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Subsidies! The Other Incentive-Based Instrument: The Case of the Conservation Reserve Program

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Abstract

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Keywords

command-and-control policy, Conservation Reserve Program, market-based instrument

Disciplines

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The Case of the Conservation Reserve Program

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Abstract

In this paper, we examine command-and-control (CAC) policies and market-based instruments (MBI) in the context of the Conservation Reserve Program (CRP). The CRP, an MBI in the form of subsidies, is by far the largest agro-environmental policy implemented to date. We compare the environmental performance of the CRP as implemented to a few counterfactual CAC polices using EPIC (Environmental Policy Integrated Climate), a bio-physical simulation model. In the context of multiple environmental indicators, no policy alternative emerges as a clear winner. The importance of the choice and design of CAC policies is emphasized.

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SUBSIDIES! THE OTHER INCENTIVE-BASED INSTRUMENT: THE CASE OF THE CONSERVATION RESERVE PROGRAM

Introduction

Environmental economists have produced numerous studies on the potential efficiency gains associated with the flexibility that firms gain from market-like or incentive-based regulatory approaches.[1] While much has been learned from these explorations, they are primarily *ex ante* in nature and designed to address questions about the potential efficiency gains that could accrue from the implementation of a well-functioning incentive-based system relative to a command-and-control (CAC) policy that has actually been in place. In contrast, there has been relatively little study of the efficiency of actual incentive-based programs, relative to a hypothetical CAC strategy.[2]

While the efficacy of the SO_2 trading program increasingly is being studied (Carlson et al. 2000; Schmalensee et al. 1998; Arimura 2002), there is in general a paucity of *ex post* studies of the effectiveness of incentive-based mechanisms. This omission has been credited largely to the sparse existence of such programs. But in fact, incentive-based instruments for environmental control are not particularly rare in one large sector: agriculture. Rather, environmental programs in agriculture have a long history of implementing incentive-based instruments, albeit with a notable twist: instead of charging fees or constructing tradable quotas, agricultural programs generally have paid farmers in the form of cost-sharing or subsidies to retire land or adopt environmentally friendly practices.

Table 1 provides a summary, adapted from Claassen et al. 2001, of some of the key programs that have been implemented by the U.S. Department of Agriculture over the last century related to environmental performance of agricultural land and practices. These programs rely on voluntary participation and direct payments. Hence, these programs can be categorized as environmental subsidies: payments for undertaking activities that benefit the environment, although they are imperfectly “Pigouvian” in the sense that the payments are not directly linked to environmental effluent or performance.[3]

TABLE 1. Summary of major USDA conservation programs related to agriculture

Title	Duration	Program Summary
Agricultural Conservation Program	1936-1996	Annual expenditures of over $175 million during 1980s and 1990s. Cost-share provided for conservation practices on agricultural land.
Conservation Compliance, Sodbuster, and Swampbuster	1985-	Requires farmers with highly erodible land to implement a soil conservation plan or lose eligibility for federal support programs.
Conservation Reserve Program	1985-	Farmers retire land for 10-15 years from production in exchange for per acre payment.
Conservation Reserve Enhancement Program	1996-	Same as the CRP except that farmers can sign up anytime of the year and it emphasizes federal and state partnership.
Emergency Wetlands Reserve Program	1993-	Paid farmers to convert flood-damaged cropland to permanent wetlands. About 90,000 acres enrolled through 1997.
Environmental Quality Incentives Program	1996-	Provides education, technical assistance, and funding to farmers to adopt practices for 5-10 years to reduce environmental problems. Payments capped at $10,000 per person.
Wildlife Habitat Incentives Program	1996-	Provides cost sharing for development of habitat for wildlife. Cost share payments of up to 75% for 5-10 year commitments.
Water Quality Incentive Projects	1990-1996	Incentive payments provided for eligible producers to undertake 3-5 agreements to implement approved management practices. Over 800,000 acres enrolled in 1995.
Wetlands Reserve Program	1990-	Easement payment and restoration costs for land permanently converted to wetlands; 915,000 acres enrolled as of 2000.
Conservation Security Program (CSP)	2002-	Green payments to provide incentives to farmers to adopt various environmentally friendly practices; details still being determined

Note: Summarized from chapter text and Appendix 1 of Claassen et al. 2001, with additional information provided on the CSP. The CSP was established in the 2002 farm bill and has not yet been implemented.

