March 2016 APEC RR16-06

Linda Grand[1], Kent D. Messer[1] and William Allen, III[2]

[1]Department of Applied Economics and Statistics, University of Delaware, [2] The Conservation Fund

APPLIED ECONOMICS & STATISTICS

ABSTRACT

Understanding and Overcoming the Barriers for Cost-Effective Conservation

Keywords: Cost-effective conservation, Conservation professionals, Conservation planning, Optimization

Despite extensive research demonstrating the benefits of applying cost-effective conservation techniques, such as optimization, a large gap remains between the evidence from research and the actions of professions as they

APEC Research Reports

Department of Applied Economics and Statistics • College of Agriculture and Natural Resources • University of Delaware

design and implement conservation programs. This study examines this gap between the research evidence and the conservation community's practice through an international survey of conservation professionals who are familiar with cost-effective conservation techniques. The results show that the vast majority of survey respondents viewed cost-effectiveness as a virtue but ultimately do not consider it as important as other program design criteria. These results suggest the advocates of cost-effective conservation need to address concerns about fairness and transparency and remedying gaps in the knowledge and expertise of professionals involved. Finally, the lack of incentive to conservation professionals to change their practices is a challenge that calls for public pressure and encouragement for experimentation and evidence-based policy to improve the cost effectiveness of conservation efforts.

ACKNOLWEDGEMENTS

This research was supported by the National Science Foundation EPSCoR Grant No. IIA-1301765. We would like to thank Maik Kecinski for his insights when developing this manuscript.

For additional information on this research course, contact:

Linda Grand

E-mail: lgrand@udel.edu

Kent D Messer

Department of Applied Economics and Statistics
207 Townsend Hall, Newark, DE 19716
Office: 1 302-831-1316 messer@udel.edu

Suggested Citation for APEC Research Reports

Grand, Linda., Messer K.D., W. Allen. 2016. "Understanding and Overcoming the Barriers for Cost Effective Conservation." *Applied Economics & Statistics Research Report*, University of Delaware, RR16-06.

Understanding and Overcoming the Barriers for Cost-Effective Conservation

Linda Grand[a], Kent D. Messer[a,1], and William Allen, III[b]

[a] University of Delaware, Department of Applied Economics & Statistics, 226 Townsend Hall, 531 South College Avenue, Newark, DE 19716, United States
[b] The Conservation Fund, 410 Market St #360, Chapel Hill, NC, 27516, United States

Abstract

Despite extensive research demonstrating the benefits of applying cost-effective conservation techniques, such as optimization, a large gap remains between the evidence from research and the actions of professions as they design and implement conservation programs. This study examines this gap between the research evidence and the conservation community's practice through an international survey of conservation professionals who are familiar with cost-effective conservation techniques. The results show that the vast majority of survey respondents viewed cost-effectiveness as a virtue but ultimately do not consider it as important as other program design criteria. These results suggest the advocates of cost-effective conservation need to address concerns about fairness and transparency and remedying gaps in the knowledge and expertise of professionals involved. Finally, the lack of incentive to conservation professionals to change their practices is a challenge that calls for public pressure and encouragement for experimentation and evidence-based policy to improve the cost effectiveness of conservation efforts.

Keywords: Cost-effective conservation, Conservation professionals, Conservation planning, Optimization

Research Highlights:

- Cost-effective conservation (CEC) is not widely practiced despite its potential.
- To find out why, we surveyed an international sample of conservation professionals.
- 91% of respondents believe that CEC is a good idea, but rank it a low priority.
- Respondents report the lack incentives as a key barrier preventing CEC approaches.
- Willingness to adopt CEC rises 23% when software and training are offered.

[1] Corresponding Author. Email: messer@udel.edu
Tel: +1 302-831-1316

Understanding and Overcoming the Barriers for Cost-Effective Conservation

1. Introduction

Research has consistently shown that organizations with the most severely limited budgets have the most to gain from adopting cost-effective conservation (CEC), a project-selection process that incorporates *both* benefits and costs to maximize the conservation outcomes generated by available funds. Over the past couple of decades, a substantial literature has developed that advocates for applying CEC techniques, such as optimization through mathematical programming, to enable conservation professionals to select a set of projects that maximizes the organizations objectives for a given budget (see for instance, Babcock et al., 1997; Polasky et al., 2001; Ferraro, 2003; Wu et al., 2001). Despite the many studies that have identified the benefits of CEC, conservation professionals remain wary (Arponen et al., 2010; Gowdy et al., 2010; Messer et al. 2016a) and its application is limited.

In general, CEC methods consider both the benefits and the costs associated with each potential project and identify a set of projects that provides the greatest aggregate benefit possible ("the most bang for the buck"). Optimization delivers CEC by using a set of mathematical programming algorithms adopted from operations research, including binary linear programming (BLP) and goal programming, to systematically address complexities (see for instance, Underhill, 1994; Babcock et al., 1997; Balmford et al., 2000; Polasky et al., 2001; 2006; Sarkar et al., 2006). Despite extensive research demonstrating the advantages of applying optimization techniques and efforts to acquaint conservation organizations with them, conservation professionals generally have not adopted cost-effective methods of project selection.

Currently, conservation programs throughout the world rely mostly on benefit-targeting (BT), also referred to as rank-based method. BT involve constructing an index of potential benefits and associated weights from offered projects. For example, US federal conservation efforts have typically used BT—such as the selections for acquisition to the national parks system and for forest preservation (Babcock et al., 1997, Messer and Borchers, 2015). BT ranks each project according to the environmental benefits provided and sequentially selects the highest-ranking projects until the budget is exhausted (Ferraro, 2003). BT performs best when the benefits of various projects vary more than the costs of those projects (Babcock et al., 1997). This benefit-only method is not cost-effective because it ignores cost as a selection criterion. BT can result in budgets quickly being exhausted by a few high-ranking but relatively expensive projects.

