Chapter 3

The CRP Balancing Act: The Sensitivity of CRP Outcomes to Changes in EBI Weights

In a voluntary conservation program, weights assigned to different environmental concerns in a selection index affect the mix of land ultimately enrolled through two distinct channels. First, they provide a guide for potential program participants in deciding which, if any, land to offer for enrollment and conservation practices to offer to adopt. The weights affect producer incentives by providing information on the likelihood that an offer will be accepted into the program and, thus, the expected returns from participation. Changes in these incentive effects may induce some current program applicants to not apply, while some who have not yet applied may make new offers to enroll land or adopt practices. The environmental and economic characteristics of this new group of offers can differ from previous groups—due to different land/practice combinations, and due to the complementarity or substitutability relationships among environmental concerns. Second, the weights provide program managers with a basis for choosing the parcels (from among those offered) to enroll. Intuition suggests that a program's environmental benefits and cost outcomes will be affected by changes in the weights through both of these channels. The question is, by how much?

Data on enrollments in the CRP help illustrate the tradeoffs between different environmental and economic concerns when different weights are assigned to those concerns. The CRP has retired nearly 34 million acres of cropland under 10-15 year contracts, making it USDA's largest conservation program. Approximately 95 percent of CRP acres are enrolled through "general" signups.[1] In general signups, offers from across the country are pooled. Program managers use an Environmental Benefits Index, or EBI, a national index that has one uniform set of objectives and weights, to rank all of the offers (app. A). The objectives in the EBI include soil erosion impacts, wildlife impacts, air and water quality impacts, and the requested payment. Program managers determine the relative importance of addressing these environmental and cost concerns (i.e., the implied weights) by establishing maximum attainable scores for each concern.

[1]The other 5 percent of acres are enrolled through noncompetitive "continuous" signups in which an index is not used.

Land is enrolled in the CRP in varying quantities and at different points in time, allowing for an analysis of the tradeoffs among environmental and economic concerns as index weights are altered. This analysis sheds light on the interdependency between environmental and cost concerns and the possible tradeoffs if changes in program priorities dictate a change in EBI weights. As outlined in table 3.1, this study included several analyses on how environmental and economic outcomes change under the following conditions:

- The weights assigned to different environmental concerns were altered in marginal (small) and nonmarginal ways.

Table 3.1
The analyses examining the sensitivity of CRP outcomes to changes in EBI weights

	Small signup	Large signup
Small change in weights	Scenario 1	Scenario 2
Large change in weights	Scenario 3	Scenario 4

Source: USDA's Economic Research Service.

- Weights were altered in different-sized enrollments; that is, when the number of acres enrolled was small (2 million acres, the size of the recent 26th signup) and large (33 million acres, about the total number of acres enrolled in CRP general signups).

- "Incentive effects" were considered; that is, producer choices about parcels to offer in the CRP were allowed to change in response to weight changes.

We analyzed the impacts of weight changes both with and without considering these incentive effects. Our analyses revealed that ignoring the incentive effects of weight changes could lead to small understatements of the environmental and cost impacts in the CRP. Results from the "with incentive effects" models follow.[2]

[2]Results of the analysis that examines how outcomes change when incentive effects are ignored are available from the authors.

The Action at the Margin: Small Changes in EBI Weights Have Relatively Small Effects

How might even small changes in the weights assigned to environmental and cost concerns affect conservation program outcomes? From the program manager's perspective, the decision process that determines the land to enroll involves selecting, from producers' voluntarily submitted offers, the parcels with the highest "scores" until a program enrollment constraint has been reached. In each signup period, program managers typically have the opportunity to alter the weights that are assigned to different concerns. The weights that program managers assign to different program objectives may have considerable impact in terms of the acceptance or rejection of "marginal" parcels (see fig. 2.2). For example, if a large number of offered parcels could provide wildlife benefits, a program manager's decision to assign a slightly larger weight to wildlife concerns could result in the selection of more parcels with wildlife benefits that would have been rejected under alternative weight schemes. The responsiveness of program outcomes to changes in weights has broad implications for other index-based USDA programs.

Scenario 1 uses data from CRP's 26th signup, for which offers were submitted in May-June 2003.[3] The database of 71,000 observations contains the EBI score for all parcels on which offers were submitted. Figure 3.1 identifies the set of national objectives and the maximum EBI scores used for the 26th signup. In scenario 1, we test the sensitivity of environmental benefits and costs by randomly altering the implied maximum weights in a narrow range (+/- 10 percent) relative to the values used in the CRP signups. This process is equivalent to altering the maximum EBI score attainable for each concern. We hold the total score (545 points) constant, so that a

[3]A parallel analysis using data from the 20th signup yielded similar results (see box, "Do Marginal Impacts Depend on the Signup?").

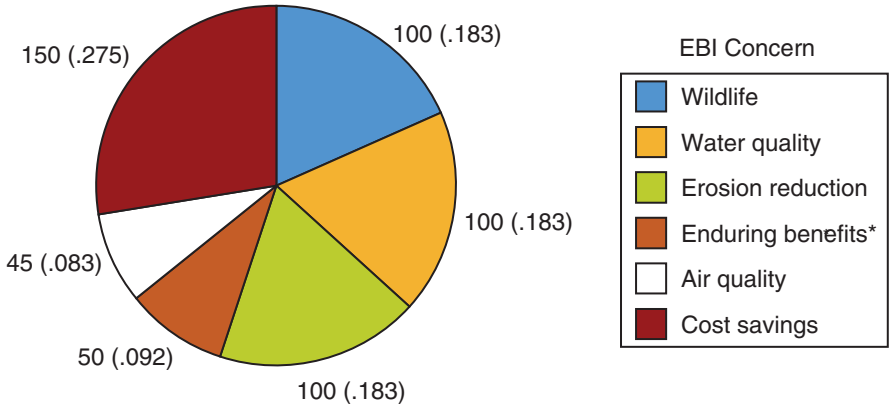
Do Marginal Benefits Depend on the Signup?

Data from the 26th signup data suggest that potential benefits are not very sensitive to marginal changes in the weights. Other signups may have different sized pools of applicants, differences in the environmental objectives and weights in the EBI, or other circumstances that may contribute to different levels of benefits when weights are altered within a narrow range. We investigated the sensitivity of our results by simulating a single signup using data from signup 20 and recalculating the elasticities. The EBI in signup 20 contained an additional objective of prioritizing offers located in "priority areas," but otherwise the objectives and weights assigned were similar to those in signup 26.