In this paper, we study a large and important example of an environmental subsidy program—the Conservation Reserve Program (CRP). The CRP was introduced in 1985. Prior to 1990, all acreage classified as “highly erodible land” (HEL) was eligible for enrollment in the program. From this set of land, administrators chose willing landowners to enroll acreage in the program when their offer prices were less than the region-specific pre-determined rental prices. There was a minimum goal of 5 million acres to be enrolled in 1986 and at least 10 million acres each year for 1987–1989. These targets were met.

The CRP is of substantial magnitude, both in terms of its budget and the environmental benefits credited to it, which include erosion control, water quality, wildlife habitat, and drinking water supplies. For example, over the period 1982-1997, total erosion on U.S. cropland declined by about 49 percent, and much of this reduction is attributed to the presence of the CRP. Feather, Hellerstein, and Hansen (1999) estimated that the annual surplus from freshwater recreation, pheasant hunting, and wildlife viewing directly associated with the CRP totals almost $500 million. By almost any standard, the CRP's budget outlay is enormous: over $15 billion was spent from 1989 through 2000 in payments to keep up to 36 million acres out of production (Claassen et al. 2001), representing about 10 percent of total crop land. In contrast, for the SO_2 trading program, the total (annualized) cost of reducing emissions by 3.9 million tons in 1995 was estimated to have been about $726 million (Schmalensee et al. 1998). To achieve the SO_2 cap of 8.95 million tons in 2010, the minimum cost is estimated to be about $1.04 billion while an "enlightened" command-and-control policy would cost $1.82 billion (Carlson et al. 2000).

While the CRP can be interpreted as a market-based incentive program in the sense that program participants are faced with a price signal in the form of payments for retiring land from production, it is important to note that there are several efficiency problems with a subsidy as a policy instrument. First, while per unit subsidies have the same short-run efficiency properties as a corresponding tax, they may generate inefficiencies in the long run because of excessive entry (Bramhall and Mills 1966; Baumol and Oates 1988). In essence, the subsidy may make it profitable for firms to remain in an industry, or for new firms to enter, when in its absence fewer firms would be present. However, an important exception for this inefficiency result occurs when there is a fixed factor associated with production of the externality-generating industry. In that case, the value of the subsidy can be expected to be capitalized into the price of the fixed factor, preventing excessive entry.[4] Given that there is a fixed stock of highly erodible land from which CRP contracts can be drawn, the long-run inefficiency associated with excessive entry may not be a significant problem in this case.

Another potential difficulty with a subsidy program is that forward-looking firms may increase their emission levels prior to the imposition of a subsidy so that they can receive higher subsidy payments to abate (Kamien, Schwartz, and Dolbear [1966] appear to have been the first to raise this concern). Probably most troublesome for the case of the CRP is the potential deadweight loss associated with the social opportunity cost of funds. This argument notes that when the revenue used to pay subsidies comes from a distortionary tax system, a dollar of program expenditure represents an opportunity cost of more than a dollar (Wu and Babcock 1999). Large subsidy payments, such as those associated with a program as large as the CRP, can then have potentially large efficiency costs, depending upon the magnitude of the distortionary tax system. The estimates we provide in this paper do not account for this second-best nature of the tax system or other distortionary programs and thus may be unduly favorable toward a subsidy system relative to a CAC alternative that does not transfer revenue from the government to individual agents.

Several previous empirical studies have considered the performance of the CRP (Osborne 1993; Reichelderfer and Boggess 1988; Babcock et al. 1996; Goodwin and Smith 2003). For example, Reichelderfer and Boggess (1988) noted that land enrolled in CRP results in reduced commodity program spending as well as savings in other conservation expenditures. They estimated these cost savings associated with the actual CRP implemented in the first year of the program and the cost savings that might have accrued had alternate selection criteria been employed in selecting parcels for enrollment.

Babcock et al. (1996) focused on environmental targeting and investigated the proportion of gains achieved by the actual CRP relative to the environmental benefits achieved under targeting. Wu (2000) studied the magnitude of the “slippage” into cropped land of land that previously had not been cropped due to the price and substitution effects of the CRP program. Finally, Goodwin and Smith (2003) evaluated how much CRP erosion reduction benefits were offset by increased erosion resulting from other government programs.

