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Understanding and Overcoming the Barriers for Cost-effective Conservation

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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 sample 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.

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, Naidoo et al., 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; Naidoo et al., 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., 2017).

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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. Pullin 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 (Qualtrics, Provo, UT). We identified valid email addresses 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 Alliance Rally, the American Farmland Trust conference, and offices of nonprofit and government agencies.[1].

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

The recruitment process consisted of emailing a survey that consisted of 43 questions to 246 individuals. To encourage people to respond to the survey, we incentivized 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 (Appendix B). The following 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

[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.

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 Fig. 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.

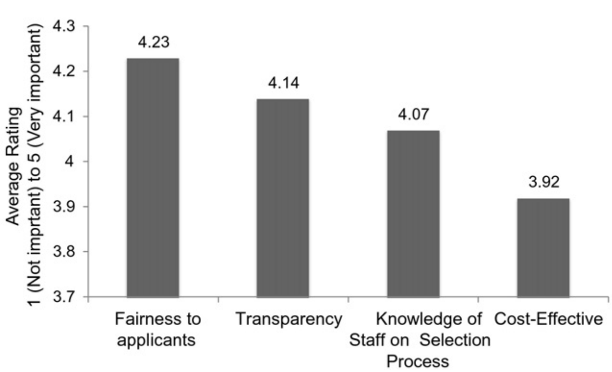

Fig. 1. Importance of criteria in the project selection process.

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 ($p = 0.014$). Other differences in means between the criteria were found to not be statistical significant.

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 1. 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 1% level.

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 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) ($p < 0.001$).

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

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

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 adopting 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

[a] Statistically significantly different from all other variables at the 5% level.

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

All seven other independent variables included in the model came from a survey question asking respondents to rate each item on a scale of 1 (not difficult/not very important) to 5 (very difficult/very important). The Lack Incentives variable addresses the perceived difficulty of changing the project selection process to optimization due to a lack of incentive to justify this switch. We expect that having a lack of incentive to change will be common in government organizations and will decrease the likelihood of adopting optimization. The Lack Experience variable addresses the perceived difficulty of adopting optimization due to lack of previous experience using this method. Similarly, we expect if lack of experience is a large obstacle, than there will be less willingness to adopt optimization. The Initial Cost variable addresses the potential that participants perceive CEC optimization as being more expensive for the organization due to the costs of staff training and related software. We expect to see initial cost of technical resources to be a significant reason why conservation professionals are not adopting optimization. The Staff Knowledge Importance variable addresses how important it is that the staff understand how to use the selection process. The Fairness Importance variable addresses how important fairness to applicants is for selection process. We expect willingness of adoption to increase if fairness is an important criterion to many conservation professionals. The Transparency Importance variable addresses how important transparency is for selection process. The concept of transparency was explained to the survey respondents as the ease of explanation to the public, advisory board, and potential applicants. Since optimization generally does not take into count transparency, we expect willingness of adoption to decrease if transparency is an important criterion. The Forgo Best Project variable addresses the perceived difficulty of adopting optimization since, unlike Benefit Targeting, optimization can frequently forgo the highest scoring conservation project, especially when those projects have relatively high costs. We expect that conservation professionals will be reluctant to forgo high costs, especially those facing imminent development (Messer and Borchers, 2015), therefore this would be an obstacle for adopting CEC.

As shown in Model 1 in Table 3, six of the independent variables were significant at the 5% level. Four independent variables positively affect willingness to adopt optimization, while two have a negative impact. We will begin discussing the variables with positive coefficients.

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 (Staff Knowledge Importance) are more 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 defined as 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 (Forgo Best Project). 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

Table 2
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

Table 3
Ordered probit regressions on willingness to adopt optimization.

	Model 1	Model 2
Understand Optimization	0.591[c] (0.126)	0.592[c] (0.163)
Lack Incentives	−0.533[c] (0.128)	−0.504[c] (0.200)
Lack Experience	−0.018 (0.148)	0.095 (0.184)
Initial Cost	0.0895 (0.097)	0.130 (0.154)
Staff Knowledge Importance	0.364[b] (0.171)	0.309 (0.190)
Fairness Importance	0.285[a] (0.119)	0.285 (0.154)
Transparency Importance	−0.541[c] (0.225)	−0.635[b] (0.262)
Forgo Best Project	0.293[b] (0.139)	0.322 (0.227)
Measure Benefits		−0.374[b] (0.159)
Willingness to Adopt LSP		0.486[b] (0.235)
Local Government		−0.865 (0.454)
Federal Government		−0.548 (0.578)
State Government		−0.121 (0.719)
Non-Profit		−0.985[a] (0.484)
Observations	73	51
Pseudo R2	0.212	0.352
Wald chi-square (10)	54.01	
Wald chi-square (14)		63.82
Prob > chi-square =	0.0000	0.0000

[a] Signifies significant at 10% level.
[b] Signifies significant at 5% level.
[c] Signifies significant at 1% level.

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 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 statistical 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 1% 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.

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Appendix A. 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

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