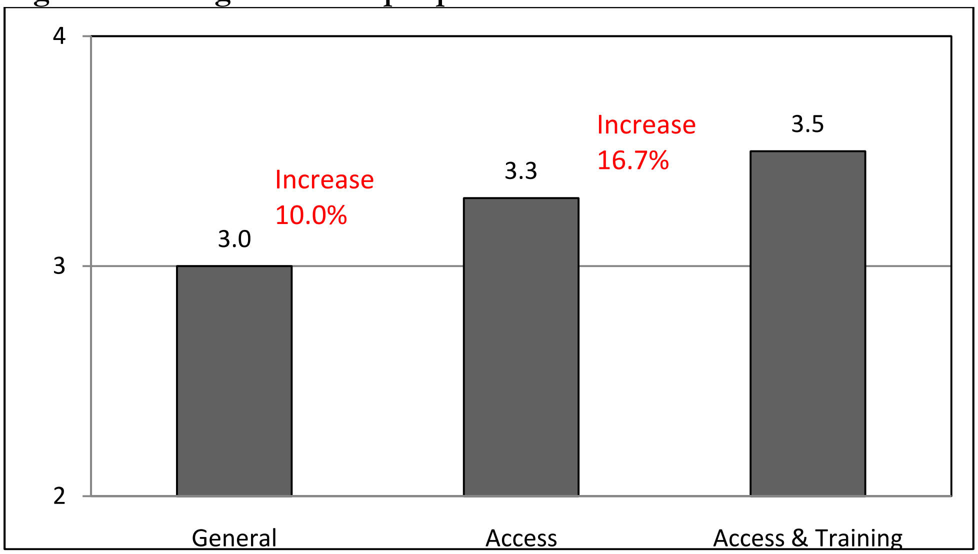
The survey results also showed that participants were not familiar with this technique before the presentations. However, after the educational presentation by Dr. Kent Messer, and experience-sharing presentation by Wally Lippincott and Robert Hirsch, there was a significant increase in understanding of the optimization and two techniques after the educational presentation. The average score for optimization knowledge before the presentation was 2.4 and rose to 3.7 after the presentations (Figure 4). This finding complements the earlier finding from the statistical model that indicates that a better understanding of optimization increases willingness to adopt it as predicted difficulties with adoption decrease.

Figure 4. Knowledge about the various techniques before and after the education session.



In post-survey, several questions were related to evaluation whether people would be more willing to adopt optimization if additional resources are offered. Survey results show that participants are more willing to accept optimization when additional resources are available As shown in Figure 5, when access to the optimization software tool was offered, willingness rose to 3.3, a 10% increase and significantly different from the previous value of 3.0. When both access and training were offered, willingness to adopt optimization increased to 3.5, a statistically significant 16.7% increase.

Figure 5: Willingness to adopt optimization under different scenarios



Baltimore County currently uses an Excel-based version of the Optimization Decision Support Tool (ODST) developed by Dr. Messer and The Conservation Fund. This tool has been used in strategic conservation and mitigation projects since 2005 (Messer, 2006; Allen et al., 2006; Messer and Allen, 2009, 2010). This tool has also been developed as a web-based platform. The ODST allows users to identify a suitable portfolio of mitigation projects based on one of three techniques: (1) identifying an optimal set of mitigation projects within a fixed budget constraint, (2) exploring the relative cost effectiveness of mitigation projects and selecting the portfolio with the highest benefit-cost ratio, or (3) identifying the minimum cost required to achieve a defined benefit level.

The best practices outlined in this report flow from the results of the survey and the corresponding statistical model of administrators willingness to adopt some type of optimization process for parcel selection.[3] Several key findings emerge from this model:

1) The more knowledge the respondent has about optimization, the more willing he or she is to adopt it.

2) The less experience a county has with optimization, the less willing the staff is to adopt it.

3) Willingness to use optimization increases when the current system is currently seen as difficult.[4]

[3] For details regarding the statistical analysis involved with this model see the appendix for this report.

4) Respondents reported that the initial cost of training and software associated with optimization were significant obstacles preventing adoption. This variable likely captures concerns both about the cost of the technology, but also the limited budgets that were affecting all levels of government in Maryland in 2009-2010.

5) County administrators also cited the lack of incentives as a key reason for the lack of adoption. Interestingly, optimization techniques are widespread in the business sector, but traditionally the use of these approaches in government and non-profit sectors has lagged. These results suggest that a major reason for this difference is the lack of direct financial incentives for the staff to alter from the status quo selection process.

6) The greater the percentage of agricultural land that the county has preserved, the more willing the county staff is to adopt optimization. Counties with greater percentages of preserved agricultural land may have larger budgets or more experienced employees, which would provide them with more resources both financially and technically. The governments in this area may place a high value on agricultural preservation and thus may be more open to embracing new ideas and approaches that help them achieve their goals.

E. Best Practices Recommendations

Recommendation A: Adopt Optimization at the County and State Levels.

The introduction of optimization is the next stage in the evolution of the decision making process for most counties involved in agricultural protection through the MALPF program. Optimization offers the chance to improve the ability of these counties to achieve their preservation objectives and increase the public confidence that taxpayer funds are being well managed through the use of an objective, merit-based decision process that relies upon a rigorous, scientific approach.

The use of optimization by MALPF staff will be consistent with the practices already used for agricultural preservation in Baltimore County and in several other prominent conservation contexts. For instance, 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, The Conservation Fund has worked with the US Fish and Wildlife Service 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 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 in the MSHCP.

[4] In Rob Hirsch's presentation about the use of optimization in Baltimore County, he specifically talked about how it had proved "easier to administer and run" than the county's old models.

Additionally, 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. SHA hopes 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. In June 2011, SHA staff were trained on optimization and the use of the Optimization Decision Support Tool

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.

Recommendation B: Simultaneously Select Projects for Multiple Funding Sources.

In counties that have a variety of funding sources that support agricultural protection efforts, such as a county's own program and the State's MALPF program, parcel selections traditionally have been done in a sequential manner with one program at a time selecting parcels. This recommendation is based on recent research (Messer, Tang, Hirsch, 2011; Kaiser and Messer, 2011) that examined the transactions for 118 parcels in Baltimore County, Maryland during a three year period (2007-2009), which illustrated how such optimization methods have dramatically improved agricultural land preservation efforts. The research applied binary linear programming such that applicants to both the county and state programs were considered simulateously in an effort to maximize the aggregate preservation outcomes. This approach is referred to as BIP-SIM (simultaneous binary integer programming) and is compared to its current use of Cost Effectiveness Analysis (CEA). The results suggest that by using BIP-SIM instead of CEA, Baltimore County could have used the same financial resources to protect an additional 242 acres of high-quality agricultural land valued at approximately $1.7 million. Keep in mind that these benefits would be *in addition* to the 680 acres worth $5.4 million that were secured by Baltimore County during this same time period by using CEA instead of the rank-based approach it previously had used.

Recommendation C: Train Staff on Optimization and Provide Related Software.

Survey results show that MALPF staff considers the two optimization approaches superior compared to their current selection approaches in terms of cost effectiveness. However, the staff also scored the cost-effectiveness criteria as the lowest in terms of importance. A challenge to the MALPF program will be in how to reconcile these two opinions. Furthermore, the public is increasingly concerned about the cost effectiveness of government and agricultural preservation programs are going to need to be able to explain the benefits of their program and how effectively they are utilizing public funding.

An important way for the MALPF program to assistant its county-level and state-level staff to overcome the perceived obstacles of implementing optimization would be to offer hands-on staff trainings and access to user-friendly software. As shown in Figure 5, the MALPF staff's likelihood of adopting optimization rose significantly when both options were offered. The training could build upon the experiences and expertise of Baltimore County staff and could follow a two-day format, such as that being conducted for staff of Maryland SHA, who will be trained on the application of optimization in June 2011.

MALPF staff should also consider offering incentives for their staff to attend trainings and adopt this approach, as survey respondents listed the lack of incentive as one of the largest obstacles facing use of this approach. While offering direct financial incentives to staff may not be feasible, it might be possible to create other incentives within the program, such as offering counties that use optimization a larger share of funding than those that do not use optimization.

Recommendation D: Adopt Other Best Management Practices in Conservation Selection

Several other best management practices can be offered that can improve the selection practices. These practices are related to not only agricultural preservation, but also to conservation programs at the county and state levels.[5]

Reduce Parcel Costs with Landowner Discounts instead of Price Caps or Formula Pricing

The search for parcels that offer a high level of benefit for a relatively low cost is an important goal and is an expressed purpose of optimization. Other approaches at lowering acquisition costs have been previously used in connection with the MALPF program, including price caps, formula pricing, and landowner discounts. While intuitively appealing, the use of price caps can be fraught with problems commonly associated when government creates price regulation in markets. Most notably, unless the appraisals are inaccurate, price caps are likely to lead to an undersupply of parcels for consideration for preservation and an increased likelihood that the parcels selected for preservation will not be the ones that were actually most likely to be developed in the absence of the program. The use of a price formula to determine the parcel cost to be paid the program, such as the formula pricing approach used in Baltimore County's agricultural preservation program, is another example of a government intervention into the market that can lead to many of the same problems found with price caps. Ultimately, the efforts required to set 'reasonable' price caps and determine cost formulas would be better invested into learning how to use optimization and to promote the MALPF program and thereby encourage more participants.

The use of discounting – the process where the landowner voluntarily offers a price discount on their parcel – is desirable and will likely lead to better outcomes than either price caps or formula pricing. As shown in Messer and Allen (2010), discounting can easily be incorporated into optimization and gives landowners a direct ability to influence their likelihood of selling their easement to the government, as the higher the landowner discount, the higher the likelihood that their parcel will be selected. Given the uncertainty of land appraisals, MALPF should consider having the landowners submit their discounts *after* the landowner learns of the appraised value for their land. This timing has been used with the Delaware Agricultural Lands Preservation Foundation and has the advantage of making the transition more transparent.

[5] More information about these and other best management practices can be found in Duke, Messer, and Dundas (2011).

Do Not Count Price as an Element of Parcel's Benefits

Some programs try to account for the desirability of a lower priced parcel by including a measure of price as a metric used in calculating the benefit score of a project. While this approach can have some intuitive appeal, research has shown that counting price as a benefit easily leads to results that end up being less cost efficient, instead of more cost efficient (Hajkowicz, Collins, and Cattaneo, 2009; Naidoo et al., 2006). Therefore, MALPF should focus its attention on deriving good measurements related to the agricultural and public benefits provided by protecting a land parcel and then using the parcel's final price (factoring in the landowner discount) separately as part of the optimization process to ensure that the aggregate benefits from the protected land are maximized given the budget constraints.

Be Cautious of Committing Future Government Resources

There has been an increased interest in using novel financing tools, such as those used by Carroll County, to preserve lands today and then spreading the costs into the future. While this approach definitely is appealing, especially during the current market conditions where the land values have decreased significantly and government revenue for conservation is low, this effort should not be entered into lightly as its advantages assume good knowledge about future land prices, government revenue and public preferences. For example, if these tools had been used in 2006 or 2007, they would likely have ended up preserving land when it was most costly and then spread the costs into periods of times when the economic conditions and government revenues are less favorable.

Account for Development Threat

To efficiently allocate funds for agricultural preservation; MALPF should develop means to predict the likelihood that the landowner would convert their agricultural land into a something less desirable if no funding is provided. While this type of metric would not be able to predict perfectly which land will and will not be developed – especially as land is passed from generation to generation – even an imperfect measure could be helpful in avoiding spending limited conservation funding to protect lands that were not likely to be developed either due to a lack of demand from developers or from a landowner's inherent unwillingness to convert their land. This measurement could include factors that are important for developers, such as distance to major roads and urban areas, slope, soil type, road frontage, school districts, and proximity to water and sewage hookups.

Since high market values tend to be correlated to high development threat, accounting for the development threat will likely mean that the cost per-acre of the preserved lands will rise and thus the MALPF's measurements of its own success should not be limited to the number of acres it has protected, but also to broader measurements that capture the social benefits achieved by the preservation activities of MALPF (i.e., sprawl reduction, number of acres involved in active farming). Once a metric for development risk has been created, it can be directly incorporated into optimization to help ensure that MALPF funds are directed towards areas where land conversion is more likely to occur (Newburn et al., 2005).[6]

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[6] Note that use of this type of measure, especially when used in a public process that could reveal the government's predictions of a landowner to develop their land, could be politically challenging. Since this element is beyond the scope of this report, we leave it to the MALPF staff to evaluate the relative advantages and disadvantages of incorporating this type of measure.

Use Optimization for Other Conservation Programs
Optimization can be used to help achieve a variety of conservation objectives, such as forest land protection, wetland mitigation and Chesapeake Bay pollution reduction. Training efforts could be coordinated with other conservation programs to help reduce costs and deliver higher quality results in a variety of contexts.

Allow for Some Discretion in Selection
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, 2011). Baltimore County initially exercised discretion in the application of optimization and ended up funding a couple of projects not recommended by the optimization selection approach. These decisions were made on a case-by-case basis and can be justified, to a certain extent, since some factors such as a parcel having unique historical significance or political importance are not generally captured in the benefit measures or the priority weighting. 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.

F. Conclusion

This report makes a variety of 'best practice' recommendations for the MALPF program at the county and state levels. For counties engaged in agricultural preservation, optimization offers significantly higher benefits and greater cost efficiency – things that are particularly valuable with public expenditures constantly under scrutiny. A point to underscore is that 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 optimization. Given Baltimore County's experience with optimization, they have an opportunity to gain further efficiency by integrating more sophisticated optimization tools that allow for the simultaneous selection of parcels for various programs. Other counties with multiple sources of funding for agricultural preservation can also benefit from simultaneously selecting projects for all programs, whenever possible. Finally, at the state level, MALPF can support these efforts by creating incentives for counties to learn about optimization and provide training and tools that would be helpful to county-level staff in making cost-effective funding recommendations.

These recommendations are based on the experiences of Baltimore County's with using optimization, analysis of a survey completed by MALPF staff, and knowledge learned from other conservation efforts. In conclusion, to build a best practice framework for MALPF, education on optimization and/or training on the optimization decision tool must first be provided to program administrators and employees. Training should address the importance of cost effective conservation and the value of being able to customize benefit factors in the analysis. Familiarity with the optimization tool will relieve concerns about implementing it, increase the willingness to reform existing processes and to employ a new decision tool.

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, 2011). Baltimore County still exercises some discretion in the application of optimization and allows funding for compelling cases. 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.

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H. Appendix A

Pre-Survey Questionnaire

1. Your name:________________________________

2. Maryland county and/or your organization:_____________________________________

3. How many years have you worked for this county/organization?_____________________

4. Your current job title:____

5. How many years have you been employed in this position?__________________________

6. How many people in your county/organization work on agricultural preservation programs?

a. Full-time employees ____________________________

b. Part-time employees ____________________________

c. Volunteers ____________________________

7. How knowledgeable are you regarding the **Maryland Agricultural Land Preservation Foundation's** (MALPF) agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

8. How knowledgeable are you regarding your **County/Organization's** agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

9. In your county, *approximately* what percentage of agricultural land, measured by acreage, has been protected by the following sources over the past five years? (Total should sum to 100%)

a. Maryland Agricultural Lands Preservation Foundation ________%

b. Your county's agricultural preservation program ________%

c. Rural Legacy Program ________%

d. Maryland Environmental Trust (MET) Program ________%

e. Program Open Space ________%

f. Other ______________ ________%

Total: 100 %

10. List, *in order of importance*, the 3 to 5 **most important benefit factors** (such as, soil quality, acres, biodiversity value, or development potential) in your county/organization's selection process.

Indicate how each benefit is measured (such as, GIS mapping, Land Evaluation and Site Assessment (LESA), or site visits).

Benefit Factor	***How Measured***
1.	
2.	
3.	
4.	
5.	

11. Who determines the benefit factors and weights for your county/organization's selection process? (Circle ALL that apply)
    a. County program staff
    b. County advisory board
    c. MALPF guidelines
    d. County guidelines
    e. Other____________________________________
    f. Don't know

12. If your county/organization has a LESA system to help determine the benefit score for any preservation program, please describe how this LESA system is used.

Program	***How LESA system is used***
1. MALPF program	
2. County Program	
3. Rural Legacy Program	
4. MET Program	
5. Program Open Space	
6. Other	

13. Do any of your preservation programs use **price caps** to determine the easement cost? (Circle one)

Yes No Unsure

If you answered "Yes", please describe what advantages and disadvantages your county has experienced with price caps:

Advantages	***Disadvantages***
______	______
______	______
______	______
______	______

If you answered "No", please complete one of the following:

We are planning to use price caps because:

____

____

____

____

We are *not* planning to use price caps because:

____

____

____

____

14. For each program in the table below, which of the following methods determines the easement cost in your county? (Please check all that apply for each program.)

Method \ Program	MALPF	County	Rural Legacy	MET	Program Open Space	Other ______
Asking price	☐	☐	☐	☐	☐	☐
Seller discount	☐	☐	☐	☐	☐	☐
Calculated easement value	☐	☐	☐	☐	☐	☐
Price caps	☐	☐	☐	☐	☐	☐
Appraised value	☐	☐	☐	☐	☐	☐
Other______________	☐	☐	☐	☐	☐	☐
Don't know	☐	☐	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐	☐	☐

15. For each program in the table below, how are easement costs factored into your county/organization's selection process? (Please check all that apply for each program.)

Program	MALPF	County	Rural Legacy	MET	Program Open Space	Other ____
Not explicitly included, except to determine whether funds are still available in the budget	☐	☐	☐	☐	☐	☐
Considered as part of the parcel benefit scoring	☐	☐	☐	☐	☐	☐
Used in an optimization process	☐	☐	☐	☐	☐	☐
Used in calculation of benefit-cost ratios	☐	☐	☐	☐	☐	☐
Other________________	☐	☐	☐	☐	☐	☐
Don't know	☐	☐	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐	☐	☐

16. For each program in the table below, how are the parcels selected for agricultural preservation in your county/organization? (Please check all that apply for each program.)

Program / Method	MALPF	County	Rural Legacy	MET	Program Open Space	Other ____
Parcels with the highest benefit scores are selected first until the budget is exhausted	☐	☐	☐	☐	☐	☐
Parcels with the highest benefit-cost ratios are selected first until the budget is exhausted	☐	☐	☐	☐	☐	☐
Parcels are selected based on advisory board recommendations	☐	☐	☐	☐	☐	☐
Parcels are selected based on political considerations	☐	☐	☐	☐	☐	☐
Parcels are selected based on their benefits and costs using binary linear programming	☐	☐	☐	☐	☐	☐
No official selection system is used	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐
Don't know	☐	☐	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐	☐	☐

Assess the **ability** of your county/organization's **current selection processes** for agricultural land preservation according to the following criteria:	Poor Excellent		Fair		
17. Maximize the number of agricultural acres protected	1	2	3	4	5
18. Maximize the open space quality of acres protected	1	2	3	4	5
19. Protect the best agricultural land in terms of soil	1	2	3	4	5
20. Preserve large blocks of contiguous agricultural land	1	2	3	4	5
21. Acquire the best deals on agricultural land	1	2	3	4	5
22. Increase incentives for participants to remain in farming	1	2	3	4	5

Assess the technique used for your county/organization's **current selection processes** for agricultural land preservation according to the following criteria:	Poor Excellent		Fair		
23. Knowledge of staff on how to use this technique	1	2	3	4	5
24. Fairness to applicants	1	2	3	4	5
25. Transparency (i.e. ease of explanation to public, advisory board, or potential applicants)	1	2	3	4	5
26. Cost-effectiveness	1	2	3	4	5
27. Ease of administration	1	2	3	4	5
28. Other	1	2	3	4	5

Please rate the following programs according to their **efficiency** in preserving agricultural land:	Low High		Medium		
29. MALPF Program	1	2	3	4	5
30. County Program	1	2	3	4	5
31. Rural Legacy Program	1	2	3	4	5
32. MET Program	1	2	3	4	5
33. Program Open Space	1	2	3	4	5
34. Other program ________________________	1	2	3	4	5

Post-Survey Questionnaire

1. Your name:____

2. Maryland county and/or your organization:__________________

Please rate the following criteria for an agricultural preservation selection process in terms of importance:	**Low**		**Medium**		**High**
3. Knowledge of staff on how to use the selection process	1	2	3	4	5
4. Fairness to applicants	1	2	3	4	5
5. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
6. Cost-effectiveness	1	2	3	4	5
7. Ease of administration	1	2	3	4	5
8. Other	1	2	3	4	5

Optimization is a process of including both benefit information and acquisition costs to identify parcels that provide a high level of aggregate benefits at the best possible price ('getting the most bang for the buck').

9. How well did you understand optimization **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

10. How well do you understand optimization **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

11. How willing do you think your county/organization would be to adopt **optimization** as the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess the **difficulty** of the following potential obstacles for adopting **optimization** as the selection process in your county/organization's agricultural preservation program:	**Not**		**Somewhat**		**Very**
12. Lack of previous experience	1	2	3	4	5
13. Administration of the process	1	2	3	4	5
14. Initial technical costs (staff training, software, etc.)	1	2	3	4	5
15. Time to implement the process	1	2	3	4	5
16. Need for cost information at the time of selection	1	2	3	4	5
17. Lack of availability of technical resources	1	2	3	4	5
18. Lack of incentives to justify a change in processes	1	2	3	4	5
19. Possibly forgoing the 'best' land regardless of cost	1	2	3	4	5
20. Other	1	2	3	4	5

21. If your county was given **access** to user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

22. If your county was given **access to and training for** user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Binary Linear Programming is an **optimization technique** that seeks to use mathematical programming software to identify the set of acquisitions that maximizes the total possible benefits given a variety of constraints (i.e. budget constraints, staff constraints, minimum acreage goals, etc.).

23. How well did you understand optimization using binary linear programming **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

24. How well do you understand optimization using binary linear programming **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess **binary linear programming** as a technique in the selection process to preserve agricultural land in your county/organization according to the following criteria:	**Poor**		**Fair**		**Excellent**
25. Knowledge of staff on how to use this technique	1	2	3	4	5
26. Fairness to applicants	1	2	3	4	5
27. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
28. Cost-effectiveness	1	2	3	4	5
29. Ease of administration	1	2	3	4	5
30. Other	1	2	3	4	5

31. How willing do you think your county/organization would be to adopt **binary linear programming** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

Cost-Effectiveness Analysis is an **optimization technique** that assesses a parcel's conservation value by taking the ratio of benefits divided by costs, and then acquiring the parcels with the highest benefit-cost ratios until the acquisition funds are exhausted.

32. How well did you understand optimization using cost-effectiveness analysis **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

33. How well do you understand optimization using cost-effectiveness analysis **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess **cost-effectiveness analysis** as a technique in the selection process to preserve agricultural land in your county/organization according to the following criteria:	**Poor**		**Fair**		**Excellent**
34. Knowledge of staff on how to use this technique	1	2	3	4	5
35. Fairness to applicants	1	2	3	4	5
36. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
37. Cost-effectiveness	1	2	3	4	5
38. Ease of administration	1	2	3	4	5
39. Other	1	2	3	4	5

40. How willing do you think your county/organization would be to adopt optimization using **cost-effectiveness analysis** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

41. Are there any other thoughts you would like to share with us concerning your county/organization's current selection process, or the optimization selection process?

42. Do you have any comments or suggestions about this survey?

If you have any further questions or suggestions, please don't hesitate to contact us:

Thank you very much for your participation.

I. Appendix B

Abbreviated Survey

1. Your name:____

2. Maryland county and/or your organization:____

3. How many years have you worked for this county/organization?_________________________________

4. Your current job title:____

5. How many years have you been employed in this position?______________________________________

6. How many people in your county/organization work on agricultural preservation programs?
   a. Full-time employees _____________________________
   b. Part-time employees _____________________________
   c. Volunteers _____________________

7. How knowledgeable are you regarding the **Maryland Agricultural Land Preservation Foundation's** (MALPF) agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

8. How knowledgeable are you regarding your **County/Organization's** agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

Please rate the following criteria for an agricultural preservation selection process in terms of importance:	**Low**		**Medium**		**High**
9. Knowledge of staff on how to use the selection process	1	2	3	4	5
10. Fairness to applicants	1	2	3	4	5
11. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
12. Cost-effectiveness	1	2	3	4	5
13. Ease of administration	1	2	3	4	5

14. How willing do you think your county/organization would be to adopt **optimization** as the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

15. If your county was given **access** to user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

16. If your county was given **access to and training for** user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

17. How willing do you think your county/organization would be to adopt optimization using **cost-effectiveness analysis** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

If you have any further questions or suggestions, please don't hesitate to contact us:

Section III. Select Publications Providing Description of Methods and Results

A. Identifying and Selecting Strategic Mitigation Opportunities: Criteria Design and Project Evaluation Using Logic Scoring of Preference and Optimization

Forthcoming -- JOURNAL OF CONSERVATION PLANNING

William L. Allen, III (corresponding author)

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Jozo Dujmović

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Abstract

State-of-the-art strategic mitigation efforts involve careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. This paper discusses how the Logic Scoring of Preference (LSP) and optimization can be integrated in a way to maximize the benefits of mitigation outcomes. The strength of this approach is demonstrated by highlighting the results from several ongoing mitigation and conservation projects.

Introduction

Human activities that result in habitat alteration and conversion are responsible for negative impacts on ecological systems and the decline of many species (Wilson, 1992). Within infrastructure development in the United States, avoidance and minimization strategies are implemented first to reduce potential impacts (CEQ, 2000). When unavoidable impacts occur to species and their habitat, compensatory mitigation is required and has been traditionally addressed through regulatory requirements during project construction (Kiesecker et al., 2009). In the recent past, compensatory mitigation occurred on an incremental, project-by-project basis (Thorne, 2009) but is beginning to be addressed before construction and from a regional perspective to improve conservation outcomes (Huber et al., 2009).

The next generation of mitigation will result in a more comprehensive approach to mitigation, use State Wildlife Action Plans and other plans to create an effective decision-making framework, and allocate compensatory funds in a manner that supports lasting and large scale ecological results (Wilkinson et al., 2009). For compensatory mitigation projects to deliver the greatest 'bang for the buck', it is critical to establish a robust decision support framework that can be used to reliably and consistently evaluate and select potential opportunities. The design and development of mitigation project selection criteria is an important step needed to take advantage of the state-of-the-art tools available to enhance environmental decision making (Amundsen, 2011).

Project selection criteria should be based on a community's conservation needs and opportunities. These criteria should be rooted in adopted land use and conservation plans and should do more than offset the negative impacts associated with the action requiring compensatory mitigation. A transparent process should be developed to design and refine criteria and ensure that the criteria are applied in a logically consistent manner. Decision makers should then have the tools to apply these criteria and quantify the benefits of project alternatives, while concurrently considering the cost of alternatives within realistic budget scenarios. Two cutting edge tools are being used in strategic mitigation projects by The Conservation Fund (the Fund) to help design criteria, evaluate project alternatives, and select projects that provide the greatest benefit at the lowest cost within constrained budgets: the logic scoring of preference (LSP) method and optimization.

Using the Logic Scoring of Preference Method to Measure Benefits

Logic Scoring of Preference is a scientifically rigorous technique originally developed for computer science applications to design project selection criteria and weightings that reflect fundamental properties of human reasoning and ensure that the benefits calculated accurately reflect the desired intent of decision makers (Dujmović, 2007). The Fund has partnered with SEAS, one of the world's pioneers in the use of LSP for decision making, to design customized desktop and web-based software to support strategic mitigation projects. The desktop (ISEE V1.1) and web-based (LSPWeb V1.0) software were first utilized in 2010 to support the compensatory mitigation needs of the NiSource Multi-Species Habitat Conservation Plan (MSHCP) project (The Conservation Fund, 2010).

In the LSP method, mitigation project criteria are developed through a collaborative process with stakeholders and subject matter experts to ensure all attributes that can be measured are included for evaluation and can represent an overall level of satisfaction of compensatory mitigation needs (Dujmović and Allen, 2011). Main steps of the LSP method are summarized in Figure 1. The first step is the development of an attribute tree, exemplified in Figure 2 for the NiSource MSHCP for potential freshwater mussel mitigation projects. The attribute tree is a set of *n* attributes used to evaluate quantitatively the benefits of potential mitigation opportunities on a consistent scale so that projects can be appropriately compared. Decision makers use the attribute tree to create all inputs needed to evaluate methodically each project, determining to what extent a potential mitigation project meets the particular mitigation needs and desires of the community. For each elementary attribute the LSP method requires an elementary attribute criterion used for evaluating the value of attribute and computing the degree of attribute suitability. In the next step, which is a unique feature of the LSP method, soft computing evaluation logic is used to aggregate all attribute suitability degrees and determine an overall suitability of the evaluated project. This process includes all necessary logic relationships between attributes and their groups. At the same time, we identify all components that affect the overall cost of the project and create an overall cost indicator. The overall suitability and the overall cost are inputs for an appropriate Cost/Suitability Analysis that generates an indicator of the overall value of each evaluated project. The overall value is used for ranking of competitive projects and justifiable selection of the most appropriate project.

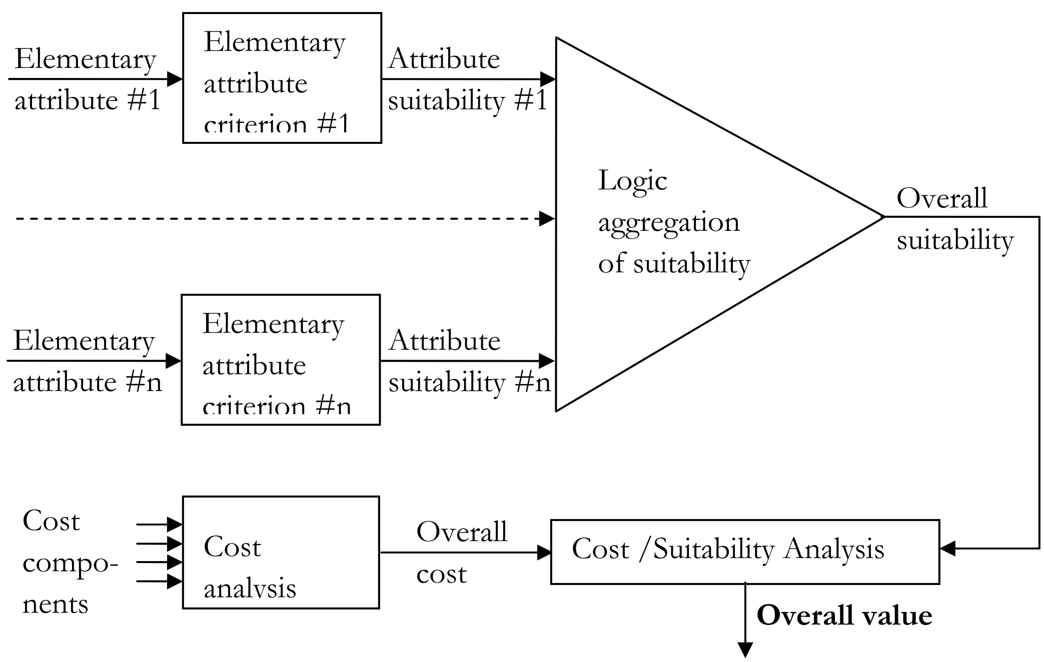

Figure 1. Main components of the LSP method

- **1 Freshwater Mussel Mitigation Projects**
  - **11 Take Species Habitat Mitigation Requirements**
    - **111 Mandatory Habitat Requirements**
      - 1111 Mitigation Units
      - 1112 Project Site Assessment
        - 11121 Buffer Size & Shape
        - 11122 Intact Buffer Sites
        - 11123 Mussel Distribution
      - 1113 Project Physical Conditions
        - 11131 Substratum
        - 11132 Water Quality
        - 11133 Bed Stability
        - 11134 Barriers to Fish Passage
      - 1114 Project Species Occurrence
        - 11141 Known & Potential Host Fish
        - 11142 Mussel Population Viability
        - 11143 Mussel Diversity
        - 11144 Mussel Density
        - 11145 Detrimental Invasive Species
      - 1115 Project Location
    - **112 Desired and Optional Habitat Requirements**
      - 1121 Likely Protection in Perpetuity
        - 11211 Point & Nonpoint Pollution Risk
        - 11212 Sedimentation & Substrate Removal Risk
        - 11213 Stream Impoundment Risk
        - 11214 Stream Buffer Clearing Potential
        - 11215 Project Monitoring Program
      - 1122 Protection of Other Listed Species
        - 11221 NiSource MSHCP Take Species
        - 11222 Other Federal and State Listed Species
  - **12 Other Conservation Goals and Benefits**
    - 121 Support for Green Infrastructure Goals
    - 122 Planning Goals and Leverage Opportunities
      - 1221 State Wildlife Action Plans
      - 1222 Other State and Regional Plans
      - 1223 Collaboration and Other Ecosystem Benefits
    - 123 Human benefits
      - 1231 State Trail, Greenway, and Bikeway Plan Support
      - 1232 Stimulation of Nature-Based Economic Development

Figure 2. An attribute tree for the NiSource MSHCP for potential freshwater mussel mitigation projects

Each criterion in the decision tree spans a range of characteristics from most to least suitable in terms of meeting mitigation requirements, known as an elementary (attribute) criteria. Where each project falls within this range is represented numerically on a standard suitability scale from 0 to 100% that represents how well it satisfies that particular criterion (100% being the most suitable or ideal). In addition, criteria in a decision tree have logic properties that designate them as mandatory, sufficient, or desired based on their contribution to fulfilling mitigation requirements. An example of an elementary criterion for branch #11122 – Intact Buffer Sites is shown in Figure 3.