While optimization through mathematical programming will always achieve the highest aggregate benefits for a given budget (assuming that the benefits are measured accurately) another CEC technique is benefit-cost targeting (BCT) which selects projects with the largest benefit-cost ratio until the budget is exhausted. BCT computes the greatest benefit per dollar and achieves greater cost-effectiveness than BT (Babcock et al., 1997; Ferraro, 2003). In most cases, CEC and BCT will yield identical selection sets, except in cases involving large budget remainders (Duke et al., 2013). A handful of conservation programs at the state level (Messer et al, 2016b) and the federal level (Wu et al., 2000; Wu et al., 2001) have used variants of BCT.

This research seeks to understand why CEC does not have widespread use by conservation professionals. Researchers have pointed out several obstacles for CEC. For instance, Sullivan et al. (2004) identified political process and perceptions of fairness by various groups as major obstacles. Gardener (1977) argued for the importance of accurately measuring the external benefits when designing conservation policies while other researchers have raised a variety of concerns

about the difficulty in accurately capturing and quantifying these environmental benefits in the context of CEC (Arponen et al., 2010; Bryan 2010; Gowdy et al., 2010; Bryan et al., 2011). Conservation professionals may resist adopting CEC methods because they are not familiar with the mathematics used in optimization or lack computer and software tools needed to implement them (Ferraro and Pattanayak, 2006). Pullin et al. (2004) pointed out that there exists a knowledge gap as conservation professionals do not have access to easily understandable scientific information. Pull et al. (2004) also noted that conservation professionals often resist change and prefer to plan as they have in the past instead of incorporating further information into their decision making process. Finally, Prendergast et al., (1999) identified the lack of awareness of optimization methods and lack of understanding of how they function as major obstacles to adoption.

This study contributes to the literature about the gap between the practices of conservation professionals and the recommendations of researchers. Importantly, this research studies the attitudes of conservation professionals who have been educated about CEC techniques, yet still generally do not use them in their work. Thus, this research provides important insights beyond the basic 'knowledge gap' arguments and suggests that other factors need to be overcome before CEC will occur on a widespread basis. The results of this study demonstrate that the vast majority of survey respondents viewed cost-effectiveness as a virtue in program design but did not consider it as important as other program design criteria. In particular, respondents emphasize the important of fairness and transparency of the selection process. A major obstacle for adoption is the lack of incentives to change existing program structures as respondents seem to receive little public pressure to be cost-effective nor receive additional recognition in their work for making their conservation programs more cost-effective. Finally, respondents indicated that their likelihood of

adoption of cost-effective conservation would increase if they can receive additional training and software to facilitate adoption of CEC.

2. Research Methods

Our study was designed to address three primary objectives:

1. Evaluate attitudes of conservation professionals about CEC.
2. Evaluate whether these attitudes varied by the type of conservation activity.
3. Identify barriers that discourage conservation professionals from adopting CEC and see whether anything could be done to overcome them.

The survey was developed in Qualtrics software. We identified valid email address for 246 conservation professionals from around the world who had attended lectures on CEC techniques presented by the study co-authors. This list of participants (see Table 1 for the organizations represented by the participants) was derived from attendance lists of 47 presentations that were made between 2005 and 2012 at the National Conservation Training Center, the Land Trust Alliance Rally, the American Farmland Trust conference, and offices of nonprofit and government agencies. Information about this sample of conservation professionals was generated from attendance sheets.

Table 1. Conservation Organizations Surveyed

1. Alachua County
2. Baltimore County Department of Environmental Protection and Sustainability
3. Black Swamp Conservancy
4. Board of County Commissioners of Washington County, Maryland
5. Burlington County Resource Conservation
6. Cambria County Conservation District
7. Charles County
8. Chester County (PA) Department of Open Space Preservation
9. Chicago Wilderness
10. City of Des Moines, Iowa
11. City of Des Moines, Iowa (Forestry Division)
12. Colorado State University - Center for Environmental Management of Military Lands (CEMML) at Fort Campbell, KY
13. Colorado State University
14. Delaware Department of Agriculture
15. Delaware Division of Parks and Recreation
16. Duke Farms Foundation
17. Environmental Education, Conservation and Research (EECORE) Cameron
18. Estes Valley Land Trust
19. Federal Highway Administration
20. Florida Department of Environmental Protection
21. Frederick County Government, Maryland
22. Fund for Women
23. Garrett County Planning & Land Development
24. Great Land Trust
25. Green Farm CO2FREE
26. Hill Country Conservancy
27. Instituto Ação Verde Institute Aí_í£o Verde
28. Inter-American Development Bank IDB
29. Jefferson County West Virginia Departments of Planning and Zoning
30. Kent County, Delaware Department of Planning and Zoning
31. Legacy Land Conservation Program, Dept. of Land and Natural Resources, State of Hawaii
32. Linn County, Iowa
33. Loudoun county government
34. Maryland-National Capital Park and Planning Commission
35. Manada Conservancy
36. Mid-America Regional Council - Regional Planning for Greater Kansas City
37. MD State Highway Administration