We found the responsiveness of the potential benefits to weights exhibits some sensitivity depending on the signup data used. This suggests that overall conditions prevailing at the time of a signup may have an effect. Some patterns are evident across the two single signups, however: (1) benefit and cost outcomes for the 26th signup appear to be more responsive to shifts in weights, (2) the effects on environmental benefits from changing weights are consistently quite weak, and (3) objectives are confirmed to be substitutes or complements based on the sign of the elasticity (with a few exceptions, where the magnitude of the elasticity, although statistically significant, was approximately zero).

Figure 3.1

EBI objectives and weights in CRP's 26th signup



Note: Implicit weights are in parentheses.

*Points awarded for "enduring benefits" are based on the likelihood that certain practices (such as tree planting) will remain in place beyond the CRP contract period.

Source: Compiled by USDA's Economic Research Service from CRP data provided by USDA's Farm Service Agency.

marginal increase in one concern's weight is matched by decreases among some or all of the other weights. These decreases could be distributed among the other weights in numerous combinations; to determine how environmental benefits and costs would change *on average*, we constructed a

thousand scenarios, each with a different set of weights. We then re-computed the EBI score of each offer according to the new weight assigned to each concern, and re-ranked the parcels based on these new scores. Offers are assumed to be accepted into the program until the acreage threshold is reached. In scenario 1, this threshold is defined as 2 million acres, the amount that was enrolled in the 26th signup.

The primary interest in these simulations is understanding the effects of altering weights on the CRP's ability to provide environmental benefits and the effects of such changes on program costs. We analyze this by defining the *potential benefits* of an offer—which measures the approximate contribution of each offer to meeting the environmental concerns contained in the index (for a full description of *potential benefits*, see box, "Potential Benefits of an Offer – Defined").[4] To investigate the outcomes that may result, given a vector of EBI weights, we used the following steps to compute the *average* potential benefits for concern *i*, APB_i:

- For a candidate vector of EBI weights, we determined the lands that will be offered and accepted in the simulated 26th signup. To accommodate changes in producers' decisions about land to offer when the EBI weights are altered, we used an expansion factor. This offer-specific expansion factor summarizes the extent to which offers submitted in the actual 26th signup are representative of a larger set of acres. As discussed in appendix B, this expansion factor is modeled as a function of a variety of offer-specific attributes, including the offer's EBI score and county-level regional socio-economic variables.

- For each accepted offer in the simulation, we computed the *potential benefits* for each of the "*i*" concerns.

- The APB_i is the weighted average, across all accepted offers, of the *potential benefits for concern i*. For each concern, we computed a separate weighted average. The acreage of the offer, and the expansion factor, is used as the weight.

How does the APB_i change as different weight vectors lead to a new pool of accepted offers, when each pool possesses a different set of environmental characteristics? Table 3.2 reports the actual APB_i's for the environmental concerns that were attained in signup 26. For an APB_i equal to 0.68, the set of offers actually accepted was expected to contribute an average of 68 percent of the maximum possible benefits for that environmental concern, based on the parcel attributes and the practices that would be implemented.

Table 3.2
Actual average potential benefits attained in signup 26

Environmental concern	Average potential benefits (APB_i)
Wildlife	0.68
Water quality	0.57
Erosion reduction	0.60
Enduring benefits	0.18
Air quality	0.37

Source: Compiled by USDA's Economic Research Service from CRP data provided by USDA's Farm Service Agency.

[4]The drawback of our definition of environmental benefits is that we relied on indirect data, whose primary purpose is to provide a rough measure of value for use in USDA's Farm Service Agency internal ranking mechanisms. An alternative would be to use biophysical data, such as data in the National Resources Inventory (NRI). The problem with using NRI data, for our application, is that although it samples extensively throughout the United States, there is no way to know how representative the sample points are of the parcels being offered for enrollment (the NRI does note whether a point is in the CRP but not if it was offered and not accepted). The definition adopted here may be subject to biases but had the advantage that the data were available for the land parcels in question.

Potential Benefits of an Offer – Defined

The key to having the weight alterations result in new EBI scores for each offer, and a reordering of the offers accepted during a signup, is that the actual attributes of each offer are assumed not to change – that is, producers do not change the set of proposed practices for the land they offer to enroll in the CRP as the weights are narrowly changed. The recomputation of each offer's EBI score, under each scenario, is based solely on the new weight vector. To understand this, we define the *potential benefits* of offer *b* as the ratio of the offer's score earned for that objective to the maximum score that could be earned. Letting $EBI_{i,b}$ represent the EBI score for concern *i* and offer *b* and $EBI_i^{\max}$ represent the maximum EBI points that can be obtained for concern *i*, the potential benefits in terms of the *i*th concern ($PB_{i,b}$) can be defined as:

$$PB_{i,b} = \frac{EBI_{i,b}}{EBI_i^{\max}}$$

The value of $PB_{i,b}$ will fall between 0 and 1 depending on how well offer *b* originally performed in terms of the ith environmental concern. For example, if an offer obtained a score of 75 for *wildlife benefits* out of the 100 available points for the category in signup 26, that offer's *wildlife benefits PB* will be 0.75. Each offer's potential benefits remains fixed, but as new weights are assigned (leading to a new maximum score for each concern) the offer's total EBI score can change.** This leads to a reordering of all the offers in each simulation (based on their total EBI scores), and, hence, a different set of lands that are enrolled.

The average potential benefits (APB_i), which is the acre-weighted average of $PB_{i,b}$ across all accepted offers, is recomputed based on the land to be enrolled and provides an indication of overall expected performance relative to the *i*th concern.

** One way to interpret this definition is that it assumes program managers will "scale up" or "scale down" the score an offer receives for each concern ($EBI_{i,b}$) proportionally to the change in the concern's weight.

A useful framework for discussing how the assigned weights affect the APB_i is to consider the elasticities of the concerns relative to the weights assigned. In essence, an elasticity indicates the effect of a one-unit change in a weight on the APB_i. For example, an elasticity of 1.0 means that a 10-percent change in weight *i* leads to a 10-percent change in APB_i, whereas an elasticity of 0.5 means that a 10-percent change in weight *i* leads to only a 5-percent change in APB_i. The relevance of the results lies both in illustrating exactly which parcels are enrolled and in determining whether benefit and cost outcomes are sensitive to minor shifts in the weighting mechanism (see box, "Computing Elasticities"). Table 3.3 reports the environmental concerns' estimated elasticities for signup 26. The bold underlined elasticities are "own-elasticities," since they represent the effect of a change in each concern's weight on its own potential benefits. The other elements in the table capture the effects of weight changes on other environ-