<table>
<tr><th colspan="2">11122</th><th>Intact Buffer Sites [0,3]</th></tr>
<tr><td>Value</td><td>%</td><td rowspan="5">The US Fish and Wildlife Service, NiSource, and the States have determined suitability based upon four potential buffer configurations that may result from a compensatory mitigation project for Endangered and Threatened freshwater mussels.

The values from 0-3 correspond to a particular percent suitability that described the desired end state of the compensatory mitigation project for mussel species of interest.

3 = Project includes one site that is internally intact (i.e. there can be no unprotected or unrestored gaps greater than 100 feet on each bank at the conclusion of the project). This is the most suitable.

2 = Two sites internally intact, but sites less than one mile upstream (as measured from the bottom of the first site to the bottom of the second).

1 = Three sites internally intact, but sites more than one mile upstream.

0 = Greater than 3 sites. This is considered unsuitable.

This criterion represents a mandatory requirement.</td></tr>
<tr><td>0</td><td>0</td></tr>
<tr><td>1</td><td>20</td></tr>
<tr><td>2</td><td>80</td></tr>
<tr><td>3</td><td>100</td></tr>
</table>

Figure 3. An elementary criterion for the attribute #11122 – Intact Buffer Sites

Relative weights for criteria within a single node of the suitability aggregation tree are assigned by stakeholders and subject matter experts since some factors are more important than others in evaluating a potential mitigation project. There are a variety of techniques to help assign weights; one of possible techniques is the Analytic Hierarchy Process (AHP) (Saaty, 1990; Duke and Aull-Hyde, 2002; Carr and Zwick, 2007; Messer and Allen, 2010). Below is an example of the weighting and logic structure for the branch of the tree with the Intact Buffer Sites criterion:

1112 Project Site Assessment [Logic structure: simultaneity]
- 11121 Buffer Size & Shape – 40%
- 11122 Intact Buffer Sites – 30%
- 11123 Mussel Distribution – 30%

Percentages correspond to the relative weights of each criterion within this branch of the tree. All parameters of the decision model (the elementary criteria, weights, and logic aggregators) are initially selected by the LSP designers (in this case The Conservation Fund and SEAS). With a simultaneity logic structure, all criteria should be, to some extent, simultaneously satisfied. For some criteria, a replaceability logic structure is more appropriate, where all inputs need to be simultaneously satisfied to some extent. In either case, a zero value for one criterion does not necessarily yield a zero output for the entire branch of the tree unless it is determined that is appropriate. It is important to emphasize that all parameters of LSP models can be finally edited and adjusted by stakeholders and subject matter experts using LSPWeb V1.0, an Internet tool developed as a decision support system for the LSP method.

Some of the decision tree criteria above are designated as mandatory while others are designated as desired. A desired criterion *cannot compensate* for the absence of a mandatory criterion, but the mandatory criterion *can significantly compensate* the absence or low value of the desired criterion. The LSP method allows decision tree designers to establish a percent penalty for a low desired value and a percent reward for a high desired value. Branch #121 – Support for Green Infrastructure Goals – represents how well a mitigation project contributes to the protection of the green infrastructure network, the "strategically planned and managed network of natural lands, working landscapes, and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations" (Benedict and McMahon, 2006).

Green infrastructure networks are helping transportation agencies meet federal guidelines for consultation, use of natural resource inventories, and consideration of environmental mitigation as specified in section 6001 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) legislation enacted in 2005 (Amundsen, Allen, and Hoellen, 2009). The NiSource MSHCP stakeholders believed that a project's ability to enhance the protected green infrastructure network was a desired characteristic of a mitigation project but that it should not entirely compensate for a low value of meeting specific endangered and threatened species mitigation needs. This logic structure seems appropriate for an array of compensatory mitigation applications, including transportation, where multiple benefits are desired but specific mitigation needs are legally required to be the priority.

In summary, decision trees were developed for all of the endangered and threatened species in need of compensatory mitigation in the NiSource MSHCP. Once all criteria values were calculated and weights and logic structures applied, each mitigation project alternative will receive a numerical score from 0-100 based upon its overall level of satisfaction in meeting compensatory mitigation needs. These quantitative suitability scores will then be considered along with the implementation costs (e.g. acquisition, management, and monitoring) of potential mitigation projects for further evaluation.

Using Optimization to Achieve Higher Efficiencies with Project Selection

Integrating economic costs into conservation planning is a key to ensuring better conservation outcomes (Naidoo et al., 2006). When trying to select the most cost-effective mix of strategic mitigation projects, it is more efficient to determine overall quality based on benefit *and* costs rather than with an analysis strictly of either cost *or* benefit (Babcock et al., 1997; Hughey, Cullen, and Moran, 2003; Perhans et al., 2008).

Optimization is a branch of economics and operations research studies that in recent years has shown conservation professionals how to get more land conserved within constrained budgets or achieve the same level of environmental benefits from land conservation projects with a smaller budget. The Fund has partnered with Innovative Conservation Solutions to develop desktop and web-based software that allows users to identify a suitable portfolio of mitigation projects based on one of three techniques: (1) identifying an optimal set of mitigation projects within a fixed budget constraint, (2) exploring the relative cost effectiveness of mitigation projects and selecting the portfolio with the highest benefit-cost ratio, or (3) identifying the minimum cost required to achieve a defined benefit level. The Optimization Decision Support Tool (ODST) has been utilized in strategic conservation and mitigation projects since 2005 (Messer, 2006; Allen et al., 2006; Messer and Allen, 2009, 2010). The Fund and Innovative Conservation Solutions have demonstrated that utilizing optimization in conservation programs yields significantly more acreage with higher overall conservation benefits than does applying more traditional project selection approaches.

Effective conservation and mitigation efforts require both sound science and sound economics, yet the most common technique used to select conservation projects can be quite inefficient. This selection technique, a "rank-based model," selects the projects with the highest benefit scores with little consideration of the relative project costs. In situations where numerous high quality projects go unfunded due to budget constraints, the rank-based approach ensures only that the available resources are spent on the highest ranked projects; however, the model frequently misses opportunities to spend the money in a cost-effective way by funding lower-cost, high-benefit alternatives that would extend limited financial resources and maximize overall conservation benefits (Allen, Weber, and Hoellen, 2010).

In contrast, an optimization model uses a mathematical programming technique called binary linear programming to identify the set of cost-effective projects that maximizes aggregate benefits (Kaiser and Messer, 2011). The optimization model uses data describing the resource benefits of the potential projects and relative priority weights that an organization assigns to each benefit measure, as well as estimated project costs and budget constraints. The optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the aggregate conservation benefits given a specified budget. The optimization model can help distinguish between the high-cost "Cadillac" projects, which can rapidly deplete available funds while making relatively small contributions to overall conservation goals, and the "best buy" projects, which individually may not appear as valuable, but when combined, provide greater aggregate benefits. An alternative optimization approach is known as Cost-Effective Analysis, which ranks benefit-cost ratios for each project from highest to lowest and then selects the highest ranked benefit-cost ratio until the budget is exhausted. Identifying the cost efficient set of projects not only helps organizations maximize their financial resources, but can also provide a science-based, economic rationale for identifying and prioritizing projects.

Optimization models enable the user to select the set of projects that maximizes the total conservation benefits. An important distinction must be underscored: "total benefits" are defined as the sum the benefits from each of the selected individual projects. Optimization focuses on the total benefits of the pool of potential projects, whereas a traditional rank-based selection process examines projects and determines their individual worth in isolation, without actually looking at the broader portfolio of potential projects.

Optimization can readily build upon the benefit criteria from the LSP method to provide a project's overall conservation benefit to the community. Optimization offers a way for those in need of mitigation to increase public confidence that taxpayer funds are being well managed, are consistent with federal funding guidelines, and that scientific, objective, merit-based decision-making process is being used. In addition, optimization 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 "good value" projects that ensure that conservation benefits are maximized given the available budget (Amundsen, Messer and Allen, 2010).

The best on-the-ground illustration of the value of using optimization is the Baltimore County Agricultural Land Preservation Program in Maryland. This program has used the ODST to save 22% more farmland than it would have otherwise over the past three years. Every year since 2007, Baltimore County has used the ODST to choose which agricultural lands to save. Optimization has helped the county protect an additional 680 acres of high-quality agricultural land, at a cost savings of roughly $5.4 million—a return on investment over three years of more than 60 to 1. In other words, for every $1 that Baltimore County spent using the ODST, it has gained more than $60 in conservation benefits (Amundsen, Messer and Allen, 2010). 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.

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 (Weber and Allen, 2010). One of the methods by which SHA aims 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 (Allen, Weber, and Hoellen, 2010). The Fund identified portfolios of environmental stewardship projects at different budget levels and then maximized the ecological benefits at each given cost. Optimization outperformed rank-based selection under all scenarios, with 69% more green infrastructure area, 68% more aggregate ecological benefits, and 1,641 more acres protected under a hypothetical $15 million environmental stewardship budget scenario (Dillaway, 2010).

Conclusion

State-of-the-art strategic mitigation efforts involve careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. This paper outlines the approach of two tools—the Logic Scoring of Preference (LSP) and optimization—and describes how they can be integrated in a way that delivers dramatically better mitigation outcomes by maximizing the effectiveness of limited financial resources. A key strength of this approach is the inherent flexibility of these tools, which make them applicable to a large array of mitigation and conservation settings.

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WORKING PAPER NO. 2011-01

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

By

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WORKING PAPER SERIES

UNIVERSITY OF DELAWARE | Alfred Lerner College of Business & Economics

DEPARTMENT OF ECONOMICS

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

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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.

JEL Codes: C61, Q2

Keywords: Mathematical Programming, Conservation Optimization, Cost Effectiveness Analysis, Strategic Conservation

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

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 in 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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C. Tight Budgets and Strategic Conservation: Selecting the Right Lands for the Right Price

Ole Amundsen – The Conservation Fund
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Strategic conservation is a planning process that 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. State strategic conservation planning efforts such as Florida Forever, Delaware Ecological Network and the Maryland Greenprint are examples of prioritization mapping efforts that illustrate an interconnected system of existing and potential preserved lands and well managed private lands. As many states are facing dramatic budget problems, resulting in significant decreases in funding for land acquisition, incorporating land costs and budget constraints strategically into the planning framework has never been more important. Fortunately, the initial applications of cost effective analysis (also referred to as optimization analysis) in concert with strategic conservation plans demonstrates that land conservation efforts can actually be strengthened by including both cost and budget elements.

Cost effective analysis is a tool of economics and operations research that in recent years has shown land conservation managers how to get more "bang for their bucks". Cost effective decision support tools have been developed to be user-friendly, spreadsheet-based applications that allow quick comparison of all possible combinations of parcels given both an agency's traditional project evaluation criteria and the agency's budget constraints, to select the set of projects that guarantees the maximum possible conservation benefits. The decision support tools have been designed to be integrated with GIS and enable a user to readily evaluate results given different constraints—such as an acreage threshold, a budget level or the maximum number of acquisitions. In fact, cost effective analysis is particularly effective when organizations face a much larger pool of potential land acquisition project costs than can be afforded given a limited budget. Finally, and importantly, the use of cost effective analysis does not require changing the existing processes or policies used by a program to evaluate a project, but rather builds directly upon the existing processes and policies and provides additional information for decision makers.

Many state agencies apply rank-based criteria to evaluate the quality of a potential land acquisition project. These rank-based processes have been useful in ensuring that state agencies are truly buying high quality lands to meet public goals, such as protecting rare and endangered species, preserving high quality soils for farming, and providing diverse recreational opportunities. However, few criteria systems take the cost of the property (either fee or easements) into account in their scoring system. By including cost as a strategic factor for evaluation and comparing cost along with other environmental and public benefits among a pool of potential projects, efficiency gains are achieved.

The Conservation Fund's Strategic Conservation Planning Program working in partnership with Dr. Kent Messer from the Department of Food & Resource Economics at the University of Delaware has applied cost effective analysis techniques to guide the evaluation processes of several public conservation programs including: the Delaware Agricultural Land Preservation Foundation and Baltimore County's Agricultural Preservation Program. The results show dramatic increases in overall environmental benefit for the same amount of program funding. For example, in the case of the Delaware Agricultural Land Preservation Foundation (DALPF), an analysis of historical data from willing sellers suggests that the use of cost effective analysis could have yielded the program an *additional* 12,000 acres of high quality agricultural land, worth an estimated $25 million for the same $93 million budget spent during the program's first decade of existence (Messer and Allen 2008). In Baltimore County, the one-year gains from adopting cost effective analysis have been estimated at $2.8 million. Additionally, a recent analysis of the 2008 application for the USDA Forest Legacy program suggests that 43.8% *more* acres (91,621 acres) could be protected by incorporating project costs strategically in the decision process.

In the coming months, the Eastern Lands and Resources Council will be sending a white paper to members with detailed examples of the use of cost effective analysis to help guide decision making with land conservation programs. Cost effective analysis can help programs achieve ambitious conservation goals even during periods of declining budgets. By using these tools, officials can demonstrate solid financial stewardship to budgeting staff, legislators and the public, laying the foundation for future support for stronger funding for land conservation when the economy has improved.

In the words of Steve Castleman III, Executive Director, Catoctin Land Trust, based in Maryland, "If you were offered an opportunity to gain $4 million worth of conservation benefits by spending only $1 million, wouldn't you be interested in learning more?"

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D. Applying Multiple Knapsack Optimization to Improve the Cost Effectiveness of Conservation

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Abstract

Landowners interested in selling their development rights frequently face a variety of government-funded conservation programs. These programs can have similar conservation objectives but make their selection decisions separately, in part, because the funds originate from different levels of government. This research illustrates how greater aggregate conservation benefits could be achieved if project selection was done simultaneously with a multiple knapsack optimization model. This model is applied to the selection of 118 land easement applications in Baltimore County from 2007 to 2009. Baltimore County is the first agricultural preservation program in the country to use the cost-effectiveness analysis method and this research also documents the efficiency gains and additional conservations benefits that this approach has yielded compared to its traditional use of the benefit-targeted method (BT).

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Introduction

As communities endeavor to set aside areas of agricultural land for conservation, they face the considerable challenge of selecting parcels that are the most cost-efficient and effective in meeting their goals within the limit of funds available. Several optimization tools have been developed to assist decision-makers with this complex process, which involves multiple agencies and budgets. These tools analyze potential transactions by the various agencies involved sequentially—one purchase at a time. To date, research in this area has examined only how optimization tools that deal with sequential purchases might potentially have improved the parcel selection process (with improvement defined as greater cost-efficiency).

This research examines transactions for 118 parcels in Baltimore County, Maryland during a three year period (2007 to 2009), and illustrates how such optimization methods have dramatically improved agricultural land conservation efforts there. To my knowledge, this study is the first to measure the actual on-the-ground benefits generated by these tools.

The analysis is extended by introducing a "multiple knapsack" optimization model called BIP-SIM (simultaneous binary integer programming) that manages simultaneous purchases rather than sequential ones. BIP-SIM offers potentially greater cost-efficiency to government agencies and nonprofit conservation groups in Maryland as they try to create the most benefit possible from often limited and even declining budgets. This study is the first to apply the BIP-SIM method of simultaneous acquisitions to this problem.

The advantages and disadvantages of the three primary methods—the benefit-targeted method (BT), cost-effectiveness analysis (CEA), and binary integer programming (BIP-SEQ)—are extensively analyzed. The cost-efficiency of each method is determined by applying it to the data and comparing the parcel selections that result from each method.

The results of the study confirm the theoretical expectation that CEA would be superior to BT by considering the factor of cost, that BIP-SEQ would be superior to CEA, and that the simultaneous BIP-SIM model would generate significant additional improvements to the overall conservation outcome. In 2008 and 2009, for example, the BIP-SIM method would have spent just 43% of the total cost while yielding 71% of the total potential benefit. By using the simultaneous approach instead of CEA, Baltimore County could have used the same financial resources to protect an additional 242 acres of high-quality agricultural land valued at approximately $1.7 million.

Productive agricultural land is finite and irreplaceable. The loss of our rural agricultural landscape would result in the loss of agricultural production and public amenities. On average, 2.2 million acres of farm land per year were converted to urban uses between 1992 and 2001, doubling the 1.1 million acres per year converted during the preceding decade (Vesterby and Krupa, 1997). According to the 2007 census of agriculture, in Maryland, the amount of farm land has decreased by more than 1.3 million acres since 1959 (Census of Agriculture, 2002, National Agricultural Statistics Service, 2007). To address the problem of agricultural land loss, more than 124 governmental entities in the United States had implemented farm land preservation programs by 2005(American Farmland Trust, 2005). Government agencies, land trusts, and other organizations nationwide have gathered about $248 million annually from local, state, and federal tax funds and millions from private sources that have been used to purchase approximately 107,000 acres agricultural easements on farm land in the United States (Census of Agriculture, 2002, Natural Resource Conservation Service, 2004). It is estimated that about 1.1 million acres of farm land nationwide have been put under easement at a cost of approximately $2.3 billion (AFT)[1]. The state of Maryland lost 25,874 acres of farm land between 2002 and 2007 and that was the smallest loss of farm land since 1978, representing only 1.2 percent of the state's farm land in 2002 due to farm land conservation activities (Census of Agriculture for Maryland and Its Jurisdictions)[2]. It becomes critical, then, for program administrators to select parcels carefully and cost-effectively given the intense competition for agricultural land and the large amount of tax money involved every year. Just one-half of the 46 key agricultural easement programs nationwide had come close to achieving their stated program goals for acreage acquisition by 2006 (Sokolow,2006).

During the past 50 years, farm land in Maryland (as in other northeastern states) has dropped from 4 million to 2.2 million acres due to residential and commercial development (Lynch and Lovell, 2003). Despite the current economic downturn, Maryland's population is projected to increase by 0.9 million from 2010 to 2030 and the number of households is expected to increase by 20% (Maryland Department of Planning, 2009). This population growth, coupled with declining household sizes and communication technologies that make it easier for people to work in widely dispersed communities, will likely increase the demand for land and drive further losses of valuable farm land. Baltimore County is located in the northern part of Maryland, just north of the city of Baltimore. The county has a total area of 682 square miles—599 square miles (87.8%) of land and 83 square miles (12.2%) of water. Farm land in Baltimore County is characterized by large contiguous areas with little fragmentation from urban development. In 2007, there were 751 farms comprising 78,282 acres in Baltimore County. The average farm size was 91 acres. Of those 751 farms, 83.7% were operated by a family or individual and 54.1% of the land was held as harvested crop land (American Community Survey, 2000, U.S. Census, 2000, Census of Agriculture for Maryland and Its Jurisdictions, 2007). Figure 1 shows a map of Baltimore County in 2008.

In Baltimore County, there are several land conservation programs, statewide and countywide, that work in conjunction with many nonprofit conservation organizations, the federal government, and local government agencies to fund agricultural and open space preservation. Two of the most important public programs are the Maryland Agricultural Land Preservation Foundation and Rural Legacy. Other conservation programs include the Maryland Environmental Trust, Local Land Trusts and the Baltimore County Agricultural Land Preservation Program.

The Maryland Agricultural Land Preservation Foundation (MALPF), established in 1977, is the oldest program. It is also widely acknowledged as one of the most successful programs of its kind. This statewide program seeks to preserve enough agricultural land to maintain the local base of food and fiber production for citizens in Maryland. Since its inception, more than 17,000 acres of farm land have been preserved. To qualify, a farm must have a minimum of 50 acres or be located adjacent to a preserved property.[3]

Rural Legacy started in 1997 and receives special funds from the State Rural Legacy Grant Program to set aside large blocks of ecologically important land in designated preservation areas to conserve natural and scenic resources and foster rural industry. More than 8,000 acres have been preserved in the five Rural Legacy areas present in Baltimore County: the Coastal Area, Piney Run, Long Green Valley, Gunpowder River Valley, and Manor.[4]

In agricultural easement acres acquired through all sources, Baltimore County ranked among the top 12 local programs in 2003. In 2006, programs in the county had reached an important milestone of preserving 40,000 acres—the halfway point toward its overall goal of 80,000 acres of preserved farm land. Agricultural easements are mostly located in designated agricultural protection areas. comprising nearly 14,000 acres in the northern part of the county. Some $86.5 million had been invested in easements by 2003 and had put large, continuous blocks of agricultural land under protection (Sokolow and Zurbrugg, 2003, Sokolow, 2006).

Given the number of established programs, a parcel of ecological significance may be identified by more than one program as a potential target. In Baltimore County, applicants are considered for one program after another in a sequential order—first for the state program MALPF, then for the county farm land protection program, and then for other funds, such as Rural Legacy.

Specific selection criteria and thresholds are placed on the pools of easement candidates to help eliminate properties that fail to meet the minimum requirements of the programs. For example, parcels submitted to Rural Legacy must be located in the designated agricultural protection area. They must be either a minimum of 50 acres or contiguous to a preserved property to be considered by the Rural Legacy program. MALPF requires that parcels be larger than 50 acres with high quality soil. Additionally, each program may appraise the parcel's value differently.

The conservation of farm land is thus a complex social problem that can benefit from the application of operations research models. Individuals responsible for selecting parcels to protect look to improve their use of the limited financial resources available and maximize the return on investment by selecting parcels that yield the most conservation benefits. This study analyzes the cost-efficiency of easements that were selected between 2007 and 2009 in Baltimore County, Maryland, using three popular optimization methods and incorporates a fourth method that allows for simultaneous consideration using the multiple-knapsack BIP-SIM model.

Literature Review

One of the most popular mechanisms for farm land preservation in the United States is to purchase agricultural conservation easements (ACEs) from landowners. The purchase permanently restricts the type and amount of development that can occur on that farm land in the future regardless of changes in ownership of the property. Conservation programs that apply this mechanism are also known as purchase of development rights (PDR) programs. By targeting desirable ACEs strategically, conservation programs can achieve a variety of objectives, including targeting farm land most vulnerable to development, adjusting existing development patterns, forming large contiguous areas of protected open space to provide social and ecological benefits, and reinforcing urban growth boundaries. These conservation activities have a positive impact on the rate and probability of farm land being preserved, block development in unsuitable areas, maintain rural amenities near urban residents, and control growth patterns (Liu and Lynch, 2006; Lynch and Liu, 2007; Stoms et al., 2009). Benefits for local communities include improved quality of life, a more secure food supply, orderly development, and the economic viability of agriculture (Lynch and Duke, 2007; Miller, 1992).

Decision analysis tools facilitate the decision making process. Among the tools that have been developed are multiple criteria analysis (MCA) (Hajkowicz and Higgins, 2008), system conservation planning (SCP) (Carwardine et al., 2007), and geographic information systems (GIS) (Horst, 2007).

Traditionally, easement acquisition decisions were made using a benefit-target algorithm (BT), which selects parcels that offer the greatest conservation benefit (Messer, 2006).

Cost-benefit analysis, cost-effectiveness analysis, and cost-utility analysis are three important frameworks that have been imported from economics and contribute to evaluating and prioritizing conservation parcels. The methods differ slightly in advantages and applications (Hughey, Cullen and Moran, 2003). A cost-benefit analysis intends to improve the quality of public decisions by measuring changes in aggregate preference resulting from changes in policy decisions. It expresses benefits and costs associated with a decision in monetary terms by measuring an individual's willingness to pay for the change (benefit) or to avoid the change (cost). The analysis measures whether a benefit outweighs its cost by taking the ratio of benefit to cost to determine the return on investment. The problem with this analysis is that measuring nonmarket values is challenging and there is considerable criticism of the assumption that aggregate social well-being can be expressed as the simple sum of the well-being of individuals (Krupnick, Kopp and Toman, 1997). A cost-effectiveness analysis (CEA) focuses on nonmonetary outcomes and seeks the least costly means by which to achieve the given policy goal. Typically, this analysis is expressed in terms of a ratio in which the denominator is a gain (such as a conservation benefit) and the numerator is the cost associated with the gain. CEA is more flexible and is particularly useful in situations in which it may be difficult to monetize social and ecological benefits, as is often the case with farm land protection.

When selecting the most cost-effective mix of projects for preservation, it is more efficient to determine overall benefits with a benefit-cost analysis than with an analysis strictly of either cost or benefit (Hughey, Cullen, and Moran, 2003; Babcock et al., 2007). As an example, one goal shared by all conservation programs is to see active farming remain viable in the long term. Maintaining a "critical mass" of farm land ensures that the infrastructure of suppliers and markets that supports farming can remain viable. It is essential that the preserved properties be in close enough proximity to retain input suppliers (Hellerstein et al., 2002). The concept of complementarity accounts for the irreplaceability of a site and for its influence on other sites (Carwardine et al., 2007). Some have suggested that focusing selection decisions on the parcels' complementarity would shift the focus from the cost of the easement to the benefits the parcels provide. Cost alone tends to be the overriding factor when sites are considered separately. All in all, the benefit-cost model is always the more cost-efficient method of selection compared to the cost-only or benefit-only model regardless of the conservation goal (Perhans et al., 2008).

Mathematical programming is introduced into the decision-making process to assure that programs reap the most benefit possible from a limited budget (Hajkowicz et al., 2007). Research by Messer (2006) demonstrated that the use of binary integer programming would have yielded additional conservation benefits worth \$3.1 to \$3.9 million (achieving the same level of conservation benefits using BT would have cost an additional \$0.9 to \$3.5 million). During the past two decades, there has been a rapid increase in development of spatially explicit mathematical programming models, mainly due to advances in heuristic methodologies and computing power (Higgins and Hajkowicz, 2007). Mathematical programming has applications in land allocation planning (Mallawaarachchi and Quiggin, 2001), watershed protection (Ferraro, 2003), habitat restoration analysis, connection of fragmented landscapes (Williams and Snyder, 2005), and soil conservation (McSweeny and Kramer, 1986).

As introduced in the previous chapter, sequential parcel selection may not take full advantage of disparities in appraised parcel values and the thresholds of various programs. In addition, budgets may be underutilized due to poor coordination between programs.

To address these issues, this study introduces a simultaneous model from the multiple-knapsack problem in operations research that considers multiple programs at the same time to generate the most cost-efficient plan for purchasing easements. Although the knapsack model is widely applied to various realms, including capital budgeting projects (Koc et al., 2009), municipal construction (Kozanidis et al., 2005), and the shipping industry (Ang et al., 2007), this is the first time it has been applied to the field of farm land conservation. By adopting a knapsack model, we can improve efficiency by taking advantage of remainders of budgets and escaping the sequential time constraint.

Data Description and Land Selection Procedures

Historically, the process of acquiring easements started with voluntary formal application for participation by owners of parcels that meet the entry threshold requirements of the programs. Once the applications have been submitted, the conservation benefits of the participating parcels are appraised extensively and ranked quantitatively by the programs involved.

To evaluate the protection benefits of the easements, conservation programs in Baltimore County have since 1989 used a land evaluation process that is based on a national ranking system called LESA, the Land Evaluation and Site Assessment program. Developed in the 1980s by the Soil Conservation Service (now the Natural Resource Conservation Service) of the U.S. Department of Agriculture, the LESA system is composed of two parts: land evaluation and site assessment. The land evaluation score focuses primarily on the productivity of the soils. Each soil is assigned a relative value after being rated from best to worst. The value ranges from 0 to 100 with higher values reflecting better soils. The site assessment score evaluates the property's location in terms of development pressure. Factors include parcel shape, parcel size, distance to towns and cities, quality of roads adjacent to the site, availability of sewer and water, and the levels of nearby agricultural support services. Once the two scores have been determined, they are summed and weighted for a total LESA score (Sokolow, 2006).

According to Messer and Allen (2010), the per-acre conservation score generated by the LESA site assessment system is multiplied by the number of acres in the parcel to determine the land's "conservation benefit." Although the site assessment process takes parcel size into consideration, the multiplication procedure for scaling purposes remains critical because the LESA value must fall between 0 and 100 while acreage has a larger value range than LESA value. Furthermore, the factors in LESA mainly relate to ecological protection and agricultural production benefits. Larger parcels may offer the additional benefit of continuity, which is important in maintaining a sustainable ecosystem or agricultural region, even though they could have relatively small per-acre agricultural values (see figure 2). By multiplying the per-acre value by the size of the parcel, large parcels can retain their advantages in the selection process. Later we will see the effect of scaling the LESA value by acreage and the result of a comparison of selections made using the BT method with and without scaling the LESA conservation value.

The monetary value of an easement is difficult to evaluate because there is no commonly used system for assigning a dollar value to factors like wildlife habitat and water quality benefit. Some market values have been calculated using econometric models in which cost functions are derived from factors that affect farm productivity based on real transactions. For MALPF, the appraised easement cost is the difference between the fair market value of the easement and its agricultural value. Applicants are encouraged to "discount" this price and to sell the easement for less than the appraised value. Baltimore County sets the easement cost using a formula in which the maximum price goes up as the soil quality, parcel size, and number of development rights increases. Here again, applicants are encouraged to discount the formula-derived price.

Due to the variety of funding sources that support agricultural protection programs in Baltimore County, parcel selections traditionally have been done in a sequential manner with one program at a time selecting parcels. State-funded programs such as MALPF typically select first (the state round), followed by county-funded ones (the county round). Sometimes, additional funding becomes available after the initial selections have been made and an extra round may be added. In the procedure used prior to 2007, the MALPF administrator in Baltimore County would go first and would purchase the maximum number of high-ranking easements possible given available funds. Easements that failed to be sold in this state round would be passed on for consideration in the subsequent county rounds or would be resubmitted in future years. The ability to resubmit depends on the policies of the programs. In this study, round-by-round analysis was used for BT, CEA and BIP-SEQ.

The study dataset covers 118 parcels that were submitted to conservation programs in Baltimore County, Maryland, between 2007 and 2009. The selection process varied slightly during those three years (see Table 1 for detailed information on each year's candidates). In 2008, the parcels had to pass a threshold of total LESA score being at least 61 to enter the MALPF program. This threshold was set at close to the mean score from the applicant pool and had the effect of removing parcels of "below average" quality. Parcels also were expected to have development potential or lie within an agricultural preservation area or Rural Legacy area to qualify for the county round. In 2007 and 2009, no specific requirement is placed on parcel candidates.

Table 1 provides descriptive statistics for the participating easement candidates for 2007, 2008, and 2009. Candidates are further divided by their qualification for state and county programs. Though candidates rejected by the state program may participate again in County programs, they are not counted here as candidates for county programs. Row 1 lists the funds available, row 3 lists the cost of acquiring all of the qualified easements, and row 4 gives the percent variance between the budget and the total acquisition cost, which reflect sufficiency of budget level. As table 1 shows, the state program generally has a more sufficient budget than the county programs.

As shown in rows 5, 7, and 10, the state program's appraised cost in 2007 averages $399,902 per parcel, 31% greater than the county programs' average cost of $304,306. In 2008, only 13 parcels satisfied the state program's threshold. MALPF's average appraised cost per parcel was $860,635, 15% higher than the county's average cost of $748,782. In 2009, MALPF's average parcel cost was 80% higher than the county programs' costs. Since MALPF consistently assigned a higher appraisal value, landowners preferred to sell their easements to the state program.

