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## **The CRP balancing act: trading off costs and multiple environmental benefits.**

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### **Introduction**

The Conservation Reserve Program (CRP), administered by USDA, is the Federal Government's single largest environmental improvement program on privately owned farms. The purpose of the CRP is to retire the most environmentally sensitive cropland and marginal pastureland from production.

Producers who voluntarily apply and are selected for participation in the Conservation Reserve Program receive annual rental payments for 10-15 years and cost-share assistance to establish permanent cover.

The goal of maximizing the net benefits of rural land conservation programs through an appropriately designed acreage selection process is continually growing in public importance. The CRP provides an excellent example of an evolving process to select appropriate acreage to conserve. At the program's outset, environmental quality improvements were viewed as correlated with reducing soil erosion, a view that led the program to enroll the maximum number of acres susceptible to soil erosion (Reichelderfer and Boggess, 1988). In recent years, this view has evolved to recognize the value of a broader set of attributes that characterize rural lands such as water quality and wildlife concerns. Beginning with the post-1990 signups, the program began to enroll land based on multiple environmental attributes and the per acre contract cost (Osborn, 1993; Osborn, 1997).

To account for the newly broadened array of objectives, USDA devised, and periodically modifies, the Environmental Benefits Index (EBI). The EBI ranks CRP offers by weighing program costs for enrolling land in CRP against six environmental objectives (Wildlife Habitat, Water Quality, Erosion Control, Enduring Benefits, Air Quality, and State or National Conservation Priority Areas). Actual

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enrollment is limited to the acres with the highest scores. Given the relatively recent introduction of the EBI, no systematic empirical studies exist concerning the environmental and program cost impacts of *changes* in the EBI weighting scheme.<sup>1</sup> This paper moves to fill this gap by using Monte Carlo simulations to systematically analyze the sensitivity of CRP enrollment to the specification of the EBI.

The main aim of the paper is to show whether the enrollment outcome is sensitive to minor shifts in the EBI weighting mechanism, and to indicate the potential cost effects of shifting preferences among objectives. The relevance of the results stems from the ability to take into consideration CRP's multiple objectives in our analysis of the program's implementation. If one accepts that a benefits index is a useful tool to administer a program with multiple objectives, but that the chosen weights may not accurately reflect societal preferences, then it is reasonable to ask how sensitive the program outcome is to changes in the weights. This subject matter has broad implications for USDA programs, since there USDA is debating the adoption of a comprehensive benefits index to be used in other conservation programs.

If the CRP, or other conservation programs, could be targeted to provide more societal benefits for the same costs, these programs would use resources more efficiently. The question of where to place future CRP acreage to obtain greater benefits can be answered by examining the magnitude and location of these benefits. Feather *et al.* (1999) examined the benefits resulting from retiring lands using the 15<sup>th</sup> signup EBI as an environmental targeting mechanism and found that, for a hypothetical 34-million-acres, CRP lands would be redistributed with increases in the North Eastern and South Eastern regions and decreases elsewhere. Using this new distribution of CRP acreage, Feather *et al.* also concluded, by examining several non-market effects, that a multi-objective EBI used as a targeting mechanism (rather than the previous criteria based primarily on erodibility) could increase CRP's environmental benefits.

Having determined that the regional distribution using the EBI improves benefits, the practical issue of how such an index should be constructed for the program to provide maximum benefits to society

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<sup>1</sup> Barbarika et al. (1994) compare the environmental and cost outcome for CRP under three different "weight" scenarios: cost minimization, erosion reduction maximization, and maximization of environmental EBI per dollar.

still remains unresolved. Babcock *et al.* (1996) examine to what extent improper targeting of CRP land would still capture a significant portion of the benefits. Their analysis indicates that environmental benefits obtained under different targeting criteria depend on the heterogeneity of environmental quality and productivity across tracts of land, as well as the correlation between the two. However, those conclusions are reached for one objective at a time, while the problem of allocating a given budget when multiple environmental objectives exist remains an open question. Along similar lines, Feather *et al.* (1999) recognize the challenges posed by valuing all the benefits associated with CRP, and make explicit reference to benefits recognized by the EBI that have not yet been valued in monetary terms.<sup>2</sup>

A further issue that arises when trying to evaluate the tradeoffs between the different CRP objectives using valuation techniques is that choosing money as the numeraire has implications when considering cost and benefits associated with a public good (Brekke, 1997).<sup>3</sup> An application that demonstrates the consequences of choosing alternative numeraires can be found in Bockstael and Strand (1985). This paper avoids defining a numeraire, focusing instead on the pairwise tradeoffs among the objectives of the program.

The paper is organized as follows: in the next section we explain the economic framework and then present the Monte Carlo simulation method used to determine how modifications in EBI objective weights affect the potential enrollment outcomes. The economic framework used for the application is also presented in the same section. This is followed by a description of the empirical application and the econometric results. The results are divided in three yet distinct subsections addressing: (i) sensitivity of the environmental outcome to changes in objective weights and marginal cost of improving an objective, (ii) the extent of the tradeoff between program cost and aggregate environmental benefits, and, finally,

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Babcock *et al.* (1996) and Reichelderfer and Boggess (1988) also compare outcomes under alternative objectives but do not take into consideration the EBI weights (the latter predates the introduction of the EBI).

<sup>2</sup> Ogg *et al.* (1989) and Young and Osborn (1990) are another source for estimates of environmental benefits from CRP.

<sup>3</sup> When a public good is involved, individual consumers' marginal rates of substitution will generally differ. Thus, the less valuable the numeraire is to a person, the higher the number required to express his net benefit, and the more will his interest weigh in the sum over consumers to obtain total benefits. The choice of money as numeraire is systematically favorable to those who value money the least, relative to alternative numeraires.

(iii) how aggregate environmental benefits are affected by the uncertainty concerning the correct weights to be used in conveying societal preferences.

### **Setting the Stage: how the CRP is administered**

Applicants may enroll in the CRP three ways. Under the *general signup*, which occurs at discrete, publicly announced time periods, applicants participate in a competitive bid process where their bid is ranked by the environmental benefits anticipated from idling the acreage and the taxpayer cost to enroll the land. The best bids are accepted for enrollment. The two other opportunities to enroll are the *continuous CRP signup* and the *Conservation Reserve Enhancement Program (CREP)*.

In addition to the opportunity to enroll in the CRP under the general competitive signups, producers may bypass the competitive bid process and enroll acreage in specific conservation practices under the *continuous CRP signup*.<sup>4</sup> Hence, if the applicant is willing to accept no more than a set per-acre payment for an eligible practice on eligible land, acceptance is automatic and is possible year-round. Finally, the *Conservation Reserve Enhancement Program* is a joint Federal-State land retirement program that uses CRP authorities under the continuous signup to allow States to supplement CRP incentives to address more State-specific goals. Approximately 95% of the acres under CRP are entered through general sign-up. This entails that the vast majority of the land in CRP is entered on the basis of whether the proposed contract has a sufficiently high EBI score to be enrolled in the program given the limit on total acreage.

The weights for the environmental objectives and the cost objective in the EBI are determined through the policy process. Conceptually, these weights affect which land is eventually enrolled in the CRP through two distinct channels. First, they provide a guide for landowners in deciding which, if any, land to offer for enrollment (by providing information on a bid's likelihood of success) and, second, they

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<sup>4</sup> These practices include: filter strips, riparian buffers, shelter belts, living snow fences, field windbreaks, grass waterways, salt-tolerant vegetation, shallow water areas for wildlife.

provide program administrators with the basis for choosing which parcels (from amongst those offered) to enroll.

The decision process to determine what land to enroll is one of identifying, among the submitted bids, the parcels with the highest EBI values, given a total acreage constraint. The weights assigned to the different objectives will obviously have a considerable impact in terms of what “marginal” parcels are accepted or rejected. Ideally the weights should be chosen so as to maximize social welfare; however, this is difficult to do from a practical standpoint. The difficulty is compounded by the fact that the bid-assessment is, in fact, a multi-period optimization, to the extent that the government wishes to avoid committing acreage to land in early rounds that will prove to be inferior to land offered later.