Computing Elasticities

A useful framework for analyzing the results is in terms of the elasticities of the environmental concerns relative to the weights assigned. This will provide a first glimpse as to the nature of the tradeoffs involved both among the environmental benefits and for program cost relative to environmental weights. The elasticity of an environmental concern relative to one of the EBI weights represents the relative change in the concern's potential benefits divided by the corresponding relative change in the weight. First, we define the e*nvironmental benefits susceptibility elasticity*:

$$\eta_{i,j} = \frac{\partial APB_i}{\partial w_j} \cdot \frac{w_j}{APB_i}$$

In a similar spirit, a related quantity that will be of interest when considering the tradeoffs between environmental benefits and program cost will be the elasticity of program cost relative to environmental *benefits*:

$$\sigma_i = \frac{\partial COST}{\partial APB_i} \cdot \frac{APB_i}{COST}$$

The regressions performed rely on the definitions of elasticities provided above. Since we are interested in the elasticities for environmental benefits susceptibility, both the independent and dependent variables were converted to a percent change relative to the values for CRP signup 26, which functions as our baseline. In this way, the coefficients obtained from the estimation are the elasticities of interest. The system of equations estimated can be represented as:

$$dAPB_i = \sum_{j=1}^{6} \eta_{i,j} \cdot dw_j + e'$$
$$dCOST = \sum_{j=1}^{6} \sigma_i \cdot dAPB_i + e'$$

The constant in the regression is constrained to equal zero so that if the weights coincide with those of the EBI used for the signup, the simulated enrollment will exactly replicate the actual enrollment and there will be no deviation in the environmental benefits. The system was estimated within Stata using Iterated Seemingly Unrelated Regression (ITSUR).[a] Although the equations are simultaneous, there is no estimation bias given that there is unidirectional dependency among the endogenous variables (in the first set of equations, the endogenous variables are determined only by exogenous variables).[b]

[a]A Breush-Pagan test for independent equations led us to reject the null hypothesis that the disturbance covariance matrix is diagonal and conclude that contemporaneous correlation between equation errors does exist.

[b]Since the EBI weights always sum to 1, the cost weight was dropped to avoid multicollinearity, and the total cost was estimated relative to the average attained benefits.

mental concerns. These "cross-elasticities" indicate of the extent to which environmental concerns are complements or substitutes in the enrollment process. The closer a value is to zero, the less sensitive an expected change in the concern's potential benefits are to a marginal change in a weight.[5]

Scenario 1

CRP's average potential benefits do not appear to be very sensitive to small weight changes in single signups

Overall, the results reported in table 3.3 imply that at a national level, the potential to achieve different environmental benefits does not appear to be very sensitive to marginal changes in the weights assigned to CRP objectives.[6] That is, no major shifts in the types of benefits that could be earned tend to occur when the weights are altered within a narrow range. The highest elasticity among the environmental concerns is 0.362 for erosion reduction benefits relative to its own weight in the EBI, but most elasticities are quite close to zero. This finding implies that as long as CRP outcomes approximately reflect relative social preferences, then few opportunities exist for obtaining improvements in environmental benefits by fine-tuning the index weights.

The values of the own-weight elasticities of environmental benefits are useful in indicating the objectives that could be improved by increasing their weight in the EBI. For example, increasing the weight of *erosion reduction or enduring benefits* by 10 percent (which is equivalent to increasing the scores for these concerns from 100 and 45 to 110 and 50, respectively) would result in approximately a 3.5-percent improvement in the average potential benefits for that environmental concern. Conversely, increasing the weights for the wildlife or the air quality objectives by 10 percent would generate 1 percent or less of an increase in those benefits.

The signs of the cross-elasticities indicate whether the selected offers tend to address multiple environmental concerns in a complementary way. These coefficients indicate that (1) complementarity exists, albeit small, between the enduring benefits and the wildlife concerns (cross-elasticity = 0.049), and (2) substitutability exists between the enduring

[5]All elasticities are significantly different from zero at the 1-percent significance level, except for those of water quality benefits relative to the weights assigned to wildlife and to air quality. Hence, this section will not discuss significance levels.

[6]These results do not exclude the possibility of larger regional or local shifts in the level of benefits. We explore regional effects in a later simulation.

Table 3.3

26th Signup estimation results: Elasticities of average potential benefits given small changes in EBI weights

Dependent variable	Independent variables				
	Wildlife weight	Water quality weight	Erosion reduction weight	Enduring benefits weight	Air quality weight
			Elasticities		
Wildlife *APB*	**0.133**	-0.015	-0.126	0.002	0.003
Water quality *APB*	0.034	**0.240**	-0.022	-0.010	0.002
Erosion reduction *APB*	-0.104	-0.039	**0.362**	-0.045	-0.025
Enduring benefits *APB*	0.049	-0.118	-0.262	**0.324**	-0.017
Air quality *APB*	-0.010	-0.068	-0.124	-0.016	**0.040**

Number of observations: 1,000. *APB* = average potential benefits.

Source: USDA's Economic Research Service.

benefits and the erosion reduction concerns (cross-elasticities = -0.262). The complementary relationship between wildlife and enduring benefits is intuitive to the extent that enduring benefits points are assigned in the EBI for tree plantings, wetland restoration, and plantings of multiple types of native grasses, which are all conducive to improving wildlife habitat. The substitutability between erosion reduction and enduring benefits could stem from (1) points awarded for erosion reduction being highest in areas such as the Northern Plains or the Midwest, where there are traditionally few tree plantings; or (2) the possibility that producers with parcels that score highly on the erosion reduction component of the EBI do not view the provision of enduring benefits as strategically necessary for the parcel to be accepted in the program.[7]

Small weight changes have greater impacts on program costs

Because the CRP is not budget constrained (rather, a cap on the total acreage that can be enrolled exists), total payments for the signups are not decided by policy. However, understanding how program costs change as environmental priorities change helps in understanding the tradeoffs that can occur in multi-objective programs, particularly in an era of tightening Federal budget constraints.

Table 3.4 shows the percent change in total cost of a signup that is needed to obtain a 1-percent change in the average potential benefits of a specific environmental objective (elasticity of total cost relative to the average potential benefits attained). Findings reveal the additional cost of obtaining marginal improvements (relative to the actual levels of expected benefits attained in the 26th signup) for a specific objective depends on initial conditions: (1) the EBI weight for that objective as adopted in the signup, and (2) the potential benefits that were actually achieved in signup 26. For example, marginal improvements in enduring benefits, which has a low weight (0.092, see fig. 3.1) and which actually provided only low potential benefits (0.18, see table 3.2), can be obtained with relatively small increases in total costs. As noted in table 3.4, a 10-percent improvement in enduring benefits would entail an approximately 5-percent increase in total costs. At the other extreme, a 10-percent increase in water quality benefits would require a 20-percent cost increase for the signup. Unlike enduring benefits, the water quality concern had a high implicit weight (.183) and provided relatively high potential benefits (0.57, see table 3.2) in signup 26.

