Understanding and Overcoming the Barriers for Cost-Effective Conservation

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 through an international survey of conservation professionals who are familiar with cost-effective conservation techniques. The primary results of this study, replicate previous results from a smaller of agricultural preservation professionals, and 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 reinforce the idea that advocates of cost-effective conservation need to address concerns about fairness and transparency and remedy 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.

Keywords: Cost-effective conservation; Replication; Conservation professionals; Conservation planning; Optimization

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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). CEC is a project-selection process that incorporates *both* benefits and costs to maximize the conservation outcomes generated by available funds (see for instance, Underhill, 1994; Babcock et al., 1997; Balmford et al., 2000; Polasky et al., 2001; 2006; Sarkar et al., 2006). 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) and its application is limited. This lack of application is perplexing to economics, which has a core principal of studying the behavior given limited resources. Previous work by Messer et al. (2016a) suggests that part of the problem is that conservation professionals do not consider cost effectiveness a priority and lack incentives to adopt new practices that could improve the cost effectiveness of conservation efforts. This research seeks to replicate the approach used by Messer et al. (2016a) by expanding the sample to an international group of professionals engaged in a variety of conservation activities. This research thus addresses the question of why conservation practitioners, who have dedicated their professional lives to environmental conservation, have not adopted cost effective selection techniques that would enable limited budgets to be further stretched to achieve greater environmental benefits.

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 (Babcock et al., 1997, Messer and Borchers, 2015). 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, Wu et al., *forthcoming*). 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; Duke et al. 2015). In most cases, CEC and BCT will yield identical selection sets, except in cases involving large budget remainders (Duke et al., 2013; Messer 2006). For instance in the context of farmland conservation, Wang and Swallow 2016 found that BCT and optimization yielded very similar outcomes when focusing on associated benefits and costs, parcel numbers, and number of acres. These authors note that when a government or agency wants to achieve more specific goals optimization is usually better than BCT. 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 to achieve CEC.

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. Gardner (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 amenities 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. 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.

Messer et al. (2016a) surveyed agricultural land professionals in Maryland and found that conservation professionals value transparency and fairness more than cost-effectiveness. This study seeks to replicate this earlier research by expanding the sample by surveying conservation professionals from organizations that have a variety of conservation objectives, not just agricultural preservation. Additionally, this study includes a broader sample of geographic regions including conservational professionals who work in international contexts. This research also helps address the so-called “replication crisis” in behavioral and social sciences. A growing number of scholars have expressed concerns that published results in the behavioral sciences, including economics, are frequently false (Ioannidis and Doucouliagos, 2013). Replication is a cornerstone of science (Moonesinghe et al., 2007) and is something that needs to occur more often in peer-reviewed articles (Hamermesh, 2007). Replication is particularly important in the context of research that has policy implications.

This study also contributes to the literature about the gap between the practices of conservation professionals and the recommendations of researchers interested in CEC. 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. We designed this study 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 determine what, if anything, can be done to overcome them.

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 CEC is the lack of incentives to change existing programs as respondents seem to receive little public pressure to be cost-effective nor receive additional recognition or financial award 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

We developed the survey using the 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 Appendix A for the organizations represented by the participants) was derived from attendance lists of 47 presentations that were made at the National Conservation Training Center, the Land Trust

137 Alliance Rally, the American Farmland Trust conference, and offices of nonprofit and
138 government agencies.¹

139 Since the sample population came from people who had previously attended lectures on
140 CEC techniques, this sample is certainly not a representative sample of all conservation
141 professionals worldwide. Instead, we selected this sample because it helps address the question
142 of why, even once educated about the virtues and techniques of cost effective, conservation
143 professionals are not adopting these approaches. Consequently, this research can move beyond
144 the simple explanation that conservation professionals are not adopting these approaches because
145 they are do not know they exist, but can instead dig deeper about what organizational and
146 attitudinal barriers continue to exist to CEC.