The EBI score is based on considering six environmental factors and a cost factor. The problem of deciding which parcels to enroll, from the program administrators’ perspective, can be characterized as follows:

$$(1) \quad \begin{aligned} & \text{Maximize} && \sum_{t \in \text{Signup}} \sum_{\text{cnty} \in \text{US}} \sum_{\text{bid} \in \text{BIDS}} \left[ \sum_{i=1}^6 w_{e_{i,t}} \cdot \text{BEN}_{i,\text{cntybid}_t} + w_{c_t} \cdot f(\text{COST}_{\text{cntybid}_t}) \right] \cdot D_{\text{cntybid}_t} \\ & \text{Subject to} && \sum_{t \in \text{Signup}} \sum_{\text{cnty} \in \text{US}} \sum_{\text{bid} \in \text{BIDS}} \text{Acres}_{\text{cntybid}_t} \cdot D_{\text{cntybid}_t} \leq \overline{\text{TOTAC}} \\ & && \sum_{\text{bid} \in \text{BIDS}} \text{Acres}_{\text{cntybid}_t} \cdot D_{\text{cntybid}_t} \leq \overline{\text{CNTYMAX}}_{\text{cnty}} \end{aligned}$$

where the decision variable,  $D_{\text{cntybid}_t}$ , is a 0/1 county-level variable expressing whether a parcel that was bid in Signup  $t$  is accepted for enrollment. The objective function weighs both environmental benefits and program costs:  $w_{e_{i,t}}$  is the weight assigned to the  $i$ -th environmental objective in Signup  $t$ ,  $\text{BEN}_{i,\text{cntybid}_t}$  is the estimated benefit of a bid for the  $i$ -th environmental objective, and on the cost side,  $w_{c_t}$  is the weight assigned to a function,  $f(\cdot)$ , of the cost objective ( $\text{COST}_{\text{cntybid}_t}$ ) as specified in the cost factor component

of the EBI. The constraints are very simple. The first constraint expresses that the sum of acres enrolled (for which  $D_{\text{countybid}} = 1$ ) has to be less than or equal to the total acreage available for signup. The second constraint represents the maximum acreage that can be enrolled in a county given that CRP enrollment in a county cannot exceed 25% of total acres of cropland in the county at any time.

Although the model presented above is a conceptually faithful representation of the underlying approach needed to determine what parcels to enroll, due to its inter-temporal nature (future bids have not been submitted), and the large number of bids, it is not possible to use it in practice to determine which offers to accept into the program. FSA assesses all bids against a constructed “likely-to-bid” curve that estimates the EBI scores of all land likely to be offered over the life of the program, and uses this information to determine what the cutoff value for the EBI should be for a particular Signup. The above description is meant to highlight the complexity of administering the CRP according to the multiple objectives that were set out for the program.

### **Modifying the EBI objective weights to determine the impact at the margin**

The importance of both the incentive effects of the weighting scheme and the inter-temporal aspects of the administrators’ decision problem, is acknowledged as an essential part of CRP enrollment process. However, here we focus principally on how marginal changes in the benefit-cost weights might alter the mix of parcels chosen from a given set of bids. The underlying objective is to determine how such changes in the land parcels chosen for enrollment in the CRP might alter the mix of environmental benefits achieved and their costs.

In this paper, we avoid the complexity of the inter-temporal aspects of the administrators’ decision problem by addressing only marginal changes in the EBI weights. This entails that we consider only the bids submitted in a single Signup, and that we will not address any incentive-to-bid effects that may arise when changing the EBI weights in a more substantial manner. The analysis is based on data

from the 20<sup>th</sup> signup that occurred in January/February 2000.<sup>5</sup> We therefore take as given the number of acres that were enrolled in the 20<sup>th</sup> Sign-up (2.3 million acres) and use a very simple loop routine to determine which parcels to accept and exit the loop when this acreage is reached. In particular:

STEP 1: order all the bids based on their EBI score,

STEP 2: beginning from the bids with the highest EBI scores accept the offer as long as the acreage in CRP for the parcel's county is less than 25% of cropland

STEP 3: compute a running sum of the acres accepted for enrollment

STEP 4: if the running sum of acres accepted is less than total allowed acreage, return to STEP 2  
Otherwise, the total acreage limit has been reached and the enrollment is complete.

The simulation of the outcomes as the EBI objective weights are changed relies on Monte Carlo methods applied to this simple procedure that determines which bids are accepted. The underlying assumption in the approach presented here is that society's true objective weights are not known with certainty beyond general terms of relative magnitude. The main task of the Monte Carlo simulation is to randomly generate sets of weights in the neighborhood of the weights adopted in the EBI for Signup 20. The simulated changes in the weights are meant to be marginal so as to not affect producers' incentives to bid land parcels into the program. This assumption allows us to utilize the bids for Signup 20 in determining alternative enrollment outcomes under different weighting schemes.

The data used to investigate the sensitivity of CRP enrollment outcome to changes in the EBI weights is bidding data from the 20<sup>th</sup> signup for which bids were submitted in January-February 2000. The database, composed of 56,000 observations, contains the land area, rental rate, and EBI score for both accepted and rejected bids. Each component score of the EBI is reported for every bid.

The EBI weights are implicit in the maximum score that can be obtained for each objective considered in the EBI. The maximum overall possible EBI score for signup 20 was 560 points (assuming a bid is perfect in all respects); therefore, the weight of any one objective can be obtained by dividing the

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<sup>5</sup> Since CRP's inception in 1986 there have been 23 signups. The EBI was introduced in the 10<sup>th</sup> Signup.



maximum allowable points for that objective by the maximum overall score. The weights for Signup 20 are presented in Table1.

<b>Objective</b>	<b>Maximum EBI score attainable</b>	<b>Implicit weight assigned</b>
Wildlife	100	0.179
Water Quality	100	0.179
Erosion reduction	100	0.179
Enduring benefits	50	0.089
Air quality	35	0.063
Priority area benefits	25	0.045
Cost savings	150	0.268
<b>Total</b>	<b>560</b>	<b>1.000</b>

**Table 1. EBI Objective weights for Signup 20**

Monte Carlo (MC) techniques are generally used to compute difficult multi-dimensional integrals. One example of this use is to combine probability distributions for several input variables to estimate probability distributions for one or more output distributions. A common byproduct of MC simulation is a probabilistic sensitivity analysis, which illustrates what input variables contribute most strongly to variation in the output variables. For the purpose of this paper, the probabilistic sensitivity analysis will be the focus of the discussion.

The basis of each simulation is that a fixed but unknown set of EBI weights correctly represents societal preferences. To determine the implications of the uncertainty concerning the “true” weights a variety of samples are drawn from a population of 1000 weights that are centered around the values used for Signup 20. The inputs in our application are the weights assigned to the EBI objectives. The weights for the environmental objectives are assumed to be uniformly distributed around their value assigned in CRP Signup 20. Since the range is meant to allow only marginal changes in the weighting scheme the extremes of the distribution are set at  $\pm 20\%$  from the CRP Signup 20 value of the environmental weights.<sup>6</sup> The cost weight for each sampling was calculated as  $(1 - \text{sum of the environmental weights})$ .

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<sup>6</sup> The uniform and triangular distributions are commonly used in stochastic modeling when the shape of the actual distribution is unknown (Kirchner 1994). When extremes and a modal or mean value of a distribution are known, the triangular distribution is the least biased assumed distribution. When only the extremes can be estimated, the uniform distribution is the least biased assumption. Here we assume a uniform distribution because the weights used in Signup 20 are not necessarily indicative of the mean value, but simply provide information around what point to

The uniform distributions were sampled using Latin Hypercube Sampling (LHS) approach, which ensures that each of the input variables has all portions of its range represented in the simulation. LHS may be viewed as a stratified sampling scheme designed to ensure that the upper or lower ends of the distributions used in the analysis are well represented. Latin hypercube sampling is considered to be more efficient than simple random sampling, that is, it requires fewer simulations to produce the same level of precision.

Multiple outputs will be considered for the results: (i) the environmental outcome for each objective, (ii) the aggregate environmental outcome and (iii) the total program cost. The last of these outputs, the total program cost, is easily computed by summing the payments for every newly accepted parcel of land (each offer includes the number of acres and the associated rental rate). The measurement of the environmental outcome is not as straightforward. Let  $EBI_{i,b}$  represent the EBI score for component  $i$  and bid  $b$ , and let  $EBI_i^{\max}$  represent the maximum EBI points that can be obtained for component  $i$ , then a proxy for the environmental benefit provided by a bid in terms of the  $i$ th objective (independent of the weights assigned to the EBI components) can be defined as the *environmental potential*:

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

The advantage of this definition of environmental benefit is that, by relying on the Signup 20 data, we can compute the environmental benefit of each bid for each objective.<sup>7</sup> The value of  $ENV_{i,b}$  will fall between 0 and 1 depending on how well bid  $b$  performs in terms of the  $i$ th environmental objective. For example, if a bid obtained a score of 75 for *Wildlife Benefits* out of the 100 available points for the category, the environmental benefit provided will be 0.75 for the wildlife benefits objective. The relevance of this definition is that the environmental potential so defined is independent of the weights assigned in our

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center the distribution. Kirchner (1994) notes that in many cases the type of distribution chosen in complex models has little effect on the form of the output distribution.