In this paper, we ask a fundamentally different question from the previous empirical studies; specifically, we investigate whether a CAC form of regulation would be less efficient than a market-based instrument (MBI), and if so, by how much. That is, we seek to assess the policy as implemented relative to an essentially different—CAC—form of regulation. We then study the *ex post* performance of the MBI. In so doing, we provide information on the degree to which MBI programs, as they have actually been implemented, have or have not lived up to the original optimism with which economists viewed such instruments. In this vein, we follow the work of Carlson et al. (2000), who undertook an *ex post* assessment of the efficacy of the SO_2 trading program in its early years, and Kolstad (1986), who studied the *ex post* performance of a variety of MBIs. Like Oates, Portney, and McGartland (1989), we study the degree to which well-conceived CAC policies can be efficient alternatives to incentive-based measures. We also investigate a particularly understudied form of MBI: the subsidy.

We begin the paper by discussing the key features of the CRP as it has been implemented and how the program has evolved over time. Next, we study the optimal *ex ante* CRP as an incentive-based instrument by providing a simple model to describe its optimal implementation in its early years. Using the same analytical framework, we describe two general types of CAC policies that might reasonably have been implemented in lieu of the actual MBI subsidy: one we term a “strict” CAC policy and the second we term an “enlightened” policy that allows more flexibility in attaining environmental improvements.

Following this discussion of the pre-1990 policy and potential CAC alternatives, we present a simple model of the *ex ante* optimal CRP as it was implemented post-1990, when a more formal targeting of environmental benefits was introduced via the Environmental Benefits Index (EBI). We note that the same two sets of CAC policies could have been implemented as alternatives to the MBI subsidy.

The second part of the paper contains a set of simulations designed to estimate the program cost and environmental consequences of counterfactual CAC policies, the *ex ante* optimal CRP as outlined in the theory section, and the actually implemented (*ex post*) CRP land allocations. We compare the incentive-based and CAC policies under two different baselines: (*a*) one in which the total amount of land acreage put into CRP is held constant between the MBI and the CAC policies, and (*b*) one in which the total cost of the program is the same under the MBI and each CAC policy. The second baseline is particularly useful for assessing the efficiency of the policies, while the first is interesting because much of the (especially early) focus of the CRP was to assure a significant amount of land retirement from agricultural production.

Incentive-Based Instruments: Actual and *Ex Ante* Optimal Conservation Reserve Program Strategies

The CRP was initially managed to retire the most acres from production allowed by the budget authorization within the class of HEL (Smith 1995; Reichelderfer and Boggess 1988; Goodwin and Smith 2003).[5] Thus, it functioned as both an environmental program and an income support plan. It was an environmental program in that it targeted land that was particularly susceptible to soil and water erosion, but only in a rough and thereby potentially inefficient way since the category of HEL contains land that differs in many important environmental characteristics. The program also was implemented with income support and production control goals, as minimum requirements on the number of acres to be enrolled were met each year and limits on the number of acres per county were required. These acreage requirements assured that a large number of farmers were included in the program and that the funds were spread widely across the United States.[6]

This program focus changed in 1990 when the EBI was initiated and used to identify land most desirable for retirement. Six environmental “factors” were used in constructing the EBI: wildlife, water quality, erosion, enduring benefits, air quality, and whether the acreage is located within a Conservation Priority Area. In sign-up 15, the first major sign-up since EBI was used, the first three factors could earn up to 100 points in the index, with 25-50 points possible for the remaining three environmental factors.[7] The cost of enrolling a parcel was a seventh factor in the index. While the weights for some factors and/or subfactors were adjusted for different sign-ups, the distribution of weights stayed largely the same.