[7]Even accounting for the weights, the cross-effects may be nonsymmetrical. For example, increasing the enduring benefits weight will lead to a decrease in *air quality* benefits, but the symmetrical effect will be minimal. This may be due to land brought into the program by increasing the *enduring benefits* weight providing less of the other benefit than the land it excludes. Instead, if the *air quality* weight is increased, the land that is brought in is very similar in terms of enduring benefits being offered to the land that becomes excluded.

Table 3.4
Elasticities of total cost relative to average potential benefits

Dependent variable	Independent variables—average potential benefits				
	Wildlife	Water quality	Erosion reduction	Enduring benefits	Air quality
Total cost – signup 26	1.378	1.995	1.905	0.487	1.530

Number of observations: 1,000.

Note: The elasticity indicates the percent change in total signup cost needed to obtain a 1-percent change in average potential benefits.

Source: USDA's Economic Research Service.

An intuitive interpretation of the results is that it can be costly to improve performance for an environmental concern that already is weighted relatively high. On one hand, little room for improvement may exist in the higher weighted environmental concerns because most of the benefits in that dimension have already been extracted from the pool of proposed offers (elasticity of average potential benefits with respect to its own-weight is low, such as is the case for water quality and wildlife). Even a large increase in the concern's weight may not obtain a significant benefit increase. Alternatively, given the pool of offers, room for improvement may exist (elasticity of average potential benefits with respect to its own-weight is higher as for erosion reduction), but the improvement is conditional on bringing more profitable (and hence more costly) land into retirement.

Note that our simulations were conducted when a significant amount of land that might be profitably enrolled was already in the program. As of the 26th signup, about 30 million acres, over 35 percent of the 80 million acres that FSA estimated could be profitably enrolled in CRP, had been previously enrolled.[8] Thus each additional signup may achieve environmental benefits that are increasingly less sensitive to weight changes since the "best" eligible acres may have already been enrolled. Our findings only apply to a relatively small proportion (about 6 or 7 percent) of the land enrolled in CRP.

[8]The national acreage that could be "profitably enrolled" is derived from FSA's "likely to bid model," a model based on both biophysical measures of the landscape (derived from the NRCS's Natural Resource Inventory data), and information on average farm production and agricultural prices.

Scenario 2
Impacts of small changes in weights are greater under the full-enrollment scenario

Another element in understanding the sensitivity of environmental benefits to changes in EBI weights considers the responses to changes when the best acres were available for enrollment, or when more significant amounts of land could be enrolled (relative to program constraints). These best acres would be available at program inception, and also when significant amounts of enrolled land are up for re-enrollment. We explore the effects of weight changes assuming the CRP could enroll all 33 million acres (close to the total program enrollment as of signup 26) and that no eligible land was already enrolled. The analysis was similar to the previous model using the 26th signup data, in which the initial set of weights were altered in a narrow range (see appendix B for technical details).

For a number of reasons, the findings from this analysis can only be considered suggestive. Most importantly, the analysis maintains the assumption that producers will not alter the set of practices they propose to implement, and hence the potential environmental benefits of any given offer will remain constant as the weights are altered. That is, the analysis assumes the marginal weight changes lead only to changes in an offer's EBI score, and not to a producer's choice of practices. Hence, the impacts due to changes in EBI weights, on the CRP as a whole, are driven by enrollment of a different set of parcels, rather than by modifications to currently enrolled parcels. This assumption may be most reasonable when producers face similar weights and environmental concerns across multiple signups. With the exception of the "priority area" objective being dropped, signup 26 was similar to previous signups in terms of weights assigned to environmental concerns. Even though weight changes were not large, the potential benefits

of previously enrolled producers' offers may not have remained constant when faced with signup 26 weights.

The APB_i's in this "full-program enrollment" scenario (table 3.5) reflect more sensitivity to changes in weights relative to the analysis where only 2 million acres were enrolled (see table 3.3). Even so, large changes in weights would still be necessary to achieve rather modest gains in environmental benefits. For example, the most significant change is the effect of an own-weight change for enduring benefits. In this scenario, a 10-percent increase in the weight on the enduring benefits concern generates an approximately 4.9-percent increase in that concern's average potential benefits, up from 3.2 percent. Perturbations to the wildlife weight generate fewer wildlife environmental improvements than in the 2-million-acre analysis, suggesting wildlife benefits may be rather uniformly distributed across all eligible CRP acres so that weight changes have little effect on outcomes.

The most noticeable change between simulating enrollment of a "full program" versus enrollment in a 2-million-acre single signup is that most of the cross-effects are complements, rather than the substitutes that were prevalent in the latter simulations (the signs on cross-elasticities changed from negative to positive). However, the effects of weight changes are still quite weak, with increases in erosion reduction being most sensitive to changes in the weight on enduring benefits (a 10-percent change generates a 1.35-percent change in the erosion concern's average potential benefits).

What are the policy implications of these changing relationships? Taken together with the single signup analysis, these results suggest that it may be easier to address environmental concerns simultaneously in the early phases of the CRP, but that achieving improvements in each concern in subsequent signups happens increasingly at the expense of the other concerns as enrollments continue to limit the pool of acres available.

Changes in total program costs exhibit larger differences in response to increases in the expected performance for particular environmental concerns (table 3.6). In these full-program simulations, total program costs ranged from $2.0 billion to $2.36 billion ($2.22 billion on average). Relative to

Table 3.5

Full-program estimation results: Elasticities of average potential benefits relative to the EBI weights, considering "full-program" signup

Dependent variable	Independent variables				
	Wildlife weight	Water quality weight	Erosion reduction weight	Enduring benefits weight	Air quality weight
			Elasticities		
Wildlife *APB*	**0.115**	0.009	-0.079	0.021	0.015
Water quality *APB*	0.028	**0.270**	0.074	0.099	0.055
Erosion reduction *APB*	-0.107	0.051	**0.467**	0.135	0.068
Enduring benefits *APB*	0.012	0.049	0.038	**0.492**	0.108
Air quality *APB*	-0.014	-0.062	-0.097	-0.005	**0.036**

Number of observations: 1,000. *APB* = average potential benefits.

Source: USDA's Economic Research Service.