<sup>7</sup> Environmental benefits are not monetized in this paper. The usefulness of monetary valuation techniques in allowing a comparison between disparate environmental effects is not in dispute. However, given the difficulty in computing monetary benefits for all the environmental factors involved in CRP, the intention here is to provide insight for each EBI objective by defining environmental benefits in terms of relative performance.

simulations: whatever set of weights is chosen from our population, the environmental potential of a bid does not change.<sup>8</sup>

<b>Objective</b>	<b>Average Environmental Potential</b>
Wildlife	0.65
Water Quality	0.38
Erosion reduction	0.42
Enduring benefits	0.53
Air quality	0.34
Priority area benefits	0.49
	<b>Average Cost Saving Potential</b>
Cost savings	0.59

**Table 2. Average Environmental Potential and Cost Saving Potential attained in Signup 20**

Every simulation will have a different outcome in terms of the bids that are accepted and those that are left out. This will entail a different set of environmental characteristics associated with the accepted bids. For presentation purposes we compute the average over all accepted bids of environmental potential that is attained for any one simulation. The average is weighted by the acreage of each bid. Let  $y bids(n)$  be the set of bids that are accepted given the sampled weights for the  $n$ th simulation, then the weighted average can be written as:

$$\overline{ENV}_i^{(n)} = \frac{\sum_{b \in y bids(n)} ENV_{i,b} \cdot AREA_b}{\sum_{b \in y bids(n)} AREA_b} \quad n = 1, 2, \dots, 1000$$

To understand the sensitivity of the average environmental potential that is attained as weights are changed a simple estimation can be carried out based on the the assumption that, as long as changes in weights are marginal, the relationship is linear in the weights. Therefore, the average attained environmental potential for the  $i$ th objective can be expressed as:

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<sup>8</sup> The drawback of our definition of environmental benefits is that we are relying on indirect data, that was not meant to be a scientific representation of benefits, but rather an indication of likely impact for FSA internal ranking purposes. An alternative would be to use data from the National Resources Inventory (NRI), which provides a nationally consistent database for all nonfederal lands, using data gathered and monitored by thousands of technical and natural resource data collection experts. The problem with using the NRI data for our application is that, although it samples extensively throughout the country, there is no way to know how representative the sample

$$\overline{ENV}_i = \mathbf{b}_{i,0} + \sum_{j=1}^6 \mathbf{b}_{i,j} w_j + e_i$$

A useful framework to analyze the results is to consider the elasticities of the objectives 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 objective relative to one of the EBI weights represents the relative change in the objective value divided by the corresponding relative change in the weight. First we define the *environmental susceptibility elasticity* as:

$$\begin{aligned} \mathbf{h}_{i,j} &= \frac{\partial \overline{ENV}_i}{\partial w_j} \cdot \frac{w_j}{\overline{ENV}_i} \\ &= \mathbf{b}_{i,j} \cdot \frac{w_j}{\overline{ENV}_i} \end{aligned}$$

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*:

$$\mathbf{s}_i = \frac{\partial \overline{COST}}{\partial \overline{ENV}_i} \cdot \frac{\overline{ENV}_i}{\overline{COST}}$$

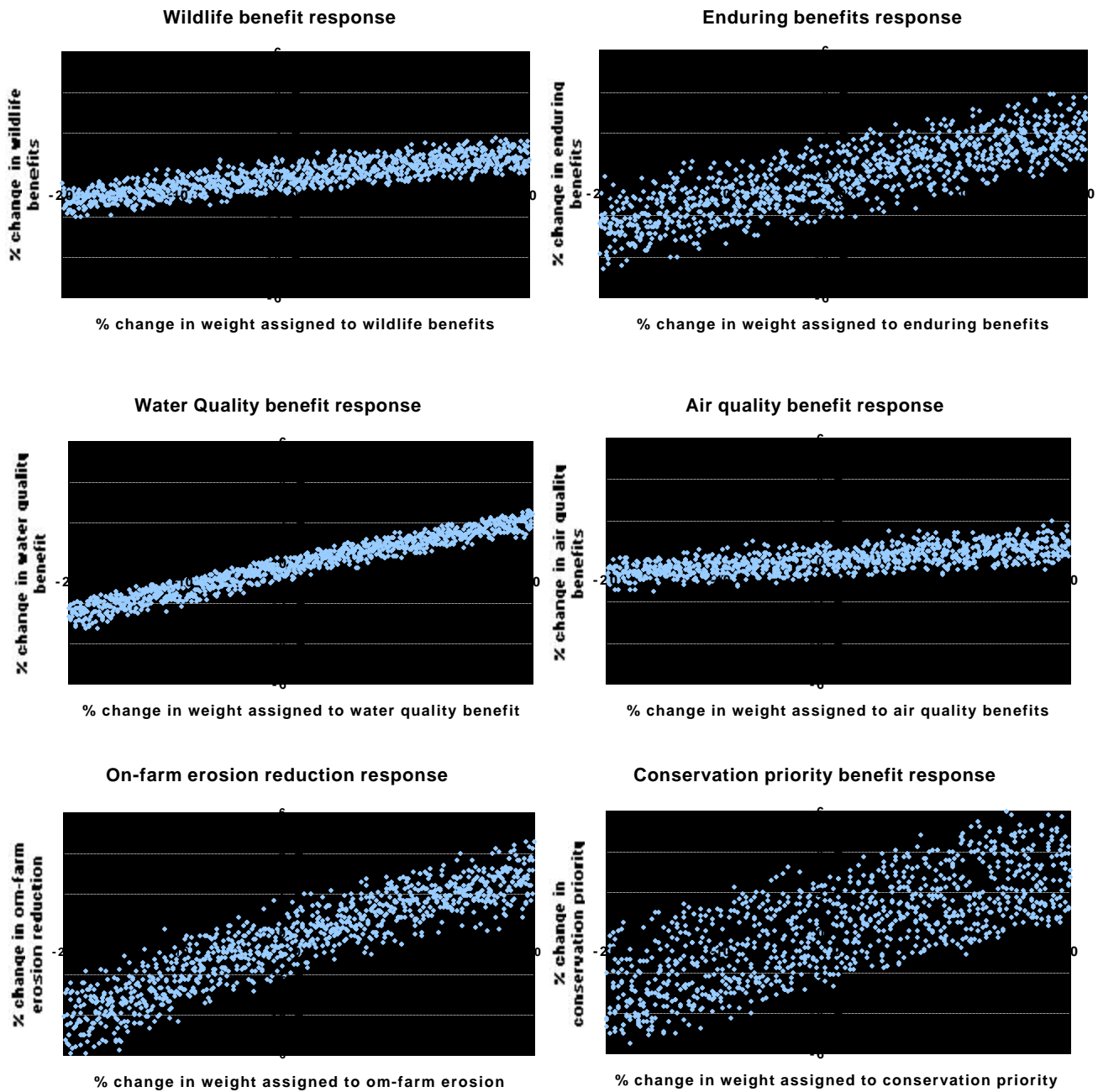
## Results and Discussion

### Environmental tradeoffs and marginal costs

We begin this section with a brief visual presentation of the results of the Monte Carlo simulation. For clarity of exposition all variables are presented as percentage changes (therefore slopes can be interpreted as elasticities).

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points are of the parcels being offered for enrollment. The definition adopted here may be subject to biases, but has the advantage that the data were entered for the land parcels in question.



**Figure 1. Graphs of environmental benefits as a function of their associated weight in the EBI**

In Figure 1 the response of the different environmental objectives is illustrated relative to changes in their own weights. The immediate conclusion is that there is a clear relationship between the benefits and their assigned weights. However, this relationship does not appear to be very strong in terms of magnitude of

changes in environmental benefits. In other words, the elasticity associated with environmental susceptibility is quite low for all 6 environmental objectives. Even so, there are considerable differences between environmental objectives in terms of how sensitive the outcome is to the weights. These points are best illustrated by the regression results.

The regression performed in this section relies on the definitions of elasticities provided in the previous section. Since we are interested in the elasticities for environmental susceptibility, both the independent and dependent variables were converted to percent change relative to the values for CRP Signup 20, which functions as our baseline. In this way the coefficients obtained from the estimation are the elasticities we are interested in. The system of equations estimated can be represented as:

$$\overline{dENV}_i = \sum_{j=1}^6 h_{i,j} dw_j + e_i'$$

$$\overline{dCOST} = \sum_{j=1}^6 s_j \cdot \overline{dENV}_i + e'$$

The constant in the regression is constrained to equal zero so that if the weights coincide with those of the EBI used for Signup 20 then the enrollment of Signup 20 will be exactly replicated and there will be no deviation of the environmental outcome. The system was estimated within Stata using Iterated Seemingly Unrelated Regression (ITSUR).<sup>9</sup> 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).<sup>10</sup>

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<sup>9</sup> Performing 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.