147 The recruitment process consisted of emailing a surveythat consisted of 43 questions
148 to246 individuals. To encourage people to respond to the survey, we incentivized participation
149 in the form of a raffle of one \$250 Amazon gift cards and four \$50 Amazon gift cards.
150 Recipients of the gift cards were to be chosen randomly after the survey had been completed.All
151 respondents were also offered the opportunity to donate the money to a nonprofit organization of
152 their choice, this option was made available as we anticipated that some government employees
153 would not be able to receive direct financial payment, but might still be motivated to participate
154 by donating the money.

155 We based the survey structure on Dillman's (1978) Total Design Method, which focuses
156 on follow-up reminders.One week after the initial email, we sent a reminder email to anyone
157 who had not yet responded and included the 43-question survey (Appendix B). The following

¹ Note that this study design differs from that of Messer et al. (2016a), which surveyed people shortly after seeing a presentation about cost effective conservation.

week, we sent a second reminder email to all non-responders again asking them to participate in the full-length 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. For people who did not respond to the longer survey after several attempts, we sent a shorter version of the survey (Appendix C). This version covered the main questions of our research and focused on how willing conservation professionals were to adopting optimization and what obstacles inhibit them from adopting this technique.

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 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.

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 (knowledge of the staff in how to use the selection process to identify good projects);
- (2) Fairness (fairness to applicants);
- (3) Transparency (ease of explanation to public, advisory board, potential applicants, etc.);
- (4) Cost-effectiveness (achieve the largest possible social benefit for a relatively low price), and
- (5) Ease (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

200 differences between fairness and cost-effectiveness ($p=0.021$). In addition, there are statistical
201 significant differences between transparency and cost-effectiveness ($p=0.014$). Other differences
202 in means between the criteria were found to not be statistical significant.

203

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 Table1. 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 paired t-test was used to evaluate the difference in the means of lack of incentive and lack of previous experience. This difference was statistically significant at the 0.01 level.

Table 1. 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 (<u>Lack Incentives</u>)	3.55	1.236
Initial cost of technical resources costs (software and staff training) (<u>Initial Cost</u>)	3.49	1.227
Difficulty in measuring benefits (<u>Measure Benefits</u>)	3.27	1.117
Possibly forgoing the ‘best’ project regardless of cost(<u>Forgo Best Project</u>)	3.23	1.047
Need for accurate cost information at the time of selection(<u>Need Cost Information</u>)	3.19	1.110
Administration of the process(<u>Administration Process</u>)	3.14	1.150
Lack of availability of technical resources(<u>Lack Technology</u>)	3.14	1.285
Time to implement the process(<u>Time to Implement</u>)	3.09	1.149
Due to Federal guidelines/ restrictions(<u>Process Not Staff Determined</u>)	3.05	1.420
Lack of previous experience(<u>Lack of Experience</u>)	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 2). This result demonstrates an important avenue by which adoption of optimization techniques could be increased, allowing conservation organizations to be more cost-effective.² Results of two tailed paired t-tests, showed statistically significant increases in willingness to adopt in response to

² To our knowledge, no environmental or conservation foundation or funder is currently providing this type of training.

226 access to such resources. There was no statistical significance between an Excel-based platform
227 or an internet- based optimization platform ($p=1.0$). We found that all types of resources were
228 significantly different from willingness to adopt with no resources. Furthermore, we find there are
229 statistically significant differences between access to training and software (Training Access)
230 and only given access to an Excel based platform (Excel Access) ($p=0.003$). In addition, we
231 found that there is a statistical significant difference between Training Access and access to an
232 web based platform (Web Access) ($p<0.001$). Lastly, we also find there are statistical significant
233 differences between given only access to software (Software Access) and being given access to
234 software and training (Training Access) ($p<0.001$).
235

236 **Table 2. Willingness to Adopt Optimization**

Variable	Survey Question	Mean	Standard Deviation
<u>Willingness to Adopt Optimization</u>	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
<u>Excel Access</u>	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
<u>Web Access</u>	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
<u>Software Access</u>	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
<u>Training Access</u>	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. Ordered probit models were used to analyze the relationships between willingness to adopt optimization and independent variables. As shown in Table 3, we conducted two models, Model 1 looks at the willingness to adopt optimization and eight independent variables. Model 2 includes variables related to the difficulty in measuring benefits, organizational variables, and the likelihood of adoption the Logic Scoring of Preferences (LSP) to help quantify benefits.