From rows 13 and 17, we see that candidate parcels in the state program had, on average, higher LESA scores and more acres than parcels that qualified only for county programs. The pool of easements that qualified for MALPF was generally more worthy of protection.

From rows 2, 3, and 13, we can determine the average cost per acre, $6,836.52, by dividing total easement cost by total acres. From rows 3 and 18, we can calculate the average cost per conservation benefit, $112.76, by dividing total easement cost by total conservation benefit. These averages are used in later to calculate cost savings.

The descriptive characteristics also provide information about the relation between acreage and LESA scores. Figure 2 shows scatter plots for 2007, 2008, and 2009. The plots demonstrate a positive relationship between conservation benefit and acreage in 2008 and 2009. In 2007, this positive relationship is far from obvious. For that year, the LESA score does not represent the acreage of the parcel well and the conservation benefit, which is the product of the LESA score and acreage, should be used as the value to be maximized.

Based on the descriptive statistics, it appears that MALPF and the county programs appraise the cost of the easements differently. If parcels overpriced by state program could be identified and passed to the county programs at the beginning of selection process, cost-efficiency of conservation programs in Baltimore County may be improved. Applying the BIP-SIM model could take advantage of the disparity and achieve an improved aggregate conservation benefit.

Mathematical Specification of the Models

Benefit Targeted Method

Consider a set of I parcels where parcel i has conservation benefit V_i (= LESA * Acreage) and cost C_i. Let R_i denote the rank of parcel i among the I parcels with respect to V_i. The benefit-targeted (BT) selection algorithm essentially prioritizes parcels for purchase according to rank R_i. That is, parcel k is first selected for purchase when $R_k = 1$. Next, parcel j is selected when $R_j = 2$. This procedure is repeated until the allocated funds have been depleted. Parcels with equal rankings are selected according to least cost.

The merits of this method are its convenience and understandability by landowners. It can assure landowners of the transparency of the process, an important requirement of most conservation programs (Hajkowicz et al., 2007).

The disadvantages, illustrated in figure 3, are obvious. Because this method ignores cost considerations, it identifies a few "crown jewels" but does not achieve the greatest possible benefit overall. In other words, it is not cost-effective (Messer, 2006). Since farm land on the fringe of a rural area tends to be more expensive and have a higher conservation benefit than more insulated properties, applying the benefit-targeted method results in preservation of fewer parcels and fewer acres of farm land. In addition, this method is inconsistent as shown in the second half of figure 3. An increase in budget does not necessarily improve the portfolio. Money may be wasted on a few high-ranking parcels, resulting in less total benefit.

Cost Effectiveness Analysis

Programs funded by Baltimore County currently apply a CEA (cost-effectiveness analysis) model (also called OPT). The CEA operates under the same procedure as BT but the parcels are ranked on a ratio (R_i) *of* conservation benefit V_i to cost C_i rather than solely targeting the benefit.

The CEA inherits the BT method's advantage as a convenient, understandable, and transparent method and outperforms BT in terms of cost-efficiency. It delivers results that approach optimization. Optimality is not guaranteed though since this method, unlike binary integer programming, fails to take all alternatives into consideration to select the portfolio that has the maximum aggregate benefit. As with BT, an increase in budget under a CEA does not necessarily improve the outcome.

Binary Integer Programming – Sequential

The binary optimization model that identifies optimal portfolios of conservation sites is generally referred to as the knapsack problem. The mechanism behind a knapsack model is described as follows.

Given a set N = {1,...,n} items and a set M = {1,…,m} knapsacks, item $i \in N$ has a weight $w_i > 0$ and benefit $u_i > 0$. Every knapsack $j \in M$ has capacity $e_j > 0$. Additionally, some items are restricted from being assigned to all knapsacks; thus, assignment of item i is limited to the set of $A_i \subseteq M$. Assume that $w_i \leq e_j$, that is, every knapsack has enough capacity for any item i. We are interested in filling the knapsack with a collection of items that will yield the maximum benefit (Dahl and Foldnes, 2006).

The sequential method takes one knapsack at a time, fills it with items to obtain the greatest possible benefit, and then moves on to the next knapsack. This mechanism ensures that each knapsack is optimized given the choice of items available to it. The aggregate benefit is calculated as the sum of the optimized benefits of the individual knapsacks.

The simultaneous method (BIP-SIM), on the other hand, takes all of the knapsacks at once and fills them to obtain the maximum aggregate benefit. It ensures that every knapsack is optimized given the entire set of items available.

In the case of land preservation, each conservation program is a knapsack with a budget limit B_j that represents the weight capacity e_j. The selection processes aims to fill those program knapsacks with land parcels to achieve the greatest conservation benefit. The sequential model is described as follows.

Suppose there are I parcels and J conservation programs. The decision variables of the model are defined as $x_{ij} \in \{0,1\}$ where 0 denotes that parcel i is not selected by program j and 1 denotes that parcel i is selected by program j. The objective function seeks to maximize the conservation benefit for program *j*. The constraint in equation (2) ensures that at most one program can purchase an easement and an easement need not be purchased. The constraint in equation (3) ensures that the purchase is made within the constraint of the program's budget.

$$\text{Max} \quad v_j = \sum_i^I X_{ij} V_i \tag{1}$$

Subject to:

$$\sum_{j=1}^{J} X_{ij} \leq 1 \tag{2}$$

$$\sum_{i=1}^{I} C_{ij} X_{ij} \leq B_j \tag{3}$$

where $i = 1,2,...,I$ denotes the parcel index and $j = 1,2,...J$ denotes the program index. In this research, $j = 1$ denotes the MALPF program and $j = 2, 3, 4$ denotes the Baltimore County programs. The program j will increase from 1 to J. So if $X_{i,j} = 1$, then $X_{i, j+1,...}$, $X_{i,J} = 0$, which means that a parcel that has been sold can no longer participate in future program selections.

V_i denotes the conservation benefit for parcel i[5],

B_j denotes the budget for program j, and

C_{ij} denotes the cost of parcel i in program j.

After the selection is made for all J programs, we calculate the aggregate conservation benefit.

$$v = \sum_j v_j \tag{4}$$

Binary Integer Programming – Simultaneous

The BIP-SIM is a simultaneous multiple-knapsack model. Suppose there are *I* parcels and *J* conservation programs. The decision variables of the model are defined as $x_{ij} \in \{0,1\}$ where 0 denotes that parcel *i* is not selected by program *j* and 1 denotes that parcel *i* is selected by program *j*. The objective function seeks to maximize the aggregate conservation benefit for *J* conservation programs. The constraint in equation (6) implies that at most one program can purchase an easement. An easement need not be purchased and the constraint in equation (7) ensures that a program's total purchases do not exceed its budget.

$$\text{Max} \quad v(X) = \sum_{i}^{I} \sum_{j}^{J} X_{ij} V_i \qquad (5)$$

Subject to:

$$\sum_{j=1}^{J} X_{ij} \leq 1 \qquad (6)$$

$$\sum_{i=1}^{I} C_{ij} X_{ij} \leq B_j \qquad (7)$$

where $I = 1,2,...,I$ denotes the parcel index and $j = 1,2,...J$ denotes the program index. In this research, $j = 1$ denotes the MALPF program and $j = 2, 3, 4$ denotes the Baltimore County programs.

V_i denotes the conservation benefit for parcel *i*,

B_j denotes the budget for program *j*, and

C_{ij} denotes the cost of parcel *i* in program *j*.

Results

The mathematical programming for BIP-SEQ and BIP-SIM is carried out using Risk Solver Platform V9.5 in Microsoft Excel. The results are presented in table 2 to table 5.

Table 2 provides the results of an analysis of the effect of scaling the LESA value. It compares the selection results of benefit targeting aimed at unscaled LESA values with targeting aimed at a scaled conservation benefit. Table 2 shows no significant difference between the two selection results. For the rest of this chapter, when BT is mentioned, it refers to targeting of the scaled conservation benefit and conservation benefits are the target of CEA and binary integer programming as well.

Table 3 compares BT and CEA. Generally, CEA can acquire greater conservation benefits, more acres, and more parcels than BT. Over the three year study period, the conservation benefit generated by CEA was 25,521 greater than that of the BT process, an 11.2% improvement valued at $2.8 million. The $2.8 million is calculated by multiplying the additional conservation benefit (25,521) by the average cost per conservation benefit of $112.76. Acreage is another important criterion in evaluating the efficiency of land selection methods. In terms of acreage, the CEA process during the study period protected an additional 596.3 acres valued at $4 million, a 17.2% improvement over BT. The cost saving of $4 million is calculated by multiplying the additional acres (596.3) by the average cost per acre of $6,836.52. The cost-savings in last two columns of table 6.3, 6.4 and 6.5 are all calculated similarly using average cost per conservation benefit or average cost per acre. The maps in figure 4 display graphically the extra acres CEA (same as OPT in the maps) was able to acquire.

By taking cost into account, the CEA algorithm does a better job than BT of targeting conservation benefits in assembling a portfolio. Note that superiority is not guaranteed. In 2008, the CEA process obtained slightly less conservation benefits than the BT process did.

Table 4 shows the comparison of the CEA and BIP-SEQ methods. The preceding chapter demonstrated that CEA does not consistently provide and cannot guarantee optimality of its targeted benefit because it cannot consider the entire range of options. Binary programming, on the other hand, can. As table 4 shows, BIP-SEQ consistently outperforms CEA in terms of the acquiring the greatest conservation benefit. During the three year study period, the conservation benefit generated by BIP-SEQ was 8,115.2 greater, a 3.2% improvement over CEA and worth $0.9 million. In terms of acreage, BIP-SEQ sometimes yielded fewer acres selected (in 2007 and 2009) since size of parcel is not its target of maximization and the size and conservation benefit of a parcel are not perfectly related. However, in the longer run of three years, BIP-SEQ managed to acquire 61 more acres than CEA with a value of $0.4 million.

Though BIP-SEQ obviously outperforms CEA, the suitability of applying mathematical programming to the needs of a specific conservation program is debatable. First, BIP-SEQ's improvement of conservation benefits (3.2%) and acreage (1.5%) over CEA is not as substantial as the improvement brought by CEA over BT (11.2% and 17.2% respectively). Also, BIP-SEQ normally requires complicated computer programming and additional software resources. Another complicating factor is that the binary programming process is less convenient, less transparent, and more difficult for landowners and program managers to understand than CEA.

Table 5 shows that the increase in cost-efficiency that comes from applying simultaneous binary programming, BIP-SIM, is substantial. In 2008, BIP-SIM yielded 9.6% more agricultural value and 7.2% more preserved acres than sequential binary programming. In 2009, it produced 7.3% more agricultural value and 4.6% more acres. The simultaneous model generated 71% of the total benefit obtained with sequential programming while spending 43% of the total cost incurred in 2008 and 2009 combined. This new approach resulted in protection of an additional 181 high-quality acres worth $1.2 million.

BIP-SIM also produces better results than CEA, the method Baltimore County has adopted. Over the 2007 to 2009 study period, the conservation benefit generated by BIP-SIM was 9.1% greater than that of the county's CEA, an improvement valued at $2.6 million. Use of the sequential method preserved 6.2% more acres of land worth $1.7 million. These improvements are significant. If we compare BIP-SIM with traditional BT (targeting scaled conservation benefits), the cost saving would be $5.5 million in terms of conservation benefit and $5.8 million in terms of acreage in three years.

Figures 5 and 6 graphically compare cost-efficiency for the five optimization methods.

These results confirm the superiority of binary integer programming in securing the best portfolio for conservation programs. Freed of the sequential constraint, the simultaneous BIP-SIM model further improves cost-efficiency and allows administrators of the various programs to coordinate their selection plans. One disadvantage of the BIP-SIM tool is the need for software resources and sophisticated programming. The complexity of an analysis increases substantially as the number of participating parcels rises.

Conclusion

A body of literature has discussed the traditional use of benefit-targeting and mathematical programming as tools in conservation programs. This study uses data from preservation easements acquired in Baltimore County, Maryland, from 2007 through 2009 to measure the benefits brought by optimization models. Baltimore County obtained an 11.2% increase in agricultural value and a 17.2% increase in acreage preserved by adopting a cost-effectiveness analysis instead of traditional benefit targeting during the three-year period. Though CEA is more effective than BT and convenient, it does not optimize the benefits to conservation programs. Sequential binary integer programming, on the other hand, can achieve the goal of acquiring as much conservation benefit as possible.

This study introduces simultaneous binary integer programming, also known as a multiple-knapsack model in operations research, and compared the results of simultaneous and sequential binary optimization. In the context of farm land conservation that involves multiple diversely funded agencies, simultaneous binary programming outperformed the sequential model, making more efficient use of remainders of budgets and distributing potential easements more effectively to state and county rounds. Over the three-year study period, conservation benefits rose by 5.7% and preserved acres increased by 4.4%. Though the improvement brought about by using BIP-SEQ over CEA is not as large as the improvement brought about by using CEA over BT, the improvement brought about by BIP-SIM is substantial.

Though easement purchasing usually operates under complex conditions, the opportunity for programs to coordinate with each other in the selection process could substantially increase the success of their efforts.

Endnotes

1. American Farmland Trust, www.farmland.org/resources/national-view/default.asp.
2. For details, see www.mdp.state.md.us/msdc/census_agriculture/Farm_Farmland/Farm_Farmland.shtml.
3. For details, see MALPF's website: www.malpf.info.
4. For details, see Rural Legacy's website: www.dnr.state.md.us/rurallegacy.
5. In this study, the conservation benefit is equal for all of the conservation programs.

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Table 1. Descriptive statistics of dataset of participating easements.

		07 State	07 County	08 State	08 County	09 State	09 County
1	**Total Budget**	$4,800,000	$3,000,000	$5,800,000	$5,000,000	$2,670,000	$1,000,000
2	**Number of Qualified Easements**	19	39	13	29	12	6
3	**Total Cost of Easements (TCE)**	$7,598,129	$10,687,214	$11,188,254	$15,081,173	$6,644,841	$645,686
4	**Budget / TCE (%)**	63%	28%	52%	33%	40%	155%
5	**Average Appraised Cost of Easement by MALPF**	$399,902	—	$860,635	—	$553,737	—
6	**Coefficient of Variation of Appraised Cost by MALPF**[a]	0.72	—	0.62	—	0.73	—
7	**Average Appraised Cost of Easement by County**	$304,306	$274,031	$748,782	$520,040	$304,485	$129,137
8	**Coefficient of Variation of Appraised Cost by County**	0.71	1.05	0.69	1.95	0.64	0.38
9	**Difference of Average Cost**[b]	$95,596	—	$111,853	—	$249,252	—
10	**% of Cost Difference**[c]	31%	—	15%	—	82%	—
11	**Maximum Acres**	156.0	269.0	228.0	187.5	133.6	49.1
12	**Minimum Acres**	8.0	4.0	37.9	17.9	20.8	25.5
13	**Average Acres**	62.0	63.0	111.7	51.9	60.8	40.4
14	**Average Easement Cost per Acre**	$6,450	$4,350	$7,705	$10,020	$9,108	$2,117
15	**Maximum LESA**	71.0	76.0	86.4	91.8	95.0	67.3
16	**Minimum LESA**	35.0	31.0	61.2	41.4	64.7	62.0
17	**Average LESA**	55.0	52.0	71.0	54.5	76.0	62.9
18	**Total Conservation Benefit of Easements**	66,469	130,077	105,402	83,672	58,883	15,267

[a] The coefficient of variation (CV) is calculated as the ratio of standard deviation of the sample over the average of the sample. Distributions with CV < 1 are considered low-variance while those with CV > 1 are considered high-variance.

[b] This is the difference in average cost appraised by MALPF and by the county programs.

[c] The percent of cost difference is calculated as 100% * Difference of Average Cost / Average Appraised Cost by County.

Table 2. Comparison of results of BT with scaled and unscaled LESA values.

	Conservation Benefit	Acreage	Parcels Selected	Money Spent
BT-LESA 2007	86,272	1,384	22	$ 7,761,955
BT-CB 2007	72,585	1,283	11	$ 7,763,496
BT-LESA 2008	110,416	1,558	18	$ 10,379,021
BT-CB 2008	117,845	1,738	15	$ 10,566,648
BT-LESA 2009	36,371	435	7	$ 3,485,990
BT-CB 2009	36,512	439	5	$ 3,558,570
BT-LESA (Total)	233,059	3,377	47	$ 21,626,966
BT-CB (Total)	226,942	3,461	31	$ 21,888,714
Difference	6117	(84)	16	

Table 3. Comparison of results of BT (scaled) and CEA methods.

	Conservation Benefit	Acreage	Parcels Selected	Money Spent	Cost Savings of CEA over BT for Benefit	Cost Savings of CEA over BT for Acres
BT 2007	72,585	1,283	11	$ 7,763,496	—	—
CEA 2007	93,218	1,691	33	$ 7,697,528	**$2,326,650**	**$ 2,789,300**
BT 2008	117,845	1,738	15	$10,566,648	—	—
CEA 2008	116,578	1,770	28	$10,175,255	**($142,871)**	**$ 218,769**
BT 2009	36,512	439	5	$ 3,558,570	—	—
CEA 2009	42,667	596	13	$ 3,490,259	**$694,060**	**$ 1,073,334**
BT (Total)	226,942	3,460	31	$ 21,888,714	—	—
CEA (Total)	252,463	4,057	74	$ 21,363,042	**$2,877,839**	**$ 4,081,402**
Difference between CEA and BT	25,521	596.3	43	—	—	—
% Increase	11.2%	17.2%	—	—	—	—

Table 4. Comparison of results of CEA and BIP-SEQ methods.

	Conservation Benefit	Acres	Parcels Selected	Money Spent	Cost Savings of BIP-SEQ over CEA for Benefit	Cost Savings of BIP-SEQ over CEA for Acres
CEA 2007	93,218	1,691	33	$ 7,697,528	—	—
BIP-SEQ 2007	93,956	1,670	30	$ 7,783,642	**$ 83,220**	**($ 143,567)**
CEA 2008	116,578	1,770	28	$ 10,175,255	—	—
BIP-SEQ 2008	122,878	1,880	29	$ 10,725,157	**$ 710,410**	**$ 752,017**
CEA 2009	42,667	596	13	$ 3,490,259	—	—
BIP-SEQ 2009	43,744	568	10	$ 3,560,051	**$ 121,446**	**($ 191,423)**
CEA (Total)	252,463	4,057	74	$ 21,363,042	—	—
BIP-SEQ (Total)	260,578	4,118	68	$ 22,068,850	**$ 915,076**	**$ 417,028**
Difference between BIP-SEQ and CEA	8,115	61	—	—	—	—
% Increase	3.2%	1.5%	—	—	—	—

Table 5. Comparison of BIP-SEQ and BIP-SIM models.

	Conservation Benefit	Acres	Parcels selected	Money Spent	Cost Savings of BIP-SIM over BIP-SEQ (CB)	Cost Savings of BIP-SIM over BIP-SEQ (Acres)
BIP-SEQ(07)	93,956	1,670	29	$ 7,783,642	**----**	**----**
BIP-SIM(07)	93,959	1,689	29	$ 7,789,066	**$ 338**	**$ 129,894**
Difference	3	19	0	----	**----**	**----**
% of increase	0%	1.1%	----	----	**----**	**----**
BIP-SEQ(08)	122,878	1,880	29	$ 10,725,157	**----**	**----**
BIP-SIM(08)	134,648	2,016	29	$ 10,728,994	**$ 1,327,227**	**$ 929,767**
Difference	11,770	136	0	----	**----**	**----**
% of Increase	9.6%	7.2%	----	----	**----**	**----**
BIP-SEQ(09)	43,744	568	10	$ 3,560,051	**----**	**----**
BIP-SIM(09)	46,928	594	11	$ 3,596,608	**$ 359,039**	**$ 177,750**
Difference	3,184	26	1	----	**----**	**----**
% of Increase	7.3%	4.6%	----	----	**----**	**----**
BIP-SEQ(total)	260,578	4,118	68	$ 22,068,850	**----**	**----**
BIP-SIM(total)	275,535	4,299	69	$ 22,114,668	**$ 1,686,604**	**$ 1,237,410**
Difference of BIP-SEQ and BIP-SIM	14,957	181	----	----	**----**	**----**
% of Difference	5.7%	4.4%	----	----	**----**	**----**

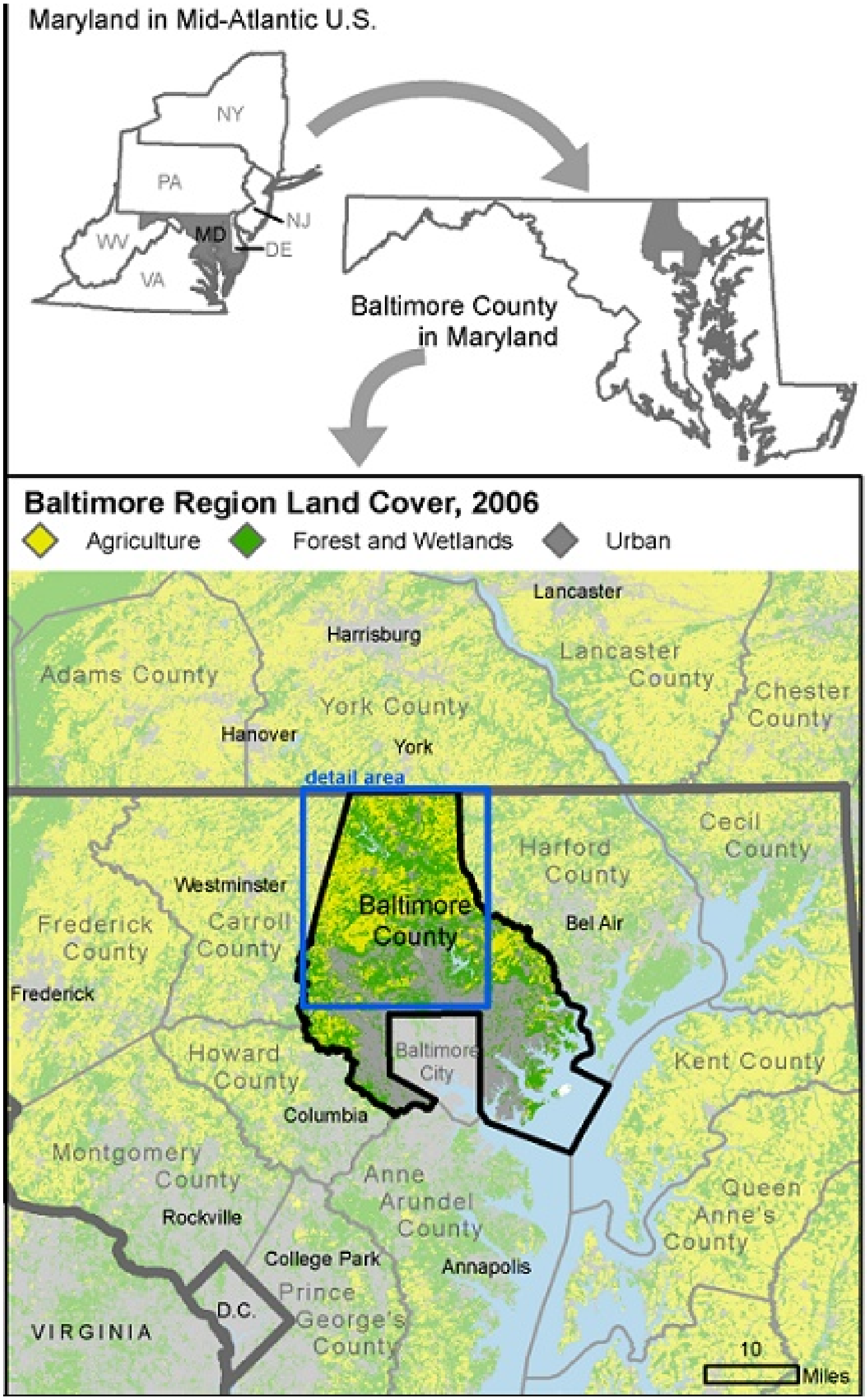

Figure 1. Map of Baltimore County in 2008.

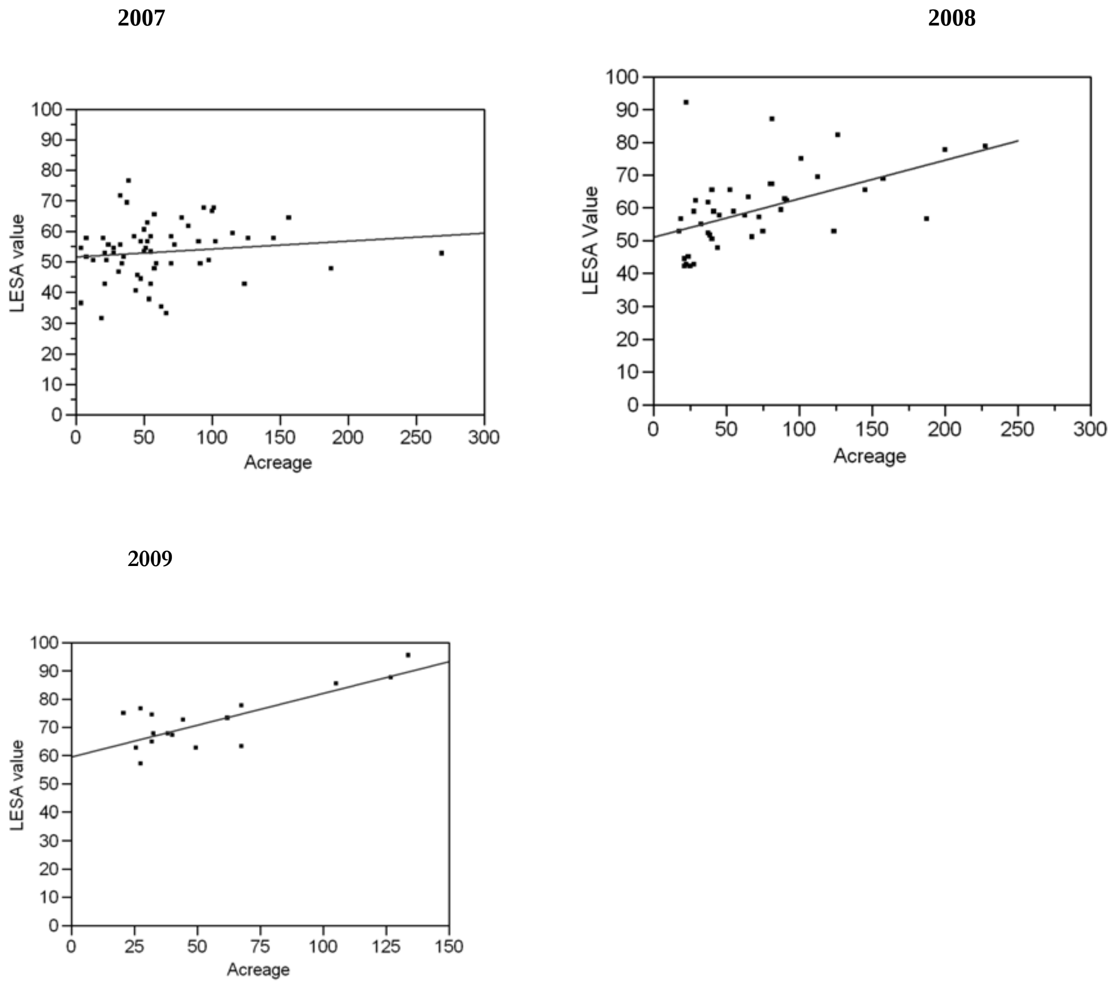

Figure 2. Scatter plots showing relations between acreage and LESA values for 2007–2009.

Parcel	Benefit	Cost	Purchase?	Remaining Budget
1	9	15	Yes	5
2	7	8	No	5
3	5	3	Yes	2
4	3	2	Yes	0
Total Benefit	17			
Budget	20			

Parcel	Benefit	Cost	Purchase?	Remaining Budget
1	9	15	Yes	8
2	7	8	Yes	0
3	5	3	No	0
4	3	4	No	0
Total Benefit	16			
Budget	23			

Figure 3. Illustration of inconsistency generated by the benefit-targeted method.

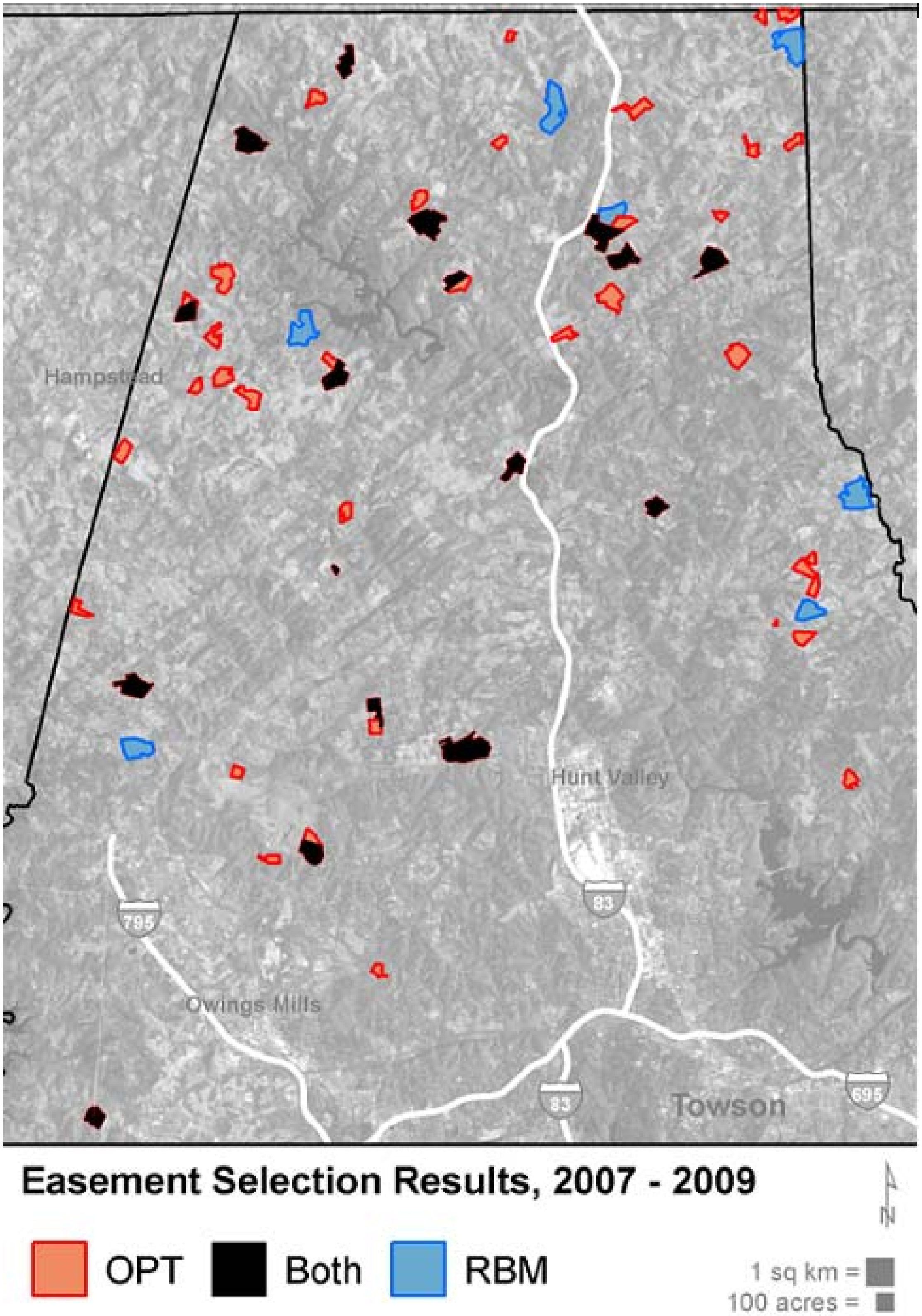

Figure 4. Geographic distribution of project selections in 2007–2009 by Baltimore County's current CEA optimization method and the BT method.