<sup>10</sup> Since the EBI weights always sum to 1, the cost weight was dropped to avoid multi-collinearity, and the total cost was estimated relative to the average attained benefits.

**Table 3. ITSUR Estimation results: elasticities of environmental susceptibility relative to the EBI weights, and elasticities of total signup cost relative to benefits (standard errors in parentheses).**

Dependent Variable	Independent variables						R <sup>2</sup>
<b>Wildlife_potential</b>	<b>Wildlife weight</b> 0.0570 (0.0002)	<b>Water_quality weight</b> -0.0039 (0.0003)	<b>Erosion reduc. weight</b> -0.0264 (0.0002)	<b>Enduring ben weight</b> 0.0192 (0.0002)	<b>Air_quality weight</b> 0.0017 (0.0002)	<b>priority_area weight</b> 0.0041 (0.0002)	0.986
<b>water_quality_potential</b>	0.0063 (0.0005)	0.1242 (0.0005)	0.0314 (0.0004)	-0.0058 (0.0004)	0.0018 (0.0004)	0.0028 (0.0004)	0.984
<b>erosion_red_potential</b>	-0.0379 (0.0013)	0.0225 (0.0014)	0.1899 (0.0011)	-0.0373 (0.0012)	0.0039 (0.0010)	-0.0364 (0.0012)	0.959
<b>Enduring_potential</b>	0.0544 (0.0006)	-0.0107 (0.0006)	-0.0562 (0.0005)	0.1186 (0.0005)	-0.0016 (0.0005)	-0.0013 (0.0005)	0.984
<b>air_quality_potential</b>	-0.0118 (0.0003)	-0.0282 (0.0003)	-0.0048 (0.0003)	-0.0211 (0.0003)	0.0352 (0.0003)	0.0075 (0.0003)	0.969
<b>priority_area_potential</b>	0.0143 (0.0008)	-0.0100 (0.0009)	-0.1373 (0.0007)	-0.0117 (0.0008)	0.0109 (0.0007)	0.1504 (0.0008)	0.985
<b>total_cost</b>	<b>Wildlife potential</b> 1.3307 (0.0251)	<b>water_quality potential</b> 0.8856 (0.0101)	<b>erosion_red potential</b> 0.8567 (0.0068)	<b>Enduring potential</b> 0.5386 (0.0120)	<b>air_quality potential</b> 0.2650 (0.0219)	<b>priority_area potential</b> 0.2322 (0.0079)	0.934

Table 1 shows the results for the elasticities discussed in the model. Among the elasticities of environmental benefits, those relative to their own weight in the EBI are the highest (as one would expect).<sup>11</sup> The cross-elasticities are an indication of the extent to which objectives are complements or substitutes in the enrollment process. Before going into the detailed description of the different environmental benefit elasticities, notice that overall, these elasticities are very low. The highest elasticity among the environmental objectives is 0.19 for erosion reduction benefits relative to its own weight in the EBI. The implication of this result is that there is no major shift in average benefits throughout the U.S. when marginal changes in the weights occur.<sup>12</sup> This is an important result since the exact weights expressing societal preferences are not known. If the weights used for the EBI in Signup 20 are close to

<sup>11</sup> All elasticities are significantly different from zero at the one percent significance level, except for those of water quality benefits relative to the weights assigned to wildlife and to air quality. Throughout this section we will therefore not explicitly make reference to significance levels in the text.

<sup>12</sup> These results do not exclude the possibility of more dramatic regional or local shifts in the level of benefits. This is likely a topic worthy of investigation. However, we do not pursue it here for reason of brevity. Further, the spirit of this paper is based on the current definition of EBI objective weights, which are specified nationally, implying that the objectives are weighted similarly throughout the country.

the true but unknown weights, then from the results we can state that the environmental outcome of the Signup process will be in the neighborhood of Pareto-optimality (relative to societal preferences).

The values of the “own-weight” elasticities of environmental benefits are useful in indicating for what objectives there may be the possibility of improvements by increasing their weight in the EBI. For example, increasing the weight of *erosion reduction* by 10% would entail approximately a 1.8 % improvement in the environmental potential attained for the same objective. This is equivalent to stating that if the maximum score for the soil erosion component of the EBI were changed from 100 to 110 (leaving the total maximum score unchanged) there would be a 1.8 percent improvement in the environmental potential attained for soil reduction. Similarly, bringing the maximum score for *enduring benefits* from 50 to 60 (equivalent to a 20% increase in weight), would lead to a 2.4 percent improvement in enduring benefits potential. If more emphasis were to be placed on enrolling land in conservation priority areas, this would have an impact: raising the maximum score from 25 to 30 would increase the priority area potential by 3 percent. Conversely, increasing the weights for the wildlife or the air quality objectives does not generate, in relative terms, much of an increase in those benefits.

Observing the sign of the cross-elasticities indicates whether objectives are complements or substitutes in the enrollment process. These off-diagonal coefficients indicate that there is (i) complementarity between the enduring benefits and the wildlife objectives ( $h = 0.05$ ), and (ii) substitutability between the enduring benefits and the erosion reduction objectives ( $h = -0.06$ ).<sup>13</sup> 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 erosion reduction could be due to (i) erosion reduction being most needed in areas such as the Northern plains or the Midwest where there are traditionally few

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<sup>13</sup> Since increasing the weight of one objective always entails decreasing the weight of one or more of the other objectives (the weights always have to sum to 1), a planner could use the complementarity/substitutability information derived here for directing changes in the benefits from a signup. For example, if the EBI weights were



tree plantings, or (ii) producers for which a parcel scores highly on the erosion reduction component of the EBI feel they do not need to provide enduring benefits for the parcel to be accepted in the program.

The role of priority areas, whether National or State, emerges as an important factor in shifting CRP away from its traditional focus on highly erodible land. This is demonstrated by the fact that when the weight of the conservation priority area component of the EBI is increased the objective that is most affected is soil erosion reduction ( $h = -0.037$ ). Conversely, when the weight of the erosion reduction component of the EBI is increased the benefits arising from priority areas decreases substantially ( $h = -0.137$ ) adding emphasis to the fact that the two are clearly substitutes.<sup>14</sup> While it is beyond the scope of this paper to investigate the impact of State-defined priority areas, the impact of the National Conservation Priority Areas (CPA) can be inferred quite easily. Of the 5 national CPAs defined for CRP enrollment, only the Prairie Pothole CPA has any significant overlap with areas that are traditionally subject to serious wind erosion problems.<sup>15</sup> Therefore, it is not surprising that the two attributes emerge as substitutes in the estimation.

The last row of Table 3 represents the elasticity of the total cost associated with Signup 20 relative to the environmental potential attained in the different objectives. The total payment for the signup is not a policy decision variable. The constraint on the program is the total acreage cap in the legislation regulating CRP. This entails that the main policy tool available to USDA in administering the

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to be changed so as to emphasize enduring benefits, then besides increasing the weight for enduring benefits, the wildlife weights could also be increased while contemporaneously decreasing the weights for erosion reduction.<sup>14</sup> The reason the two symmetrical cross-elasticities are so different is that their respective weights in the signup 20 EBI are very different. In Table A1, in the appendix, the results are presented relative to the actual change in weight (rather than relative to the base value of the weight in signup 20). In the appendix a 1% change in weight represents an increase of 0.01 in the weight, and similarly a 1% change in an environmental potential variable represents a 0.01 increase in the value of the variable. This can be done because all variables (except total\_cost) are defined as shares. When the cross-effects are analyzed accounting for the difference in weights, the cross-effects between priority area and erosion reduction are very similar in magnitude.

Even accounting for the weights, the cross-effects may be non-symmetrical. For example, increasing the enduring benefits weight will lead to a decrease in *air quality* and *priority area* benefits, but the symmetrical effect will be minimal. This may be due to the fact that, the land that is brought into the program by increasing the *enduring benefits* weight provides less of the other two benefits 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.