38. Midpeninsula Regional Open Space District
39. Minnesota Department of Natural Resources
40. National Parks Conservation Association
41. New York State Department of Environmental Conservation
42. Open Space Institute, Inc.
43. Parish of Caddo
44. Patuxent Tidewater Land Trust
45. Prince Georges Soil Conservation District
46. Queen Anne's County Planning & Zoning
47. Siskiyou Land Trust
48. St. Mary's County Government
49. Talbot County Maryland Planning and Permits Department
50. The Conservation Fund
51. The Hampshire County Farmland Protection Board
52. The Nature Conservancy
53. US Fish and Wildlife Service
54. US EPA Region 3
55. US Geological Survey
56. Whatcom Conservation District
57. Worcester County

The recruitment process consisted of emailing a survey (followed by reminder emails) consisting of 43 questions (see Appendix A) to the 246 individuals identified with an incentive for their participation in the form of a raffle of one $250 Amazon gift cards and four $50 Amazon gift cards. Recipients of the gift cards were to be chosen randomly after the survey had been completed. All respondents were also offered the opportunity to donate the money to a nonprofit organization of their choice, this option was made available as we anticipated that some government employees would not be able to receive direct financial payment, but might still be motivated to participate by donating the money.

We based the survey structure on Dillman's (1978) Total Design Method, which focuses on follow-up reminders. One week after the initial email, we sent a reminder email to anyone who had not yet responded and included the 43-question survey. The following week, we sent a second reminder email to all non-responders again asking them to participate in the full-length survey but also offered the option of taking a shorter 10-question version of the survey. The versions of the survey were attached to that reminder. One week after that, we sent a final reminder email to all non-responders that included a revised version of the short survey (to include a question about attendance at recent presentations about CEC).[2]

Twenty-four of the original email addresses proved to be nonfunctional, reducing the number of professionals contacted to 246. The rate of response to the initial survey request was 26.4%. After completion of all of the follow-up emails, we had obtained responses from 85

[2] We sent a shorter version of the survey to people who did not respond to the longer survey. This version covered the main questions our research focused on including how willing conservation professionals were to adopting optimization and what obstacles inhibit them from adopting this technique (Appendix B).

individuals, representing a final response rate of 34.6%. The 85 responses consist of 65 from the long survey and 20 from the short survey. The questions asked in the survey are shown in Appendix A.

3. Results

At the beginning of the survey, respondents were asked to rate their knowledge of their own conservation programs on a scale of 1 (not knowledgeable) to 5 (expert). All of the respondents reported having expert or near expert knowledge with an average rating of 4.52. In terms of familiarity with optimization generally, which was rated on a scale of 1 (not at all) to 5 (very well), the average response was 3.14. Respondents who had heard a presentation on optimization rated their retention of the material presented fairly high—an average of 3.58 on a scale of 1 (remember nothing) to 5 (remember most of the information). Similarly, respondents who had read information on optimization techniques reported an average retention rating of 3.32.

A very high percentage of respondents viewed optimization as a good idea (91%). However, only 55.4% thought it was applicable to their organizations, while 39% said that they did not know whether optimization would be applicable to their organization. Respondents were asked to rate the importance of five criteria on a scale of 1 (not important) to 5 (very important) in their project selection processes:

(1) knowledge of the staff in how to use the selection process to identify good projects;

(2) fairness to applicants;

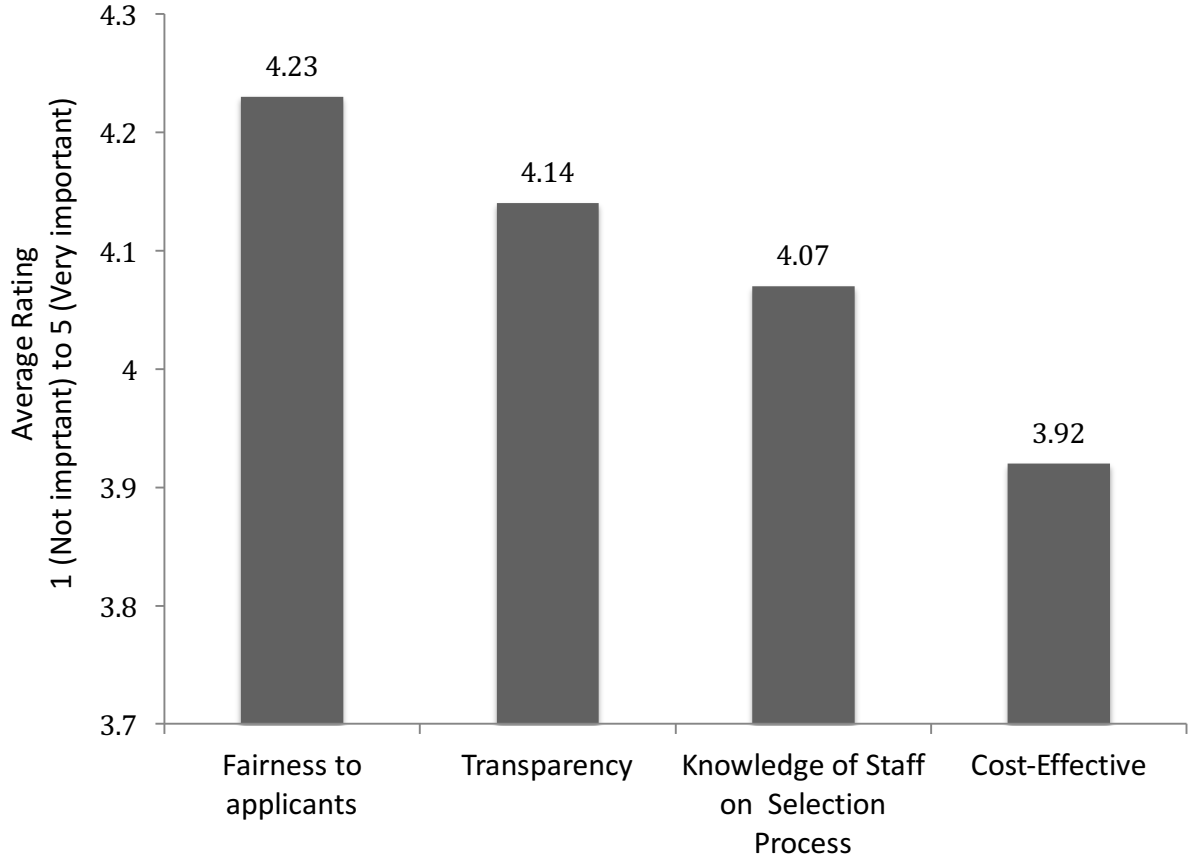
(3) transparency;