MBI policy 1. The pre-1990 CRP: Ex ante *optimal CRP with an acreage maximization objective.* Suppose there are N parcels, each with a size of $\bar{x}_n$. The cost of converting a parcel to CRP is b_i. As described above, in the pre-1990 CRP, land was chosen for enrollment from among the bids offered primarily to maximize the amount of land enrolled. A regulator interested in maximizing acres enrolled from among the eligible land would solve the following:[8]

$$\max \sum_{\mathrm{i}} x_i \quad \text{such that} \quad x_i \geq 0, \text{ and } \sum_{\mathrm{i}} b_i x_i \leq B, \;\; x_i \in X^{HEL} \tag{1}$$

where the total budget, B, for the CRP is the total program expenditure, x_i is the amount of parcel *i*th land to be enrolled, and $\mathrm{X}^{\mathrm{HEL}}$ is the set of all land classed as highly erodible.[9] The first-order conditions (FOCs) to this problem are simply

$$\begin{aligned} x^*_i &= \overline{x}_i, \quad && if \;\; \mathrm{b}_i - \lambda^* < 0; \\ x^*_i &= 0, \quad && if \;\; \mathrm{b}_i - \lambda^* > 0; \\ x^*_i &= X - \sum_{\{i:\, \mathrm{b}_i - \lambda^* < 0\}} x^*_i, \quad && if \;\; \mathrm{b}_i - \lambda^* = 0 \end{aligned} \tag{2}$$

where λ^* is the optimized value of the Lagrange multiplier from the budget constraint.[10] A heuristic solution to this problem can be obtained simply by ranking each piece of land from lowest to highest in terms of its bid price and then accepting land into the program starting at the top until the budget is expended.

Denote the total acreage, environmental benefit, and budget level associated with this solution as X^0, E^0, and B^0. Once the accepted acres are identified, the environmental benefits of the program can be computed as $E^0 = \sum_i x^*_i e_i$, where the environmental improvement on parcel i is represented by $e_i = \sum_k \theta^k e^k_i$. The vector $(e^1_i,\; e^2_i,\; ...,\; e^m_i)$ measures the various environmental features of interest such as soil erosion, nutrient runoff/leaching, wildlife habit, and carbon sequestration, and the weight placed on attribute e^k_i is θ^k. Thus, e_i can be interpreted as an environmental index for each parcel. The EBI of the post-1990 CRP is an example of one such index, but others are possible. Alternatively, e_i could be a measure of a single environmental amenity, such as the contribution of that parcel of land to improved water quality. This is equivalent to setting θ^k for all other factors to zero.

If landowners bid their opportunity cost, then the budgetary outlay (B) represents the social cost of the program as well as the program costs.[11] In the *ex ante* optimal policy, farmers with low-cost land should offer it for bid and the regulator should choose the cheapest land to put into the program.

Whether the actual CRP points correspond to the *ex ante* optimal ones depends upon whether the owners of the lowest-cost land enter low-cost bids, which then get selected. While we would predict that outcome in a full information market setting with no transaction costs, there may be a number of reasons why, in practice, the actual CRP land allocations do not match this optimal one. Carlson et al. (2000) ask whether the SO_2 program as implemented actually solved the trading problem efficiently; that is, whether the “right” firms traded so that all the gains from trade were truly exhausted. In the same way, we compare the optimal acreage-maximizing solution to the actual CRP policy. We refer to the actual CRP land allocation as the "*ex post*” or “actual” policy.

In addition to assessing whether the CRP policy as actually implemented prior to 1990 achieved the greatest acreage at least cost, we are also keenly interested in the environmental efficacy of the program after the environmental benefits index was adopted to target land for participation. Thus we next consider the following:

MBI policy 2. The post-1990 CRP: Ex ante *optimal CRP with an environmental maximization objective.* A regulator interested in maximizing acres enrolled from among the eligible land would solve the following:[12]

$$\max_{x_i} \sum_{\mathrm{i}} e_i x_i \quad \text{such that} \quad x_i \geq 0, \text{ and } \sum_{\mathrm{i}} b_i x_i \leq B,\ x_i \in X^{HEL} \qquad (3)$$

where the objective function now is to maximize environmental gain from the program. The FOCs to this problem are

$$\begin{aligned} x^*_i &= \bar{x}_i, \quad && \mathit{if}\ \mathrm{e_i/b}_i - \lambda^* > 0; \\ x^*_i &= 0, \quad && \mathit{if}\ \mathrm{e_i/b}_i - \lambda^* < 0; \\ x^*_i &= X - \sum_{\{i:\, \mathrm{b}_i - \lambda^* < 0\}} x^*_i, \quad && \mathit{if}\ \mathrm{e_i/b}_i - \lambda^* = 0, \end{aligned} \qquad (4)$$

where λ^* is again the optimized value of the Lagrange multiplier. Ranking each parcel from highest to lowest based on its environmental contribution per cost and choosing those parcels to enroll until the budget is exhausted will yield an optimal solution. This, of course, corresponds to the efficient solution. Again, once the accepted acres are identified, the environmental benefits of the program can be computed.