<sup>15</sup> The 5 CPAs are: (i) Chesapeake Bay, (ii) Longleaf Pine, (iii) Great Lakes, (iv) Prairie Pothole, and (v) Long Island.

program is the determination of the set of EBI weights. However, when analyzing the program costs it is more informative to regress them against the benefits obtained when the weights are modified, which is what is presented here. What transpires from Table 4 is that *the additional cost of obtaining marginal improvements (relative to the realized signup 20) in an objective is proportional to the EBI weight for that objective as adopted in signup 20*. For example, marginal improvements in *air quality* and *priority area* benefits, which had the two lowest weights, can be obtained with relatively small increases in total costs. More specifically, a 10 percent improvement in benefits stemming from land in priority areas would entail a 2.3 percent increase in total costs for the signup. At the other extreme, a 10 percent increase in wildlife benefits would require a 13% cost increase for the signup.

The intuitive interpretation of the results is that it is costly to improve performance for an objective that is already considered to be important. This may occur for two reasons: (i) there is room for improvement in the objective being considered (given the pool of offers), but the improvement is conditional on bringing in more profitable land into retirement, and/or (ii) there is little room for improvement (environmental potential elasticity is low) because most of the benefits in that dimension have already been extracted from the pool of proposed offers, so that a large increase in the objective weight is required to obtain a benefit increase.

An instance of the former reason is provided by the *erosion reduction benefits*, while the latter case is an accurate description of what occurs to *wildlife benefits*. Both these objectives were assigned the same weight (0.179) in the EBI for Signup 20. However, the average environmental potential that is attained is very different for the two objectives, being 0.65 for wildlife benefits while only 0.42 for erosion reduction. It therefore appears that it would be difficult to improve wildlife benefits since the average is already at 65 percent of the maximum attainable. This is reflected in the low environmental potential elasticity (0.055) for wildlife, which implies that a 20 percent increase in the weight would produce only a 1 percent increase in benefits. The large increase in the weight implies that other weights would have to be reduced substantially, and among them the weight associated with cost savings.

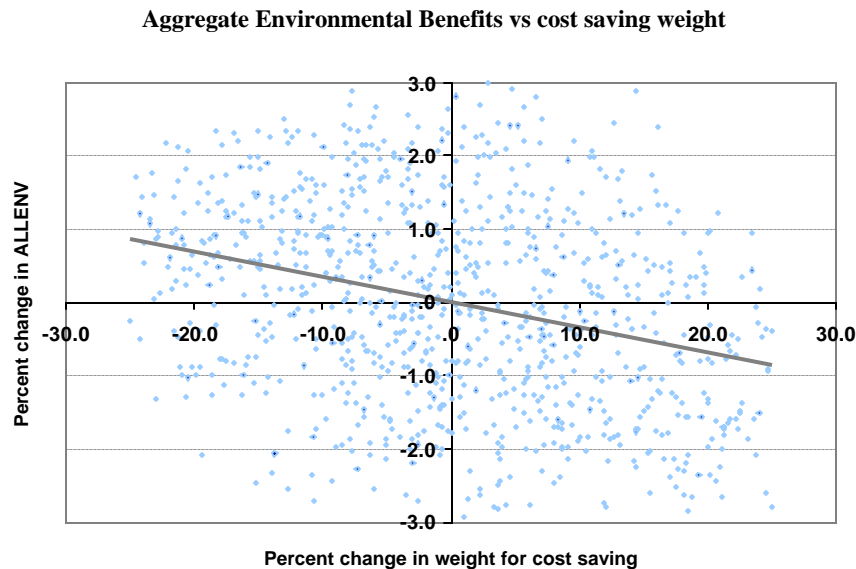
As mentioned above, *erosion reduction benefits* was assigned an identical weight as that assigned to *wildlife benefits*, but the average environmental potential attained was considerably lower. This could indicate that there may be low cost parcels with considerable erosion benefits that were not accepted in signup 20. However, because the weight assigned to erosion reduction was quite high, a parcel with a high score for erosion reduction would most probably have been accepted, especially considering that at very high erosion levels the rental rate requested is probably lower. This leaves out of the program the parcels with intermediate erodibility levels, which are more productive, and therefore more expensive to retire (assuming they provide few other environmental benefits). Improving the erosion reduction objective will then require dropping acres that were approved not for a strong erosion reduction component, and bringing into the program the intermediate erodibility parcels.

#### Evaluating Aggregate Environment-Cost Tradeoffs

If we assume that the weights used in the EBI specification for Signup 20 adequately represent societal preferences, then we can use the weights to aggregate the environmental benefits into a one-dimensional measure. This aggregate measure of environmental benefits can be used to examine the tradeoffs involved between overall environmental objectives and the cost saving objective. Following the definition adopted in the previous section for the average benefits we can define the *aggregate environmental potential* as:

$$\overline{ALLENV}^{(n)} = \frac{\sum_{i=1}^6 \overline{EBI}_i^{(n)}}{\sum_{i=1}^6 EBI_i^{MAX(n)}}$$

The aggregate environmental potential, as defined above, represents the average share of total environmental EBI points attained in simulation  $n$ . The percent change of this aggregate measure of benefits can be plotted against the percent change in total cost to provide an indication of the extent of the tradeoff at the aggregate level. Figure 2 presents the plot along with the regression line for total costs relative to aggregate environmental benefits.



The trend line shown represents an elasticity of cost relative to benefits equal to -0.03. The elasticity is significant at the 1% level, however  $R^2=0.09$  implying that the change in the cost saving weight does not explain the variability in aggregate environmental benefits.

**Figure 2. Trading-off aggregate environmental benefits and cost**

Upon visual inspection of the plot it is clear that there is not a strong relationship between the two variables. This is confirmed by the low  $R^2$  (0.09) obtained when regressing one against the other. Even though the elasticity of cost relative to aggregate benefits is significantly different from zero at the 1% level, the result cannot be considered robust given the limited overall explanatory power. The main implication of this result is that *given a fixed amount of acres to be enrolled there is no clear tradeoff between program cost and aggregate environmental benefits*. Increasing the importance of the EBI weight for cost saving will not necessarily reduce aggregate environmental benefits. Independently of the

direction of change, it also appears that the range of change in aggregate environmental benefits ( $\pm 3\%$ ) is quite small compared to the changes in the EBI weight for cost saving ( $\pm 25\%$ ) as shown in Figure 2.

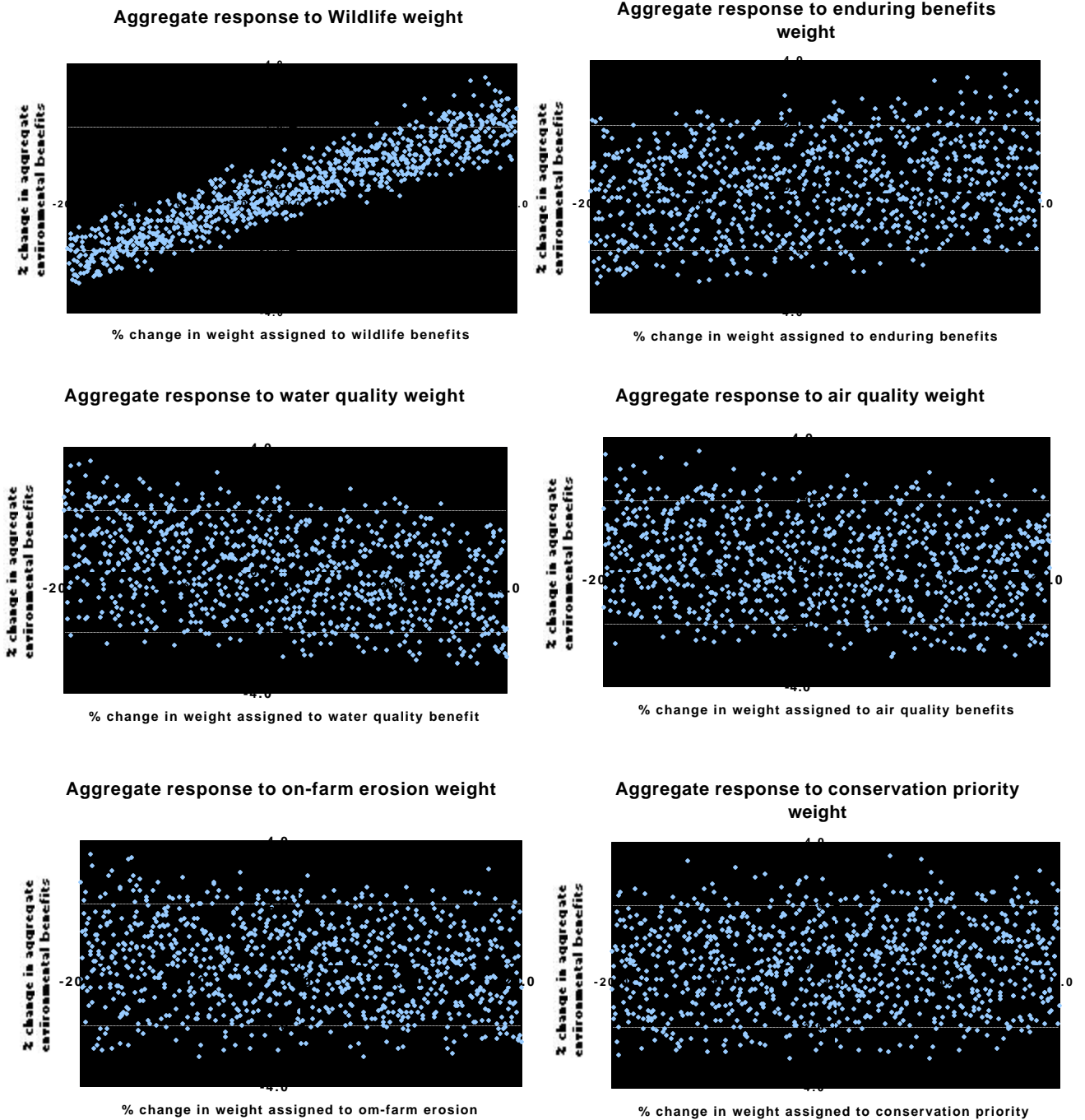
The limited impact on aggregate environmental benefits of marginal changes in the EBI cost saving weight can be attributed to the fact that, in aggregate, the environmental component is weighed much more heavily than the cost component. For Signup 20 the environmental components of the EBI sum up to 410 available points out of a total maximum score of 560 points. This entails that if the EBI weight for cost saving is increased, the decision of which environmental weights to reduce (since the weights must always sum to 1) may be more important in determining aggregate environmental benefits than the change in the cost weight. In the next subsection we investigate this possibility.