(4) cost-effectiveness, and

(5) ease of administration.

As shown in Figure 1, fairness to applicants was the most important criterion (average score of 4.23). The second most important criterion (average score of 4.14) was transparency, which was described in the survey as the ease of explaining the process to various interest groups. Knowledge of staff ranked third (average score of 4.07). Interestingly, the cost-effectiveness of the process (described as achieving the largest possible total benefit for a relatively low price), while considered an important criterion, was ranked lowest (average score of 3.92) despite most conservation programs' limited budgets. We performed a two-tailed paired t-test for differences in the means between the criteria. The results showed statistically significant differences between fairness and cost-effectiveness ($p=0.021$). In addition, there are statistical significant differences between transparency and cost-effectiveness ($p=0.014$).

Figure 1: Importance of Criteria in the Project Selection Process



Several survey questions sought to evaluate the degree of difficulty of the challenges that have been associated with adopting optimization: Respondents rated the difficulty of each on a scale from 1 (not difficult) to 5 (very difficult) and the results are shown in Table 2. The lack of an incentive to justify a change in the method used was seen as the biggest obstacle to adopting optimization (average rating of 3.55), followed by the initial cost of technical resources (3.46). Lack of previous experience with optimization was rated as least challenging (2.72). A two-tailed Pearson chi-squared test to evaluate the difference in the means of lack of incentive and lack of previous experience was statistically significant ($p<0.001$).

Table 2. Difficulty of the Potential Obstacles to Adopting Cost Effective Conservation, Descriptive Statistics.

Question 18: "Assess the difficulty of the following potential obstacles for adoption optimization as the selection process in your organization's conservation program:	Mean	Standard Deviation
Lack of incentives to justify a change in process (*Lack Incentives)*	3.55	1.236
Initial cost of technical resources costs (software and staff training) (*Initial Cost)*	3.49	1.227
Difficulty in measuring benefits (*Measure Benefits)*	3.27	1.117
Possibly forgoing the 'best' project regardless of cost *(Forgo Best Project)*	3.23	1.047
Need for accurate cost information at the time of selection *(Need Cost Information)*	3.19	1.110
Administration of the process *(Administration Process)*	3.14	1.150
Lack of availability of technical resources *(Lack Technology)*	3.14	1.285
Time to implement the process *(Time to Implement)*	3.09	1.149
Due to Federal guidelines/ restrictions *(Process Not Staff Determined)*	3.05	1.420
Lack of previous experience *(Lack of Experience)*	2.72 [a]	1.106

The survey also asked questions designed to measure how planners' willingness to adopt optimization would be influenced by the availability of additional resources, such as user-friendly software and training. From an initial willingness of 2.95 (on a scale of 1 to 5), access to software raised average willingness to adopt to 3.34, a 13% increase, and access to both software and training raised willingness to adopt an additional 9% to 3.63 (Table 3). This result demonstrates an important avenue by which adoption of optimization techniques could be increased, allowing conservation organizations to be more cost-effective.[3] Results of two tailed paired t-tests, showed statistically significant increases in willingness to adopt in response to access to such resources. There was no statistical significance between an Excel-based platform or an internet- based optimization platform ($p=1.0$). We found that all types of resources were significantly different from willingness to adopt with no resources. Furthermore, we find there are statistically significant differences between access to training and software (*Training Access*) and only given access to an Excel based platform (*Excel Access*) ($p=0.003$). In addition, we found that there is a statistical significant difference between *Training Access* and access to an web based platform (*Web Access*) ($p<0.001$). Lastly, we also find there are statistical significant differences between given only access to software (*Software Access*) and being given access to software and training (*Training Access*) ($p<0.001$).

[3] To our knowledge, no environmental or conservation foundation or funder is currently providing this type of training.

Table 3. Willingness to Adopt Optimization

Variable	Survey Question	Mean	Standard Deviation
Willingness to Adopt Optimization	How willing do you think your organization would be to adopt optimization as the selection process for your conservation program in the future?	2.93	1.011
Excel Access	If your organization was given **access** to user-friendly Excel-based software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?	3.38	0.964
Web Access	If your organization was given **access** to user-friendly web-based software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?	3.38	0.871
Software Access	If your organization was given **access to** user-friendly software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?	3.34	0.831
Training Access	If your organization was given **access to** *AND* **training for** user-friendly software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?	3.62	0.853

We also conducted an analysis of factors that influence conservation professionals' willingness to adopt optimization as their primary selection process. An ordered probit model was used to analyze the relationships between willingness to adopt optimization and eight independent variables: Each variable came from a survey question asking respondents to rate the item on a scale of 1 (not difficult / not very important) to 5 (very difficult / very important). The data set for the analysis consisted of observations, from respondents who had some previous knowledge of optimization. As shown in Model 1 in Table 4, six of the independent variables were significant at the 5% level.