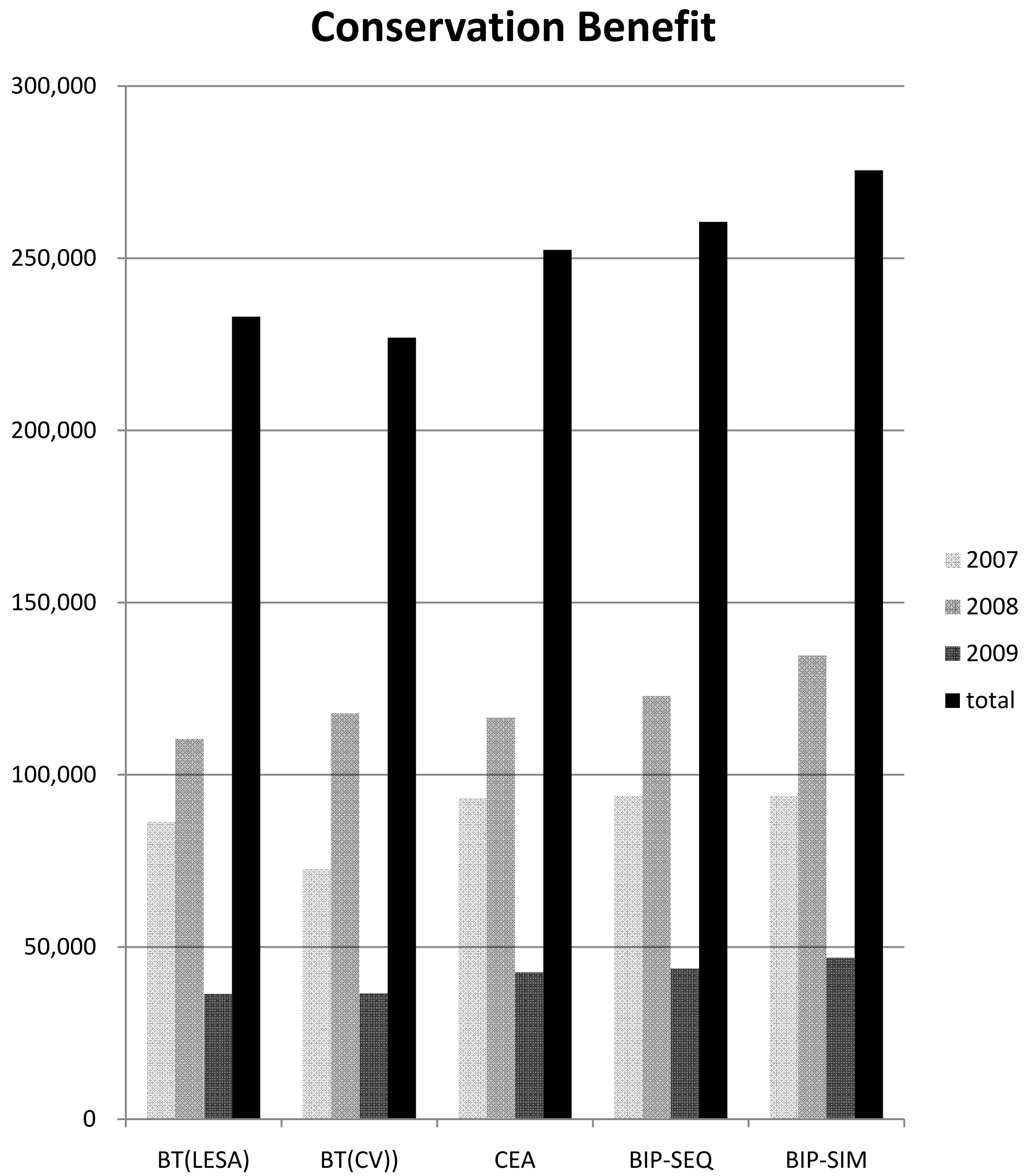

Figure 5. Level of conservation benefit achieved by each optimization method for 2007–2009 and total.

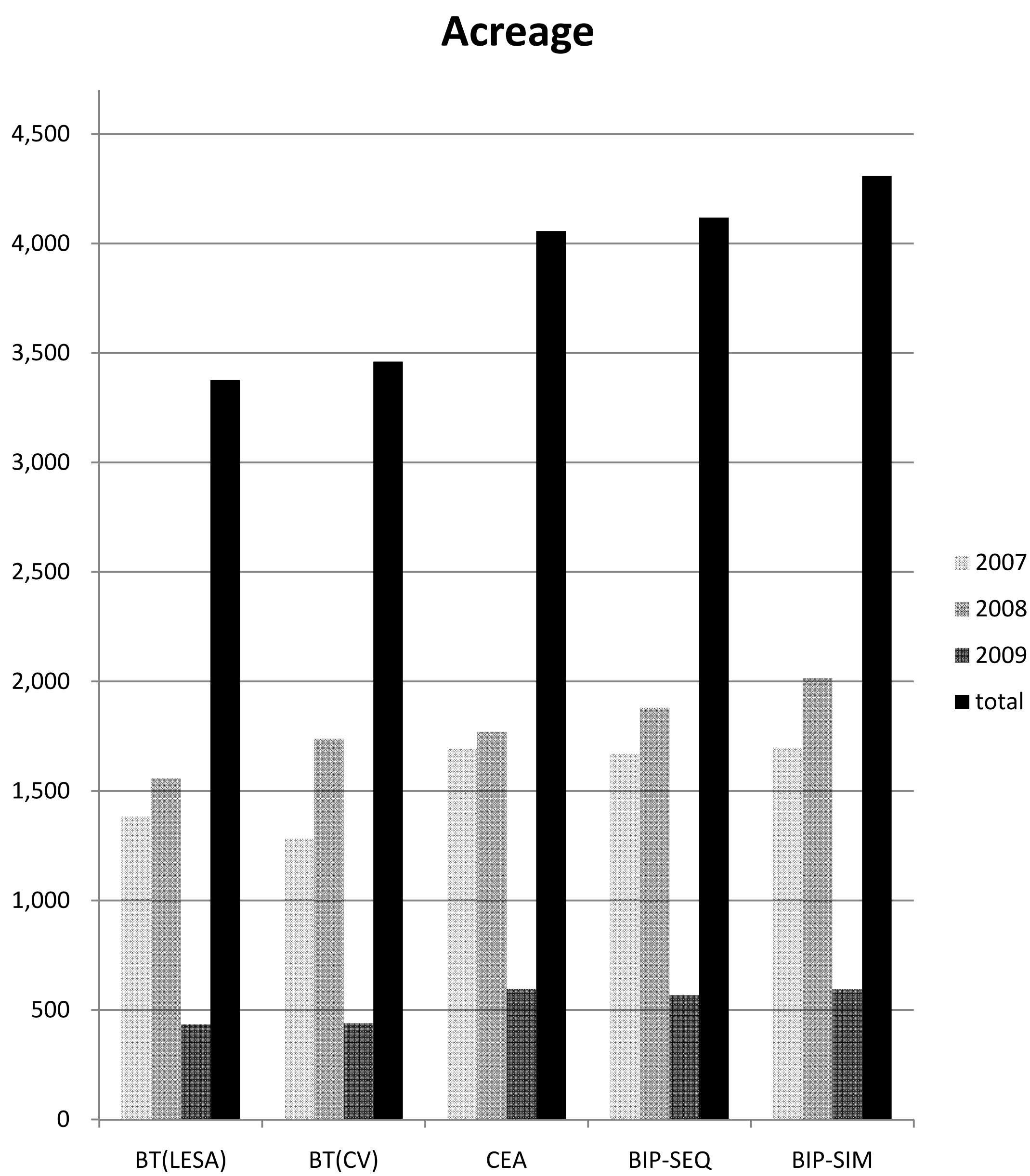

Figure 6. Number of acres preserved by each optimization method for 2007–2009 and total.

E. Developing a Best Practice Framework for the Maryland Agricultural Land Preservation Foundation: Why Don't Conservation Professionals Use Optimization?

by

Yu Chen

A thesis submitted to the Faculty of the University of Delaware
in partial fulfillment of the requirements for the degree of
Master of Science in Operations Research and Agricultural Economics

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Abstract

In the state of Maryland, government agencies charged with preserving agricultural land traditionally employ a rank-based selection process that ignores opportunities to acquire low-cost, high-benefit parcels. The potential benefit of applying an optimization method to these selection processes has been established in the literature but not recognized in practice. This study examines the methods currently in use by Maryland's counties in selecting parcels for preservation. It then identifies obstacles to adoption of optimization methods and, using a two-part survey instrument, examines the effect of an educational presentation about optimization on administrators' willingness to adopt it. Administrators put a high value on the fairness and transparency of the selection process. Parcel costs are rarely part of the calculation so funds may be used inefficiently.

The survey results indicate that a better understanding of optimization increases willingness to adopt it and decreases predicted difficulties with adoption. Also, administrators in metro areas are more willing to consider optimization methods than those in more rural areas. The study shows that lack of experience with optimization, the initial technical investment required to use it, and a lack of incentive to change selection methods are the main obstacles that influence these decisions.

Chapter 1 – Introduction and Background

Land serves as an important stimulus to overall development of the nation. It is the crucial asset and major input of world agriculture. Farmland preservation programs have received nationwide public support. U.S. citizens are willing to finance programs designed to preserve farmland, open space, and other amenities. Local and state governments approved conservation funding of $7.4 billion in 2000, $1.8 billion in 1999, and $8.3 billion in 1998 (Lynch & Lovell, 2003). According to the Land Trust Alliance in 2008, voters have approved a record $8.4 billion in new funding for conservation that year, despite tough economic times. Not surprisingly, these governments have taken a variety of steps to protect farmland from encroaching urban development. All 50 states have enacted some form of a right-to-farm law and at least 22 states have established protective zoning for agricultural land (Nelson 1998).

Farmland preservation programs became a magnet for economic, ecological and even policy studies in which program effectiveness was the essential theme (Deaton, Norris & Hoehn, 2003; Horowitz and Lynch 2003; Lynch & Duke, 2007; Lynch, 2008). These studies have outlined the theoretical basis for cautioning conservation organizations against directing financial resources to land acquisition without regard to cost, especially if the land that offers the greatest ecological value also tends to cost the most. Optimization, an approach commonly used in operations research, was consequently applied to these conservation efforts. Messer and Allen (2010) examined the selection approach applied by the Delaware Agricultural Land Preservation Foundation's (DALPF's) decade-old farmland protection program. They found that DALPF could have protected an additional 12,000 acres worth approximately $25 million if optimization techniques had been applied when it spent $93 million over the preceding decade. In addition, Baltimore County in Maryland confirms the optimality of this approach. Wally Lippincott, Baltimore County's land preservation administrator, said "After trying for years to balance price with farm quality using rank based methods, we switched to optimization. In the first three years of using optimization, Baltimore County has been able to protect an additional 680 acres for the same amount of funds that would otherwise have been spent. This also translates into a savings of approximately $5.4 million." (Lippincott, personal communication, 2010).

Therefore, to help Maryland Agricultural Land Preservation Foundation (MALPF) build a best practice framework for county land protection programs in Maryland, academic research gives the answer of "optimization". (Messer, 2006; Messer & Amundsen, 2009; Messer & Allen, 2010) Apply optimization to their county land selection processes would allow the counties to more efficiently use the funds available and save more of Maryland's productive land. This thesis employs a survey instrument to review the use of benefit factors, cost factors, and the selection process of the MALPF program. It investigates the degree to which MALPF administrators in Maryland's 23 counties understand optimization techniques and are willing to adopt them. The aim is to gather information needed to customize optimization techniques for each county and thus to recommend a "best practice framework"—a deployment strategy that will optimize each county's farm and forest protection program.

MALPF was created in 1977 by the Maryland General Assembly to purchase easements on agricultural land that permanently prevent the property from being developed for nonagricultural uses. The foundation's mission is to "preserve productive farmland and woodland for the continued production of food and fiber for all present and future citizens of the state."[8] Attention is focused

[8] MALPF report, page 1

on parcels with the best productive quality, preservation of large blocks of contiguous properties, and increasing incentives to bring critical parcels into the program, which represents the core of the state's preservation efforts.

MALPF has a 12-member board of trustees and a staff of seven administrators who work closely with local governments. Each county designates an employee as the MALPF county administrator who functions as the primary contact and the bridge between MALPF and the local agricultural community. The responsibilities of the county administrator include "monitoring MALPF properties, helping landowners prepare applications and subsequent requests, and advising landowners on MALPF and other programs available to help landowners seeking to preserve their properties."[9]

In cooperation with other agencies and programs in the state that include Rural Legacy, GreenPrint, and a number of county programs, MALPF and the State of Maryland have permanently preserved more productive farmland than any other state in the country. By the end of 2006, MALPF had purchased conservation easements on 1,933 farms comprising 265,691 acres. In 2007, the foundation managed a public investment of almost $500 million in preserved land valued at more than $1.5 billion at the acquisition costs.[10]

When development rights or easements are purchased, specific selection algorithms are used by decision-makers to determine which properties to preserve. Three selection algorithms are well defined in farmland preservation studies: benefit-target ranking, discount ranking, and optimization (Messer & Allen, 2010). Benefit-target ranking seeks to first acquire the parcel that has greatest benefit as defined by the conservation organization. Once rights to the highest ranked parcel have been purchased, the organization then seeks to acquire the rights for the parcel with the next highest rank and so forth until all funds available have been exhausted. Discount ranking captures some information about the cost of preservation by ranking the discounts offered by applicants. This method seeks to first purchase the parcel with the largest discount (calculated by the appraised value of the parcel and owner's offering price) and then to work down the list ranked by discount until the budget is exhausted. Optimization seeks to acquire a set of parcels that maximizes total benefit given existing constraints. Different techniques can be used to implement optimization, for example, binary linear programming (BLP) or cost-effectiveness analysis (CEA).

Binary linear programming is an algorithm widely used in operations research. It can assure optimal results under multiple simultaneous constraints. However, it requires complex computation and an intensive investment in explaining how it works to both program staff and the public. Literature search in the database of EconLit finds that cost-effectiveness analysis has been applied traditionally in the fields of health, medicine, and education. It compares the relationship between an activity's cost and outcomes. In farmland preservation, this analysis uses each parcel's benefit-cost ratio to determine which parcels to preserve. It is easy to calculate and to explain but there is no guarantee of optimality.

MALPF uses a combination of benefit-target ranking and discount ranking to select parcels. There are two rounds of selection. In the first round, a county determines its priorities and ranks parcels accordingly using a system that follows the state's guidelines, which emphasize the degree of quality of the property. These ranking systems vary in how they apply benefit factors and weights. For

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[9] MALPF report, page 2.
[10] MALPF report page 1

example, some counties incorporate size of the parcel into benefit calculation, others do not. Some counties take soil quality as the most important benefit factors while others only attach a relative low importance.

During the second statewide round, MALPF selects parcels using traditional discount ranking. A discount ratio is determined by dividing the landowner's asking price by the appraised value of the easement, which is calculated as:

Appraised fair market value – Agricultural value = Appraised value

The appraised fair market value is obtained from appraisals conducted by the state and any submitted by the landowner. Agricultural value is the lower of two figures: the average five-year cash rent rate for the county and the amount calculated by land rent based on soil productivity. If the discount ratio is less than 1, the landowner is willing to sell the parcel at a discount. The parcel with the best (lowest) discount ratio ranks first. MALPF makes purchases according to this ranking until the annual budget is exhausted.

A significant gap exists between theoretical understanding and actual practice (Prendergast, John, Quinn, Rachel, Lawton, John, 1999). This study not only recognizes and identifies the disconnection between literature in agricultural and resources economics and real world application, but also explores the underlying forces in policy making by evaluating the responses of individual counties in Maryland to enhance their land preservation programs. This thesis asks:

- What is the benefit that the program administrator is seeking? What is the cost of the target parcel?
- What are the current practices of MALPF and the counties? How do the programs select parcels to preserve?
- Does the county's current system meet the administrator's needs? How do the administrators assess the selection process?
- How do the program administrators view optimization? How willing are the programs to adopt optimization?
- What are obstacles to adoption of optimization? How can optimization be customized to improve cost-effectiveness given the counties' priorities in preservation?

Chapter 2 - Literature Review

The literature on farmland preservation, and on conservation as a whole, has advocated for cost-efficiency by preservation programs through theory and case studies (Deaton, Norris & Hoehn, 2003; Drechsler, Johst, OHL & Watzold, 2007; Kelsey & Lembeck, 1998). Indeed, great effort has been put into development of theories and techniques to increase the efficiency of conservation programs but these methods are not frequently used by those in charge of conservation planning (Predergast et al, 1999; Lynch, 2008). This chapter begins with the recognition of the gap in theory and in practice, which is one of the motivations for this study, and then reviews the representativeness of benefit factors, which is an important consideration in cost effectiveness study. Following is a discussion of cost factors that identifies issues involved in computing the quantity of farmland that is optimal to balance the social benefit and social cost at the margin. In addition, research on the use of selection algorithms by which optimal and suboptimal results can be obtained mathematically is shown and described.

Prendergast et al. (1999) recognized the gap between accomplishments in academic research and practical application and discussed it with ecologists, conservationists, and land managers from Europe and the United States. They concluded that the main reason for the low level of adoption of these sophisticated tools was lack of awareness of their existence. Additionally, insufficient funding, lack of understanding about the purpose of the tools, and general antipathy toward what was perceived as a prescriptive approach influenced practitioners' decisions. They called for more communication between theoreticians and practitioners, perhaps through short workshops and internet presentations. Prendergast et al. suggested that theorists should customize the tools to the needs of practical conservationists, who should actively seek scientific information to bridge the gap between the two sides.

This study seeks to discover benefit factors the conservation professionals used in their programs and examines the efficiency of such benefit calculation concept. Most written work to date has identified and measured the benefits of farmland preservation (Gardner 1977; Kline and Wichelns 1996; Rosenberger 1998; Duke and Hyde 2002). These studies suggest that cost-effective policy design should incorporate reasons to support from the public into the framework and build in an appropriate specification of public demand for nonmarket attributes. Among the four main sources of public support – agriculture, environmental, growth control, and open space – agriculture and environmental concerns play a more important role to satisfy public's preference in preserving farmland (Kline and Wichelns 1996; Duke and Hyde 2002). Protecting water quality or groundwater is especially concerned by the public.

Gardner (1977) identified four benefits of preserving agricultural land: sufficient food and fiber, a viable local agricultural industry, open space and environmental amenities, and more efficient urban development. He analyzed sources of market failure and questioned the basis for agricultural land preservation programs. He argued that agricultural land cannot be viewed as a collective good and cannot deliver relevant externalities to justify interference with the land market. However, Gardner admitted that markets fail to create open space and environmental amenities. In addition, he pointed out that solely using agricultural productivity as the criteria by which to select farmland parcels would not provide optimal quantities of open space and that equity problems might not be explicitly recognized given the absence of discussion.

Kline and Wichelns (1996) recognized that agricultural objectives are the primary focus of preservation programs. However, legislative objectives for the programs also include maintaining the environment, controlling growth, and retaining open space. Motivated by the discrepancy in perspectives, Kline and Wichelns surveyed 515 residents in Rhode Island and established mean ratings of importance for reasons to preserve land from the public side. By examining specific pubic preferences regarding farmland preservation objectives, they sought to incorporate the public's view into policy objectives and thereby improve the social efficiency of these programs. Factor analysis of the ratings revealed that environmental objectives such as protecting groundwater, wildlife habitat, and natural places were rated higher than agrarian goals of providing local food and keeping farming as a way of life. As a result, Kline and Wichelns suggested that purchases of development rights could be more socially efficient if environmental criteria represented by water and wildlife quality were given more consideration while attention to agricultural criteria represented by soil quality and farm productivity were reduced.

Kline and Wichelns (1996) ranked the broad categories of factors in descending order of importance as environmental, aesthetic, agrarian, and anti-growth. Rosenberger (1998) commented on Kline and Wichelns' work and reversed the positions of aesthetic and agrarian interests. Rosenberger argued that expanding program objectives to meet the public's preferences may not necessarily increase efficiency for private programs and that specialization in land preservation may more efficiently produce a specific set of benefits than programs aimed at multiple goals. He suggested that some form of cooperation between public and private programs could improve land preservation by generating a larger pool of resources and public support.

Duke and Hyde (2002) confirmed public support of farmland preservation in the interest of gains from environmental benefit. They measured public demand for various attributes of preservation within four broad categories: agriculture, environmental, growth control, and open space. Within these categories, the eight reasons to preserve land proposed by Kline and Wichelns (1996) were extended to ten qualities. Duke and Hyde then applied the analytic hierarchy process to compare public support for each reason. Results from survey data for the general population of Delaware demonstrated strong public support for the environmental attribute, which is consistent with findings from other studies in this area. However, the survey sample in their research placed the most importance on agricultural attributes and least on open space. Specifically, providing locally grown food, keeping farming as a way of life, and protecting water quality were the top three attributes sought by the public from preserved land. Protecting agriculture as an important industry, preserving natural places, and providing breaks in the built environment received the least support.

While the potential benefits of preserved farmland have generated a large body of work, little has been done to examine the cost side. Some of the literature has paid attention to the absence of research. But the concept of cost has generally been used in a broader sense of conservation, mainly the cost of ecological conservation. Therefore, answers to choices of cost factors and their calculation from this study can generate great interests both academically and politically.

Naidoo et al. (2006) divided conservation costs into five categories: acquisition, management, transaction, damage, and opportunity. They discussed a method by which to estimate costs and show efficiency gains by incorporating costs into conservation planning. They pointed out that a cost study also can contribute to an analysis of tradeoffs between obtaining a higher level of a conservation target and the increase in cost necessary to obtain it. Therefore, a cost analysis provides useful information to decision-makers. The study by Naidoo et al. listed three reasons for lack of attention to costs both in practice and in the literature. They considered the prospects for integrating costs into conservation planning and suggested that benefits, costs, and threats should all be taken into consideration when conservation priorities are selected and that frameworks that include dynamics in the level of threat and conservation costs could significantly impact the ultimate conservation portfolio.

Dillman (1984) also recognized that costs have been incompletely considered in farmland preservation. He took the opportunity cost of agricultural land as its real social cost and computed it by the discounted future value of net returns to the land when it is employed in its most productive use. Dillman argued that opportunity cost is a good measure of public cost and that it is real, leading to higher prices in tax bills as well as in goods and services.

Although direct studies of the costs of farmland preservation have been rare, other studies might shed some light on the effect of costs on society for decision-makers indirectly. American Farmland Trust (1999) conducted a cost of community services (COCS) analysis in six U.S. states. The COCS analysis assesses the overall fiscal contribution of current land uses. It compares revenue and expenditure based on existing land use patterns (AFT, 1999). According to their report, the cost of preserving farm, forest, and open land includes expenditures to buy development rights and expenses for public services and works. Public works consist of roads, solid waste systems, equipment rentals, buildings, special paths, drainage utilities, river improvement, and sub-flood control zone districts.

Studies in identifying and measuring benefit and cost factors ultimately contribute to the selection process to improve the cost-efficiency of preservation programs. Apparently, the selection algorithm employed should be analyzed to secure the most cost-efficient results. Literature in this area emerges mostly from environmental and ecological conservation (Underhill 1994; Pressey et al. 1996; Rodrigues et al. 2000). Therefore, this paper first examines the optimality of the selection algorithm in environmental and ecological conservation, and then moves to the discussion of cost-effectiveness studies in farmland preservation.

Underhill (1994) compared reserve selection algorithms that are referred to as "greedy algorithms" to a standard algorithm from operations research. He stated that these greedy algorithms were not optimal as claimed and were in fact suboptimal. Underhill presented a simple counter-example that proved that the greedy algorithm could not assure a minimal number of reserves with a goal of conserving every species. He appealed for closer cooperation between biologists and mathematicians in the development of selection algorithms. He also suggested using techniques from operations research, such as integer programming and multiple-criteria decision-making, in biological conservation.

Pressey et al. (1996) compared optimizing algorithms such as integer linear programming and branch and bound algorithms with heuristic approaches to determine their efficiency and feasibility for conservation planning. They used the term "heuristic" to refer to greedy and rarity algorithms (adopted by Underhill (1994)) and recognized the suboptimality of those algorithms from a mathematical viewpoint. However, they argued that an appropriate heuristic method yields as good or even better solutions than optimizing algorithms because it possesses substantial compensatory advantages. Because optimizing algorithms require intensive computer resources for large regional data sets and have failed to find optimal solutions in complicated cases because of limitations on hardware and/or software, they have not been practical for real-world application.

Although the concerns expressed by Pressey et al. regarding computing speed and the capacity of optimizing algorithms has been greatly reduced and perhaps eliminated today, their hypothesis that good heuristics can be reliable comparative tools still holds. Furthermore, adjustment of the acquisition priorities can influence the optimal result to a large extent. Therefore, the criteria used to assess the utility of various algorithms must be broadened.

Experts and scholars who study farmland preservation endeavor to design the best framework for various conservation programs and focus on either benefits' attributes or selection mechanisms. Lynch and Musser (2001) built a Farrell efficiency model to determine both technical efficiency and cost-effectiveness for three types of preservation programs in four Maryland counties. They specified four goals in the model: (1) maximize the number of preserved acres; (2) preserve productive farms; (3) preserve farms most threatened by development; and (4) preserve large blocks of land. Lynch and Musser collected data on parcel characteristics to proxy the achievement of these goals and discussed how programs trade off the four objectives. They confirmed that MALPF's purchases of development rights provided greater technical efficiency and cost-effectiveness. Parcel size, percent of prime soil, and percent of crop land were found to affect efficiency measures most. Their work suggests that development threat or proximity to other preserved parcels is not prioritized by preservation programs.

Machado et al. (2006) described a method by which to evaluate sets of farmland parcels—the land evaluation and site assessment or LESA system. They claimed that LESA-type index models consider the full range of socially defined objectives. The primary objectives they identified were maintaining agricultural viability, preserving rural amenities or ecosystems, and directing urban growth. They aggregated the social value of the objectives for each site and then used the overall value as the final benefit score. The cost factor was calculated by the cost of the conservation action—the price of purchasing an agricultural conservation easement and/or the transaction cost of accepting a donated easement. The ratio of the aggregated social value to the predicted easement price was computed and referred to as the "conservation value." Conservation value identifies the most cost-effective sites. Because this framework requires data that can be obtained by methods similar to traditional ones used by preservation program administrators, it is more likely to be accepted. They concluded that the LESA framework provides a sounder conceptual basis for transforming data into useful information and can bolster the decision-making process.

Messer and Amundsen (2009) promoted the use of cost-effectiveness analysis for land acquisition projects. They defined strategic conservation as "a planning process that seeks to select the highest quality lands given limited financial resources." They pointed out that traditional conservation ensures the purchase of high quality land by creating prioritization maps and applying rank-based criteria when evaluating the quality of a potential project. However, few states incorporated land costs into the planning framework. Cost-effectiveness analysis, on the other hand, includes costs in the evaluation process. It compares costs and benefits for each potential project, therefore strengthening land conservation efforts and achieving efficiency gains. Based on empirical examples, they concluded that cost-effectiveness analysis results in more successful conservation decisions, especially in times of dramatic budget problems.

Similarly, Horowitz and Lynch (2003) recommended comparing benefits and costs. They framed farmland preservation programs in Maryland as one of three types: bidding, "menu-based," and bargaining. They examined MALPF's programs to determine whether the program selects the "right" parcels. MALPF used a selection algorithm that ranked the ratio of the easement's value to the farmer's bid. In the analysis, the land's development value and the farmer's desire to continue farming were identified as the essential characteristics for decision-making in farmland preservation. Because the easement value captures information from both characteristics, it was taken as the gauge of the parcel's benefit. The farmer's bid was viewed as the cost of the parcel. Horowitz and Lynch concluded that, by introducing both the easements' values and the farmers' bids into the selection process, MALPF had preserved larger parcels with a lower price per acre than menu-based programs and that the selection process had performed relatively more efficiently than others. Meanwhile, the competition among farmers to bid could reduce the cost of the easements. MALPF's discount selection process increased competition among landowners and therefore contributed to the efficiency of the program. This study did not take attributes such as environmental and open space into consideration. Rather, only the market attribute was calculated in the efficiency formula.

More complex and comprehensive calculation of preservation benefits was conducted by Messer and Allen (2008). They distinguished three selection algorithms: benefit-targeting, the DALPF algorithm,[11] and optimization. The benefits were determined by the LESA score and a Core GI[12]

[11] DALPF selects parcels based on a discounting system. The parcel with the greatest discount will be purchased first, the second greatest next.

[12] The Conservation Fund defines "core green infrastructure" (Core GI) as "an interconnected network of natural areas, green spaces, and working landscapes that protect natural ecological processes and support wildlife."

score. An analytic hierarchy process was applied to obtain weights on the LESA and Core GI scores and then the aggregated conservation benefit was derived by combining those three values. The number of parcels preserved also served as a criterion for the benefit comparison. The purchase price was taken as the only cost factor. The study demonstrated that optimization using binary linear programming preserves more parcels of land, thus producing more conservation benefits than either the DALPF algorithm or benefit-targeting given the same budget. Messer's (2006) study in Maryland further assured the cost-effectiveness of the optimization algorithm. In that study, benefit-targeting and optimization were compared for a case in the Catoctin Mountains of Maryland. He first suggested including development risk in the analysis because adding values based on threat of development can impact the conservation values significantly under both benefit-targeting and optimization. Messer then concluded that benefit-targeting, viewed as a type of "greedy" algorithm in ecological conservation, can lead to highly inefficient results while optimization generates in a higher level of conservation benefit at the same level of purchase cost.

In summary, literature has proved the optimality of optimizing algorithms such as integer programming both mathematically and empirically (Underhill, 1994; Messer & Allen, 2010). However, a real application of such algorithms is in question. Machado et al's "conservation value" is merely heuristic, although it sounds acceptable. Therefore, whether the optimal algorithms are adopted or will be adopted, how conservation professionals view "optimality" in their daily work, how they distinguish heuristic algorithms from optimal ones, are the questions that should be answered by further research. Motivated by the lack of literature on this issue, this study tries to make some effort in filling the blank in optimal algorithm's real-world application.

Chapter 3 - Research Approach

In this chapter, the research approach is described step by step, including the survey construction, the pre-test of the survey, the revision process, the administration of the survey and the follow-up procedure. Overall, response rate of the survey is 100%. More than 30 responses are received by March, 2010. (See Table 3.4 for details.)

Borrowed the idea of optimization from operations research, this study uses the term "Optimization" later in the survey as a selection approach in farmland preservation. It is defined as a process "to provide a high level of aggregated benefits at the best possible price." (See Appendix A) Two specific optimization techniques are brought up. One is called binary linear programming[13], which is the assured optimal algorithm as in literature. The other is names as cost-effectiveness analysis, which resembles the calculation of "conservation value" (Machado et al, 2006). The main objectives of the survey are to identify:

4. Preservation program selection criteria in each county and how these benefit factors are measured.

5. The methods used by programs in each county to measure the easement cost and how those costs are incorporated into the selection process.

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[13] Binary linear programming is one kind of integer programming. Its decision variable(s) are binary and the constraint equation(s) is/are linear.

6. The selection techniques used by the county programs to assess the performance of selections made and the criteria used.

7. Administrator's willingness to adopt optimization as a selection process and compare the feasibility of two optimization techniques.

8. Obstacles to adopting optimization and the severity of the obstacles.

Target participants in the survey are the program administrators in Maryland counties. Since there are 23 counties (see Figure 3.1), 23 survey subjects are expected. Two survey instruments were used—a pre-survey and a post-survey (See Appendix A). The pre-survey was conducted before educational material about optimization was presented. The post-survey was conducted after discussions with the administrators about optimization techniques, the results of its application in Baltimore County, and other related issues.

The pre-survey contains five parts. The first part collects background information, including personal information and the program's historical performance. Personal information consists of the participant's name, years of employment in current position, and degree of professional knowledge. It serves to confirm that targeted participants are surveyed and thus that the results obtained from them are valid. The second part uses open questions to determine the program's beneficial factors and how they are measured. Individual programs that make up the county's conservation efforts are distinguished so the selection criteria and calculation system are not only specific to that county and but are customized by program. The third part seeks to answer questions about the cost formulation used. Participants are asked to identify the method the county uses to determine the cost of an easement and how it is factored into the selection process. In the following part, the selection process is investigated. The algorithms are described and participants can choose the method or methods they employ from the listed choices. Then they can evaluate their current selection process in terms of the program's goals. The final part assesses the current selection techniques and overall efficiency for each distinct county program.