LSP is a technique originally developed in computer science to help develop project selection criteria and corresponding weightings. LSP incorporates fundamental properties of human reasoning and seeks to develop a means for measuring project benefits in a way that corresponds to the intent of decision makers (Dujmović, 2007, Allen et al., 2011). Since questions about organization type, LSP and benefit measures were not included in the short survey, Model 2 has a smaller sample size. The data set for the analysis consisted of observations, from respondents who had some previous knowledge of optimization.

In Model 1, we estimate the impact of eight independent variables on conservation professionals' willingness to adopt optimization. The independent variables in Model 1 are Understand Optimization, Lack Incentives, Lack Experience, Initial Cost, Staff knowledge, Fairness Importance, Transparency Importance, and Forgo Best Project. The Understand Optimization variable is the response to the question that asked respondents to rate their understanding of optimization from 1 (not at all) to 5 (very well). We included these independent variables in the model, because we expected them to have an impact on conservation professionals' willingness to adopt optimization. For instance, as the understanding

260 of optimization increases (Understand Optimization), we would expect to observe a greater
 261 willingness to adopt optimization.

262 All seven other independent variables included in the model came from a survey question
 263 asking respondents to rate each item on a scale of 1 (not difficult / not very important) to 5 (very
 264 difficult / very important). The Lack Incentives variable addresses the perceived difficulty of
 265 changing the project selection process to optimization due to a lack of incentive to justify this
 266 switch. We expect that having a lack of incentive to change will be common in government
 267 organizations and will decrease the likelihood of adopting optimization. The Lack
 268 Experience variable addresses the perceived difficulty of adopting optimization due to lack of
 269 previous experience using this method. Similarly, we expect if lack of experience is a large
 270 obstacle, then there will be less willingness to adopt optimization. The Initial Cost variable
 271 addresses the potential that participants perceive CEC optimization as being more expensive for
 272 the organization due to the costs of staff training and related software. We expect to see initial
 273 cost of technical resources to be a significant reason why conservation professionals are not
 274 adopting optimization. The Staff Knowledge Importance variable addresses how important it is
 275 that the staff understand how to use the selection process. The Fairness Importance variable
 276 addresses how important fairness to applicants is for selection process. We expect willingness of
 277 adoption to increase if fairness is an important criterion to many conservation professionals.
 278 The Transparency Importance variable addresses how important transparency is for selection
 279 process. The concept of transparency was explained to the survey respondents as the ease of
 280 explanation to the public, advisory board, and potential applicants. Since optimization generally
 281 does not take into account transparency, we expect willingness of adoption to decrease if
 282 transparency is an important criterion. The Forgo Best Project variable addresses the perceived

283 difficulty of adopting optimization since, unlike Benefit Targeting, optimization can frequently
284 forgo the highest scoring conservation project, especially when those projects have relatively
285 high costs. We expect that conservation professionals will be reluctant to forgo high costs,
286 especially those facing imminent development (Messer and Borchers, 2015), therefore this
287 would be an obstacle for adopting CEC.

288 As shown in Model 1 in Table3, six of the independent variables were significant at the
289 5% level. Four independent variables positively affect willingness to adopt optimization, while
290 two have a negative impact. We will begin discussing the variables with positive coefficients.