Command-and-Control Alternatives

In considering the CRP as a market-based instrument and comparing its efficiency to a CAC policy that might have been implemented instead, we define two types of CAC regimes, employing the terminology of Carlson et al. (2000). A "strict CAC" regime is one that treats all sources of environmental damage (or benefit) the same, regardless of (*a*) the costs of compliance or provision of the environmental service, and (*b*) the benefits associated with compliance or provision. In such a policy, each firm or farm faces the same standard, technology requirement, or other obligation. In contrast, an "enlightened CAC" regime treats all sources the same in one of the two dimensions, costs, or benefits, but makes allowance for variation in the sources costs of environmental compliance *or* in the heterogeneity in benefits, but not both. Clearly, a "super-enlightened" CAC regime that took account of both would be on a par with a well-functioning MBI from an efficiency perspective. We consider counterfactual policies of both CAC types beginning with a strict CAC approach.

CAC policy 1. Strict CAC, equal percentage reduction in HEL. In its purest form, this policy would require that all farms with HEL retire a fixed percentage of HEL land from active production. This approach clearly would be in the spirit of CAC since all farms are treated the same, regardless of the opportunity cost of retiring land or the erosion benefits from doing so. This policy could be implemented on a farm scale (its purest form), on a county scale (equal percentage reduction required of all counties), or possibly on a state scale. Denote the total acreage, environmental benefit, and budget level associated with this solution as X^1, E^1, and B^1. Note that $X^1 = X^0$.

This policy also could be implemented by enrolling land into the program until the total cost is the same, resulting in different levels of acreage enrolled. In this case the program would yield $B^1 = B^0$, but not $X^1 = X^0$.

CAC policy 2. Enlightened CAC policy, erosion index ranking. In this case, the policy will target land for enrollment based on a measure of environmental performance. Here we choose the erodibility index as a likely candidate since during the 1980s erosion control was a primary environmental concern for agricultural land.

The policymaker's problem is to maximize the environmental benefit by deciding which land to enroll. The optimization could occur at the entire state level or within a specific county; in either case, the policymaker wants to choose the parcels to enroll based on a specific environmental index (e_i) to maximize erosion benefits. Thus, the policymaker's objective is to

$$\max_{x_i} \sum_i x_i e_i \quad \text{such} \quad \text{that} \quad x_i \geq 0. \tag{5}$$

In this case, e_i is a scalar measure of erosion benefits. A comparison between this policy and the incentive-based policies can be accomplished in two different ways. First, the total amount of land in the state enrolled in the program can be held constant so that the regulator faces the constraint that $\sum_i x_i = X$. The first-order conditions for this problem are

$$\begin{aligned} & x^*_i = \bar{x}_i, \quad \textit{if} \;\; \mathrm{e}_i - \lambda^* > 0; \\ & x^*_i = 0, \quad \textit{if} \;\; \mathrm{e}_i - \lambda^* < 0; \\ & x^*_i = X - \sum_{\{i:\, \mathrm{e}_i - \lambda^* > 0\}} x^*_i, \quad \textit{if} \;\; \mathrm{e}_i - \lambda^* = 0. \end{aligned} \tag{6}$$

The conditions indicate that the optimal policy is to enroll land into the program until the total acreage cap X is reached. Denote as $\bar{e}$ the EBI as the erosion benefit of the parcel where $e_i = \lambda^*$. Another way to interpret the first-order conditions is that parcel i should be enrolled in CRP i.f.f. $e_i \geq \bar{e}$.

Heuristically, the solution can be found by ranking the parcels from highest to lowest in terms of the value of their environmental index. Parcels would then be accepted into the program until the acreage constraint is satisfied. Denote the total acreage, environmental benefit, and budget level associated with this solution as X^2, E^2, and B^2. Again, $X^2 = X^1$ by construction.

A second way to compare this policy to the incentive-based approach is to hold the total program cost constant. In this case, parcels are accepted into the program until the budget is exhausted: $\sum_{\mathrm{i}} b_i x_i \leq B.$[13] In this case, by construction, $E^2 = E^1$.