Table 4. Ordered Probit Regressions on Willingness to Adopt Optimization.

	Model 1	Model 2
Understand Optimization	0.591*	0.531*
	(0.126)	(0.151)
Lack Incentives	–0.533*	–0.499*
	(0.128)	(0.177)
Lack Experience	–0.018	0.125
	(0.148)	(0.174)
Initial Cost	0.0895	0.178
	(0.097)	(0.142)
Staff Knowledge	0.364**	0.221
	(0.171)	(0.188)
Fairness Importance	0.285**	0.263
	(0.119)	(0.159)
Transparency Importance	–0.541**	–0.612**
	(0.225)	(0.249)
Forgo Best Project	0.293**	0.338
	(0.139)	(0.181)
Measure Benefits		–0.407*
		(0.154)
Willingness to Adopt LSP		0.519**
		(0.248)
Observations	73	51
Pseudo R2	.2119	.3171
Wald chi-square (10)	54.01	47.77
Prob > chi-square =	0.0000	0.0000

Notes: *signifies significant at 10% level. * *signifies significant at 5% level.

First, willingness to adopt optimization (*Understand Optimization*) increases with respondents understanding of optimization. Recall that the respondents had a generally good understanding of optimization (the average rating of understanding was 3.14), which is not surprising considering our international sample of professionals had all been exposed to information about the value of CEC techniques relative to BT. Thus our results are different from those reported in (Prendergast et al., 1999) where the sample reported that most conservation professionals remain unaware of these substantial benefits due to lack of information on the reasons for adopting CEC.

Second, respondents who believed that their organization's staff is knowledgeable (*Staff Knowledge*) about CEC were more willing to adopt optimization. In the survey, the average rating of staff knowledge was 4.07. Thus, respondents seemed to be relatively confident that their organizations could easily learn to incorporate optimization.

Third, respondents who emphasized a fair process as important (*Fairness Importance*) (average rating was 4.23) were more willing to adopt optimization. Fairness to applicants was defined as the organization showing no bias and giving the same consideration to each project. It makes sense that individuals who want to be fair are more likely to use optimization, which eliminates political considerations and biases and analyzes each potential project using the same mathematical method.

Fourth, a surprising positive coefficient was the coefficient related to the relative difficulty of foregoing the highest-ranking projects (*Forgo Best Project*). This suggests a rather contradictory idea that the more likely respondents were to adopt optimization, the less willing they were to

forego the best available projects. The average rating of the difficulty of this obstacle was 3.22 (representing "somewhat" difficult). A possible explanation for this result is that respondents may have already been passing on the highest-ranking projects due to political pressures and thought that switching to CEC might make the process less political and thus better outcomes would result. As noted in Duke et al. (2013, p. 128), "nongovernmental organizations may win political favors or improve fundraising by, at times, focusing on high-profile projects, even if they come at a relatively high cost."

The coefficients of the independent variables for the lack of incentives (*Lack Incentives*) to switch and transparency of the process (*Transparency Importance*) are significant and negative. Lack of incentives was rated as most challenging of the obstacles listed (average rating of 3.55). This could be because the organizations, the public, and/or their donors are not demanding that these programs be more cost-effective. Alternatively, the program administrators may be reflecting the incentive structures common to most government agencies and non-governmental organizations that do not reward staff for being more cost-effective. When asked to evaluate how cost-effective their organization's current selection processes, the average rating was 3.76 out of 5 (somewhat cost-effective); therefore, many of the respondents viewed their current processes as less cost-effective than they could be. Change tends to be difficult and thus is unlikely to occur without some kind of incentive provided to the staff involved with implementing CEC.

The coefficient for transparency in the selection process was negative so willingness to adopt optimization declined with the importance of having a transparent process. Recall that this criterion had a relatively high average rating of 4.14. This result may be related to the perceived complexity of optimization methods, which could be viewed as confusing by the organization's staff and thus difficult to explain to stakeholders. These concerns might be alleviated by using

BCT, since it only uses simple ratios of benefits and costs, instead of mathematical programming as a means of achieving CEC.

The results of Model 1 show that the lack of experience and the initial cost of implementing optimization were not significant. These results are particularly interesting since conservation programs often have limited budgets. Since all of the respondents in this data set had been exposed to at least one presentation on optimization, their awareness of the method and availability of free or inexpensive software packages may have reduced their concerns about cost.

Table 4 also reports on a second model that includes variables related to the difficulty in measuring benefits and the likelihood of adoption the Logic Scoring of Preferences (LSP) to help quantify benefits. Both of these variables (*Willingness to Adopt LSP*) and (*Measure Benefits*) were measured on a 1 to 5 scale. Since questions about LSP and benefit measures were not included in the short surveys, the sample size was smaller, however, similar results were found to Model 1. Interestingly, the coefficients for the variables related to staff knowledge of optimization, the fairness of the process, and the inability to forgo the best projects were no longer statistically different than zero. Instead the other two variables were statistically significant and the overall explanatory power of Model 2 rose by 10.5%.

The coefficient for the variable related to the difficulty of measuring benefits was statistical significant and negative at the 10% level. This indicates that respondents who view benefit measurement as challenging are less likely to adopt optimization. This result makes sense because optimization requires that numeric values be assigned to all benefits. If conservation professionals already find it difficult to capture measures of benefits, they are unlikely to use a method that makes this a requirement.

