Indices in a Multi-Objective Program: Experience and Design in U.S. Conservation Programs

Over the last 20 years, the Federal Government has established a number of agricultural land conservation programs. While these programs do not seek the exact same types of environmental improvements, the goal of achieving multiple objectives within the confines of a single program is widespread. Multi-objective programs include the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP), which seek environmental improvements by retiring farmland; the Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP), which are designed to improve environmental outcomes on "working" agricultural lands; and the Farm and Ranch Lands Protection Program (FRPP), which seeks to prevent the loss of environmental resources to nonagricultural uses.

Experience in U.S. Conservation Programs

Conservation programs continue to rely on voluntary participation, and producer interest in participating continues to outpace budgetary outlays or acreage constraints. The need for methods to select among applicants in multi-objective programs likewise continues.

Many Federal conservation programs seek to achieve multiple objectives, but not all use the same mechanism for choosing between competing offers (table 2.1). For example, in most multi-objective programs, program managers use a "parcel selection index" to target enrollments on the basis of environmental benefits and costs. In the CSP, however, the concept of an index is embodied in the use of benefits-based payments (higher payment rates for producers providing greater levels of environmental benefits).

Even when programs use a parcel-selection index in some fashion, the elements of the indices can vary. For example, as a component of the CRP's environmental benefits index (EBI), cost directly affects the selection of land for enrollment. Conversely, cost is not an explicit factor in selecting lands into the CSP, though it does serve to limit overall program size. Also, while several programs focus on the same type of environmental resource (improving water and soil quality, for example), some have standards for reducing environmental degradation while others (i.e., the CSP) seek improvements beyond those standards. These uses of indices have been supplemented through geographic targeting and other mechanisms to enhance the ability of the programs to achieve multiple objectives (app. A).

Differences in program structure can give rise to the use of multiple indices within a single program. For example, decentralized programs such as EQIP and FRPP use indices in a two-step process. First, Federal program managers use a "budget allocation" index to allocate the Federal budget to various States. This index can incorporate a number of factors, such as

Table 2.1
Using Indices To Balance Objectives in Major U.S. Conservation Programs

Program	Program objectives	How objectives are balanced
Conservation Reserve Program	1985-89: Reducing soil erosion	1985-1989: Applications were approved on the basis of ability to reduce soil erosion.
	1990-present: Providing wildlife benefits, improving water quality, reducing soil erosion, providing enduring benefits, improving air quality, clustering in priority areas, and providing cost savings.	1990-present: Environmental benefits index (EBI) used to target enrollments on the basis of multiple environmental objectives and cost.
Environmental Quality Incentives Program	Reducing soil erosion, improving water quality, providing wildlife benefits, and improving air quality on working agricultural lands.	One index is used to allocate program funds to States; State (and county, in some cases) indices are used to target enrollments on the basis of multiple environmental benefits. Some States also consider cost.
Conservation Security Program	Improving soil quality, water quality, air quality, wildlife habitat, and energy on working agricultural lands.	Enrollment categories are used to rank applicants, where soil quality and conservation *effort* determines category assignment. Also, benefits-based payments embody the index concept by paying higher payments to producers who adopt more conservation practices.
Wetlands Reserve Program	Increasing wetland functions and values, including wildlife habitat.	One index is used to allocate program funds to States, on the basis of ecological concerns, State performance, producer interest, and cost. State indices are used to target enrollments on the basis of wetland benefits and program costs.
Farm and Ranch Lands Protection Program	Preventing the loss of prime agricultural land and important topsoil to nonagricultural uses (primarily urban uses).	One index is used to allocate program funds to States, partly on the basis of recent rates of farmland loss, program costs, and States' performance. State and local entities use indices to target enrollments based on environmental measures, farmland management efforts, development pressure, and location.

State-level measures of environmental resources and data on past performance of State-level programs. Second, State and local program managers typically use a multi-objective parcel selection index to prioritize and select offers. These parcel selection indices can prioritize offers on the basis of parcel-level environmental characteristics (e.g., percent of prime or erosive soils), implementation costs, and other factors.

Designing an Index

Program managers use indices in multi-objective conservation programs to weigh the different environmental concerns of interest. Each index computes, for each producer's offer to enroll land in the program, a score that can be used to rank the offers. However, from a program-design perspective, weighing the environmental concerns and computing an offer's score are simply the final steps of the process. Developing an index that

allows multidimensional information to be aggregated into a single summary number requires the following steps:

1) *Choice of objectives*—Clearly defined program objectives form the basis of the index. These objectives can include environmental objectives, such as reducing soil erosion, and economic objectives, such as minimizing program costs.

2) *Choice of indicators*—For each program objective, quantifiable variables must be defined to measure the likely environmental or cost impact of an offer. For example, for wildlife benefits, indicators may include the diversity of species planted for wildlife habitat or the number of endangered species that are expected to benefit from a given combination of lands and practices that producers offer for enrollment. Cost impacts are measured based on monetary measures of different land/practice combinations.