291

292 **Table 3. Ordered Probit Regressions on Willingness to Adopt Optimization.**

	Model 1	Model 2
<u>UnderstandOptimization</u>	0.591*** (0.126)	0.592*** (0.163)
<u>LackIncentives</u>	-0.533*** (0.128)	-0.504*** (0.200)
<u>LackExperience</u>	-0.018 (0.148)	0.095 (0.184)
<u>InitialCost</u>	0.0895 (0.097)	0.130 (0.154)
<u>StaffKnowledgeImportance</u>	0.364** (0.171)	0.309 (0.190)
<u>FairnessImportance</u>	0.285* (0.119)	0.285 (0.154)
<u>TransparencyImportance</u>	-0.541*** (0.225)	-0.635** (0.262)
<u>Forgo Best Project</u>	0.293** (0.139)	0.322 (0.227)
<u>Measure Benefits</u>		-0.374** (0.159)
<u>Willingness to Adopt LSP</u>		0.486** (0.235)
<u>Local Government</u>		-.865 (.454)
<u>Federal Government</u>		-.548 (.578)
<u>State Government</u>		-.121 (.719)
<u>Non-Profit</u>		-.985* (.484)
Observations	73	51
Pseudo R2	.212	.352
Wald chi-square (10)	54.01	
Wald chi-square (14)		63.82
Prob > chi-square =	0.0000	0.0000

Notes: *signifies significant at 10% level. **signifies significant at 5% level. ***signifies significant at 1% 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.

Second, respondents who emphasized staff knowledge of the selection process(StaffKnowledgeImportance)aremore willing to adopt optimization. In the survey, the average rating of staff knowledge importance was 4.07. Thus, respondents seemed to be relatively confident that their organizations could easily learn to incorporate optimization by teaching their staff about the selection process.

Third, respondents who emphasized a fair process as important (Fairness Importance) (average rating was 4.23) were more willing to adopt optimization. In this context, fairness to applicants can be definedas the organization showing no bias and have the conservation project given the same consideration to each project and applicant. 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 (ForgoBestProject). This suggests a rather contradictory idea that the less willing they were to forego the best available projects, the more likely respondents were to adopt optimization.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 (LackIncentives) to switch and transparency of the process (TransparencyImportance) 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 3 also reports on a second model that includes variables related to the difficulty in measuring benefits, organizational type, and the likelihood of adoption LSP to help quantify benefits. Several of the results of Model 2 are similar to those shown in Model 1; and the overall explanatory power of Model 2 rose by 14% compared to Model 1. In Model 2, the coefficient for the variable related to the difficulty of measuring benefits was statistically significant and negative at the 5% 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 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). In Model 2, the variables related to staff knowledge and the importance of fairness are no longer statistically significant. Finally, the coefficient for *Non-Profit* was negative and significant at the 0.01 level. This suggests professionals who work for non-profit organizations are less likely to adopt optimization, likely due to the fact that non-profit organizations tend to be donation driven

and do not have the pools of yearly funds available to select amongst a variety of available projects.

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). This lack of application is perplexing to economics, which has a core principal of studying the behavior given limited resources. In response to this situation, 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. The advantage of this sample is that it enabled the research to focus on a group of education conservation professionals that has otherwise not been studied; however, this sample does limit the generalizability of the results to the broader conservation professionals who have not attended trainings. Future research on this broader population and what is inhibiting these professionals from adopting cost effective conservation is warranted.

Similar to the results found in Messer et al. (2016a), in this study 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 also replicate the findings of Messer et al. (2016a) that 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. The replication of the results of the earlier study, suggests that these findings are robust and 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.

406

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496 **Appendix A - Conservation Organizations Surveyed**

497

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. InstitutoAção VerdeInstitute Aí_ífo 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

Appendix B –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

Somenwhat 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

540

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

541

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

542

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)	1	2	3	4	5

for a relatively low price)					
Ease of administration	1	2	3	4	5
Other					

543

544 **Optimization** is a branch of economics and operations research studies that has shown
545 conservation professionals how to get more projects conserved within a constrained budget or
546 achieve the same projects with a smaller budget. Optimization involves a set of mathematical
547 programming algorithms from operations research, such as binary linear programming and goal
548 programming. It is a process of including both monetized benefit information and acquisition costs
549 to identify projects that provide a high level of aggregate benefits at the best possible price ('getting
550 the most bang for the buck'). The optimization model evaluates each of the possible sets of available
551 projects and selects the set that maximizes the aggregate conservation benefits given a specified
552 budget maximizing the effectiveness of limited financial resources

553 9. Have you heard XXXX speak about optimization previously?