Table 3.6
Elasticities of total signup cost relative to average potential benefits, considering "full-program" signup

Dependent variable	Independent variables—average potential benefits				
	Wildlife	Water quality	Erosion reduction	Enduring benefits	Air quality
			Elasticities		
Total cost (33-million-acre enrollment)	0.528	0.173	-0.216	-0.233	-1.314

Number of observations: 1,000.
Source: USDA's Economic Research Service.

single-signup simulations (scenario 1), the change in costs is significantly smaller with respect to each objective. In fact, cost elasticities are negative for erosion, enduring benefits and air quality, suggesting that additional environmental benefits could be achieved without increases in total program costs. This effect is intuitively appealing because offers providing higher levels of benefits, and which cost relatively less, were more likely to have been previously accepted into the CRP—hence, such lands were only considered eligible for enrollment in the 33-million-acre simulation. Combined with the total cost impacts for a single signup reported in table 3.4, it appears that, overall, it is less expensive to achieve environmental benefits when pre-existing enrollments are limited. As signups continue to enroll eligible land, program costs per unit of expected benefit rise as the pool of available acres becomes more constrained. Findings also suggest that program managers are enrolling better and cheaper lands first, and that producers are more likely to first offer lower productivity lands.

When Changes Are Nonmarginal: Larger Changes in EBI Weights Have Larger Impacts

Small changes in the weights associated with the environmental concerns in the EBI have small effects on CRP outcomes, at least the way we have measured environmental benefits. The implication of this limited effect is that little would be gained from more precisely determining the numerical value of the weights – as long as they approximate society's preferences. If new information reveals that program outcomes do not reflect relative societal values, or that values change, the question then is how sensitive environmental benefits are to bigger relative changes in the weights. Put another way, is the CRP always enrolling more or less the same type of acres regardless of the weights on different objectives?

Using elasticities to measure the impacts of weight changes is accurate only for marginal changes. However, we can estimate the impacts of larger weight changes through their effects on average potential benefits. From the patterns evident in the calculations, we can infer the effect of weight changes, including complementarity and substitutability of the environmental concerns (whether more or less average potential benefits would be achieved, respectively, when other weights are increased). As with the marginal analyses, we examine the responses in benefits and costs for both single signup and full-program enrollments.

Scenario 3
Large weight changes and single signups : erosion reduction most affected by weight changes

Figures 3.2a – 3.2e depict the impacts for a single signup of 2 million acres when one weight at a time is increased up to 80 percent.[9] The first data points in each graph are the same and represent the baseline average potential benefits achieved in signup 26 (i.e., the points correspond to the average potential benefits in table 3.2). In these simulations, we again account for incentive effects by allowing the pool of land offered for enrollment to change as the weights are changed.

The figures reveal similarities between, and some differences from, the results in scenario 1's single signup analysis when weights changed by only small amounts (see table 3.3). In both cases, the own effects of the weight changes are consistently positive: increases in a weight lead to more benefits of the associated environmental concern. Also, most of the environmental concerns still appear to be substitutes with each other—the slopes of the lines of other environmental concerns (those whose weights are not the focus of interest) are mostly decreasing, comparable to the negative signs on the cross-elasticities in table 3.3. However, one difference from the earlier results is that erosion benefits are now the most sensitive to changes in other weights (as evidenced by the steeper decline in the erosion line in the figures of the other environmental concerns).

This analysis reveals further insights into the "locality" of the findings of the marginal analysis. Specifically, it appears that the few complementary relationships previously noted—such as the positive relationship between the wildlife weight and both water quality and enduring benefits, as well as between air quality and wildlife benefits—may exist only for weights that are similar to the actual weights used in the 26th signup. This is revealed by noting the initial slight upward slopes of, for example, the water quality and enduring benefits lines in figure 3.2a where the wildlife weight is significantly altered.

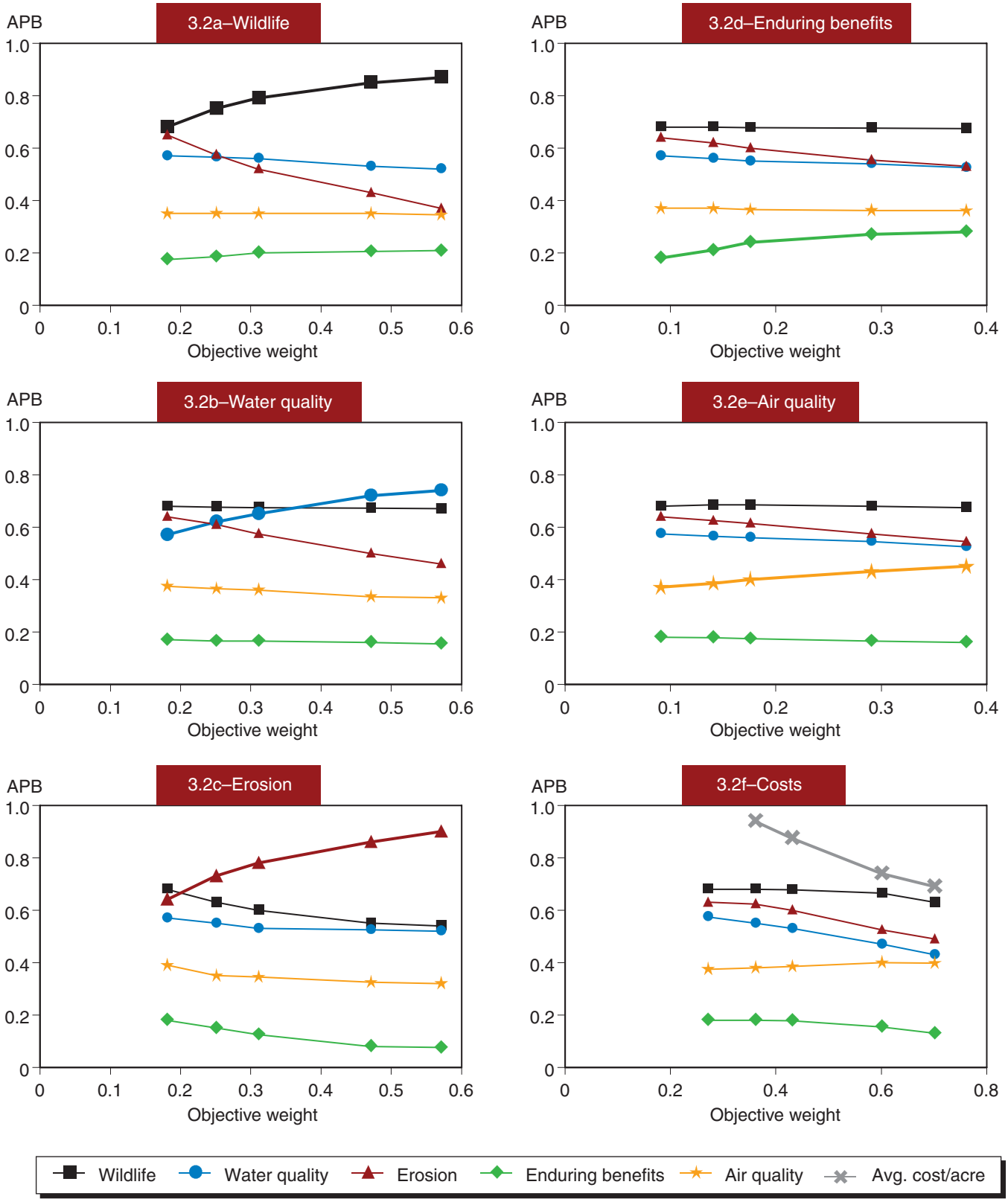
Perhaps the most significant policy implication of these results is the relationship between erosion reduction benefits and the other environmental concerns. On one hand, the loss in erosion reduction benefits is consistently most pronounced when the weights on other environmental concerns are increased. This effect is most evident when the wildlife weight is increased. The average potential benefits for erosion reduction drops from about .62 to about .40 as the wildlife weight increases up to 57 percent of total EBI points. Increasing the weight for water quality instead of wildlife also results in a notable loss of erosion benefits, from an average of .65 to .48. On the other hand, comparing data in figure 3.2c with that in figures 3.2a, 3.2b, 3.2d, and 3.2e reveals that increases in the erosion reduction weight lead to the broadest collective negative impacts on the remaining environmental concerns. Potential wildlife benefits decline the most in this case.