3) *Assignment of unit values for each of the indicator variables*—These values could be represented in physical units (tons, acres, etc.) or through a relative scale for the indicator (a 0 to 100 percent range). For example, the wildlife habitat benefits from planting cover crop X might achieve 75 percent of the wildlife benefits provided by the best possible cover crop.

4) *Choice of weights*—Weights signal tradeoffs. A decision must be reached in terms of the relative importance of different program objectives.

5) *Choice of functional form used for index*—The functional form is used to aggregate the indicator variables for an offer into a single value. Any given functional form represents how different objectives combine to yield an overall value. Different functional forms can yield different orderings from the same underlying set of environmental concerns and weights. To be useful, the ordering represented by the index needs to be unambiguous.[1]

Using these steps, the score for an offer using an additive functional form can be calculated as:

Score (for offer i) = $(w_1 * x_1) + (w_2 * x_2) + (w_3 * x_3) + (w_4 * x_4)$ ...

The *x*'s represent the indicator variables expressed in unit values, and the *w*'s are the weights assigned to the associated environmental concern.

Illustrative example: The effect of index weights on program outcomes depends on linkages between environmental resources

In Chapter 1, we described how environmental resources can be linked – either as "complements," so that improvements to one resource lead to improvements in the other, or as "substitutes," for which improvements to one resource have no impact or a negative impact on the other. Understanding what type of linkages exist between resources is an important part of designing an index because they affect what type of response

[1] Avoiding ambiguity requires the ordering to be invariant to the choice of units. Ebert and Welsch (2004) identify the conditions under which an environmental index provides an unambiguous ordering. One of their major findings is that indices in the form of a weighted geometric mean (Cobb - Douglas type – e.g., Total Score = $x_1^{w_1} \cdot x_2^{w_2} \cdot x_3^{w_3} \cdot x_4^{w_4}$ ... where x_{1-4} are indicator variables and w_{1-4} are the weights assigned to the environmental concern) are generally preferable to those obtained using a weighted arithmetic mean.

occurs when program managers set up or change index weights—and, importantly, whether complementary relationships may be strong enough to contribute to unintentional weighting of a resource objective in excess of the weight that is directly assigned to that objective. As the next several figures demonstrate, outcomes may be more predictable in response to a weight change if resources are complements, but may be less so if resources are substitutes.

Figure 2.1 illustrates how the choice of weights in an index affects which offers, or producer applications, a program manager accepts for enrollment in a multi-objective program. The hypothetical program aims to reduce both soil erosion and excess nitrogen from agricultural production. Producers make decisions about what land to enroll and what practices to offer to implement. Each dot in the figure represents a producer's offer to participate in the program, with its horizontal position in the graph determined by the per acre nitrogen and its vertical position determined by the erosion reduction of the proposed land/practice combination (we assume all offers have the same cost). With an additive functional form, the score for application i is: $Score_i = (w_N * x_{N_i}) + (w_E * x_{E_i})$. The weights assigned to the two environmental concerns determine the slope of the "cutoff line" ($slope = w_E / w_N$) separating accepted offers (white dots) from those that are rejected. The position of the line will depend on the available budget: with a limited budget, only those offers providing the most erosion reduction and the most nitrogen reduction will be accepted (the dots farthest from the origin). Increasing the budget (shifting the line down) allows more offers to be accepted (grey dots).

How the offers (the sets of dots) are distributed in the graph will depend on whether the two objectives are complements or substitutes. The greater the amount of complementarity, the more the offers will be clustered about a

Figure 2.1

Tradeoffs between environmental outcomes and weights
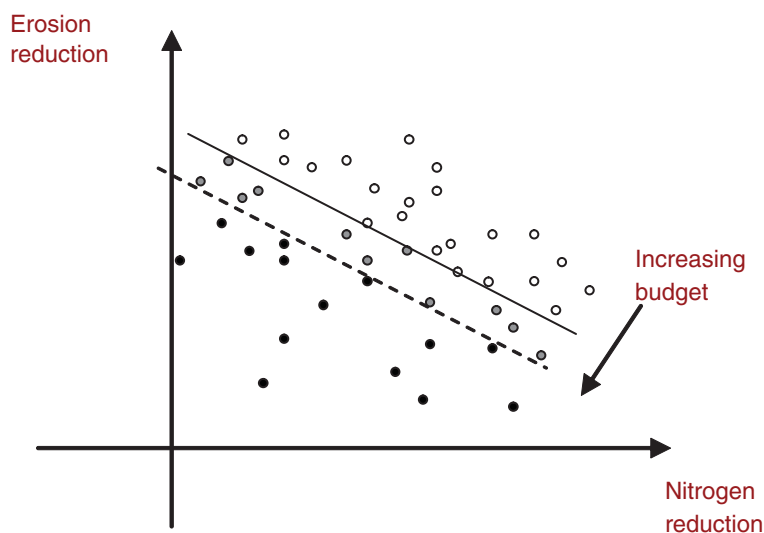
Notes: Each offer (point) is assigned a score for nitrogen reduction and erosion reduction. White dots represent accepted offers.