554 a. Yes

555 b. No

556

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

558 *Nothing* *Some* *Most*

559 1 2 3 4 5

560 11. Have you heard read something XXXX about optimization previously?

561 a. Yes

562 b. No

563

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

565 *Nothing* *Some* *Most*

566 1 2 3 4 5

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

568 *Not at all* *Somewhat* *Very well*

569 1 2 3 4 5

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

571 *Not at all* *Somewhat* *Very well*

572 1 2 3 4 5

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

574 a. Yes

575 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?

596	<i>Not at all</i>		<i>Somewhat</i>		<i>Very willing</i>
597	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?

602	<i>Not at all</i>		<i>Somewhat</i>		<i>Very willing</i>
603	1	2	3	4	5

605 **LSP Section**

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

- 607 a. Yes
608 b. No

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

612	<i>Not at all</i>		<i>Somewhat</i>		<i>Very well</i>
613	1	2	3	4	5

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

618 **24.** Have you heard XXXX speak about LSP previously?

- 619 a. Yes
620 b. No

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

623	<i>Nothing</i>		<i>Some</i>		<i>Most</i>
624	1	2	3	4	5

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

- 627 a. Yes
628 b. No

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

631	<i>Nothing</i>		<i>Some</i>		<i>Most</i>
632	1	2	3	4	5

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

635 *Not at all* *Somewhat* *Very well*

636 1 2 3 4 5
637

638 **29.** In general, do you think LSP is a good idea?

639 a. Yes

640 b. No, If no why not? _____

641

642 **30.** Do you think LSP is applicable to your program?

643 a. Yes

644 b. No

645 c. Not sure

646

647 **31.** How willing do you think your organization would be to adopt LSP as the selection
648 processfor your conservation program in the future?

649 *Not at all*

Somewhat

Very willing

650 1 2 3 4 5

651

652 **About your organization**

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

654

655 **33.** Your current job title: _____

656

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

658

659 **35.** What type of organization/agency do you work for? (circle one)

660 a. Federal agency

661 b. State agency

662 c. Local agency

663 d. National non-profit organization

664 e. Regional non-profit organization

665 f. Local non-profit organization

666 g. Consulting business

667 h. Other business _____

668 i. Other _____

669

670 **36.** What projects are of primary concerns for your organization/agency? Check all that apply.

671 ☐ Farmland conservation

672 ☐ Historic conservation

673 ☐ Forest conservation

674 ☐ Open space conservation

675 ☐ Park development

676 ☐ Water protection

677 ☐ Wildlife preservation

- 678 ☐ Military readiness
 679 ☐ Other _____

680
 681 **37.** How many new projects investments does your organization make per year?
 682 _____
 683

684 **38.** Where are the primary activities of your agency/organization in the United States? (circle all
 685 that apply)

- 686 a. Northeast
 687 b. South
 688 c. Midwest
 689 d. Mid-Atlantic
 690 e. West
 691 f. International
 692 g. Other _____
 693 h. Not applicable
 694

695 **39.** How many employees (full-time equivalents) has your organization employed in each of the
 696 following years:

697 2011 _____
 698 2012 _____
 699 2013: _____

700 **40.** What have been the *annual* project budgets for your organization in each of the following
 701 years:

702 2011 \$ _____
 703 2012 \$ _____
 704 2013: \$ _____
 705

706 **41.** Are there any other thoughts you would like to share with us concerning your organization's
 707 current selection process, or the optimization selection process?
 708

709 **42.** Would you like to be contacted to learn more about optimization?

- 710 a. Yes
 711 b. No
 712

713 **43.** Would you like to be contacted to learn more about LSP?

- 714 a. Yes
 715 b. No
 716

717 *Thank you very much for your participation.*
 718

Appendix C –Short 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. 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?