#### Sensitivity of the Aggregate Environmental Outcome to EBI Weight Specification

Acknowledging that the weights employed in the EBI may reflect societal preferences more or less accurately justifies trying to determine whether the aggregate environmental benefits (aggregated according to the signup 20 weights) are sensitive to the environmental weights assigned to the EBI components. Upon visual inspection of the plots in Figure 3 it becomes immediately apparent that there is a clear positive relationship between the weight assigned to wildlife benefits and aggregate environmental benefits.<sup>16</sup> Instead aggregate environmental benefits appear to have only a weak negative relationship with the water quality weight, and a weak positive relationship with the enduring benefits weight. The remaining weights exhibit no clear impact on aggregate environmental benefits.

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<sup>16</sup> The variable  $ALLENV^{(n)}$  is a function of  $EBI_i^{(n)}$  and  $EBI_i^{\max(n)}$ , therefore each point in the plots represents a different preference set.



**Figure 3. Graphs of aggregate environmental benefits as a function of their associated weight in the EBI**

The conclusions reached through visual inspection are confirmed by the OLS regression reported below in which percent change in aggregate environmental benefits are regressed relative to the percent

change in EBI objective weights. The coefficients in table 4 express a much stronger effect on aggregate environmental effect of the EBI wildlife weight than all other weights.<sup>17</sup>

**Table 4. Estimation of elasticities of aggregate environmental benefits relative to the EBI weights (standard errors in parentheses).**

	EBI weights					
	Wildlife	Water quality	Erosion Reduction	Enduring benefits	Air Quality	Priority area
<b>ALLENV</b>	0.1099 (0.0003)	-0.0280 (0.0003)	-0.0106 (0.0003)	0.0244 (0.0003)	-0.0204 (0.0003)	0.0056 (0.0003)

The reason for the importance of wildlife benefits in determining aggregate environmental benefits is not immediately clear. The difference does not seem to be exclusively attributable to the value of the weight for wildlife benefits since it is in the same range of those for water quality and soil erosion reduction. One possible explanation is that there exist complementarities between wildlife and other objectives. Another possibility is that an increase (decrease) in wildlife weight brings about an increase (decrease) in wildlife benefits that more than compensates at the aggregate level for the loss (gain) in other benefits.<sup>18</sup> To distinguish between these two possibilities we must decompose the substitution/complementary effects. This can be done because in the proximity of the weights used for Signup 20, the elasticity of aggregate environmental benefits can be approximated by (see appendix for mathematical derivation):

$$e_{ALL,i} \approx \left[ \mathbf{a} \cdot \sum_{j=1}^6 \frac{\partial \overline{EBI}_j}{\partial w_i} + \mathbf{g} \right] \cdot \frac{w_i}{ALLENV}$$

<sup>17</sup> As the standard errors indicate, the coefficients were all significant beyond the 1% level; however, performing multiple regressions using bootstrap resampling indicated that there is some variability in the coefficients when subsets of our sample are used. In spite of this variability, the sign and relative magnitude of the estimated elasticities were found to be stable.

<sup>18</sup> One must keep in mind that the aggregation is relative to the weights used in each simulation. Therefore, the aggregate environmental benefits being referred to ( $ALLENV^{(n)}$ ) are not objectively comparable to the extent that they are obtained with (marginally) different preference sets. They can be compared in the context of our experiment in which we are interested in understanding the impact of not knowing the exact preference weights held by society.

Where  $\alpha$  and  $\beta$  are constants that are independent of the objective  $i$ . Therefore, these two constants play no role in determining the differences between the elasticities for the different objectives. The difference in magnitude between elasticities is related exclusively to the weight,  $w_i$ , of the component being considered and the derivatives relative to  $w_i$  of each component's average EBI score.

**Table 5. Derivatives of EBI score relative to environmental objective weights: estimated values (standard errors in parentheses).**

EBI component scores	constant	EBI weights					
		Wildlife	Water quality	Erosion Reduction	Enduring benefits	Air Quality	Priority area
EBI wildlife	-3.24 (0.05)	385.00 (0.10)	-1.50 (0.10)	-9.66 (0.10)	13.76 (0.19)	1.91 (0.27)	5.55 (0.38)
EBI water_qual	-5.89 (0.05)	1.15 (0.10)	236.36 (0.10)	6.41 (0.10)	-2.66 (0.19)	1.05 (0.27)	2.47 (0.38)
EBI erosion_red	-3.90 (0.07)	-9.07 (0.13)	4.51 (0.13)	275.21 (0.13)	-17.91 (0.26)	2.82 (0.36)	-33.94 (0.52)
EBI enduring	-2.63 (0.04)	7.91 (0.08)	-1.60 (0.08)	-8.36 (0.08)	329.76 (0.15)	-0.88 (0.22)	-0.48 (0.31)
EBI air_qual	0.29 (0.01)	-0.78 (0.02)	-1.88 (0.02)	-0.33 (0.02)	-2.82 (0.04)	195.19 (0.06)	2.06 (0.09)
EBI priority_area	-0.15 (0.03)	0.91 (0.07)	-0.72 (0.07)	-9.29 (0.07)	-1.74 (0.14)	2.09 (0.19)	314.28 (0.27)
$\sum_{j=1}^6 \frac{\partial EBI_j}{\partial w_i}$		<b>385.1</b>	<b>235.2</b>	<b>254.0</b>	<b>318.4</b>	<b>202.2</b>	<b>289.9</b>

Table 5 presents the estimation results using the EBI weights as explanatory variables for the EBI scores. The coefficients in this table share the same sign as the environmental potential elasticities presented in Table 3. However, the relative magnitudes are very different. The reason for this difference is that the EBI score variables used in Table 5 as the dependent variables depend not only on the benefits provided by a bid for an objective, but also on the weight associated with the benefits for that objective. The coefficients are to be interpreted as the rate of change in EBI score for a component (in the row) when a weight (in the column) is changed. The coefficients along the diagonal of the table (excluding the “constant” column) represent the own-effect of changing a weight, while the off-diagonal elements represent the complementarity/substitutability between objectives.



From comparing the diagonal elements in Table 5 to the off-diagonal ones, one can conclude that the own-effects of changing a weight dominate by far all the substitution/complementarity effects. The bottom row sums all the coefficients in the column, to obtain the net effect on the rate of change of the environmental total of the EBI score. What emerges from this sum is that changes in the EBI weight for wildlife cause the greatest change in total environmental score of the EBI. When one considers that the elasticity of aggregate environmental benefits also depends on the weight assigned to wildlife (0.179, see Table 1), which is the highest environmental weight assigned, then it becomes clear why the wildlife weight has such an impact on aggregate environmental benefits.