Source: USDA, Economic Research Service.

ray extending from the origin. The left graph in figure 2.2 illustrates complementarity: for example, a proposed nutrient management plan may simultaneously reduce excess nitrogen and phosphorus.

The right graph illustrates the substitution that occurs when a proposed plan to reduce runoff from animal waste problems improves water quality but worsens air quality (from increased emissions). In such cases, the offers will tend to be spread out perpendicular to a ray from the origin.

These figures emphasize the importance of interdependency relationships in understanding the tradeoffs that may occur when index weights are changed (i.e., as the "cutoff line" is rotated). When resource objectives are comple-ments, even though some offers may be dropped and others accepted as a result of a change in weights, the environmental characteristics of the offers that are dropped and accepted are roughly similar. However, if the two objec-tives are substitutes, the offers that are dropped and those that are accepted can have quite different environmental characteristics, even for small changes in weights. That is, a small weight increase on the water quality objective could significantly increase the amount of water quality benefits obtained, but only at the expense of air quality benefits.

In a voluntary program, the willingness of eligible producers to partici-pate will be a determinant of program outcomes. The prior discussion assumed a fixed set of producer offers and examined how the weights assigned to each objective affect which offers are accepted. However, and possibly of greater importance, the weights may affect producers' incen-tives to submit offers. A producer's willingness to submit an offer in a program will depend, among other things, on the likelihood of being accepted—which depends on the weights assigned to the environmental concerns. For example, producers who are better positioned (due to loca-tion, land characteristics, management skills, etc.) to provide one benefit

Figure 2.2

Effect of weight change determined by the degree of complementarity between objectives
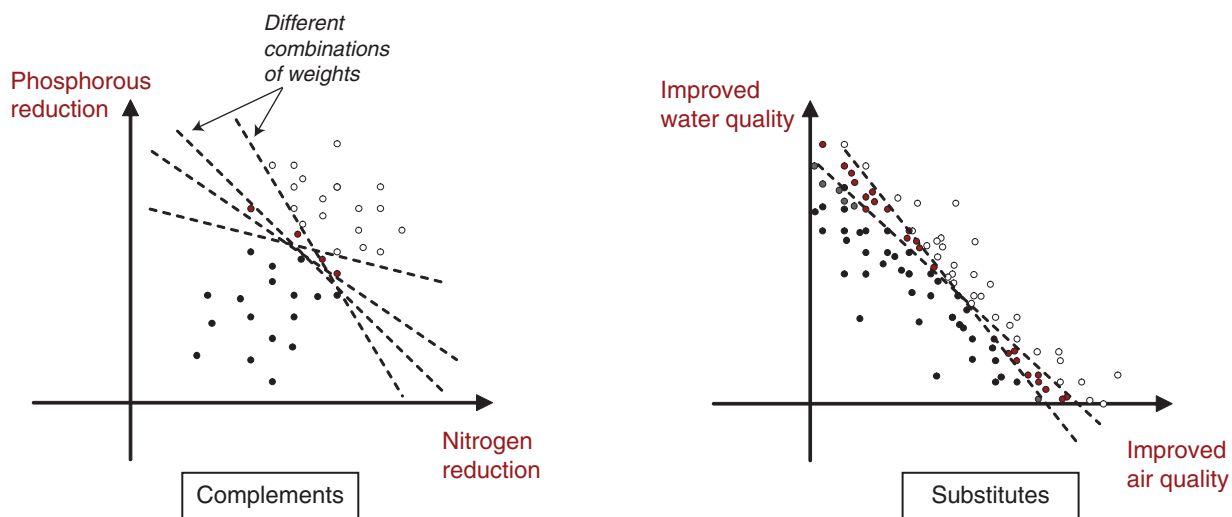
Source: USDA, Economic Research Service.

versus another may be more likely to offer land for enrollment if the weight assigned to that particular benefit is higher.

If these incentive effects matter[2] (meaning the weights affect the type of offers made), then analyzing the tradeoffs that occur when index weights are altered requires simulating the outcomes using models that predict what offers producers will submit as the vector of weights change.

[2]Incentive effects are greatest when producers face large transaction costs of making an offer. Basically, producers with low index scores may conclude that their offer is unlikely to be accepted, and will probably not take the time and expense to make an offer. They will only make an offer when a weight change increases their index score sufficiently. However, if the time and expense of making offers is minimal, producers who consider enrolling will always make an offer, regardless of their index score—and in this case, incentive effects will not be present even with large changes in weights.