The post-survey contains six parts. The first part collects the participant's name and the county's name. It helps to match the results from the post-survey with those from the pre-survey, making paired comparisons and tests feasible. In the second part, the importance of the criteria for applying a selection technique is valued. The criteria are identical to the ones used in the fifth part of the pre-survey when the current selection technique is assessed. The third part of the post-survey investigates the participant's understanding and willingness to adopt an optimization process for the preservation programs. The fourth and fifth parts discuss two optimization techniques—binary linear programming and cost-effectiveness analysis, respectively. Identical formatting is applied in each part. Knowledge of each technique, its predicted ability according to the criteria set out in the second part of the post-survey, and willingness to adopt the process are measured on a scale of one to five. The questionnaire ends with two open questions and acknowledgement of their participation. The first open question gathers additional thoughts from program administrators about the selection process currently used and the optimization selection process. The second asks for comments and suggestions about the survey.

Survey Pre-test

On August 20, 2009, the survey instruments (both the pre-survey and post-survey questionnaires) were pre-tested by a critical review panel. The panel was given the following tasks:

- Confirm the most appropriate method to define selection criteria and its calculation mechanism.
- Review the terms that county administrators could use to describe easement costs and select the best terms to provide a clear and understandable definition.
- Modify survey questions specifically related to county and state government contexts.
- Review the survey language and administration to ensure that it met current standards for academic research.

Several revisions were made after the August meeting. First, based on MALPF officials' opinions and county representative experience, we changed the comparison list of preservation programs. The final program choices were MALPF, the County program, the Rural Legacy program, the Maryland Environmental Trust (MET) program, and Program Open Space. In case counties had additional special programs, "Other" was presented as a final option. Second, questions on benefit factors, cost factors, and the selection process were customized for programs within a county. In other words, participants were asked to explain the benefits, cost factors, and selection algorithm they used for each specific program in the county. Third, the criteria for evaluating the programs' current selection process were reduced from fifteen to six. This change was related to concerns about the length of the questionnaires, readability, and ease of completion. The previous list contained 15 items, some of which were derived from the literature on public preference. The revised list included only six items that were derived from MALPF's program guide. In addition, we added one question about price caps, which have been used by many counties at the request of MALPF officials. This question queried the advantages and disadvantages of this method in the eyes of the county administrators. It also revealed the demand for the "price cap" method and barriers to adopting it. A price cap is the up-limit of the price that a county sets to purchase an easement.

Administration of the Survey

On November 19, 2009, MALPF held an annual conference at Annapolis for all county administrators. Representatives from 12 counties attended the meeting. Another five county representatives used the video conference software to participate. Pre-surveys and materials for the optimization presentation were prepared for each seat before the meeting. After several county reports, the pre-survey was conducted. Twenty-three pre-survey questionnaires were collected: 18 from administrators and staff members of the 12 counties at the meeting, one from a county using video conference software, one from a MALPF board member, and three from MALPF staff members (See Table 3.1.).

After the pre-survey data were collected, Dr. Kent Messer, University of Delaware, gave an educational presentation on optimization. He explained how the approach performs, how to implement it, and what had been achieved after its application. He also compared two optimization techniques this study defines: binary linear programming (BLP) and cost-effectiveness analysis (CEA). After his speech, Wally Lippincott and Robert Hirsch, MALPF county administrator and GIS analyst from Baltimore County, Maryland, gave a presentation on improved results generated in Baltimore County after applying cost-effectiveness analysis to its county preservation program.

During the presentation, Mr. Lippincott and Mr. Hirsch expressed very positive sentiments about Baltimore County's experience with optimization including the following statements:

> "After trying for years to balance price with farm quality using rank based methods, we switched to optimization. In the first three years of using optimization, Baltimore County has been able to protect an additional 680 acres for the same amount of funds that would otherwise have been spent. This also translates into a savings of approximately $5.4 million." (Lippincott, personal communication, 2010).
>
> "Optimization has proven easier to administer and run than our old methods. During our rank-based days, we performed extra administrative and mathematical work in order to solicit discounts and award extra LESA points for discounting. With optimization, this is no longer required." (Hirsch, personal communication, 2010).

The post-survey was then conducted and 21 responses were received: 17 from county representatives at the meeting, one from a user via the video conference, and three from MALPF staff members. (See Table 3.2.)

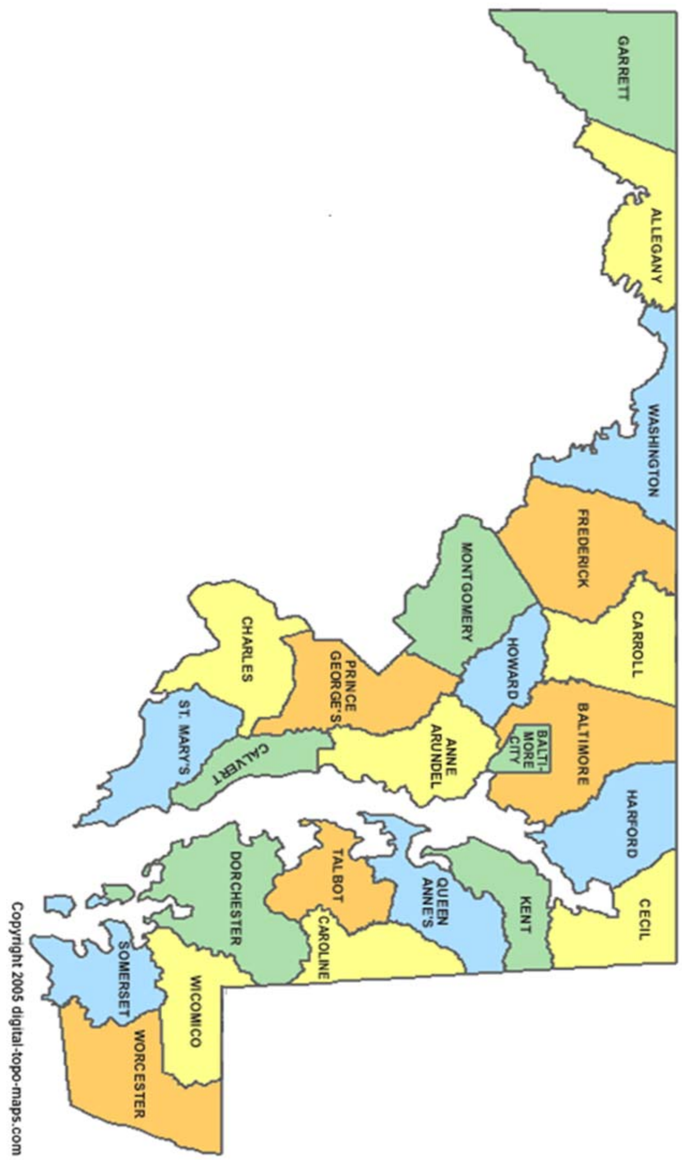
Follow-up for Non-responses

Based on the concept of Dillman's (1978) total design survey method, emails were sent to four participants who used the video conference but did not respond to the survey as a reminder on December 7. Six other county administrators who could not participate in the November 19 meeting and the survey also received emails that introduced the MALPF project and explained the purpose of the survey, how to participate in it, and how to obtain help. Written letters were sent to these ten county administrators immediately after the email with a printed pre-survey and a prepaid return envelope enclosed. Two weeks later, a DVD and post-survey were mailed to the six county administrators who did not attend the November 19 meeting. On the DVD was a Powerpoint file with Dr. Messer's narration, providing them with the same presentation he made at the meeting. The administrators were asked to watch the DVD first and then to complete the questionnaire. Emails with the post-survey and the Powerpoint presentation attached were also sent to those target subjects. To the four county administrators who used the video conference, both an email and a hard copy of the post-survey were sent. These mentioned the availability of the DVD and expressed our willingness to provide them with the disk on their request.

Prior to January 7, 2010, we received a completed pre-survey from one county and a completed post-survey from another county. Telephone calls were made to county administrators who had not completed one or both of the surveys. If not connected, a message is left, asking for their help to complete the surveys. On January 20, we called the remaining five county administrators who had not sent back the surveys. We sought to help them with the survey questions if necessary and ensure that they had all of the materials needed to answer the questions. On January 25, another round of emails and phone calls was made. Only four counties remained listed on the follow-up list on that date. Two confirmed that they received all of the materials and agreed to mail back the questionnaires soon. One county asked for copies of the surveys while another county expressed concern about available hours to complete them.

On February 12, 2010, responses from only two counties were still missing. Considering that both counties were having difficulty finishing the surveys, we abridged the two questionnaires into one for those counties and kept only the key questions that collected data for comprehensive conclusions (see Appendix B). These abridged surveys were emailed and mailed to the two counties with a return envelope enclosed. These last two counties returned their surveys by March 10, 2010. (Summary of the follow-up procedure can be found in Table 3.3.)

Figure 3.1: Maryland County Map[14]



[14] Image is retrieved from www.digital-topo-maps.com/county-map/maryland.shtml. Permission to use this image is provided in Appendix C.

Table 3.1: Responses to the pre-survey at the November 19, 2009, meeting.

	County			MALPF			Total
	Admin	Staff	Total	Staff	Board	Total	
At the meeting	12	6	18	3	1	4	**22**
Through video conference	0	1	1	0	0	0	**1**
Total	12	7	19	3	1	4	**23**

Table 3.2: Responses to the post-survey at the November 19, 2009, meeting

	County			MALPF			Total
	Admin	Staff	Total	Staff	Board	Total	
At the meeting	11	6	17	3	0	3	**20**
Through video conference	0	1	1	0	0	0	**1**
Total	11	7	18	3	0	3	**21**

Table 3.3: Number of counties that responded to the survey between November 19, 2009, and March 10, 2010.

Date	Event	Survey response*		
		Pre-survey	Post-survey	Response rate
November 2009	MALPF meeting	12	11	52.2%
December 2009	Initial reminder	15	14	65.2%
	Duplicate packets			
January 2010	Initial phone calls	21	21	91.3%
	Second round calls			
	Follow-up reminder			
Feb.–Mar., 2010	Revised survey	23	23	100.0%

* The survey response counts only the number of counties that responded to the survey.

Table 3.4: Overall responses to the pre-survey

	County			MALPF			Total
	Admin	Staff	Total	Staff	Board	Total	
Complete	19	8	27	3	1*	4	**31**
Abridged	2	0	2	-	-	-	**2**
Total	21	8	29	3	1*	4	**33***

* No response was received from board members on the post-survey so the total number of responses for the post-survey is 32.

Chapter 4 - Descriptive and Survey Results

Having described the manner in which the survey tool was administered with all of the counties in Maryland, this chapter presents the results from the survey: a description of the data set, the histogram and box plot from the data analysis, and a table comparing the criteria for assessing specific selection techniques. The five criteria were knowledge, fairness, transparency, cost-effectiveness, and ease of administration.

County Information

The first eight questions in the pre-survey collected personal information about the participants. It was used to distinguish the target subjects and verify their professional ability to validate the continued analysis. Following are the names of the variables:

- Years-for-county: number of years the survey participant worked for the county.
- Years-for-job: number of years the survey participant worked at the current position.
- Know-MALPF: knowledge about MALPF's program.
- Know-county: knowledge about the county's program.

County administrators were asked to fill in the blanks the number of years they worked in the county or at the current position. Their knowledge of MALPF's program and county program was measured on a scale of one to five with one standing for not knowledgeable, three for somewhat knowledgeable, and five for expert. Two and four meant the degree between. All 33 responses provided answers to these questions. The average working experience of participants is 11.85 years. When MALPF's staff members are excluded from the sample, the average working experience of the county participants is 11.91 years. Participants have spent an average of 8.31 years in the current job position. The know-MALPF and know-county variables measured how much participants knew about the two types of programs. The results show that all 29 county representatives obtained an average score of 4.02 for MALPF's program and 4.43 for their county programs (see Table 4.1). It can be concluded that the surveyed participants have a high level of knowledge in the field of land preservation and therefore represent the understanding and opinions of preservation program administrators in general. And that the problems they reveal are representative in practice and worthy of study and theoretical research.

Identifying Benefit Factors

Question ten in the pre-survey asked participants to list the three to five most important benefit factors that their programs use in the selection process. We used the data from 23 senior representatives of counties.[15] These participants included 21 program administrators who were the original targets of the survey and two senior county staff members who were representatives of their administrators.

Nineteen counties listed soil quality as one of the most important benefit factors that their programs aim to obtain. Eighteen counties considered location-related factors when selecting parcels. Eleven counties listed parcel size and ten stated an interest in development-related issues. Other benefit

[15] Unless stated otherwise, data from these 23 observations are used in the rest of the chapter.

factors were mentioned by one or two counties (see Table 4.2 for detailed information). In conclusion, soil quality is the benefit factor measured by almost all of the counties surveyed. Location of the parcel and its size are also widely considered. Almost half of the counties consider development pressure as another influential element. Concern about agricultural land, environmental benefits, and economic viability also draw some attention.

Incorporating Cost Information

Question 14 asked participants to check the factors they use in calculating the cost of an easement for various types of preservation programs. (The variables for easement cost factors in pre-survey question 14 are presented in Table 4.3.) Five programs were listed on the survey: the MALPF program, the county program, the Rural Legacy program, the Maryland Environmental Trust program, and Program Open Space. Participants could specify a program in the line of "Other" if their counties worked with additional programs that were not listed. MALPF's program adopts diversified methods for calculating the easement value. Asking price, seller's discount, a calculated easement value, and the appraised value all help to determine the ultimate easement cost. The county program also takes multiple factors into account. Appraised value, asking price, and a calculated easement value are the three major factors. Rural Legacy's program uses a price cap and a calculated easement value most. Only four counties have Maryland Environmental Trust programs and two of those do not know what factors are used for easement cost calculations. Most of the counties do not have Program Open Space and know little about it. Four counties operate programs other than the listed five. (Details can be found in Table 4.4 and Figures 4.1 through 4.3.)

Question 15 investigates the actual usage of cost information in various types of preservation programs. Participants were asked how cost factors are incorporated into the selection process. (The variables for cost usage in pre-survey question 15 are listed in Table 4.5.) Nearly half of the counties do not include cost information in the selection process and do not use it to determine the priority for MALPF programs. Cost only signals the balance of the available funds. More than a quarter of the counties do not think easement cost is applicable in their MALPF programs. Similarly, the county and Rural Legacy programs usually do not take the easement cost into consideration when parcels are selected and Maryland Environmental Trust and Program Open Space make little use of cost information. (Details are presented in Table 4.6 and Figures 4.4 through 4.6.) Only one county uses cost as part of a benefit calculation in its MALPF program. Baltimore County uses cost information in its optimization process both for MALPF and its county program. Another county claims to use cost information in optimization process for its Rural Legacy program. In the MALPF, county, and Rural Legacy programs, administrators noted that they use easement costs in other ways but they did not specify how.

Identifying the Selection Process

Question 16 investigated the selection process and identified the techniques used in each program. Selection algorithms and general guidelines could both be applied to determine which parcel to purchase. (The variables for selection techniques in pre-survey question 16 are shown in Table 4.7.) The MALPF program values the parcels with the greatest benefit most. Therefore, 16 counties rank the parcels based on a benefit score. The county program uses benefit ranking and board recommendations to select parcels. The Rural Legacy program selects parcels based on flexible standards that incorporate the benefit score, benefit-cost ratio, board recommendations, political advice, and other criteria. Again, the criteria used by Maryland Environmental Trust and Program Open Space were mostly unknown to the administrators. In addition, 43% of the responding administrators do not view the standard selection process as applicable while 20% of the programs use benefit ranking to determine selection priorities. (Details can be found in Table 4.8 and Figures 4.7 through 4.9.)

Questions 17 through 22 asked participants to evaluate the performance of the current selection process using given criteria. (The variables for the evaluation criteria can be found in Figure 4.10.) Results show that their current selection processes have done best protecting soil and large blocks of contiguous land. On a scale of one to five, protecting soil receives a score of 4.10 and protecting large blocks of land receives 4.05. The selection processes have some ability to maximize the number of agricultural acres (score of 3.6) and the quality of open space (score of 3.06). But the existing processes do poorly in acquiring the best deals and increasing incentives to remain in farming. Administrators give scores of only 2.76 and 2.95, respectively, to those two criteria. Figure 4.10 uses the box plot to show the results with regard to the six evaluation criteria.

Questions 23 through 28 asked participants to assess various techniques used in their current selection processes according to a set of given criteria. (The variables for the evaluation criteria can be found in Figure 4.11.) Of the 23 senior county representatives who participated, 21 responded to these questions. A mean score of 4.10 on knowledge of the techniques demonstrates that these administrators are well versed in how to use them. Senior representatives think that their current techniques are fair and transparent. They give fairness a score of 4.05 and transparency a score of 4.0. They do not, however, find the techniques easy to administer, giving a score of 3.74. And the techniques used do only moderately well in terms of cost-effectiveness with a score of 3.16 (see Figure 4.11).

Importance of the Selection Criteria

Questions three through eight of the post-survey measured how important various attributes of the selection process are to the administrators. (Descriptions of the variables can be found in Figure 4.12.) The importance of each attribute is measured on a scale of one to five with one standing for not important, three for somewhat important, five for very important, and two and four between. Statistical results from responses by the 23 senior representatives show that fairness of the selection process is valued most. It generates a mean score of 4.65. Transparency, scoring 4.48, is also very important. Knowledge of the selection process, including understanding of the selection techniques used, rates a score of 4.26. Ease of administration of the process and the cost-effectiveness of the resulting selections were only moderately important, generating scores of 3.87 and 4.17 respectively. (See Figure 4.12.)

Optimization

Questions nine and ten compared administrators' understanding of a selection process using optimization techniques before and after the educational presentation by Dr. Messer and experience-sharing presentation by Wally Lippincott and Robert Hirsch. These questions quantify the effects of short seminars as a means of communication between an academic and practitioners. Twenty-one of the 23 senior representatives answered these questions. There was a significant increase in understanding of optimization methods after the educational presentation. The mean score for optimization knowledge, a measure of the administrators' confidence in their understanding of the program, before the presentation is 2.43. After the two presentations, this score rose to 3.70. (See Figure 4.13.)

Question 11 evaluated a general willingness to adopt optimization while Questions 21 and 22 provided further information on their willingness when some additional resources are offered. In Question 21, access to user-friendly software to help with optimization is offered. In Question 22, both access to and training for such software are offered. General willingness to adopt optimization gave a score of 3.0, meaning they are somewhat willing. When access to the optimization software tool was offered, willingness rose to 3.30, a 10% increase and significantly different from the previous one at 1% level. When both access and training were offered, willingness increased to 3.5, a 16.7% increase and also significantly different from general mean of 3.0 at 1% level. Therefore, survey results show that participants are more willing to accept optimization when additional resources are available (see Figure 4.14).

Questions 12 through 20 described potential obstacles to adopting optimization as the selection process. (Descriptions of the variables can be found in Figure 4.15.) The survey listed eight obstacles and asked participants to assess the difficulty each one presented on a scale of one to five. One signified for not difficult at all, three signified for somewhat difficult, and five signified for very difficult. Two and four signified a level of difficulty between the adjacent two numbers. All eight obstacles received a mean score of about 3, suggesting that challenges to incorporating an optimization process do limit its use. No one obstacle was dominant (see Figure 4.15).

Binary Linear Programming

Questions 23 and 24 compared the administrators' knowledge of binary linear programming before and after Dr. Messer and Baltimore's presentations. Twenty-one participants answered the two questions. The average score of their prior knowledge was only 2, falling between "Not at all" and "Somewhat." After the presentation, their knowledge level averaged a score of 3, "Somewhat" (see Figure 4.16). So, while the increase in understanding was significant, binary linear programming was still difficult to understand for most participants.

Questions 25 through 30 of the post-survey used the same criteria as pre-survey questions 23 through 28 and were designed to assess administrators' views of binary linear programming as a selection technique. The variable names were identical to the pre-survey ones (shown in Figure 4.11). Participants from 20 counties answered the questions. Per their responses, binary linear programming is viewed as cost-effective and fair. Cost-effectiveness scored highest of the five attributes. However, participants do not feel knowledgeable about this technique (score of 2.26). Therefore, they do not consider it to be easy to administer or transparent to explain (see Figure 4.17).

Cost-Effectiveness Analysis

Questions 32 and 33 identified the participants' knowledge regarding another optimization technique, cost-effectiveness analysis, before and after the presentation. Participants were not familiar with this technique before the presentations so their understanding improved. The score of their knowledge level rose from 2.43 to 3.48, an increase of 33.8% (see Figure 4.18).

Questions 34 through 39 used the same five criteria for assessing binary linear programming to evaluate cost-effectiveness analysis. Twenty county representatives evaluated this tool. For these participants, the cost-effectiveness analysis was viewed as yielding efficient results (score of 3.78). Although not thoroughly knowledgeable about this tool, they scored it fairly high in terms of fairness, transparency, and ease of administration (see Figure 4.19).

Statistical Comparison

In both the pre-survey and the post-survey, six criteria were given to assess a specific selection technique: knowledge, fairness, transparency, cost-effectiveness, ease of administration, and "Other." None of the participants provided additional criteria in the "Other" line. Therefore, only five criteria are used by the participants. This section compares the three selection techniques—current techniques, binary linear programming, and cost-effectiveness analysis—according to those five criteria. The importance of the criteria is also surveyed.

Of the 23 participants who completed surveys, 21 assessed their current techniques, 20 assessed linear programming and cost-effectiveness analysis, and all rated the importance of the five criteria. Fairness and transparency rank at the top in terms of importance, followed by knowledge of the application. Cost-effectiveness is less important and ease of administration is the least concern. Pair-wise t-tests show that fairness (score of 4.65) and transparency (score of 4.17) are not significantly different from each other but both are significantly different from the other three at a 5% significance level. With regard to current techniques, participants feel that they are knowledgeable about them (score of 4.10) and that the techniques are fair (score of 4.05) and transparent (score of 4.00). These scores are not significantly different from one another but vary significantly from scores for the other two techniques at a 10% level of significance. The ease of administration score is highest for participants' current techniques (3.74), most likely because they are less familiar with the other two. Cost-effectiveness scored only 3.16, the lowest rating in this section for current techniques. It is also lower than cost-effectiveness score that cost-effectiveness analysis receives (3.78). However, pair-wise t-tests show that it is not significantly different from the average score that binary linear programming receives (3.56).

Hence, one can conclude that participants admit that their current selection techniques are less cost-effective than cost-effectiveness analysis, but as better as binary linear programming in terms of cost-effectiveness. They view the cost-effectiveness analysis as fiscally more efficient than binary linear programming, which is not correct according to the properties of the two techniques. There are a couple of explanations for the misunderstanding. First, participants have a least knowledge about binary linear programming. They have limited knowledge of the two techniques and do not fully understand the algorithms underlying them. Second, the name "cost-effectiveness analysis" may influence perceptions of the optimality of the technique itself, thus leading to a misinterpretation of the power of the selection algorithm. It also seems like they find the cost-effectiveness analysis intuitively easier to understand. Because they feel like they understand it better, they may view it as more successful. Table 4.9 records the mean scores for each technique.

Table 4.1: Average number of years working and mean score of knowledge level

	Number of observations	years-for-county	years-for-job	know-MALPF	know-county
Senior Representative.	**23**	**14.0** (9.11)	**9.6** (6.53)	**4.1** (0.52)	**4.5** (0.72)
County Representative	**29**	**11.9** (9.12)	**8.31** (6.37)	**4.0** (0.54)	**4.4** (0.68)
All Responses	**33**	**11.9** (9.05)	**8.75** (6.83)	**4.02** (0.57)	**4.3** (0.90)

Note: Numbers in ( ) are the standard errors.

Table 4.2: Benefit factors listed from results in question 10 of the pre-survey

County	Soil	Location	Size	Development	Others
	Benefit Factors				
Allegany	-	-	-	-	-
Anne Arundel	Soil quality			Development potential	Resource protection
Baltimore	Soil quality	Contiguous			Price
Calvert	Soil quality	Location	Size		Site index
Caroline	Soil quality	Easement adjacency	Area of preservation		
Carroll	Soil quality	Adjacency to other protected land	Size	Development right	Streams, sensitive space, woodland
Cecil		Adjacent preserved properties			Owner, operator
Charles	Soil quality	Contiguity to other preservation	Size	Development potential	Amount of land devoted to agricultural use
Dorchester	Soil quality	Proximity to other preserved land			Consistency of preserved land
Frederick	Soil quality	Contiguousness	Size	Development	
Garrett	Soil quality	Proximity to other preserved land	Size		
Harford			Size	Development potential	Capital income; LESA score; types
Howard	Soil quality	Adjacency	Size		

Table 4.3: Variable names in pre-survey question 14

Variable	Description of Variable
Asking price	The price farm owners offer in the application
Seller discount	Discount farm owners offer in the application
Calculated easement value	Value calculated by special scoring systems
Price cap	Maximum price a county is able to pay for one parcel
Appraised value	Value calculated by the easement value formula
Others	Other factors not list above
Don't know	Factors that are unknown
N/A	Program does not exist

Table 4.4: Number of responses that indicates easement cost factors considered and/or calculated

	Asking Price	Seller Discount	CEV	Price Cap	Appraised value	Others	Don't know	N/A
MALPF	14	8	10	2	15	1	0	1
County	2	2	7	2	5	3	0	8
Rural Legacy	1	2	11	6	5	4	1	4
MET	0	0	0	0	1	1	2	16
Open Space	1	0	1	0	3	0	7	11
Other	0	0	3	0	1	1	0	17

Table 4.5: Variable names in pre-survey question 15

Variable	Description of Variable
Not included	Cost is not explicitly included except to determine whether funds are still available
Part of benefit	Cost is considered as part of the parcel benefit scoring
Used in OP	Cost is used in an optimization process
Used in B/C ratio	Cost is used to calculate benefit-cost ratio
Other	Other usage not list above
Don't know	Cost usage is unknown
N/A	The program does not exist

Table 4.6: Number of responses that indicates easement cost usage in different programs

	Not included	Part of benefit	Used in OP	Used in B/C ratio	Other	Don't know	N/A
MALPF	10	1	1	0	3	0	6
County	6	0	1	0	1	0	13
Rural Legacy	8	0	1	0	2	3	7
MET	0	0	0	0	0	5	15
Open Space	1	0	0	0	1	7	12
Other	2	0	0	0	0	0	19
Sum	**27**	**1**	**3**	**0**	**7**	**15**	**72**

Table 4.7: Variable names in pre-survey question 16

Variable	Description of Variable
Highest benefit	Parcels with the highest benefit scores are selected first until the budget is exhausted
Highest B/C ratio	Parcels with the highest benefit-cost ratios are selected first until the budget is exhausted
Board recommend	Parcels are selected based on advisory board recommendations
Political advice	Parcels are selected based on political considerations
BLP	Parcels are selected based on their benefits and costs using binary linear programming
Not used	No official selection system is used
Other	Other method not list above
Don't know	Selection method is unknown
N/A	The program does not exist

Table 4.8: Number of responses that indicates different techniques used in the selection process

	Highest benefit	Highest B/C ratio	Board Rec.	Political advice	BLP	Not used	Other	Don't know	N/A
MALPF	16	4	6	1	0	0	2	0	1
County	8	2	5	2	0	1	1	0	8
Rural Legacy	5	2	3	3	0	0	6	0	4
MET	0	0	0	0	0	0	1	5	15
Open Space	0	0	0	0	0	0	0	8	14
Other	1	0	0	0	0	0	0	0	20
Sum	**30**	**8**	**14**	**6**	**0**	**1**	**10**	**13**	**62**

Table 4.9: Assessment of preservation selection techniques from senior representatives

	Knowledge	Fairness	Transparency	Cost-effectiveness	Ease of administration
Importance of criteria	4.26 (0.62)	4.65** (0.65)	4.48** (0.79)	4.17 (0.65)	3.87 (0.76)
Current technique	4.10*,[b,c] (0.62)	4.05*,[b,c] (0.74)	4.00*,[b,c] (0.92)	3.16[c] (0.96)	3.74[b,c] (0.81)
BLP	2.26[a,c] (1.19)	3.11 [a] (0.83)	2.67 [a] (0.97)	3.56* (0.70)	2.78 [a,c] (0.94)
CEA	2.63 [a,b] (1.16)	3.33 [a] (0.84)	3.11 [a] (1.08)	3.78*,[a] (0.73)	3.17 [a,b] (0.92)

Notes:

1) * and ** denote number(s) significantly different from the rest in the corresponding row at the 10% and 5% levels respectively.
2) [a] denotes number significantly different from that with current technique at 5% level.
3) [b] denotes number significantly different from that with BLP at 5% level.
4) [c] denotes number significantly different from that with CEA at 5% level.