A more intuitive explanation can be given by taking into account the average environmental potential attained for the wildlife objective in signup 20. At 65% it was the highest attained, followed by enduring benefits with 53%. Increasing the weight of the wildlife component will lead to acceptance into the program of parcels that are considered “marginal” for wildlife purposes, but that nonetheless provide substantial wildlife benefits. So much so, that the added wildlife points they obtain more than compensate the points lost for the other objectives due to parcels being dropped to make space for the new entry. The considerable weight assigned to wildlife will also count in determining the extent of the impact on the aggregate environmental benefits since there is a linear relationship between the benefits provided and the weight for a given level of environmental potential attained by a bid. For example, enduring benefits performs well, but has less of an impact on the aggregate environmental benefits because its weight is half that of wildlife in the EBI index.

The broader implication of the discussion presented above is that *if limited research resources are available, then correctly capturing societal preferences for wildlife will yield higher returns relative to other environmental objectives*. The reason this occurs is the confluence of two mechanisms. Firstly, the performance of the wildlife objective relative to the others, for the parcels offered, is high. Secondly, the importance attributed by society to the wildlife objective as implied by the EBI objective weights, although difficult to quantify exactly, is assumed to be at comparable in magnitude to that of water quality and soil erosion.

More specifically, the EBI weights are an implicit valuation of benefits arising from different environmental services, be they water quality, wildlife, or other services. If we accept this valuation, we can aggregate the benefits in these multiple dimensions into a scalar. However, the issue arises that if the weights used do not reflect societal preferences exactly, then the calculation of the aggregate environmental benefits may be flawed. For example, assume that the weight for wildlife has been underestimated by 10% in Signup 20. This would mean that in Signup 20 *wildlife benefits* in the amount of 6 % of those actually obtained were foregone (from Table 3). What it also means, however, is that 1% of attainable *aggregate environmental benefits* was also foregone. While the former point was to be expected, and applies to every objective (to a greater or lesser degree), the latter occurs only for the weighting of the wildlife objective.

## **Conclusions**

For both theoretical and practical reasons it is difficult to assign a monetary value to benefits generated by CRP. From the theoretical standpoint, aggregating benefits to the national level is subject to biases, and in practice it is very challenging to compute monetary benefits for all the environmental factors involved in CRP. Given these difficulties in computing monetary benefits, this paper provides insight for each EBI objective by defining environmental benefits in terms of relative performance using information on bids collected in the CRP application process. The results presented in this paper addressed several questions related to the multi-objective nature of the CRP program and its use of the EBI index. The results can be summed up as follows:

- (i) sensitivity of the environmental outcome to marginal changes in objective weights: (a) there is no major shift in average benefits throughout the U.S. when marginal changes in the weights occur, and (b) priority area weights, whether National or State, play a role in shifting CRP away from its traditional focus on highly erodible land, and (c) there is complementarity between the enduring

benefits and the wildlife objectives and substitutability between the enduring benefits and the erosion reduction objectives;

- (ii) sensitivity of program cost to changes in environmental benefits: the additional cost of obtaining marginal improvements (relative to the realized signup 20) in an objective is proportional to the EBI weight for that objective as adopted in signup 20;
- (iii) how aggregate environmental benefits vary with cost: given a fixed amount of acres to be enrolled, at the margin there is no clear tradeoff between program cost and *aggregate* environmental benefits;
- (iv) how aggregate environmental benefits are affected by the accuracy of the weights in capturing societal preferences: *if limited research resources are available, then correctly capturing societal preferences for wildlife will yield higher returns relative to other environmental objectives.*

The paper explicitly distinguishes between the environmental potential attained for an objective by a bid and the weight assigned to the objective in the EBI index. The distinction is central to understanding how correctly identifying societal preferences for some objectives, rather than others, is more important for aggregate environmental benefits.

## References

- Babcock, B.A., P.G. Lakshminarayan, J.J. Wu, and D. Zilberman (1996) "The Economics of a Public Fund for Environmental Amenities: A Study of CRP Contracts," *American Journal of Agricultural Economics* 78:961-971.
- Barbarika, A., T. Osborn, and R. Heimlich (1994). "Using an environmental index in the Conservation Reserve Program," Proceedings of the NCT-163 *Post Conservation Reserve Program Land Use* Conference. Denver, Colorado. January 10-11. Pages 118-133.
- Bockstael, N. E. and I.E. Strand (1985). "Distributional Issues and Nonmarket Benefit Measurement," *Western Journal of Agricultural Economics* v10, n2 (December 1985): 162-69.
- Brekke, K. A. (1997). "The Numeraire Matters in Cost-Benefit Analysis," *Journal of Public Economics* v64, n1 (April 1997): 117-23

- Feather, P., D. Hellerstein, and L. Hansen. (1999) *Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP*. Agricultural Economics Report No. 778. 64 pp, April 1999.
- Ogg, C.W., M.P. Aillery, and M.O. Ribaldo (1989). *Implementing the Conservation Reserve Program: Analysis of environmental Options*. Agricultural Economics Report No. 616, U.S. Dept. Agr., Economic Research Service, Oct. 1989.
- Osborn, C.T. "The Conservation Reserve Program: Status, Future, and Policy Options," *Journal of Soil and Water Conservation*, 48(4), July-Aug. 1993:271-78.
- New CRP Criteria Enhance Environmental Gains, In *Agricultural Outlook*. U.S. Dept. Agr., Economic Research Service, Oct. 1997.
- Reichelderfer, K. and W.G. Boggess, (1988). "Government Decision Making and Program Performance: The Case of the Conservation Reserve Program," *American Journal of Agricultural Economics* v70(1): 1-11.
- Young, C. E. and C. T. Osborn. (1990). "Costs and benefits of the Conservation Reserve Program," *Journal of Soil and Water Conservation*, Vol. 45:370-373.

## Appendix 1: Calculations relating to the aggregate environmental potential

The definition of aggregate environmental potential that was given in the body of the paper is:

$$\overline{ALLENV}^{(n)} = f\left(\overline{EBI}_i^{(n)}, EBI_i^{MAX(n)}\right) = \frac{\sum_{i=1}^6 \overline{EBI}_i^{(n)}}{\sum_{i=1}^6 EBI_i^{MAX(n)}}$$

Differentiating relative to  $w_i$  we obtain, for the  $n$ th simulation, the marginal change in the average aggregate environmental potential when  $w_i$  is varies in the neighborhood of its value for that simulation:

$$\begin{aligned} \frac{\partial \overline{ALLENV}^{(n)}}{\partial w_i} &= \sum_{j=1}^6 \frac{\partial f}{\partial \overline{EBI}_j^{(n)}} \cdot \frac{\partial \overline{EBI}_j^{(n)}}{\partial w_i} + \sum_{j=1}^6 \frac{\partial f}{\partial EBI_j^{MAX(n)}} \cdot \frac{\partial EBI_j^{MAX(n)}}{\partial w_i} \\ &= \sum_{j=1}^6 \frac{1}{\sum_{k=1}^6 EBI_k^{MAX(n)}} \cdot \frac{\partial \overline{EBI}_j^{(n)}}{\partial w_i} - \frac{\sum_{j=1}^6 \overline{EBI}_j^{(n)} \cdot \frac{\partial EBI_j^{MAX(n)}}{\partial w_i}}{\left(\sum_{k=1}^6 EBI_k^{MAX(n)}\right)^2} \end{aligned}$$

Given the population of weights was constructed sampling from independent uniformly distributed probability densities, there is no correlation between the environmental weights. Furthermore, since the maximum EBI score is 560 and the relationship between weight  $i$  and  $EBI_i^{MAX(n)}$  is linear and goes through the origin, then 560 is the slope of this relationship. This implies that:

$$\begin{aligned} \frac{\partial EBI_j^{MAX(n)}}{\partial w_i} &= 0 \quad \forall i \neq j \\ \frac{\partial EBI_i^{MAX(n)}}{\partial w_i} &= 560 \quad \forall i \end{aligned}$$

Therefore, equation can be expressed as:

$$= \frac{\sum_{j=1}^6 \frac{\partial \overline{EBI}_j^{(n)}}{\partial w_i}}{\sum_{k=1}^6 EBI_k^{MAX(n)}} - \frac{560 \cdot \sum_{j=1}^6 \overline{EBI}_j^{(n)}}{\left(\sum_{k=1}^6 EBI_k^{MAX(n)}\right)^2}$$

We can therefore state, by substituting the point values (and dropping the index n), that in the neighborhood of the assigned Signup 20 EBI weights:

$$\begin{aligned} \frac{\partial \overline{ALLENV}}{\partial w_i} &= \frac{\sum_{j=1}^6 \frac{\partial \overline{EBI}_j}{\partial w_i}}{410} - \frac{560 \cdot 195}{(410)^2} \\ &= 0.0024 \cdot \sum_{j=1}^6 \frac{\partial \overline{EBI}_j}{\partial w_i} - 0.708 \end{aligned}$$