In terms of the impacts of changing the cost weight, figure 3.2f reveals that average per acre cost (relative to the baseline cost from signup 26) decreases as the cost weight increases. Not surprisingly, most of the average potential benefits decrease as the cost weight increases: the more a land retirement

[9]As before, the total EBI score is held constant. As the weight on one environmental concern is increased, the weights on all the others decrease proportionally—the weights of these "other" factors all move together. For example, as the wildlife weight increases, the (water quality weight)/(erosion weight) ratio will always equal 1.0, and the (water quality)/(enduring benefits) ratio will always equal 2.0.

Figure 3.2

Changes in average potential benefits (*APB*) as particular EBI weights are increased — large changes and small program enrollments



Source: USDA's Economic Research Service.

program focuses on enrolling the least expensive cropland first, the greater the likelihood environmental benefits will decline. The exception is air quality, which shows a slight increase in benefits. This effect may be explained by the relatively low cost of enrolling land that is most subject to wind erosion (such as land in the Northern Plains). While it is difficult to compare these findings with the small change-single signup findings (scenario 1) because the analyses are constructed differently, it is worth noting that both analyses suggest the greatest tradeoffs exist between water quality benefits and cost, and between erosion benefits and cost: additional benefits for these two environmental concerns are the most costly to attain (they have the largest elasticities with respect to total program cost in table 3.4), and benefits fall at a greater rate with large increases in the cost weight (they have the steepest slopes in the nonmarginal analysis in figure 3.2f).

Scenario 4

Large weight changes affect erosion reduction benefits similarly in the full program and the single signup enrollments

In this last set of analyses we simulated how large weight changes would affect outcomes when significantly more land is enrolled—33 million acres. Our findings, depicted in figures 3.3a – 3.3f, are fairly consistent with previous analyses. Large changes in weights affect the ability to achieve erosion reduction benefits the most, regardless of program enrollment size, with increases in wildlife and water quality weights generating the greatest losses in erosion reduction benefits.

As noted in the marginal analyses (comparing tables 3.3 and 3.5), having the flexibility to enroll the full 33 million acres softens substitution effects, so that fewer tradeoffs amongst potential benefits occur as weights are changed. However, far fewer complementary relationships remain when viewed from a national perspective (see box, "Strong and Weak Complementarity"). The most complementary effects – providing more of one benefit without sacrificing others – are achieved by increasing the weight on enduring benefits. In fact, only large changes in the enduring benefits weight generate additional benefits for every other environmental concern in this analysis.[10] Overall, a comparison of the "full-program enrollment" scenarios 2 and 4 with the "single signup" scenarios 1 and 3 supports a key finding from the marginal analysis: improvements in each environmental concern are increasingly achieved at the expense of improvements in other concerns as existing enrollments limit the pool of available acres.

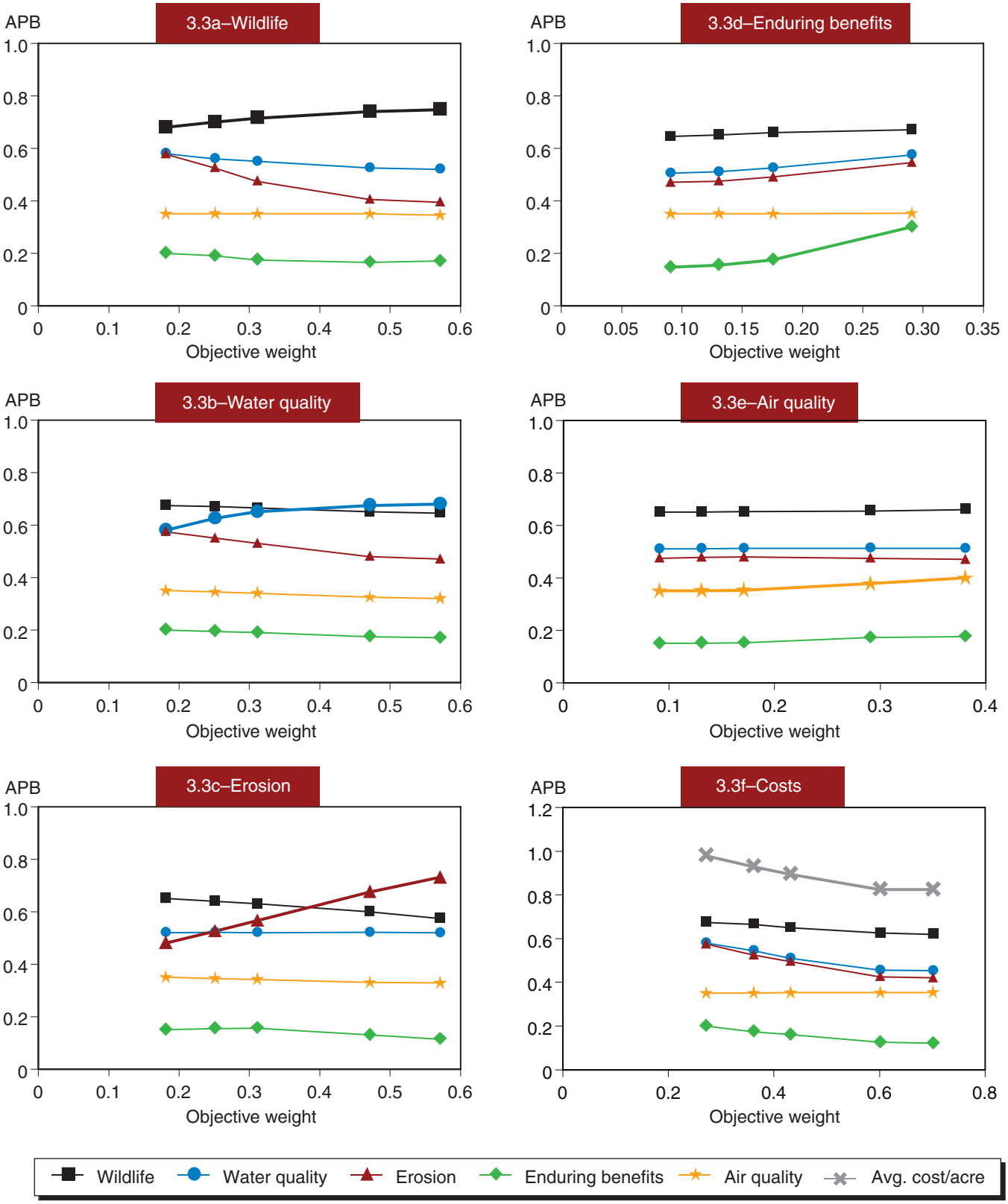
Comparisons of the cost impacts of a single signup and a full-program enrollment, using figures 3.2f and 3.3f, do not reveal any major differences. In both, as the cost factor increases, the per acre cost decreases, and the average potential benefits for most environmental concerns decrease (air quality again is slightly increasing).[11] Though not major, some differences are evident, however. In the single signup, it appears that as the cost factor weight increases, the losses of environmental benefits accelerate—the lines' slopes become steeper. In a full-program enrollment, the converse is true—the lines' slopes become less steep. That is, the tradeoffs between cheaper program costs and environmental benefits are greater in a single signup when large portions of eligible land are not available because they are already enrolled. This finding is consistent with our findings in the marginal