Figure 4.1: Easement cost factors considered and/or calculated by MALPF's program

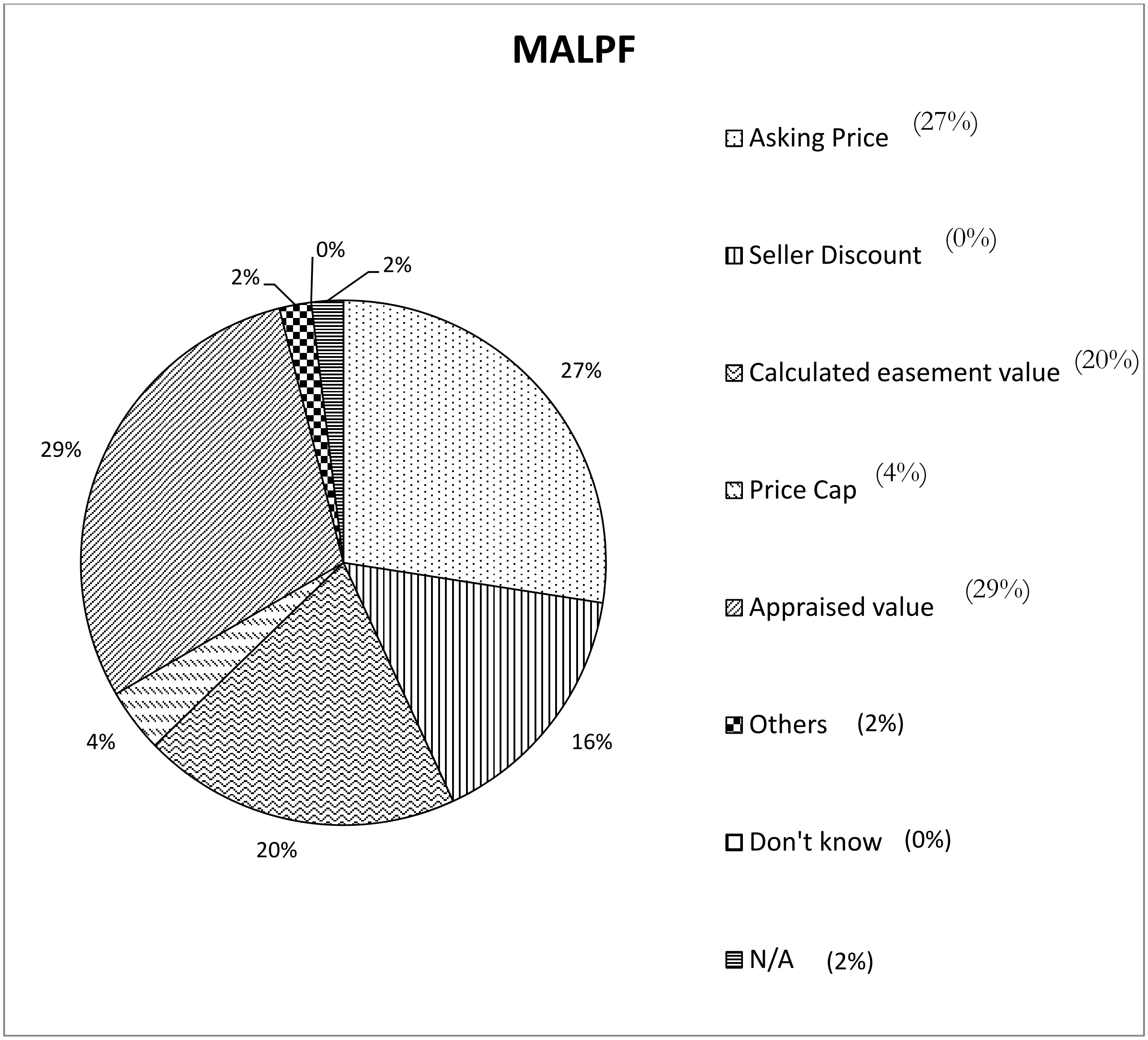


Figure 4.2: Easement cost factors considered and/or calculated by the county's program

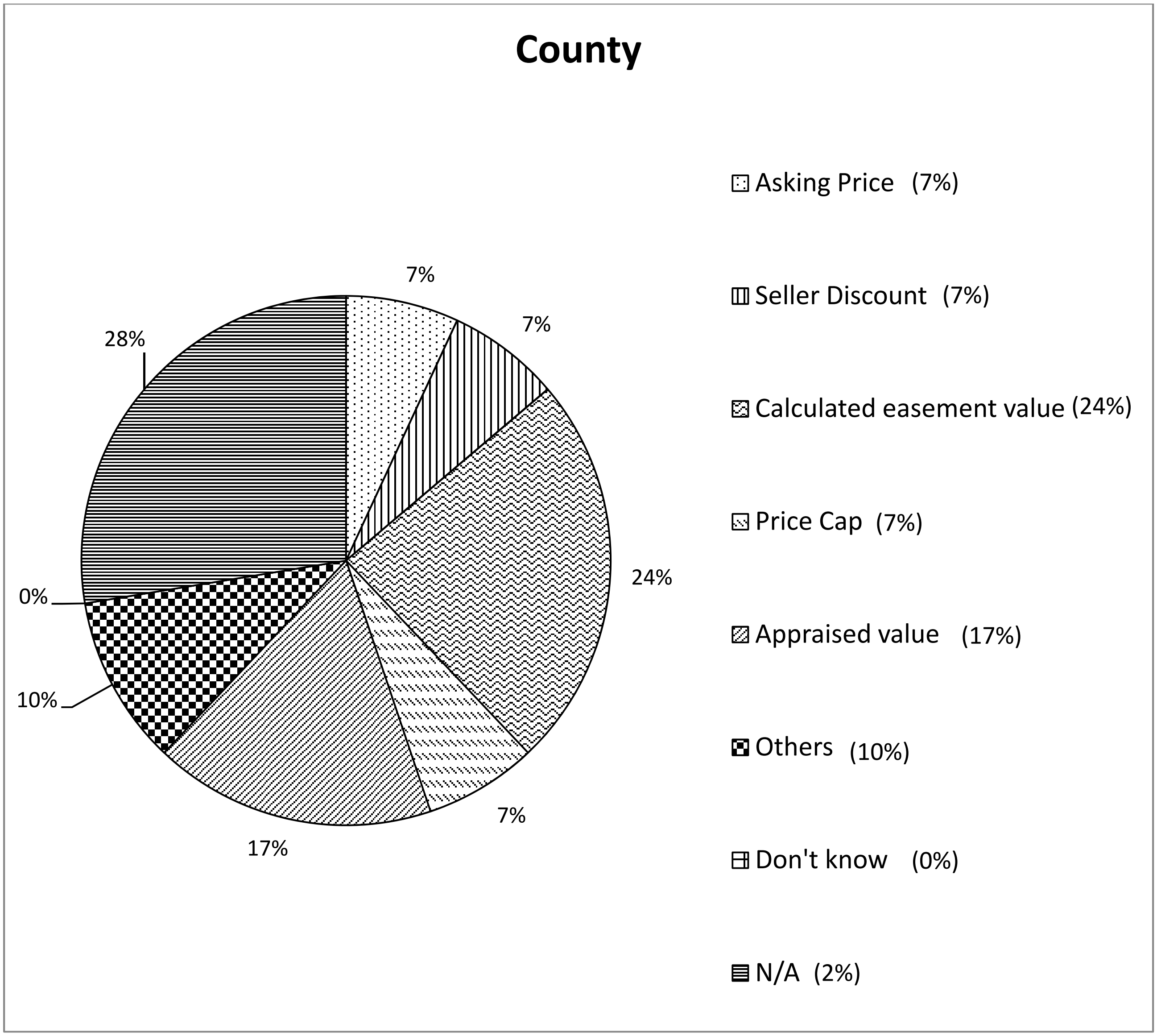


Figure 4.3: Easement cost factors considered and/or calculated by the Rural Legacy program

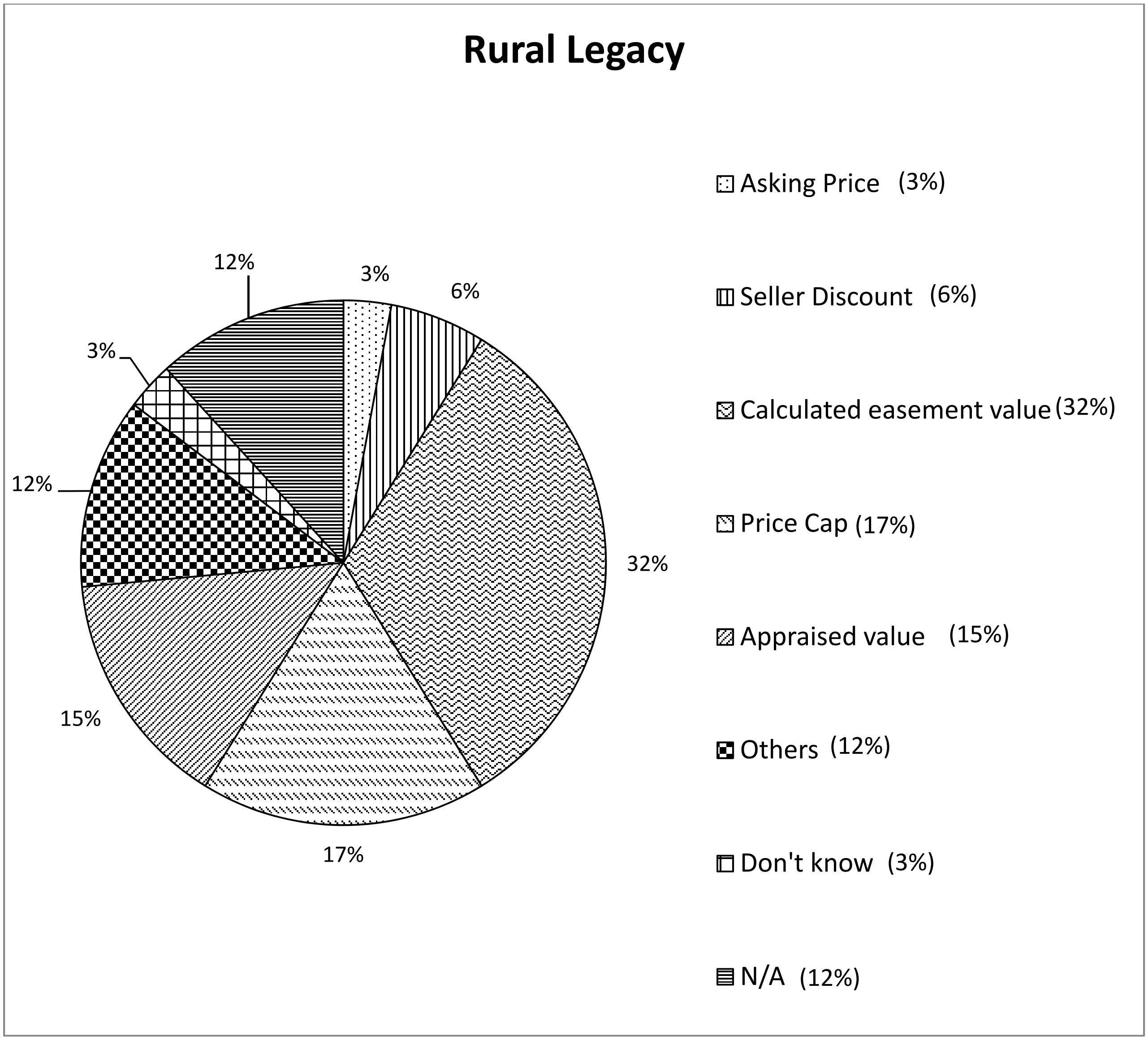


Figure 4.4: Use of easement cost in MALPF's program

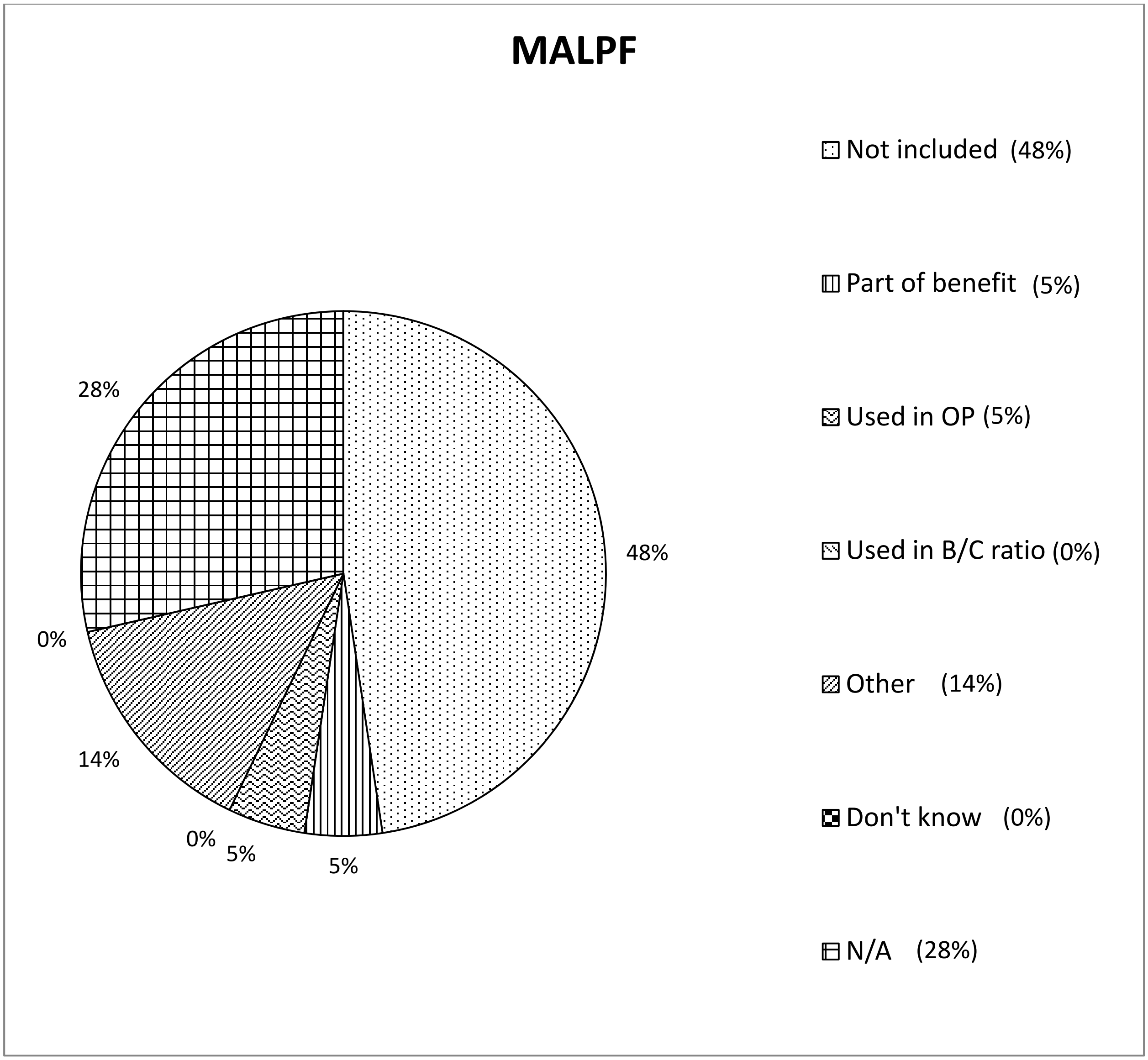


Figure 4.5: Use of easement cost in the county's program

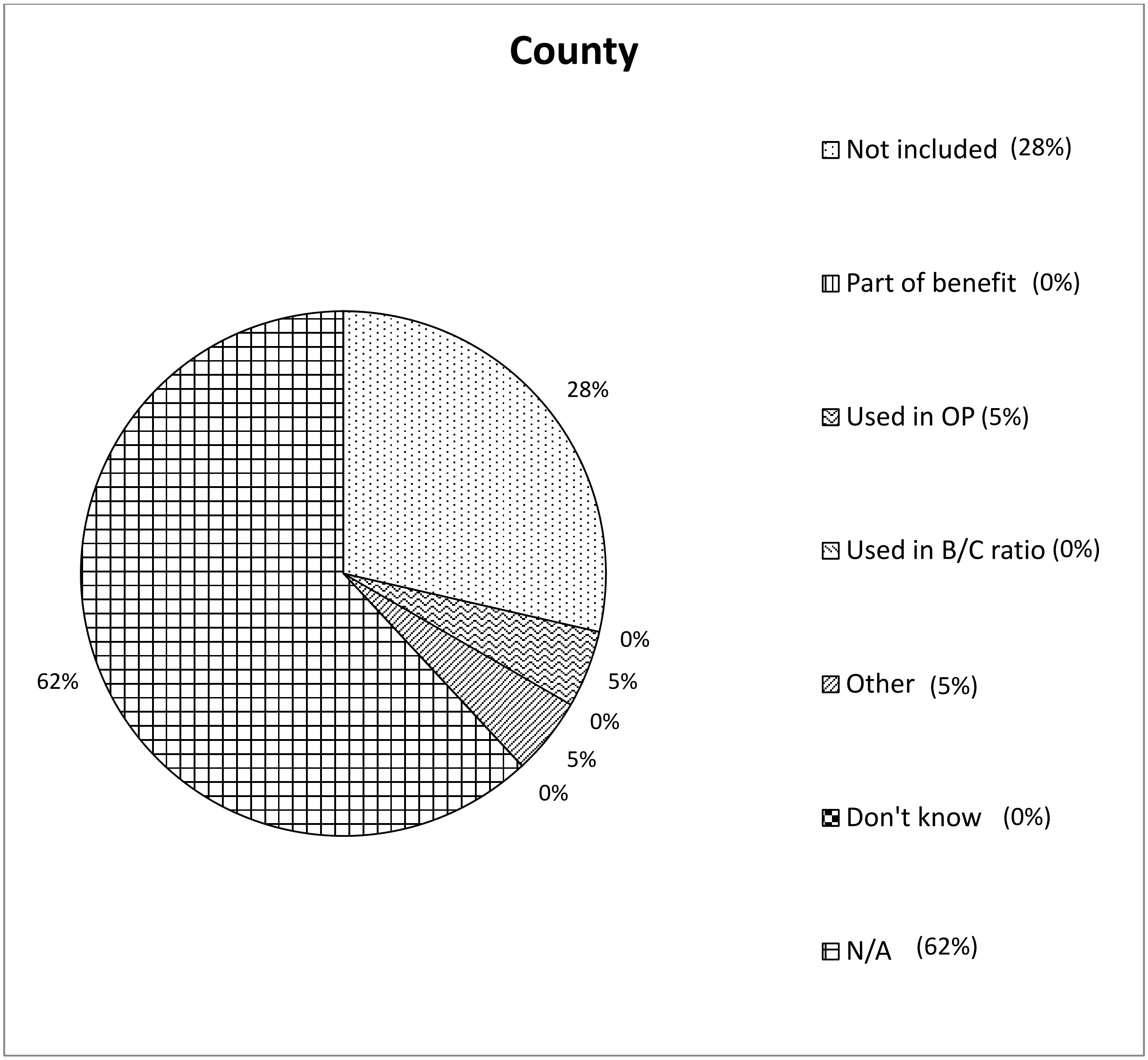


Figure 4.6: Use of easement cost in the Rural Legacy program

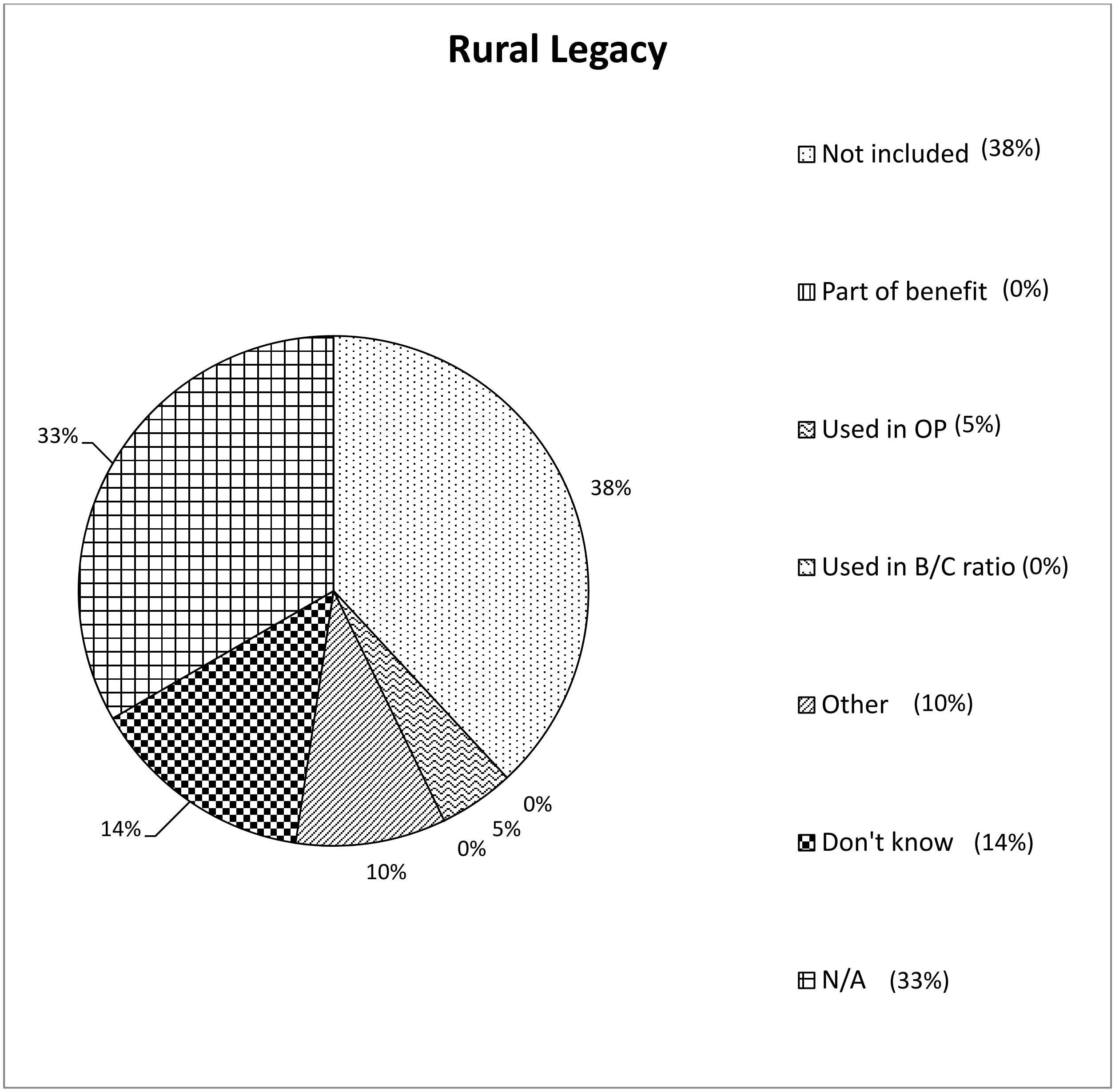


Figure 4.7: Use of selection process techniques for MALPF's program

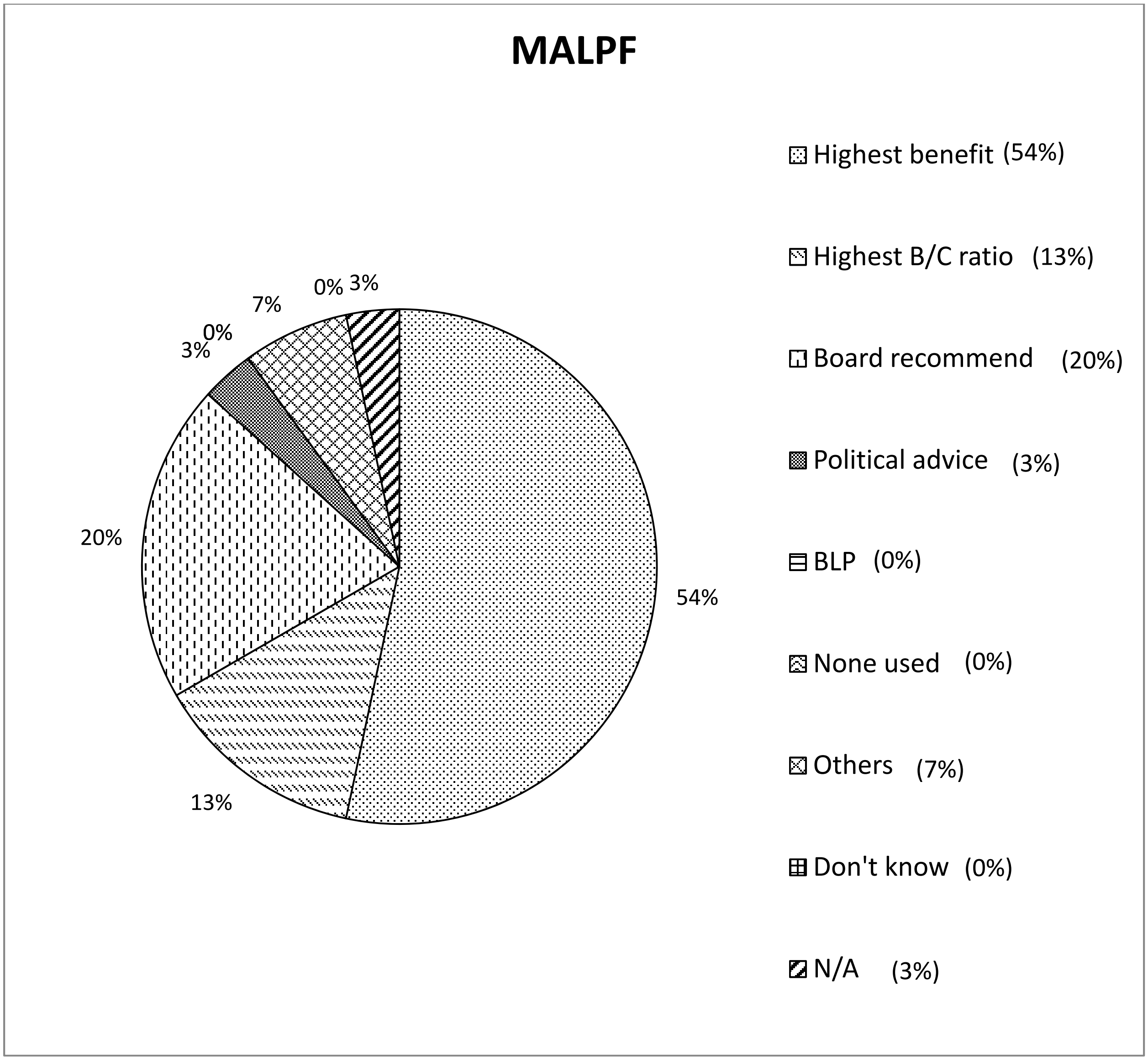


Figure 4.8: Use of selection process techniques by the county program

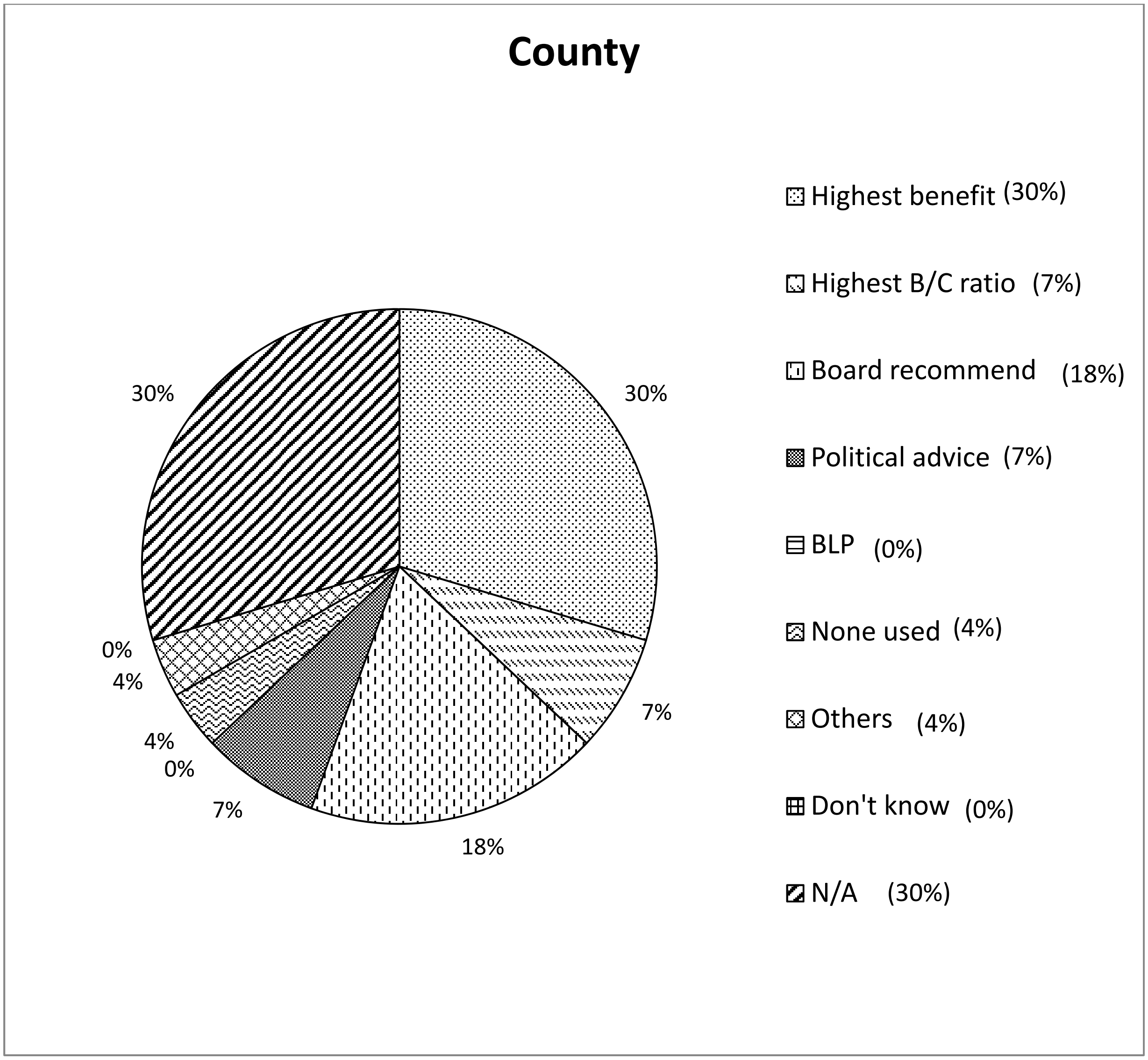


Figure 4.9: Use of selection process techniques for the Rural Legacy program

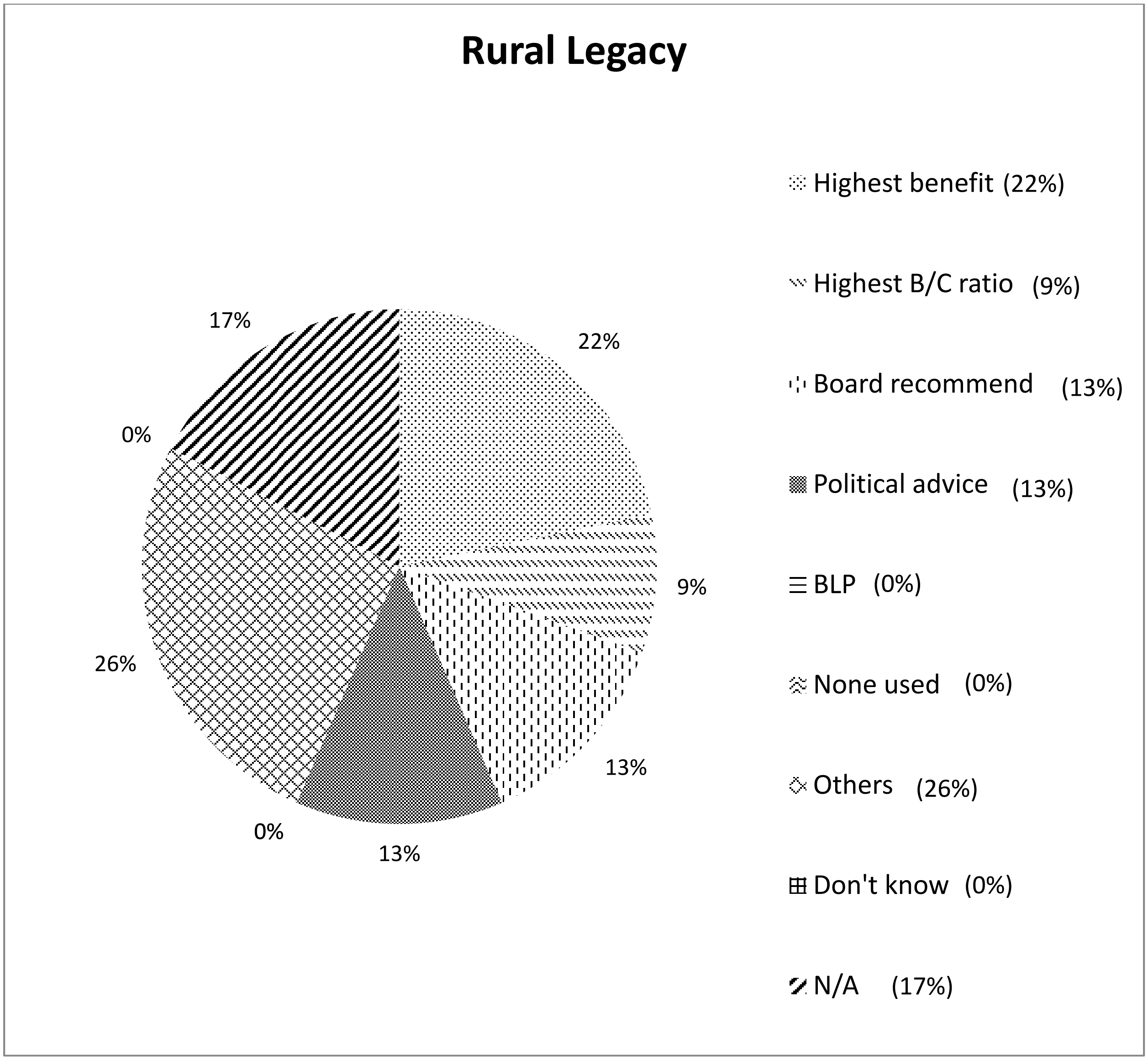
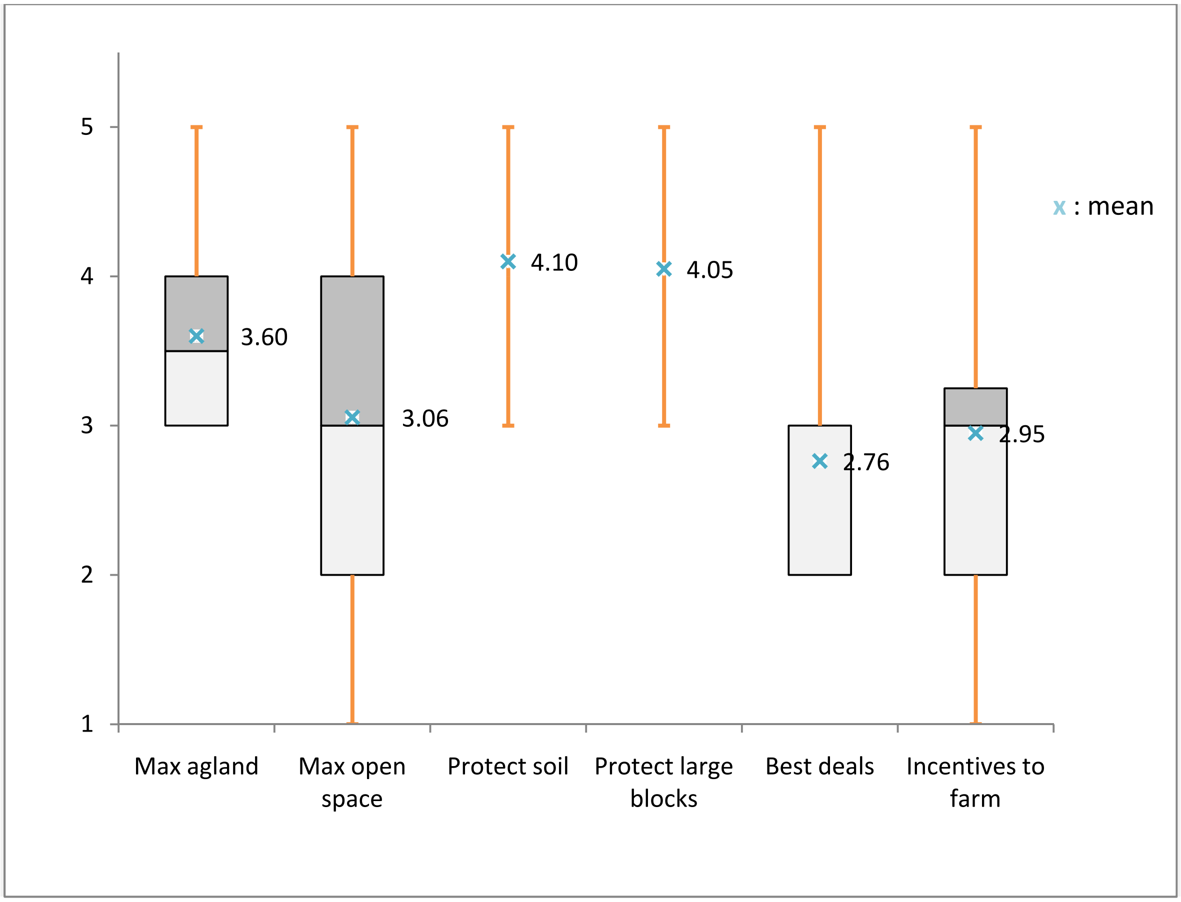