The coefficient for willingness to adopt LSP was positive level and statistically significant at the 5% level. This suggests that the more willing respondents are to adopt LSP, the more willing they are to adopt optimization which makes sense as LSP is designed to help make various benefit measures more quantifiable (Dujmović and Allen, 2011; Allen et al., 2011).

4. Conclusion

Despite extensive research demonstrating the advantages of applying cost-effective conservation (CEC) techniques, such as optimization, conservation organizations generally have not adopted such methods and continue to use less cost-effective techniques such as benefit targeting (BT). Researchers have identified a number of potential obstacles to adoption including concerns about the fairness and transparency of such methods, political considerations, challenges of measuring environmental benefits, adverse incentives within public bureaucracies, and lack of awareness and understanding of optimization.

This research surveyed conservation professionals who had been educated about CEC. While the vast majority of the survey respondents indicate that cost-effectiveness is a virtue in conservation programs, they do not consider it as important as other program design criteria. The results point not to one particular barrier that predominantly impedes adoption, but to a handful of significant issues that need to be addressed. We find that concerns about fairness and transparency of the process, a lack of confidence in the organization's ability to understand and use optimization, and a lack of incentives to change the method currently used to a more cost-effective approach all have an impact on willingness to adopt optimization. These results suggest that expanding training efforts to introduce optimization to conservation professionals and providing user-friendly

software are likely to be crucial in promoting CEC methods. This suggests that philanthropic foundations and government agencies should consider investing in trainings and software development.

These results also suggest that public pressure may need to be applied to conservation professionals to make them more responsive to concerns about cost effectiveness. Interestingly, this pressure could come from either side of the political spectrum as environmental advocates want to see more on-the-ground conservation given the limited funds available and good governance advocates want to see taxpayer money used as effectively as possible. Since some of the statutes that created government conservation programs call for the efforts to be conducted in a way that maximizes conservation benefits, the continued failure of some of these groups to use CEC methods may make them vulnerable to legal challenges. Finally, given recent federal efforts to encourage federal agencies to develop evidence-based policy and programs, efforts should be undertaken to use randomized controlled trials to test various selection methods and see how best to overcome the identified obstacles currently inhibiting the adoption of cost effective conservation.

Acknowledgements

This research was supported by the National Science Foundation EPSCoR Grant No. IIA-1301765. We would like to thank Maik Kecinski for his insights when developing this manuscript.

References

Allen, W.L., Amundsen, O.M., Dujmović, J.J., Messer, K.D., 2011. Identifying and selecting strategic mitigation opportunities: Criteria design and project evaluation using logic scoring of preference and optimization. *Journal of Conservation Planning* 7, 61–68.

Arponen, A., Cabeza, M., Eklund, J., Kujala, H., Lehtomaki, J., 2010. Costs of integrating economics and conservation planning. *Conservation Biology* 24, 1198–1204.

Babcock, B.A., Lakshminarayan, P.G., Wu, J., Zilberman, D., 1997. Targeting tools for the purchase of environmental amenities. *Land Economics* 73, 325–339.

Balmford, A., Gaston, K.J., Rodrigues, A.S.L, James, A., 2000. Integration of costs of conservation into international priority setting. *Conservation Biology* 14, 567–605.

Bryan, B. A., Raymond, C., Crossman, N. D., & King, D." Comparing spatially explicit ecological and social values for natural areas to identify effective conservation strategies." *Conservation Biology* 25.1 (2011): 172-181.

Bryan, B. A. "Development and application of a model for robust, cost-effective investment in natural capital and ecosystem services." *Biological Conservation* 143.7 (2010): 1737-1750.

Dillman, D.A., 1978. *Mail and telephone surveys: The total design method*. New York: John Wiley & Sons.

Dujmović, J.J., Allen, W.L., 2011. A family of soft computing decision models for selecting multi-species habitat mitigation projects. World Conference on Soft Computing, San Francisco, May 2011.

Duke, J.M., Dundas, S.J., Messer, K.D., 2013. Cost-effective conservation planning: Lessons from economics. *Journal of Environmental Management* 125, 126–133.

Ferraro, P.J., Pattanayak, S.K., 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biology* 4(4), e105.

Ferraro, P.J. Assigning priority to environmental policy interventions in a heterogeneous world. *Journal of Policy Analysis and Management* 22.1(2003), 27–43.

Gardner, B.D., 1977. The economics of agricultural land preservation. *American Journal of Agricultural Economics* 59, 1027–1036.

Gowdy, J., Hall, C., Klitgaard, K., Krall, L., 2010. What every conservation biologist should know about economic theory. *Conservation Biology* 24, 1440–1447.

Messer K.D., W. Allen, M. Kecinski, and C. Chen. 2016a. Agricultural Preservation Professionals' Perception and Attitudes about Cost-effective Land Selection Methods. *Journal of Soil & Water Conservation*. 71(2):148-155.

Messer K.D and A. Borchers. 2015. Choice for Goods under Threat of Destruction. *Economic Letters*. 135: 137-140. doi:10.1016/j.econlet.2015.07.026.

Messer, K.D., M. Kecinski, X. Tang, and R. Hirsch. 2016b. Applying Multiple Knapsack Optimization to Improve the Cost Effectiveness of Land Conservation. *Land Economics*. 92(1):117-130.

Polasky, S., Camm, J.D., Garber-Yonts, B., 2001. Selecting biological reserves cost-effectively: An application to terrestrial vertebrate conservation in Oregon. *Land Economics* 77(1), 68–78.