[10]Regional variation exists in response to changing the enduring benefits weight, with the Eastern Uplands, Northern Great Plains, and Southern Seaboard regions experiencing the largest losses in other benefits (12-, 9-, and 3-percent declines in soil erosion benefits, respectively) when the enduring benefits weight is doubled. For a description of ERS Farm Resource Regions, see www.ers.usda.gov/publications/aib760/.

[11]Caution should be used when comparing results across figures 3.3a to 3.3e. In particular, to ensure simulation of a full 33-million-acre program, different "EBI cutoffs" were used in several of the sets of simulations. In particular, enduring benefits required use of a low cutoff (since most CRP offers have no enduring benefits points).

Figure 3.3

Changes in average potential benefits (APB) as particular EBI weights are increased — large changes and full-program enrollments



Source: USDA's Economic Research Service.

Strong and Weak Complementarity

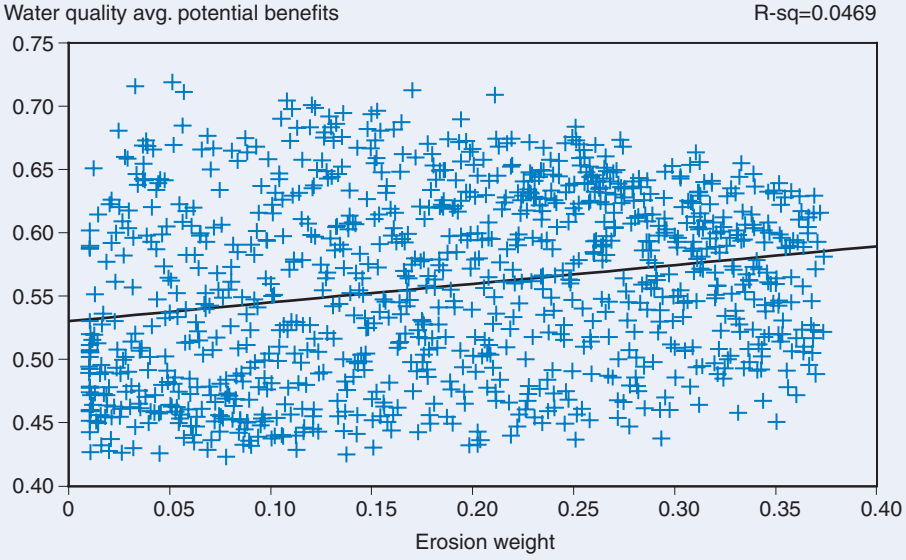
Complementarity between two environmental concerns is defined as a positive correlation between two APB_i's. Our marginal analyses (small change in weights) indicates that a number of complements exist, such as the 0.051 elasticity of the erosion reduction APB_i and the water quality weight. However, the nonmarginal analyses (scenarios 3 and 4) suggest little complementarity when weights are changed by large amounts (though water quality and erosion reduction do seem to be complements of enduring benefits).

It is useful to distinguish between two types of complementarity: strong and weak. These are defined in terms of how APB_i's change as EBI weights change.

- Strong complementarity: when the weight on factor A increases, the APB_i of factor B will increase even though the weight on factor B decreases proportionally.
- Weak complementarity: when the weight on factor A increases, the APB_i of factor B will increase so long as the weight on factor B stays constant.

To look for weak complementarity, we examined the set of 1,000 simulations using regression analysis and comparisons across quintiles. Both methods allow for all the EBI weights to vary, rather than the simple rule that the increase in one weight is offset by decreases in some or all other weights.

Using these tools, we find evidence of weak complementarity that closely reflects the findings from the marginal analysis. For example, the figure below shows a regression fit of the water quality APB_i as the erosion reduction weight changes – revealing that as the erosion reduction weight increases, the water quality APB_i also tends to increase.



Source: USDA's Economic Research Service.

analyses—by assuming no acres were previously enrolled and simulating a full-program enrollment, additional environmental benefits are achieved at lesser costs.

From a national perspective, these analyses of large weight changes (scenarios 3 and 4) uncover no stark results. However, they do show that the choice of weights assigned to environmental concerns can matter—with a sufficiently high weight, improvement is obtainable in a targeted environmental concern. These improvements come at a cost: in general, benefits from all the other environmental concerns decrease (sometimes noticeably). In fact, strong complements do not appear to exist—assigning a large weight to one environmental concern does not generally result in substantial additional benefits from other environmental concerns. However, this conclusion is tempered by a few other findings:

- The impacts on environmental benefits from large changes in the EBI weights can be even larger when viewed from a regional perspective than they appear when examining impacts from a national perspective (see box, "Regional Impacts of Large Changes in EBI Weights").

- Evidence of weak complements exists – increasing the weight on one concern can increase the APB_i of another concern, as long as this other concern's weight does not decline (see box, "Strong and Weak Complementarity").