**Table A1. Derivative of the environmental potential relative to the objective weights (denv/dw).**

	EBI weights					
	Wildlife	Water quality	Erosion Reduction	Enduring benefits	Air Quality	Priority area
ben_wildlife	0.2078	-0.0142	-0.0962	0.0700	0.0063	0.0148
ben_water_qual	0.0133	0.2616	0.0662	-0.0122	0.0039	0.0058
ben_erosion_red	-0.0880	0.0524	0.4417	-0.0867	0.0090	-0.0845
ben_enduring	0.3216	-0.0634	-0.3322	0.7009	-0.0097	-0.0077
ben_air_qual	-0.0634	-0.1516	-0.0258	-0.1136	0.1895	0.0402
ben_priority_area	0.1565	-0.1094	-1.4990	-0.1282	0.1193	1.6424

The values in this table are obtained by multiplying the elasticities in Table 3 by  $(w_i/ENV_i)$ . The results here are presented relative to the actual change in weight (rather than relative to the base value of the weight in signup 20). A 1% change in weight represents an increase of 0.01 in the weight, and similarly a 1% change in an environmental potential variable represents a 0.01 increase in the value of the variable

## **Appendix2: How the Environmental Benefits Index was computed for Sign-up 20**

The Environmental Benefits Index (EBI) is used to evaluate and rank land offered for enrollment in the Conservation Reserve Program (CRP) during a general signup. Scores are based on the expected environmental benefits to soil resources, water quality, wildlife habitat, and other resource concerns during the time the land is to be enrolled in the program. Each offer submitted is assigned a point score based on its relative environmental benefits. Each offer is compared nationally with all other offers at the end of the sign-up. Offers are determined acceptable or rejected based on the ranking results.

### **EBI Components**

The EBI for Sign-Up 20 is composed of six environmental factors, plus a cost factor. The six environmental factors are:

#### **N1 - Wildlife Factor**

##### **(0 to 100 points)**

Evaluates the expected wildlife benefits of the offer and is composed of six subfactors. The formula is:  
$$N1 = (N1a \div 50) \times (N1a + N1b + N1c + N1d + N1e + N1f).$$

N1a Wildlife Habitat Cover Benefits (0 to 50 points) - This subfactor evaluates the cover offered. Certain cover practice planting mixtures have been assigned points based on the value to wildlife within the State. The better cover types for wildlife are awarded the higher scores. If the offer is for enhancing an approved existing cover on acreage under an eligible expiring CRP contract or certain land that was previously enrolled in CRP, at least 51 percent of the acreage offered must be improved.

With acreage not under an expiring CRP contract, at least 90 percent must be devoted to the approved cover to receive the points associated with the approved cover. If the offer is a combination of new acreage and existing CRP acreage, at least 70 percent must be devoted to the approved cover to be awarded higher points.

All acreage (100 percent) devoted to trees, existing or new, must be thinned or planted to be awarded the applicable higher point score NOTE: Cover selection is the most critical factor impacting wildlife benefits. Optimum cover types (50 points score) will significantly increase the point score for this factor.

N1b Endangered species (0 to 15 points) - Evaluates the expected benefits to Federal and State Threatened and Endangered (T&E) plant or animal species. The USDA Service Center can provide a list of areas that have T&E species and the cover types that provide them a benefit. Point scores are awarded based on Table 2.

N1c Proximity to Water (0, 5 or 10 points) - Evaluates the proximity of the offer to permanent water. Point scores are awarded based on Table 3. Permanent water sources developed for wildlife that provide year-round water beneficial to wildlife may include spring developments, wildlife watering facilities, shallow water areas for wildlife, and farm ponds. The distribution of water development(s) must meet the requirements of NRCS practice 648 -Wildlife Watering Facility .

N1d Adjacent protected areas (0, 5, or 10 points) - Evaluates the proximity of the acreage offered to protected wildlife habitat. Point scores are awarded based on Table 4. Protected areas must provide wildlife protection for at least the term of the contract.

N1e Wildlife Enhancement (0 or 5 points) - Evaluates the potential wildlife enhancement by establishing wildlife food plot or restoring wetlands.

N1f Restored Wetland and Upland Cover (0 or 10 points) -Evaluates the upland acres relative to associated wetlands. Offers with the appropriate restored wetlands and associated uplands providing the

optimum nesting habitat for waterfowl are awarded 10 points. Wetlands must be restored to receive these points.

## **N2 - Water Quality Factor (0 to 100 points)**

Evaluates the potential impacts that CRP may have on both surface and ground water quality. CRP will reduce the amount of sediment, nutrients, and pollutants that enter our Nation's waters. N2 is composed of four subfactors:

N2a Location points - Evaluates the impact of continued crop production, by location, on the impairment of ground or surface water quality. States have identified water quality areas for protection. At least 51 percent of the acreage offered must be within an approved designated area to receive 30 points. The local USDA Service Center has detailed maps of the approved designated areas.

N2b Ground water quality benefits points - Evaluates by soil the downward movement of pesticides and nutrients into ground water and the population using groundwater for drinking. Point scores are based on the soils offered for enrollment into the program.

N2c Surface water quality benefits points - Evaluates the amount of sediment that may be delivered into streams or other water courses and the population that may be impacted. This factor is determined by the potential water erosion, distance to the water, and the county in which the offer is located. The USDA Service Center will provide details on this factor. The water quality improvements associated with wetlands. If 10 percent or more of the acreage offered is cropped wetlands, 10 points are awarded.

## **N3 - Erosion Factor (0 to 100 points)**

Evaluates the inherent potential (measured using Erodibility Index(EI)) for the land to erode as the result of either wind or water. Enrollment in CRP will help maintain the long-term productivity of the land for future generations. NRCS will calculate the weighted average EI for each offer and assign points starting at 5 points for EI=4 and increasing up to 80 for EI=19 (in 5 point increments). EI=20 is assigned 90 points, and EI>20 obtains 100 points.

## **N4 - Enduring Benefits Factor (0 to 50 points)**

Evaluates the likelihood of certain practices to remain in place beyond the contract period and for other purposes, including the capture of carbon dioxide. Points are awarded by the sum of N4a and N4b scores. The total score cannot exceed 50 points. To determine the N4a value, calculate the weighted average score for all practices using Table 7. N4b points are awarded on the highest applicable score (from Table 8) that is present on the offer.

## **N5 - Air Quality Benefits From Reduced Wind Erosion (0 to 35 points)**

Evaluates the air quality improvements from reducing airborne dust and particulate from cropland by wind erosion. This factor is comprised of 3 subfactors. The formula is:

$$N5 = (N5a + N5b + N5c).$$

N5a Wind Erosion Impacts (0 to 25 points) - NRCS will determine the potential for the site to have wind erosion damage. Points will be awarded based on potential wind erosion and the amount of population that may be impacted by wind erosion.

N5b Wind Erosion Soils List (0 or 5 points) - A list of soils has been developed that are susceptible to wind and contribute significantly to non-attainment of air quality standards. These soils have a dominant component of volcanic or organic materials that are highly erodible and can be transported great distances



on the wind. If at least 51 percent of the soils on the offer are comprised of these soils, the offer is awarded 5 points.

N5c Air Quality Zones (0 or 5 points) - If at least 51 percent of the acreage offered is located in an area designated as contributing to non-attainment of air quality standards or impacting air quality zones, such as National Parks, and the calculated weighted wind Environmental Index is equal to or greater than 4, 5 points are awarded.

**N6 - State or National Conservation Priority Areas (CPA) (0 or 25 points)**

This factor evaluates the location of the offer relative to these national or approved State CPA designations. If at least 51 percent of the acreage offered is located within a CPA and the offer is consistent with goals of the CPA, and certain other criteria are met, 25 points are awarded.

EXAMPLE: If a CPA is approved for water quality, acreage offered that is located in the water quality CPA will receive 25 points for factor N6 - if 40 or more points are awarded to factor N2, Water Quality Benefits.

**N7 - Cost**

The cost factor is comprised of three sub-components.

- 1. N7a** Provides points based on the per-acre rental rate offered. Lower per-acre rates receive higher scores. The weighting of this subfactor is determined after signup **concludes**.
- 2. N7b** Provides 10 additional EBI points if no government cost-share is requested.
- 3. N7c** Provides 1 additional EBI point for every whole dollar below the Maximum Acceptable Payment Rate, not to exceed 15 points. (EXAMPLE: The offer's Maximum Acceptable Payment Rate is \$80/acre. A producer that offers \$76 /acre would receive 4 additional EBI points under this subfactor.)