Prendergast, J.R., Quinn, R.M., Lawton, J.H., 1999. The gaps between theory and practice in selecting nature reserves. *Conservation Biology* 13(3), 484–492.

Pullin, Andrew S., et al. Do conservation managers use scientific evidence to support their decision-making? *Biological conservation* 119.2 (2004): 245-252.

Sarkar, S., et al., 2006. Biodiversity conservation planning tools: Present status and challenges for the future. *Annual Review of Environmental Resources* 31: 123–159.

Sullivan, P., et al., 2004. The conservation reserve program: Economic implications for rural America. *Agricultural Economic Report* 834, U.S. Department of Agriculture Economic Research Service.

Underhill, L.G., 1994. Optimal and suboptimal reserve selection algorithms. *Biological Conservation* 70(1), 85–87.

Wu, J., Adams, R.M., Boggess, W.G., 2000. Cumulative effects and optimal targeting of conservation efforts: steelhead trout habitat enhancement in Oregon. *American Journal of Agricultural Economics* 82, 400-413.

Wu, J., Zilberman, D., Babcock, B.A., 2001. Environmental and distributional impacts of conservation targeting strategies. *Journal of Environmental Economics and Management.* 41(3), 333-350.

Appendix A –Long Survey

We are conducting a research study on conservation programs and attitudes towards applying optimization. The purpose of the survey is to figure out how conservation professionals have responded to the use of optimization in a variety of environmental contexts. The survey should take five to ten minutes to fill out. Participation is completely voluntary and all information will be kept confidential.

Attitudes towards Adoption of Optimization in Conservation Planning

1. Your name:_____

2. Name of your organization:_____

3. How knowledgeable are you regarding your organizations conservation program(s)? (Circle one)

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

4. What software does you currently use (Circle ALL that apply)
   a. GIS
   b. Excel
   c. SAS
   d. Solver
   e. Logic Scoring of Preferences – web version (LSPweb)
   f. Optimization Decision Support Tool – Excel version (ODST Excel)
   g. Optimization Decision Support Tool – web version (ODSTweb)
   h. inVEST
   i. Not applicable
   j. Don't know

5. What software does your organization currently use for project selection? (Circle ALL that apply)
   a. GIS
   b. Excel
   c. SAS
   d. Solver
   e. Logic Scoring of Preferences – web version (LSPweb)
   f. Optimization Decision Support Tool – Excel version (ODST Excel)
   g. Optimization Decision Support Tool – web version (ODSTweb)
   h. inVEST
   i. Not applicable
   j. Don't know

6. Assess the **ability** of your organization's **current selection processes** according to the following criteria:	**Poor**		**Fair**		**Excellent**
Maximize protected areas	1	2	3	4	5
Maximize the quality of protected areas	1	2	3	4	5
Protect the best land in available	1	2	3	4	5
Preserve large blocks of contiguous land	1	2	3	4	5
Acquire the best projects currently available	1	2	3	4	5

7. Please rate the following criteria in terms of importance:	**Low**		**Medium**		**High**
Knowledge of staff on how to use your selection process to identify good projects	1	2	3	4	5
Fairness to applicants	1	2	3	4	5
Transparency (ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
Cost-effectiveness (achieve the largest possible social benefit for a relatively low price)	1	2	3	4	5
Ease of administration	1	2	3	4	5
Other:_____	1	2	3	4	5

8. Assess your organization's **current selection process** according to the following criteria:	**Poor**		**Fair**		**Excellent**
Knowledge of staff on how to use your selection process to identify good projects	1	2	3	4	5
Fairness to applicants	1	2	3	4	5
Transparency (ease of explanation to public, advisory board, or potential applicants)	1	2	3	4	5

Cost-effectiveness (achieve the largest possible social benefit for a relatively low price)	1	2	3	4	5
Ease of administration	1	2	3	4	5
Other					

Optimization is a branch of economics and operations research studies that has shown conservation professionals how to get more projects conserved within a constrained budget or achieve the same projects with a smaller budget. Optimization involves a set of mathematical programming algorithms from operations research, such as binary linear programming and goal programming. It is a process of including both monetized benefit information and acquisition costs to identify projects that provide a high level of aggregate benefits at the best possible price ('getting the most bang for the buck'). 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 maximizing the effectiveness of limited financial resources

9. Have you heard XXXX speak about optimization previously?
   a. Yes
   b. No

10. If yes, to question 9, how much do you remember?

Nothing		*Some*		*Most*
1	2	3	4	5

11. Have you heard read something XXXX about optimization previously?
   a. Yes
   b. No

12. If yes, to question 11, how much do you remember?

Nothing		*Some*		*Most*
1	2	3	4	5

13. How well do you think you understand optimization overall?

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

14. How well do other people in your organization understand optimization?

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

15. In general, do you think optimization is a good idea?
   a. Yes

b. No, *If no why not?* _____

16. Do you think optimization is applicable to your program?

a. Yes
b. No
c. Not sure

17. How willing do you think your organization would be to adopt optimization as the selection process for your conservation program in the future?

Not at all *Somewhat* *Very willing*

1 2 3 4 5

18. Assess the difficulty of the following potential obstacles for adopting optimization as the selection process in your organization's conservation program:	**Not Difficult**		**Somewhat**		**Very Difficult**
Lack of previous experience	1	2	3	4	5
Administration of the process	1	2	3	4	5
Time to implement the process	1	2	3	4	5
Need for accurate cost information at the time of selection	1	2	3	4	5
Lack of availability of technical resources	1	2	3	4	5
Initial cost of technical resources costs (software and staff training)	1	2	3	4	5
Lack of incentives to justify a change in processes	1	2	3	4	5
Possibly forgoing the 'best' project regardless of cost	1	2	3	4	5
Due to Federal guidelines/ restrictions	1	2	3	4	5
Difficulty in measuring benefits	1	2	3	4	5
Other _____					

19. If your organization was given **access** to user-friendly Excel-based software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?