Weight changes can affect the geographic distribution of enrolled acres

Large weight changes may also affect the distribution of enrolled acres across the United States. Some large weight changes may enable counties to gain CRP acres, while others cause counties to lose CRP acres. To explore these impacts, we generated six different simulations. In each simulation, one objective weight was doubled for a full-program enrollment. Figure 3.4 shows the biggest absolute change in CRP acres that each county would experience across these simulations. Counties colored dark red in the figure have CRP enrollment levels that are the most sensitive; these counties lose or gain at least 100 percent of their enrolled acres in at least one weight change scenario. Note, though, that in these counties other scenarios may have generated lesser impacts on enrollment.

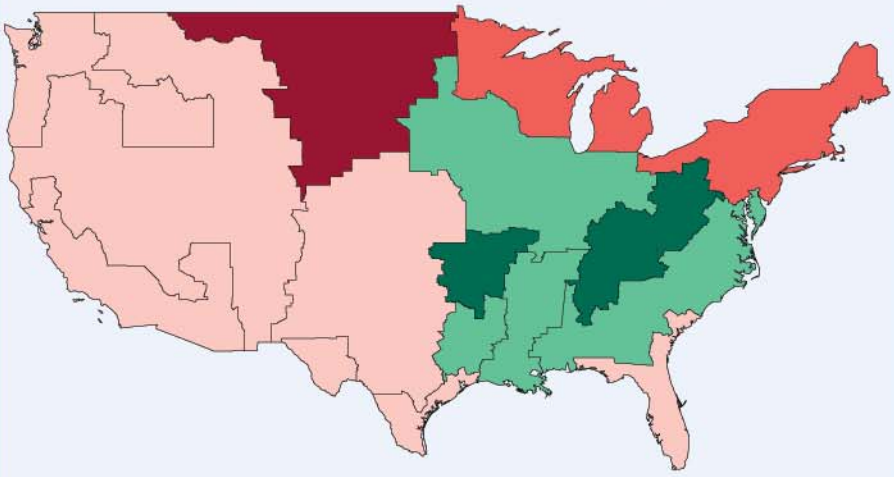
Every county with land eligible for CRP enrollment experiences a change in enrolled acreage in at least one weight change scenario. Enrollment patterns were most sensitive to doubling the weight on the wildlife factor, the water quality factor, and the cost factor (i.e., doubling each of these weights, one at a time, generates the most dark-red counties). Most of these impacts tend to be concentrated in the Northern Great Plains. For example, doubling the wildlife weight or the cost weight tends to generate large percentage *increases* in enrolled acres in this region. Yet, doubling the water quality weight generates large percentage *losses*. In general, CRP enrollment levels in the Southern Seaboard region tend to be the least impacted when an objective weight is doubled.

Regional Impacts of Large Changes in EBI Weights

An analysis of average potential benefits across regions in the full-program simulations revealed the following:

- Some results do hold across regions. For example, the greatest losses of erosion reduction benefits occur when wildlife and water quality weights are doubled. These losses range from 7 to 25 percent when the wildlife weight is doubled and from 11 to 23 percent when the water quality weight is doubled.
- In other cases, results vary significantly by region. For example, doubling the weight of enduring benefits generates average gains in benefits for other environmental concerns, but the average gain in erosion reduction benefits—due largely to the 29-percent gain in the Northern Crescent—masks 9-percent and 13-percent losses in erosion reduction benefits in the Southern Seaboard and Eastern Uplands regions, respectively.
- Similarly, on a national scale, doubling the weight for wildlife benefits appears to generate only a modest decline in enduring benefits but the following map reveals larger regional differences.

Change in enduring benefits APB when wildlife weight is doubled



Change in enduring benefits APB

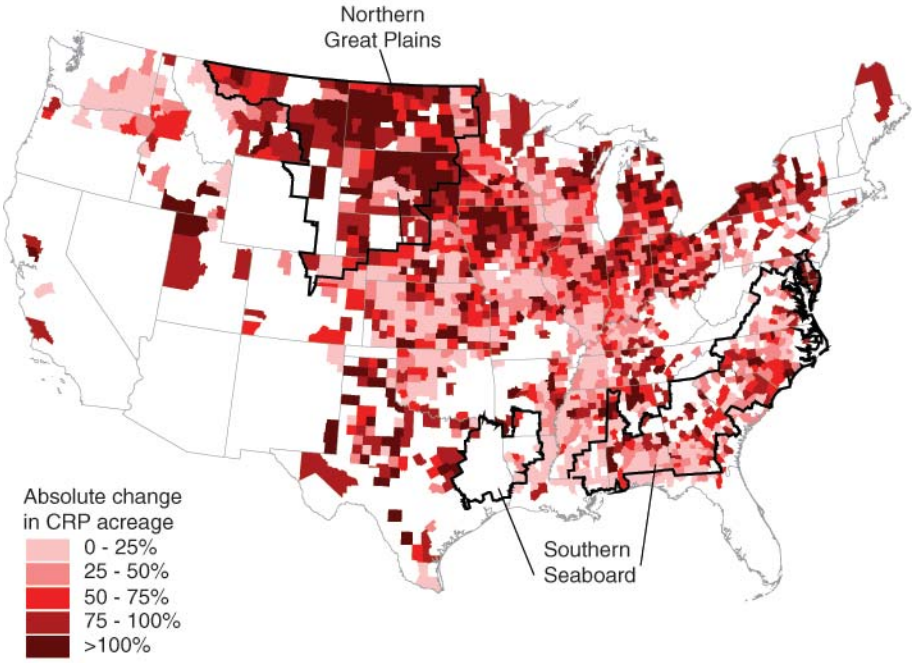
- 30.1 - 45% loss – Northern Great Plains
- 15.1 - 30% loss – Northern Crescent
- 0 - 15% loss – Prairie Gateway, Fruitful Rim, Basin
- .01 - 15% – Heartland, Mississippi Portal, Southern Seaboard
- 15.1 - 30% – Eastern Uplands

For a description of ERS's Farm Resource Regions, see http://www.ers.usda.gov/publications/aib760/.

Source: USDA's Economic Research Service.

Figure 3.4

Impact of doubling weights on CRP acreage, by county



Note: CRP enrollments in each county are sensitive to change in EBI weights. This map shows the largest percentage change in acres (in absolute terms) a county would experience, if any objective weight in signup 26 was doubled.

Source: USDA's Economic Research Service.

In some cases, doubling a weight induced new enrollments in some counties that previously had no CRP participation. In other cases, doubling completely eliminated enrollments in a county. Doubling the cost weight induced new enrollments in the greatest number of counties (66 counties), while doubling the wildlife weight eliminated enrollments in the greatest number of counties (111 counties).