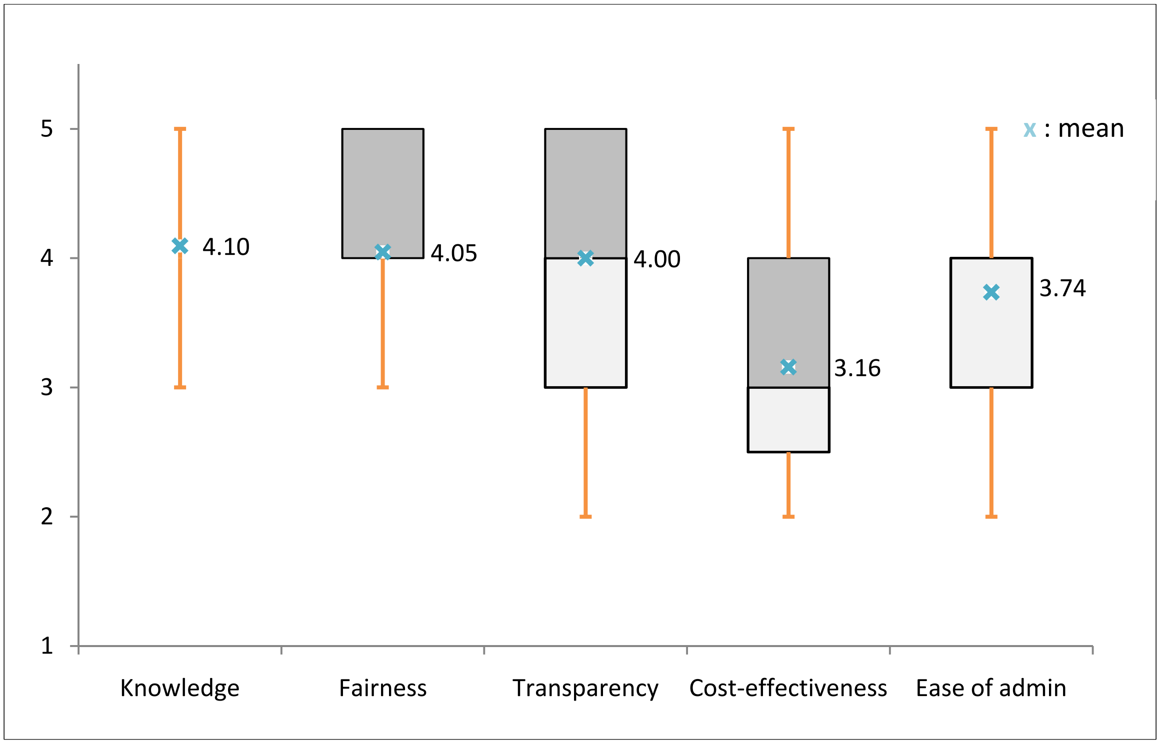
Figure 4.10: Assessments of the performance of current selection processes



<u>Variable descriptions:</u>

Max agland	Maximize the number of agricultural acres protected.
Max open space	Maximize the open space quality of acres protected.
Protect soil	Protect the best agricultural land in terms of soil.
Protect large blocks	Preserve large blocks of contiguous agricultural land.
Best deals	Acquire the best deals on agricultural land.
Incentives to farm	Increase incentives for participants to remain in farming.

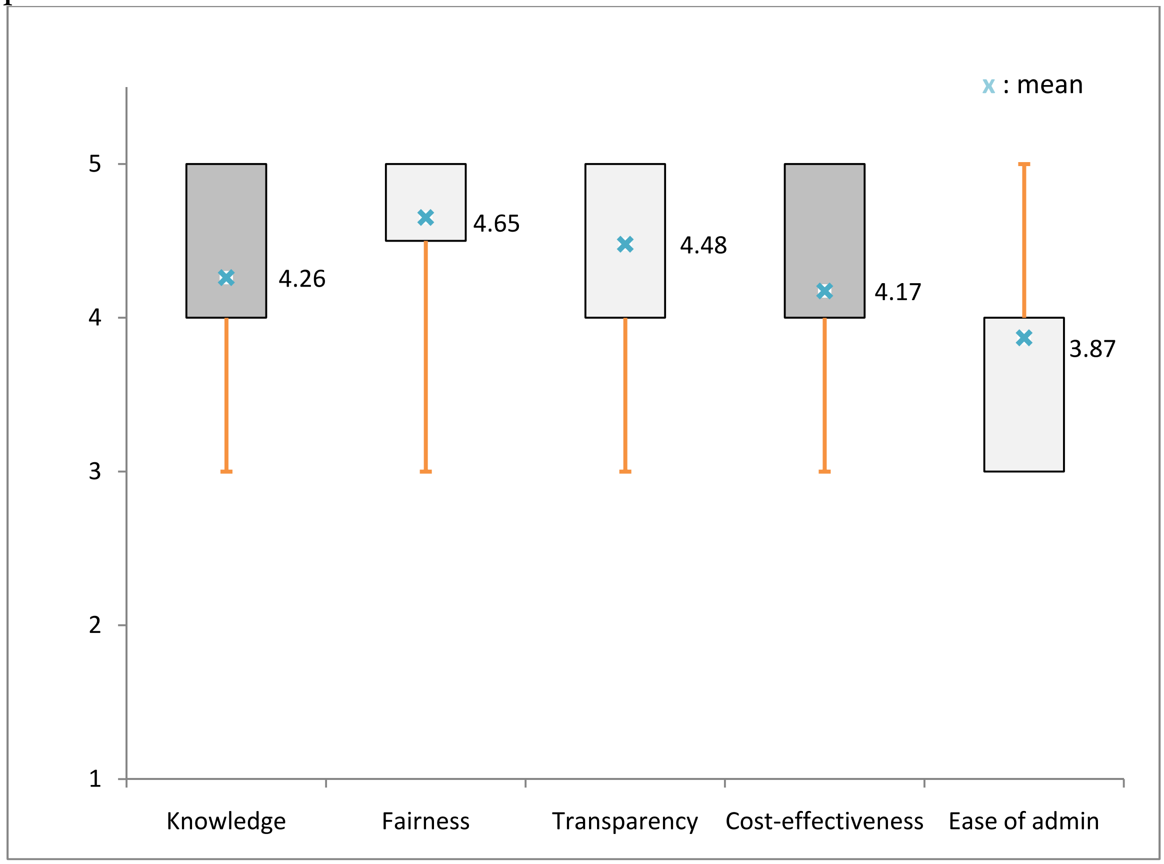
Figure 4.11: Assessment of various techniques used in current selection processes



Variable descriptions:

Knowledge	Knowledge of staff on how to use this technique.
Fairness	Fairness to applicants.
Transparency	Transparency denotes ease of explanation to the public, advisory boards, potential applicants, etc.
Cost-effectiveness	Cost-effectiveness of the selection process
Ease of admin	Ease of administration.
Others	Other criteria not list above.

Figure 4.12: Box plot of average score for importance of criteria used to assess the selection process



__Variable Description:__

Knowledge	Knowledge of staff on how to use the selection process.
Fairness	Fairness to applicants.
Transparency	Ease of explanation to the public, advisory boards, potential applicants, etc.
Cost-effectiveness	Cost-effectiveness of the selection process.
Ease of admin	Ease of administration.
Others	Other criteria not list above.

Figure 4.13: Education effect on knowledge of optimization

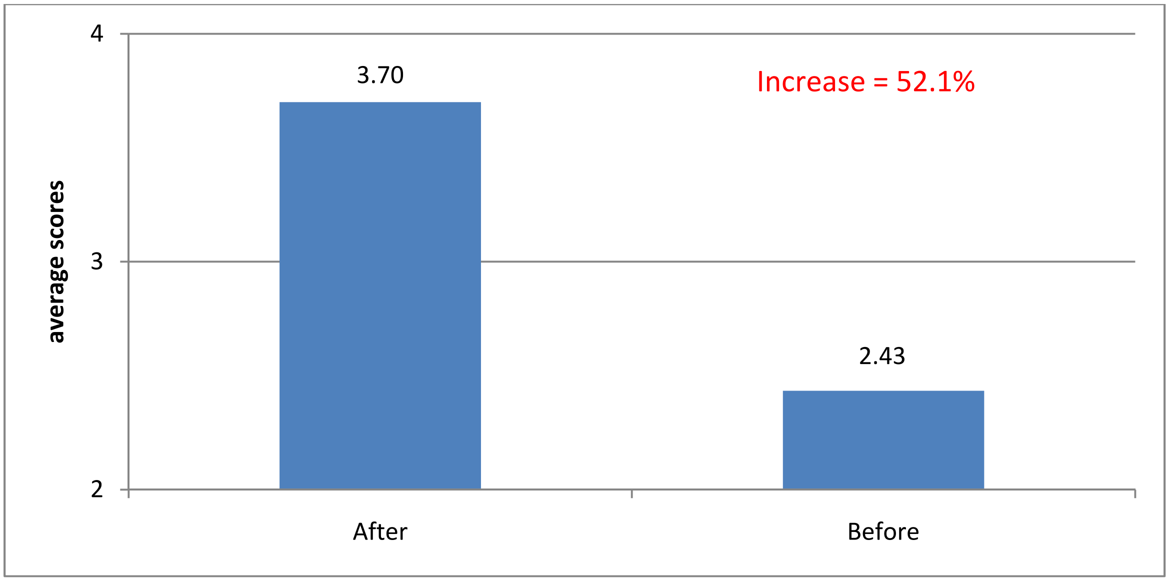


Figure 4.14: Willingness to adopt optimization under different scenarios

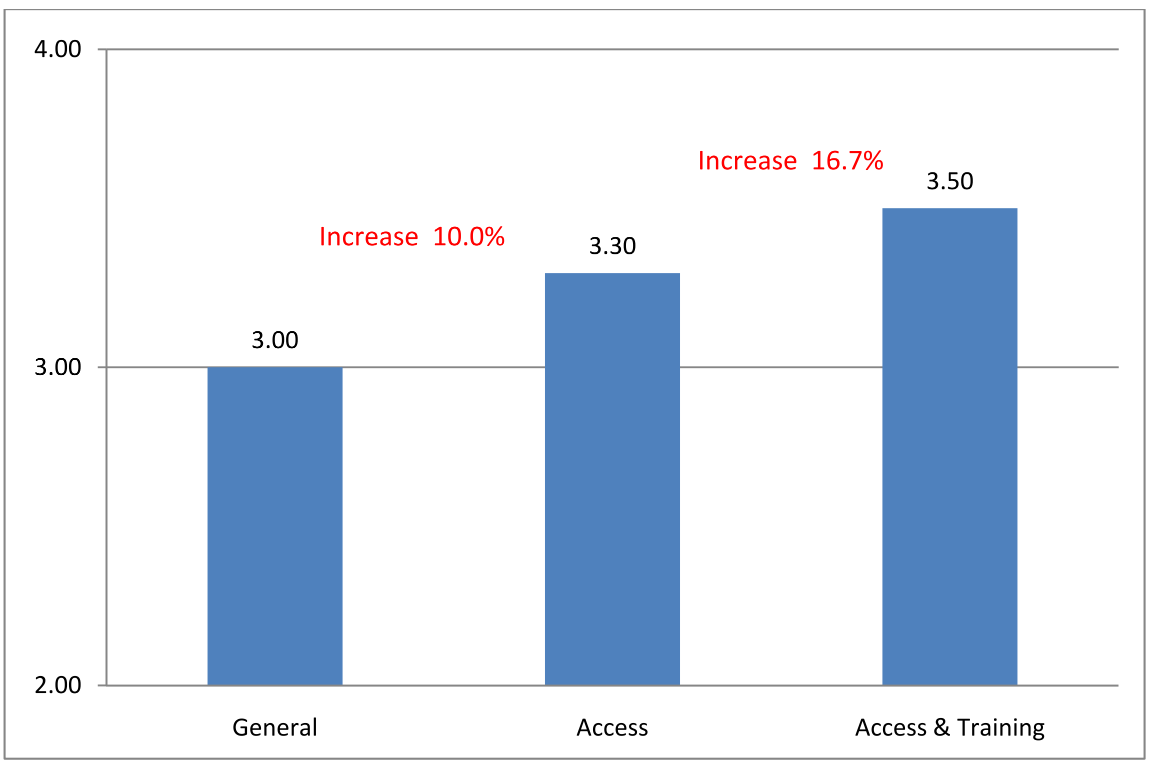
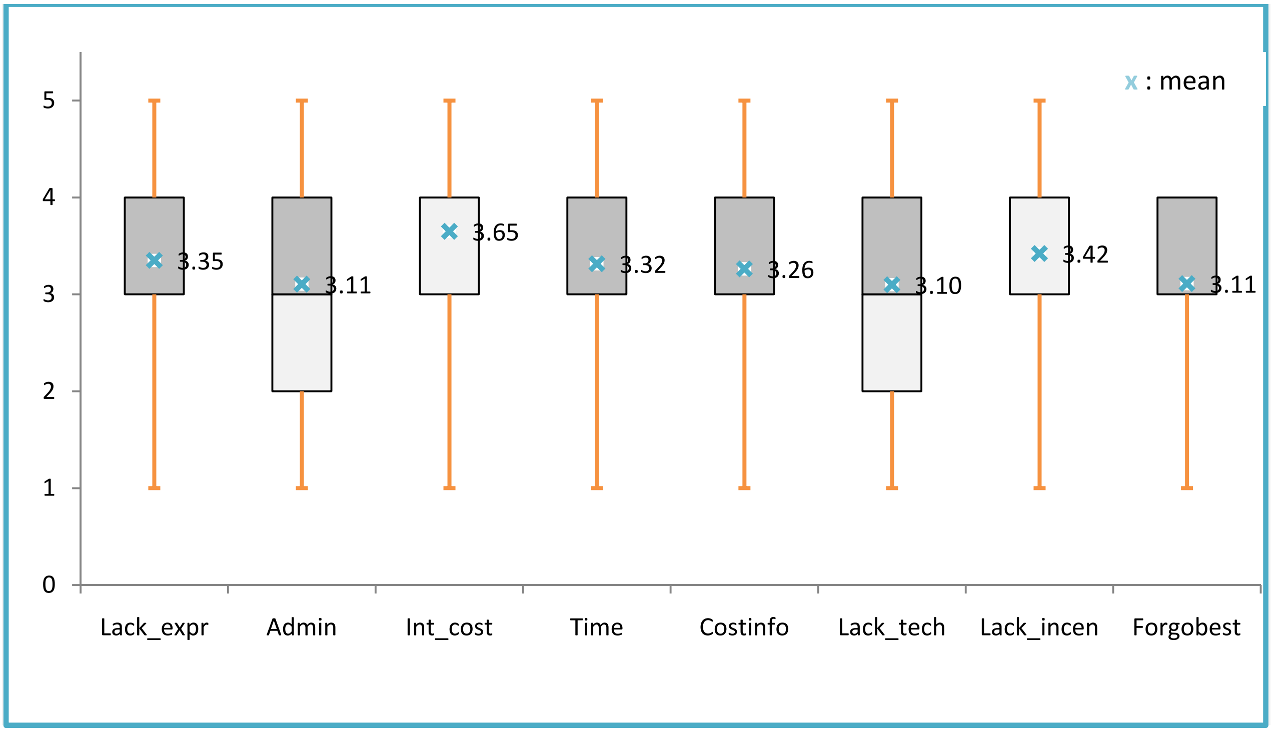


Figure 4.15: Obstacles to adopting optimization



<u>Variable descriptions:</u>

Lack_expr	Lack of previous experience.
Admin	Administration of the process.
Int_cost	Initial technical cost.
Time	Time to implement the process.
Costinfo	Need for cost information at the time of selection.
Lack_tech	Lack of availability of technical resources.
Lack_incen	Lack of incentives to justify a change in process.
Forgobest	Possibly forgoing the "best" land regardless of cost.
Other	Other obstacles not listed above.

Figure 4.16: Education effect on knowledge of binary linear programming

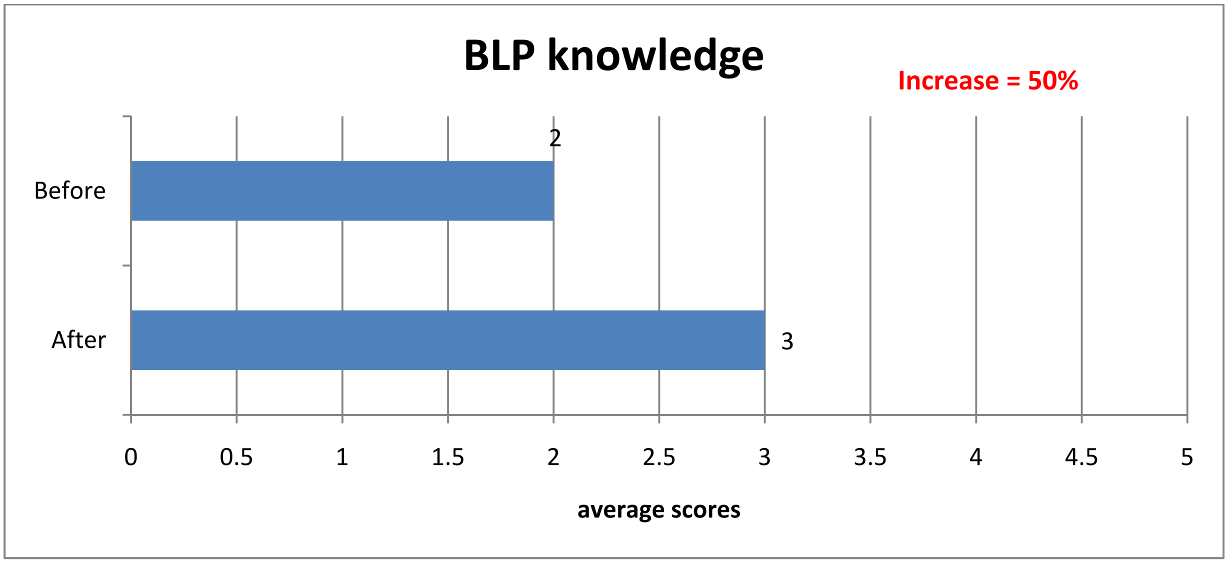


Figure 4.17: Assessments of Binary Linear Programming as a selection technique

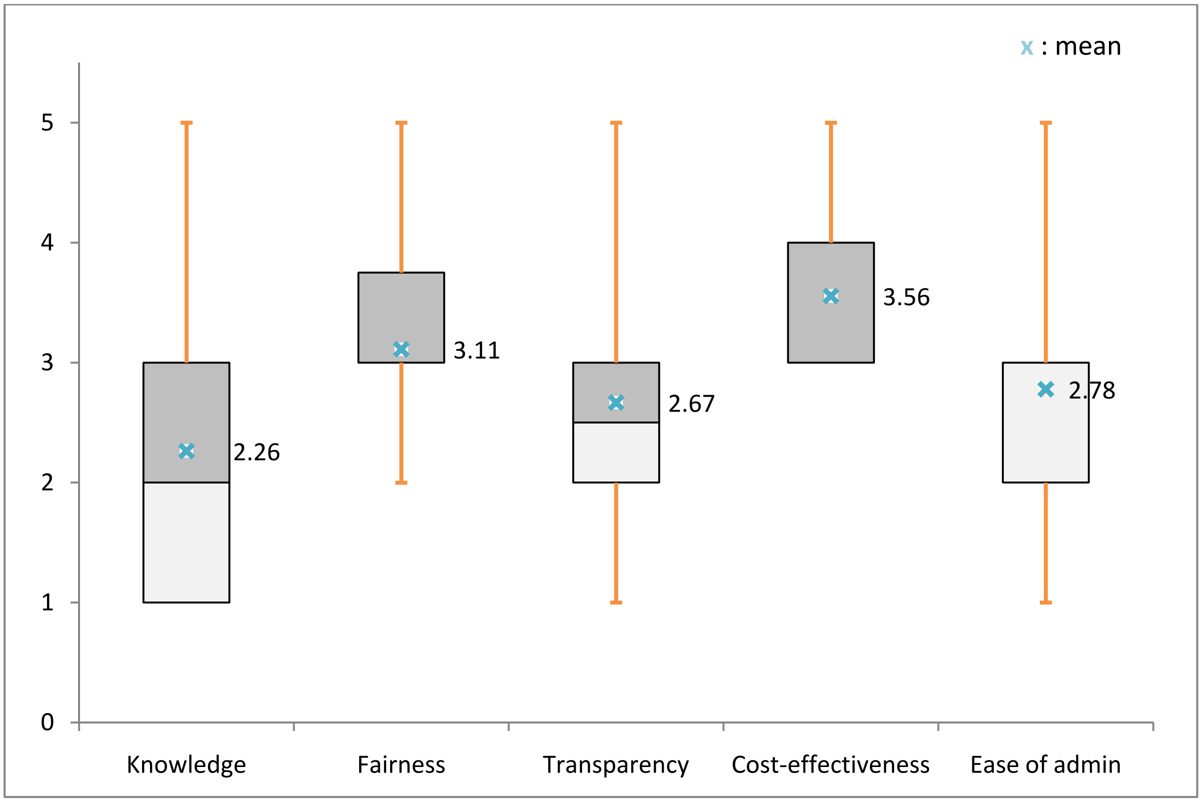


Figure 4.18: Education effect on knowledge of cost-effectiveness analysis

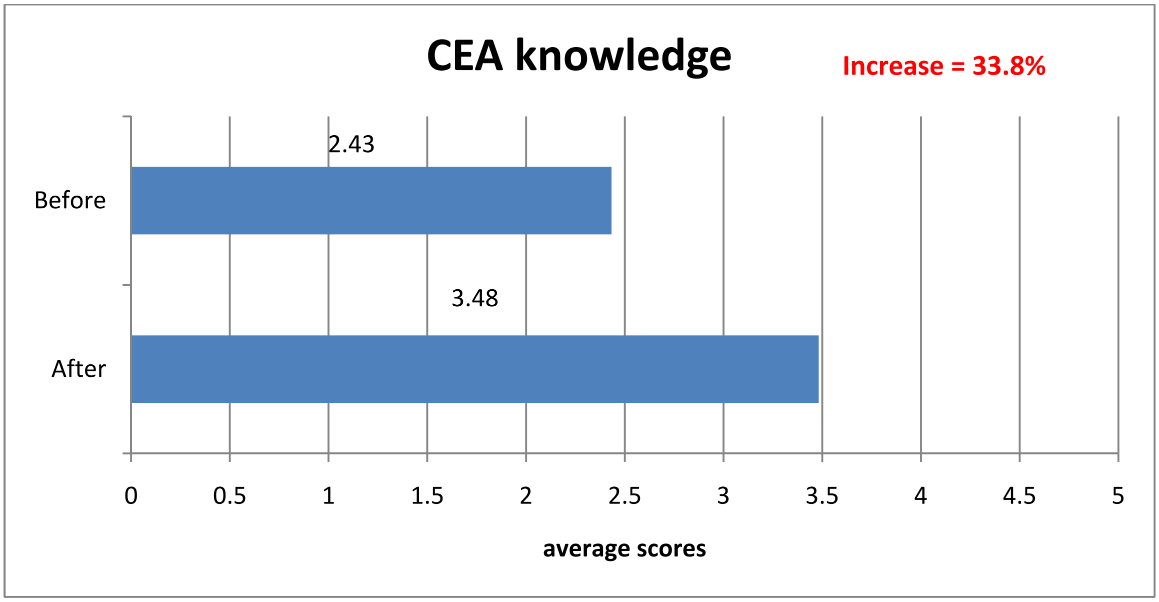
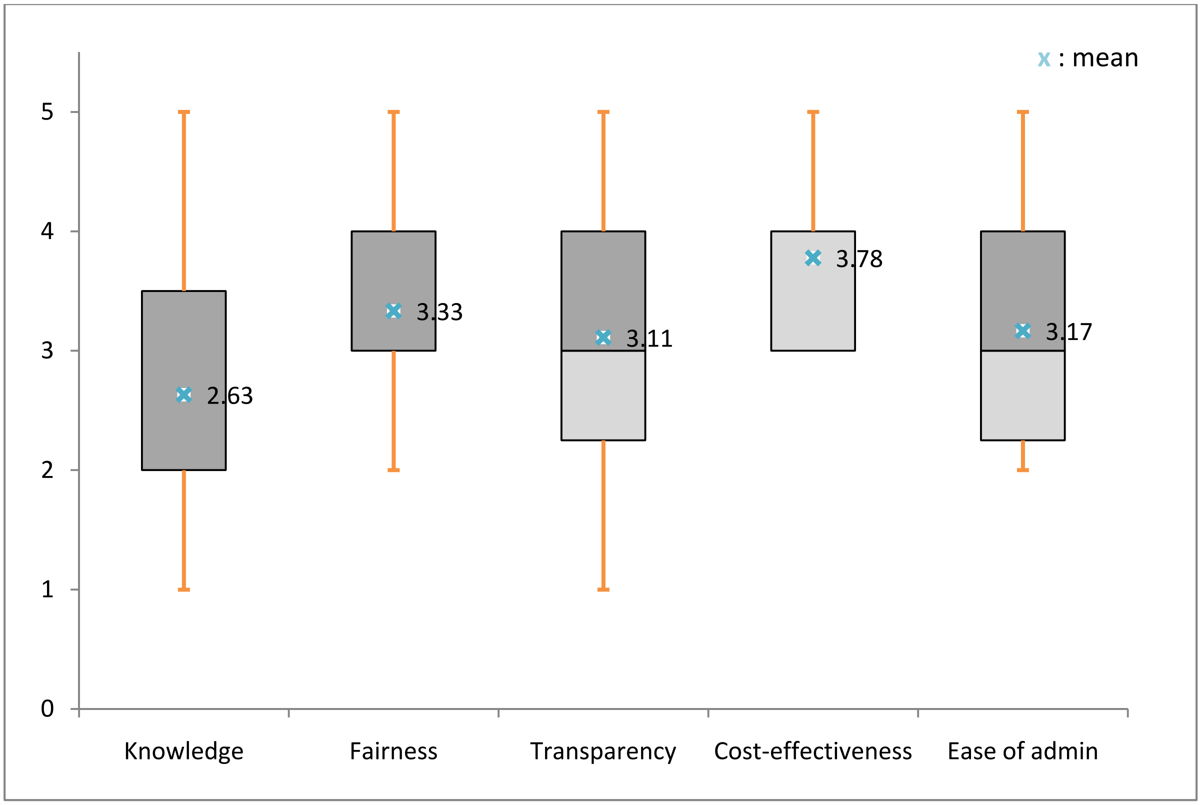


Figure 4.19: Assessment of cost-effectiveness analysis as a selection technique



Chapter 5 - Statistical Analysis

This chapter explores the answer to the main question posed in this thesis: Why is optimization rarely adopted by conservation professionals? Using data collected from the survey, along with data from Maryland State Data Center, an ordered Probit model is applied to analyze the relationships between willingness to adopt optimization and the regressors. Another linear regression is then produced to describe how professionals assess the difficulty presented by potential obstacles differently. This chapter provides a description of the data set, the coefficients of the ordered Probit model and linear regression, and interpretation of the parameters and their meaning.

Data Set of the Ordered Probit Model

The ordered Probit model analyzes factors that potentially influence a program administrator's decision to adopt optimization as a selection approach. The data set is comprised of 27 observations from administrators and senior staff members from every county in Maryland except Baltimore County. Included are 22 senior representatives, one from each of 22 counties, and five other county staff representatives. Baltimore County is excluded from the analysis because it had already adopted optimization in its MALPF and county programs.

The dependent variable WILLING represents the willingness of administrators to adopt optimization as the selection process for agricultural land preservations in the future and was collected from question 11 in the post-survey. WILLING is measured on a scale of one to five.

Dependent Variable: WILLING

= 1 if the respondent is not willing to adopt optimization at all

= 2 if the respondent is slightly willing to adopt optimization

= 3 if the respondent is somewhat willing to adopt optimization

= 4 if the respondent is willing to adopt optimization

= 5 if the respondent is very willing to adopt optimization

The regressors in the ordered Probit model are OPKNOW, LACK_EXPR, ADMIN, INT_COST, LACK_INCEN, PCT_PRESV, and RURALITY. Five of these independent variables are measured on a scale of one to five by the survey. OPKNOW is rated by responses to question 10 of the post-survey. It describes the respondents' level of knowledge and understanding of the optimization method after Dr. Messer's presentation.

Independent Variable: OPKNOW

= 1 if the respondent does not understand optimization at all

= 2 if the respondent understands optimization a little

= 3 if the respondent understands optimization somewhat

= 4 if the respondent understands optimization well

= 5 if the respondent understands optimization very well

LACK_EXPR, ADMIN, INT_COST, and LACK_INCEN represent data gathered by questions 12, 13, 14, and 18 in the post-survey. These factors describe potential obstacles to adopting optimization as the selection process. LACK_EXPR is lack of previous experience in applying optimization. ADMIN is the administrative requirements of the process. INT_COST is the initial technical cost for staff training and software. LACK_INC is a lack of incentive to justify a change in process. Respondents rated the difficulties presented by these obstacles on a scale of one to five.

Independent Variable: LACK_EXPR, ADMIN, INT_COST, LACK_INCEN

= 1 if the respondent views the obstacle as not difficult at all

= 2 if the respondent views the obstacle as slightly difficult

= 3 if the respondent views the obstacle as somewhat difficult

= 4 if the respondent views the obstacle as difficult

= 5 if the respondent views the obstacle as very difficult

PCT_PRESV is the percentage of total agricultural land that was preserved by individual counties from 2002 through 2007. The amount of farmland preserved comes from MALPF's 2002–2007 annual report. Information on the total number of acres of land in farms in Maryland in 2007 is from the 2007 Census of Agriculture collected by the U.S. Department of Agriculture's (USDA's) National Agricultural Statistics Service.