Not at all *Somewhat* *Very willing*

1 2 3 4 5

20. If your organization was given **access** to user-friendly web-based software to help implement optimization, how willing do you think your organization would be to adopt

optimization in the future?

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

21. If your organization was given **access to** *AND* **training for** user-friendly software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?

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

LSP Section

22. Do you numerically score benefits of the conservation projects?

a. Yes
b. No

23. If you answered yes to 50, how well do the numeric scored benefits reflect on the ground reality?

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

Logic Scoring of Preference (LSP) is a scientifically rigorous technique to design project selection criteria and weightings and ensure that the benefits calculated accurately reflex the desired intent of decision makers.

24. Have you heard XXXX speak about LSP previously?

a. Yes
b. No

25. If yes, to question 55, how much do you remember?

Nothing		*Some*		*Most*
1	2	3	4	5

26. Have you heard read something by XXXX about LSP previously?

a. Yes
b. No

27. If yes, to question 50, how much do you remember?

Nothing		*Some*		*Most*
1	2	3	4	5

28. How well do you think you understand LSP overall?

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

29. In general, do you think LSP is a good idea?
   a. Yes
   b. No, If no why not? _____

30. Do you think LSP is applicable to your program?
   a. Yes
   b. No
   c. Not sure

31. How willing do you think your organization would be to adopt LSP as the selection process for your conservation program in the future?

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

About your organization

32. How many years have you worked for this organization?_____

33. Your current job title:_____

34. How many years have you been employed in this position?_____

35. What type of organization/agency do you work for? (circle one)
   a. Federal agency
   b. State agency
   c. Local agency
   d. National non-profit organization
   e. Regional non-profit organization
   f. Local non-profit organization
   g. Consulting business
   h. Other business_____
   i. Other _____

36. What projects are of primary concerns for your organization/agency? Check all that apply.
   □ Farmland conservation
   □ Historic conservation
   □ Forest conservation
   □ Open space conservation
   □ Park development
   □ Water protection

□ Wildlife preservation
□ Military readiness
□ Other _____

37. How many new projects investments does your organization make per year?
_____

38. Where are the primary activities of your agency/organization in the United States? (circle all that apply)
a. Northeast
b. South
c. Midwest
d. Mid-Atlantic
e. West
f. International
g. Other _____
h. Not applicable

39. How many employees (full-time equivalents) has your organization employed in each of the following years:
2011 _____
2012 _____
2013: _____

40. What have been the *annual* project budgets for your organization in each of the following years:
2011 $_____
2012 $_____
2013: $_____

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

42. Would you like to be contacted to learn more about optimization?
a. Yes
b. No

43. Would you like to be contacted to learn more about LSP?
a. Yes
b. No

Thank you very much for your participation.

Appendix B – Sample Short Survey

XXX is conducting a research study on conservation programs and attitudes towards applying optimization. The purpose of the survey is to figure out how conservation professionals have responded to the use of optimization in a variety of environmental contexts. The survey should take five to ten minutes to fill out. Participation is completely voluntary and all information will be kept confidential.

Attitudes Towards Adoption of Optimization in Conservation Planning

1. Your name:_____

2. Please rate the following criteria in terms of importance:	**Low**		**Medium**		**High**
Knowledge of staff on how to use your selection process to identify good projects	1	2	3	4	5
Fairness to applicants	1	2	3	4	5
Transparency (ease of explanation to public, advisory board, potential applicants, etc.)	1	2	3	4	5
Cost-effectiveness (achieve the largest possible social benefit for a relatively low price)	1	2	3	4	5
Ease of administration	1	2	3	4	5

Optimization is a branch of economics and operations research studies that has shown conservation professionals how to get more projects conserved within a constrained budget or achieve the same projects with a smaller budget. Optimization involves a set of mathematical programming algorithms from operations research, such as binary linear programming and goal programming. It is a process of including both monetized benefit information and acquisition costs to identify projects that provide a high level of aggregate benefits at the best possible price ('getting the most bang for the buck'). 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 maximizing the effectiveness of limited financial resources

3. How well do you think you understand optimization overall?

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

4. In general, do you think optimization is a good idea?

a. Yes

b. No*, If no why not?* _____

5. How willing do you think your organization would be to adopt optimization as the selection process for your conservation program in the future?

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

6. Assess the difficulty of the following potential obstacles for adopting optimization as the selection process in your organization's conservation program:	**Not Difficult**		**Somewhat**		**Very Difficult**
Lack of previous experience	1	2	3	4	5
Need for accurate cost information at the time of selection	1	2	3	4	5
Initial cost of technical resources costs (software and staff training)	1	2	3	4	5
Lack of incentives to justify a change in processes	1	2	3	4	5
Possibly forgoing the 'best' project regardless of cost	1	2	3	4	5
Difficulty in measuring benefits	1	2	3	4	5

7. If your organization was given **access** to user-friendly software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?

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

8. If your organization was given **access** AND TRAINING to user-friendly software to help implement optimization, how willing do you think your organization would be to adopt optimization in the future?

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

9. Would you like to be contacted to learn more about optimization?

a. Yes
b. No

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