PCT_PRESV = Acres of Preserved Agricultural land ÷ Acres of Total Agricultural land

RURALITY measures the rurality of each county using data derived from urban influence codes (UIC) formulated by USDA's Economic Research Service (ERS).[16] It is one of three widely accepted rural classification systems. Based on the concepts of central place theory in regional economics, these codes were developed to account for factors such as population size, urbanization, and access to larger economies (Parker, 2007). The 2003 urban influence codes categorize counties as "metro" (metropolitan) and "nonmetro." Metro counties are then divided into two groups by the size of the metro area. Nonmetro counties are located outside of the boundaries of metro areas and are further subdivided into two types: micropolitan areas, which are defined as centered on urban clusters of 10,000 or more persons, and all remaining "noncore" counties. Micropolitan counties fall into one of three groups that are defined by adjacency to urban areas while noncore counties are divided into seven groups based on their adjacency to metro or micro areas and whether they have their "own town" of at least 2,500 residents (Cromartie, 2007). (See Table 5.1.).

[16] The urban influence coding structure does not reflect a continuous decline in urban influence. Therefore, RURALITY cannot be used to explain the relationship between urban influence and program administrators' willingness to adopt optimization. Rather, the relationship provides a legitimate assumption that adjacency to metro areas brings a strong development threat to agricultural lands and breeds motivation among administrators to improve their selection techniques and processes.

Data Set of Linear Regression

The linear regression describes differences in the degree of difficulty that obstacles to adopting optimization present to respondents. These results analyze possible influences on program administrators' opinions regarding barriers to adoption. The data set contains 24 valid observations. Baltimore County is again excluded from the analysis because of prior adoption. The dependent variable of the regressions, MDIFF, which is the mean score of the eight obstacle variables, is generated from questions 12 through 19 of the post-survey (see Table 4.5). The degree of obstruction from the eight factors was measured on a scale of one to five. Therefore, the mean falls within the same range. The greater the mean, the more difficulty respondents predicted in adopting optimization.

The regressors are OPKNOW_NONE, OPKNOW_LITTLE, OPKNOW_SOME, OPKNOW_GOOD, and OPKNOW_EXCT. The independent variables are binary variables taking a value of either zero or one. They distinguish the level of knowledge and understanding of optimization expressed by the respondents. Therefore, this regression is called the knowledge model. It summarizes the relationship between the mean of the obstacle difficulty level and the knowledge level.

Independent Variable:

OPKNOW_NONE: the observation has no knowledge about optimization
= 1, if OPKNOW = 1
= 0, otherwise

OPKNOW_LITTLE: the observation has very little knowledge about optimization
= 1, if OPKNOW = 2
= 0, otherwise

OPKNOW_SOME: the observation has some knowledge about optimization
= 1, if OPKNOW = 3
= 0, otherwise

OPKNOW_GOOD: the observation has good knowledge about optimization
= 1, if OPKNOW = 4
= 0, otherwise

OPKNOW_EXCT: the observation has excellent knowledge about optimization
= 1, if OPKNOW =5
= 0, otherwise

Model Specification and Results

An ordered Probit model is used with the survey data to estimate relationships between an ordinal dependent variable and a set of regressors. The ordinal variable is WILLING, which is categorical and ordered and indicates the respondents' willingness to adopt optimization from low to high. In the ordered Probit model, an underlying score is estimated as a linear function of the regressors and a set of cut points. The probability of observing outcome *k* corresponds to the probability that the estimated linear function plus residuals is within the range of the cut points estimated for the outcome.

$$P(willingness = 1 \mid X) = P(Xi'\beta + \xi i \leq U_1 \mid X) = \Phi(U_1 - Xi'\beta)$$

$$P(willingness = 2 \mid X) = P(U_1 < Xi'\beta + \xi i \leq U_2 \mid X) = \Phi(U_2 - Xi'\beta) - \Phi(U_1 - Xi'\beta)$$

$$P(willingness = 3 \mid X) = P(U_2 < Xi'\beta + \xi i \leq U_3 \mid X) = \Phi(U_3 - Xi'\beta) - \Phi(U_2 - Xi'\beta)$$

$$P(willingness = 4 \mid X) = P(U_3 < Xi'\beta + \xi i \leq U_4 \mid X) = \Phi(U_4 - Xi'\beta) - \Phi(U_3 - Xi'\beta)$$

$$P(willingness = 5 \mid X) = P(Xi'\beta + \xi i > U_4 \mid X) = 1 - \Phi(U_4 - Xi'\beta)$$

In other words, we assume that each observation has an underlying real willingness that takes a value of U. The probability that observation i has a willingness of 1 equals the probability that his or her real willingness, U, is no bigger than U_1. The probability that observation i has a willingness of 2 equals the probability that his or her real willingness, U, is between U_1 and U_2.

STATA software is used to conduct the analysis. The actual values of the coefficients are irrelevant except that larger values are assumed to correspond to "higher" outcomes. A positive sign on the coefficients represents a positive influence on the dependent variable. Table 5.2 displays the regression results from the equations previously described. Six of the seven explanatory variables are significant at the 95% level. The survey's parameter estimators of OPKNOW and ADMIN are significantly positive. The positive OPKNOW coefficient is 2.31, indicating that the more knowledge the respondent has about optimization, the more willing he or she is to adopt it. The positive ADMIN coefficient is 2.79, indicating that willingness increases when more difficulties are predicted in administration of the optimization process. This may imply that program administrators' assumptions about the superiority of a method are in direct proportion to the method's perceived sophistication. It may also imply that the administrative process is not the major concern in determining whether a new method shall be adopted. Participants may assume that optimization can ultimately simplify the whole administration process once people have abundant experience with it. Baltimore County's story validates that assumption. Robert Hirsch said "Optimization has proven easier to administer and run than our old methods. During our rank-based days, we performed extra administrative and mathematical work in order to solicit discounts and award extra LESA points for discounting. With optimization, this is no longer required." In addition, a WALD test shows that the coefficient of ADMIN is not statistically different from that of OPKNOW at the 10% significance level (see Table 5.3). Therefore, both variables have essentially the same influence on willingness.

Three survey parameter estimators—LACK_EXPR, INT_COST, and LACK_INCEN—have a negative sign. These estimators represent obstacles to use of optimization. The LACK_EXPR coefficient is -1.88, showing that the less experience a county has with optimization, the less willing it is to adopt it. The INT_COST coefficient is -2.66, indicating that the initial technical cost is a considerable obstacle to adoption. Both limited budgets and a prediction of high technical costs discourage administrators from using optimization. The LACK_INCEN coefficient is -2.85. The more unwilling a county is to change the status quo, the less willing it is to adopt a new approach. The three coefficients are not statistically significantly different from one another. Therefore, lack of experience, the initial technical cost, and a lack of incentive to change have about the same effect on the decision.

The PCT_PRESV coefficient is significantly positive, meaning that the greater the percentage of agricultural land that the county has preserved, the more willing it is to adopt optimization. Counties with greater percentages of preserved agricultural land may have larger budgets or more experienced employees, which would provide them with more resources both financially and technically. Such counties may also have more incentive to develop better practices, further improving their effectiveness. Their administrators may place a high value on techniques in the preservation process and be more open to embracing new ideas and approaches. The absolute value of the coefficient is not comparable to those of the previously discussed parameters because this variable is not a categorical value obtained from the survey but is a very small contiguous percentage number instead.

The RURALITY estimator takes a negative sign and a value of -0.33, which is not significant at the 10% level but is significant at the 15% level. Our sample was comprised of only 22 observations. As a result, the negative coefficient can be viewed as significant. It reflects the strong development pressures that can arise from high population densities and access to larger economies that are centers of information, communication, trade, and finance. These pressures are a major concern for preservation program administrators. Therefore, the more urban a county is or the closer it is to an urbanized area, the more willing program administrators are to use a highly cost-effective approach to preserve agricultural lands.

Knowledge Model

The dependent variable in the knowledge model is the mean of the eight obstacle variables. The independent variables are binary. Therefore, the knowledge model can use a linear regression without a constant to estimate the population mean for the overall difficulty level at each knowledge level. The knowledge model can be expressed as follows:

$$\text{(1)}\quad MDIFF = \beta1 * OPKNOW\_NONE + \beta2 * OPKNOW\_LITTLE + \beta3 * OPKNOW\_SOME + \beta4 * OPKNOW\_GOOD + \beta5 * OPKNOW\_EXCT$$

OPKNOW_NONE has only one value, zero. Hence, it is omitted from the regression estimation.STATA software is used to conduct the analysis. After the parameter estimation is complete, a WALD test is formulated to test the true value of these parameters. By restricting one parameter to being equal to another, we can compare differences in knowledge levels. Table 5.5 provides the regression results. Table 5.6 provides the WALD test results. All respondents had at least some knowledge about optimization after the presentation; therefore, OPKNOW_NONE is zero for all observations and omitted from the regression. The remaining four parameters are significant at the 99% level. According to the WALD test, they are significantly different from each other at the 95% level. The coefficients of OPKNOW_LITTLE, OPKNOW_SOME, OPKNOW_GOOD, and OPKNOW_EXCT are 1.88, 1.18, 0.81, and 0.4, respectively, with a steady decrease in order. This result illustrates that an administrator who feels knowledgeable about the approach will predict less difficulty in adopting it. It suggests that increasing administrators' understanding of the approach dispels their doubts about using it. Consequently, education can promote adoption of optimization in practice.

Table 5.1: 2003 Urban influence codes

Code	2003 Urban Influence Codes
1	Large—in a metro area with at least 1 million residents or more
2	Small—in a metro area with fewer than 1 million residents
3	Micropolitan area adjacent to a large metro area
4	Noncore adjacent to a large metro area
5	Micropolitan area adjacent to a small metro area
6	Noncore adjacent to a small metro area with town of at least 2,500 residents
7	Noncore adjacent to a small metro area and does not contain a town of at least 2,500 residents
8	Micropolitan area not adjacent to a metro area
9	Noncore adjacent to micro area and contains a town of at least 2,500 residents
10	Noncore adjacent to micro area and does not contain a town of at least 2,500 residents
11	Noncore not adjacent to a metro/micro area and contains a town of 2,500 or more residents
12	Noncore not adjacent to a metro/micro area and does not contain a town of at least 2,500 residents

Table 5.2: Ordered Probit regression

Number of ob. = 22
LR chi2(7) = 37.25
Prob > chi2 = 0.0000
Log likelihood = -11.422877
Pseudo R2 = 0.6199

WILLING	Coef.	Std.	z	P>|z|	[95% Conf. Interval]	
OPKNOW	2.317214	0.980028	2.36	0.018	0.396394	4.238035
LACK_EXPR	-1.88336	0.857706	-2.2	0.028	-3.56444	-0.20229
ADMIN	2.791324	1.123973	2.48	0.013	0.588379	4.99427
INT_COST	-2.66958	1.057707	-2.52	0.012	-4.74265	-0.59652
LACK_INCEN	-2.85349	1.014945	-2.81	0.005	-4.84275	-0.86424
PCT_PRESV	241.2943	93.11752	2.59	0.010	58.7873	423.8013
RURALITY	-0.32926	0.227968	-1.44	0.149	-0.77607	0.117552

Table 5.3: WALD test of ordered Probit model

P(Willingness=k) = Φ ($U_{k-1} < U \leq U_k$)

U = β1 * OPKNOW + β2 * LACK_EXPR + β3 * ADMIN + β4 * INT_COST + β5 * LACK_INCEN + β6 * PCT_PRESV + β7 * RURALITY

Null Hypothesis	**Test Statistics**		
	Chi^2 (n)	**n**	**Prob > Chi^2**
B1 = β3	0.63	1	0.4284
β2 = β4	1.69	1	0.1939
β2 = β5	2.01	1	0.1566
B4 = β5	0.08	1	0.7800
β2 = β4 = β5	2.50	2	0.2870

Table 5.4: 2003 urban influence codes for Maryland Counties

County Name	2003 Urban Influence Code*	2000 Population	Persons per Square Mile in 2000
Allegany	2	74,930	176.13
Anne Arundel	1	489,656	1,177.23
Baltimore	1	754,292	1,260.12
Calvert	1	74,563	346.52
Caroline	4	29,772	93.00
Carroll	1	150,897	335.98
Cecil	1	85,951	246.89
Charles	1	120,546	261.49
Dorchester	5	30,674	55.02
Frederick	1	195,277	294.59
Garrett	7	29,846	46.06
Harford	1	218,590	496.40
Howard	1	247,842	983.35
Kent	4	19,197	68.70
Montgomery	1	873,341	1,762.49
Prince George’s	1	801,515	1,651.14
Queen Anne’s	1	40,563	108.98
St. Mary’s	3	86,211	238.65
Somerset	2	24,747	75.63
Talbot	3	33,812	125.63
Washington	2	131,923	287.96
Wicomico	2	84,644	224.42
Worcester	5	46,543	98.35

Table 5.5: Knowledge model

Number of ob.	=	24
F(4, 20)	=	217.79
Prob > F	=	0.0000
R-squared	=	0.9776
Adj. R-squared	=	0.9731
Root MSE	=	0.54838

MDIFF	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
OPKNOW_LITTLE	1.875	0.274188	6.84	0	1.303054	2.446946
OPKNOW_SOME	1.184028	0.0527675	22.44	0	1.073957	1.294099
OPKNOW_GOOD	0.8125	0.04847	16.76	0	0.7113933	0.9136067
OPKNOW_EXCT	0.4	0.063321	6.32	0	0.2679147	0.5320853

Table 5.6: WALD test of knowledge model

MDIFF = β1 * OPKNOW_NONE + β2 * OPKNOW_LITTLE + β3 * OPKNOW_SOME + β4 * OPKNOW_GOOD + β5 * OPKNOW_EXCT

Null Hypothesis	**Test Statistics**	
	F (1, 20)	**Prob > F**
β2 = β3	6.12	0.0224
β2 = β4	14.56	0.0011
β2 = β5	27.47	0.0000
B3 = β4	26.89	0.0000
B3 = β5	90.48	0.0000
B4 = β5	26.76	0.0000

Chapter 6 - Summary and Conclusion

This last chapter summarizes major conclusions from the survey and the two regressions. It discusses the best practice framework for MALPF to cost-effectively preserve agricultural lands. It also outlines the limitations of the study. Suggestions for future research are given at the end.

Descriptive statistics revisit the current usage of benefit factors, cost factors, selection algorithms in each county as well as their perception to the new selection approach – optimization. Since county difference is targeted, survey data from the 23 senior representatives is used to conduct the analysis. The 23 senior representatives include 21 MALPF's county administrators and 2 senior staff, one from each of 23 counties.

According to the descriptive statistics from the pre-survey, respondents in the study have a profound level of knowledge and experience with agricultural land preservation. The survey results identify levels of performance and procedures used by Maryland's current programs. The one fact universally used to measure the benefits of a parcel under consideration for protection is soil quality. The parcel's size and the development pressure to which it is subject are the next two most often used benefit factors included in decision-making. Environmental factors are not taken into consideration in most of the counties, which contradicts prior research on the public's preference (Kline & Wichelns, 1996; Duke & Hyde, 2002). The public attaches great importance to environmental benefits when preserving agricultural land. However, this study shows that professionals are more interested in agriculture benefits such as soil quality, or development threat issues.

Meanwhile, a cost analysis is seldom used. Cost is typically viewed as the asking price of the parcel or the amount required to purchase the development rights. Acquisition and transaction costs are easy to calculate and comparable in practice, which helps to explain why professionals take them as the easement's cost. However, even when cost is calculated, it is not generally included as a criterion in the selection process. More than half (57.6%) of the programs in Maryland's 23 counties do not consider a cost analysis as applicable; 21.6% use the easement cost solely to determine the availability of funding. A small number of the respondents, 12%, did not know whether they use cost information in the selection process. Because so little attention is paid to costs, most counties use a simple but biased formula when they calculate the cost at all. It is not surprising, then, that program administrators do not attend to the cost until they come up against a budget restraint. Given their priorities in current selection processes, administrators are confident that they are successfully protecting high-quality soils, large blocks of land, and agricultural uses. Nevertheless, they acknowledge that the programs may not be as cost-effective as they could be.

According to the descriptive statistics from the post-survey, cost-effectiveness is not the top selection criterion. Therefore, although optimization can improve the overall efficiency and effectiveness of the parcels selected by maximizing their combined benefits and/or minimizing the cost of achieving the preservation goal, it may not appeal to conservation professionals in practice until they understand what this operations research tool has to offer. The administrators' willingness to adopt optimization increases when their knowledge of it grows. Prendergast et al. (1999) suggested that lack of awareness is the main reason for low levels of adoption of advanced conservation techniques and that communication between theoreticians and practitioners by way of workshops could help bridge the gap. This study demonstrates that an administrator's level of knowledge increases significantly after an educational presentation on optimization. That knowledge does, however, remain limited. A comparison of the two optimization techniques, binary linear programming and cost-effectiveness analysis, indicates that conservation professionals generally do not have enough expertise to understand their relative advantages. The respondents highly value fairness and transparency and do not pay much attention to the ease of administration.

Both in order probit mode and knowledge model, a second sample population was employed to complete the analysis. This sample is comprised of 27 observations, including 22 senior representatives, one from each of 22 counties, and five other county staff representatives. Baltimore County is excluded from the analysis because it had already adopted optimization in its MALPF and county programs. As a result, some county would have more than one observation to account for their willingness. However, instead of modeling each county's willingness, our model explores individual's willingness and potential forces to influence their personal decision making. Therefore, all 27 observations shall be viewed as one sample, representing the community of conservation professionals in Maryland counties, where optimization has not been adopted yet.

The ordered Probit model shed further light on improvements we can make in an effort to build a best practice framework using optimization. The primary survey results demonstrate that a better understanding of optimization increases willingness to adopt it. In addition, the required initial investment in technical resources has prevented program administrators from using this new approach. If there is no perceptible incentive to alter the current system, they surely will not be willing to put optimization to use. Administrators who have been the most successful in protecting land in terms of the percentage of farmland available are most willing to adopt more advanced approaches. Similarly, metro areas that are experiencing particularly strong development pressures are more willing than nonmetro areas to step up their efforts by adopting "sophisticated" but cost-effective preservation techniques. The knowledge model indicates that administrators' predictions about obstacles to adoption are related to how much they know about the new approach. The more people know about optimization, the less difficulty they perceive.

In conclusion, to build a best practice framework for MALPF, education on optimization and/or training on the optimization decision tool must first be provided to program administrators and employees. Training should address the importance of a cost analysis and the value of being able to customize benefit factors in the analysis. Familiarity with the optimization tool will relieve concerns about implementing it, increase the incentive to reform existing processes, and increase willingness to employ a new tool. To customize optimization for Maryland's counties, the percentage of preserved land and geographic context should be used in the analyses. Optimization can be applied to counties in metro areas with greater percentages of preserved agricultural lands first. Since those counties are facing the greatest development pressure, relief of that pressure should be incorporated into the benefit calculation. These counties' experience with optimization could then be passed on first to counties in micropolitan areas and then to those in noncore areas. In terms of which optimization technique to use, a cost-effectiveness analysis seems to be a better starting point than binary linear programming because people feel more confident with the cost-effectiveness analysis, viewing it as easier and more straight-forward to understand.

Several limitations of this study should be mentioned. First, the survey questions on potential obstacles to adoption of optimization may not have fully represented actual barriers faced by county administrators. The administrators admit that the listed obstacles have some influence but none was fundamentally critical to the final decision. Only three county administrators mentioned obstacles other than the ones presented and they did not disclose the nature of those obstacles. It is possible that some county administrators encounter difficulties that were not listed but did not identify that fact in the survey.

Second, since our survey subjects were targeted, the model is based on a small sample. To design the best possible model, several versions were pretested. Tested ordered Probit models either included all of the obstacle variables or used different combinations of the regressors. Our final choice omitted some obstacle variables because their coefficients were not significant in the test model. One could argue that the regressors in the ordered Probit model could be varied according to observers' perceptions. As a result, there could be different explanations for why counties fail to adopt an optimization approach.

Third, our model considers obstacles that prevent programs from adopting optimization. It also includes some historical and geographic factors that can be easily obtained. However, it does not discuss what may motivate conservation professionals to actively adopt the new approach. This other side of the story, the reasons why counties do adopt optimization, could provide valuable insight into this question. Reasons for adopting may not correspond to predicted obstacles to adoption. In other words, why people refuse to adopt optimization may not be the same as why people do adopt the approach.

Suggestion for Future Research

Given the sparse number of studies on cost-effectiveness in land conservation, future research could be aimed at identifying and measuring preservation costs to help county officials incorporate a cost analysis into their selection processes.

Future study could also be dedicated to identifying the forces that motivate people's willingness to adopt optimization. In our model, the geographic variable RURALITY demonstrates some influence on the decision-making process. A close examination of regional differences might reveal the forces driving that reform. In addition, an index derived from the urban influence codes could replace the original value for RURALITY so that urban influences could be modeled and applied as a way to customize optimization in each county. Moreover, decision-makers' knowledge of an approach or technique has proven to be key to adopting the approach or technique. Communication between academic researchers and administrators certainly bridges the gap of understanding. Therefore, identification of the most effective communication channels begs for further experiment and study.

Appendix A

Pre-Survey Questionnaire

35. Your name:____

36. Maryland county and/or your organization:____

37. How many years have you worked for this county/organization?_________________________________

38. Your current job title:____

39. How many years have you been employed in this position?_____________________________________

40. How many people in your county/organization work on agricultural preservation programs?

a. Full-time employees _____________________________

b. Part-time employees _____________________________

c. Volunteers _____________________________

41. How knowledgeable are you regarding the **Maryland Agricultural Land Preservation Foundation's** (MALPF) agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

42. How knowledgeable are you regarding your **County/Organization's** agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

43. In your county, *approximately* what percentage of agricultural land, measured by acreage, has been protected by the following sources over the past five years? (Total should sum to 100%)

a. Maryland Agricultural Lands Preservation Foundation	______%
b. Your county's agricultural preservation program	______%
c. Rural Legacy Program	______%
d. Maryland Environmental Trust (MET) Program	______%
e. Program Open Space	______%
f. Other _______________	______%
Total:	100 %

44. List, *in order of importance*, the 3 to 5 **most important benefit factors** (such as, soil quality, acres, biodiversity value, or development potential) in your county/organization's selection process.

Indicate how each benefit is measured (such as, GIS mapping, Land Evaluation and Site Assessment (LESA), or site visits).

Benefit Factor	***How Measured***
1.	
2.	
3.	
4.	
5.	

45. Who determines the benefit factors and weights for your county/organization's selection process? (Circle ALL that apply)

a. County program staff
b. County advisory board
c. MALPF guidelines
d. County guidelines
e. Other____
f. Don't know

46. If your county/organization has a LESA system to help determine the benefit score for any preservation program, please describe how this LESA system is used.

Program	***How LESA system is used***
1. MALPF program	
2. County Program	
3. Rural Legacy Program	
4. MET Program	
5. Program Open Space	
6. Other	

47. Do any of your preservation programs use **price caps** to determine the easement cost? (Circle one)

Yes No Unsure

If you answered "Yes", please describe what advantages and disadvantages your county has experienced with price caps:

Advantages	***Disadvantages***

If you answered "No", please complete one of the following:

We are planning to use price caps because:

____

____

____

____

We are *not* planning to use price caps because:

____

____

____

____

48. For each program in the table below, which of the following methods determines the easement cost in your county? (Please check all that apply for each program.)

Program / Method	MALPF	County	Rural Legacy	MET	Program Open Space	Other ______
Asking price	□	□	□	□	□	□
Seller discount	□	□	□	□	□	□
Calculated easement value	□	□	□	□	□	□
Price caps	□	□	□	□	□	□
Appraised value	□	□	□	□	□	□
Other______________	□	□	□	□	□	□
Don't know	□	□	□	□	□	□
Not applicable	□	□	□	□	□	□

49. For each program in the table below, how are easement costs factored into your county/organization's selection process? (Please check all that apply for each program.)

Program	MALPF	County	Rural Legacy	MET	Program Open Space	Other ____
Not explicitly included, except to determine whether funds are still available in the budget	□	□	□	□	□	□
Considered as part of the parcel benefit scoring	□	□	□	□	□	□
Used in an optimization process	□	□	□	□	□	□
Used in calculation of benefit-cost ratios	□	□	□	□	□	□
Other__________________	□	□	□	□	□	□
Don't know	□	□	□	□	□	□
Not applicable	□	□	□	□	□	□

50. For each program in the table below, how are the parcels selected for agricultural preservation in your county/organization? (Please check all that apply for each program.)

Program / Method	MALPF	County	Rural Legacy	MET	Program Open Space	Other ____
Parcels with the highest benefit scores are selected first until the budget is exhausted	□	□	□	□	□	□
Parcels with the highest benefit-cost ratios are selected first until the budget is exhausted	□	□	□	□	□	□
Parcels are selected based on advisory board recommendations	□	□	□	□	□	□
Parcels are selected based on political considerations	□	□	□	□	□	□
Parcels are selected based on their benefits and costs using binary linear programming	□	□	□	□	□	□
No official selection system is used	□	□	□	□	□	□
Other	□	□	□	□	□	□
Don't know	□	□	□	□	□	□
Not applicable	□	□	□	□	□	□

Assess the **ability** of your county/organization's **current selection processes** for agricultural land preservation according to the following criteria:	**Poor**		**Fair**		**Excellent**
51. Maximize the number of agricultural acres protected	1	2	3	4	5
52. Maximize the open space quality of acres protected	1	2	3	4	5
53. Protect the best agricultural land in terms of soil	1	2	3	4	5
54. Preserve large blocks of contiguous agricultural land	1	2	3	4	5
55. Acquire the best deals on agricultural land	1	2	3	4	5
56. Increase incentives for participants to remain in farming	1	2	3	4	5

Assess the technique used for your county/organization's **current selection processes** for agricultural land preservation according to the following criteria:	**Poor**		**Fair**		**Excellent**
57. Knowledge of staff on how to use this technique	1	2	3	4	5
58. Fairness to applicants	1	2	3	4	5
59. Transparency (i.e. ease of explanation to public, advisory board, or potential applicants)	1	2	3	4	5
60. Cost-effectiveness	1	2	3	4	5
61. Ease of administration	1	2	3	4	5
62. Other	1	2	3	4	5

Please rate the following programs according to their **efficiency** in preserving agricultural land:	**Low**		**Medium**		**High**
63. MALPF Program	1	2	3	4	5
64. County Program	1	2	3	4	5
65. Rural Legacy Program	1	2	3	4	5
66. MET Program	1	2	3	4	5
67. Program Open Space	1	2	3	4	5
68. Other program ________________________________	1	2	3	4	5

Post-Survey Questionnaire

43. Your name:____

44. Maryland county and/or your organization:___________________

Please rate the following criteria for an agricultural preservation selection process in terms of importance:	**Low**		**Medium**		**High**
45. Knowledge of staff on how to use the selection process	1	2	3	4	5
46. Fairness to applicants	1	2	3	4	5
47. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
48. Cost-effectiveness	1	2	3	4	5
49. Ease of administration	1	2	3	4	5
50. Other	1	2	3	4	5

Optimization is a process of including both benefit information and acquisition costs to identify parcels that provide a high level of aggregate benefits at the best possible price ('getting the most bang for the buck').

51. How well did you understand optimization **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

52. How well do you understand optimization **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

53. How willing do you think your county/organization would be to adopt **optimization** as the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess the **difficulty** of the following potential obstacles for adopting **optimization** as the selection process in your county/organization's agricultural preservation program:	**Not**		**Somewhat**		**Very**
54. Lack of previous experience	1	2	3	4	5
55. Administration of the process	1	2	3	4	5
56. Initial technical costs (staff training, software, etc.)	1	2	3	4	5
57. Time to implement the process	1	2	3	4	5
58. Need for cost information at the time of selection	1	2	3	4	5
59. Lack of availability of technical resources	1	2	3	4	5
60. Lack of incentives to justify a change in processes	1	2	3	4	5
61. Possibly forgoing the 'best' land regardless of cost	1	2	3	4	5
62. Other	1	2	3	4	5

63. If your county was given **access** to user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

64. If your county was given **access to and training for** user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Binary Linear Programming is an **optimization technique** that seeks to use mathematical programming software to identify the set of acquisitions that maximizes the total possible benefits given a variety of constraints (i.e. budget constraints, staff constraints, minimum acreage goals, etc.).

65. How well did you understand optimization using binary linear programming **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

66. How well do you understand optimization using binary linear programming **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess **binary linear programming** as a technique in the selection process to preserve agricultural land in your county/organization according to the following criteria:	**Poor**		**Fair**		**Excellent**
67. Knowledge of staff on how to use this technique	1	2	3	4	5
68. Fairness to applicants	1	2	3	4	5
69. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
70. Cost-effectiveness	1	2	3	4	5
71. Ease of administration	1	2	3	4	5
72. Other	1	2	3	4	5

73. How willing do you think your county/organization would be to adopt **binary linear programming** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

Cost-Effectiveness Analysis is an **optimization technique** that assesses a parcel's conservation value by taking the ratio of benefits divided by costs, and then acquiring the parcels with the highest benefit-cost ratios until the acquisition funds are exhausted.

74. How well did you understand optimization using cost-effectiveness analysis **before today**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

75. How well do you understand optimization using cost-effectiveness analysis **now**?

Not at all		*Somewhat*		*Very well*
1	2	3	4	5

Assess **cost-effectiveness analysis** as a technique in the selection process to preserve agricultural land in your county/organization according to the following criteria:	**Poor**		**Fair**		**Excellent**
76. Knowledge of staff on how to use this technique	1	2	3	4	5
77. Fairness to applicants	1	2	3	4	5
78. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
79. Cost-effectiveness	1	2	3	4	5
80. Ease of administration	1	2	3	4	5
81. Other	1	2	3	4	5

82. How willing do you think your county/organization would be to adopt optimization using **cost-effectiveness analysis** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

83. Are there any other thoughts you would like to share with us concerning your county/organization's current selection process, or the optimization selection process?

84. Do you have any comments or suggestions about this survey?

Thank you very much for your participation.

If you have any further questions or suggestions, please don't hesitate to contact us:

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Appendix B

Abbreviated Survey

18. Your name:____

19. Maryland county and/or your organization:____

20. How many years have you worked for this county/organization?____________________________________

21. Your current job title:____

22. How many years have you been employed in this position?____

23. How many people in your county/organization work on agricultural preservation programs?

a. Full-time employees ________________________________
b. Part-time employees ________________________________
c. Volunteers _______________________

24. How knowledgeable are you regarding the **Maryland Agricultural Land Preservation Foundation's** (MALPF) agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

25. How knowledgeable are you regarding your **County/Organization's** agricultural preservation program? (Circle one)

Not Knowledgeable		*Somewhat Knowledgeable*		*Expert*
1	2	3	4	5

Please rate the following criteria for an agricultural preservation selection process in terms of importance:	**Low**		**Medium**		**High**
26. Knowledge of staff on how to use the selection process	1	2	3	4	5
27. Fairness to applicants	1	2	3	4	5
28. Transparency (i.e. ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
29. Cost-effectiveness	1	2	3	4	5
30. Ease of administration	1	2	3	4	5

31. How willing do you think your county/organization would be to adopt **optimization** as the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

32. If your county was given **access** to user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

33. If your county was given **access to and training for** user-friendly software to help with optimization, how willing do you think your county/organization would be to adopt this selection process in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

34. How willing do you think your county/organization would be to adopt optimization using **cost-effectiveness analysis** in the selection process for agricultural land preservation in the future?

Not at all		*Somewhat*		*Very willing*
1	2	3	4	5

If you have any further questions or suggestions, please don't hesitate to contact us:

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Appendix C

Proof of Image using permission

from **Hobart King** <hobart@digital-topo-maps.com>
to Yu Chen <yuchen@udel.edu>
date Wed, Jul 28, 2010 at 10:00 AM
subject Re: Image use permission

Dear Yu Chen,

You have permission to use the map in your thesis.

Good luck with your work.

Hobart King
Digital-Topo-Maps.com

On Wed, Jul 28, 2010 at 9:59 AM, Yu Chen <yuchen@udel.edu> wrote:

> Dear Sir/Madame,
>
> I'm a Master Graduate at the University of Delaware. I'm doing a thesis on the farmland preservation in Maryland and need a map of Maryland counties. I found a perfect one at your website. It says that I can use it in my website, but I will use it in my thesis and later my school will print it out and put it in the library. Therefore, may I have your permission to include this picture in my paper? Here is the link to this image:
>
> http://www.digital-topo-maps.com/county-map/maryland.shtml
>
> It will still have your copyright stamp in the picture and I will give citation to the original website. Thank you very much.
>
> Best,
> Yu Chen

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