Data and the Environmental Benefits Model

The data for simulations come from the National Resource Inventory (NRI). The NRI sample design ensures statistical reliability for state and multi-county analysis of non-federal land (Nusser and Goebel 1997). Since the bulk of Iowa private land is in agricultural use, the NRI sample is ideally suited to represent Iowa agricultural land. In the simulations, we regard each NRI point as representing one producer with a farm homogeneous in management and in natural conditions. The size of the farm is assumed equal to the number of acres represented by the point (the NRI expansion factor).

The 1997 NRI data are based on surveys conducted at five-year intervals since 1982. The data provide information on land use and natural resource characteristics of the land in the survey years. In addition, land use information is available for the three years preceding the survey years. For the NRI points in CRP, the information on conservation practices established and the year of CRP sign-up is provided. For the NRI points in crop production, information on the crop grown and conservation practices is available.

A site-specific erodibility index, $e_i^1 = EI_i$, is provided in the NRI. To compute the estimates of other environmental improvements from CRP enrollment, we use the Environmental Policy Integrated Climate (EPIC) model version 1015 (Izaurralde et al. 2002)[14]. EPIC is a simulation model commonly used for large regional analyses (e.g., Plantinga and Wu 2003; Babcock et al. 1997b. We use EPIC to obtain the estimates of water erosion, wind erosion, N loss in sediment, NO_3 loss in runoff, NO_3 subsurface loss, NO_3 leaching, labile P loss in runoff, and P loss in sediment.

At each of the NRI data points, two 30-year EPIC simulations are run, one assuming continuous cropping, and another assuming that the point is in CRP. The NRI database provides baseline land use and other input data for the simulations. The quantities of the environmental benefits from CRP are computed as the differences between appropriate EPIC outputs under continuous cropping and CRP, averaged over the 30 years.

A site-specific per acre opportunity cost of converting a parcel to CRP, b_i, was estimated using a CRP rental rate function. The rental rate function, fitted on the census of Iowa 1987 CRP contracts, relates the CRP rental rate to the parcel location and its suitability for agricultural use. Details on the rental rate function estimation are provided in the Appendix.

Simulation Results

Because the 1997 NRI contains resource information in five-year intervals since 1982 and the CRP was initiated in 1986, we had three possible years from which to choose: 1987, 1992, or 1997. We chose CRP land enrolled in 1987 as our baseline. The other NRI years are less suitable for our study. Compared to 1987, there was little CRP enrollment in 1992, making meaningful study difficult. For 1997, the NRI does not have site-specific enrollment information for land enrolled in that year. A CRP parcel's enrollment year is important because we need to choose CAC points in the same year as the actual CRP points' enrollment year in order to make valid comparisons.

Table 2 gives a list of the policy scenarios studied, along with their total CRP acreage, average erodibility index (EI)[15] number of enrolled land, and total EI gained by each program. For the CRP program as implemented, 800 NRI points in Iowa were enrolled in 1987, with a total of X^0 = 1,095,800 acres at an annual cost of B^0 = \$90,519,251. The total acreage (X^0) or the annual program cost (B^0) is used to ensure that alternative policy scenarios have comparable scales. Because the pre-1990 CRP is more consistent with targeting HEL acreage rather than maximizing environmental benefits, we analyzed only one *ex ante* optimal MBI designed to maximize the amount of HEL in the program. In line with this focus, the only strict CAC policy evaluated is the one for which the total acreage enrolled equals the acreage for the CRP as implemented. In the case of enlightened CRP, the CAC policy enrolls land into CRP with the highest EI until the total acreage is reached or until the total program cost is exhausted. When the total

TABLE 2. Summary of CRP policies studied

Policies	Total acres	Average EI	Total EI
MBI policy 0: the actual CRP (X^0, B^0)	1,095,800	20.1	22,025,580
MBI policy 1: the *ex ante* optimal CRP (X^1, B^0)	1,288,641	24.4	31,442,840
CAC policy 1: the strict CAC CRP (X^0, B^2)	1,095,800	53.9	59,063,620
CAC policy 2a: the enlightened CRP—equal acres(X^0, B^3)	1,095,800	56.4	61,803,120
CAC policy 2b: the enlightened CRP—equal costs (X^4, B^0)	1,174,300	55.0	64,586,500

acreage is used as a cap, we call the CAC policy based on EI the “equal acreage enlightened CAC.” When the total cost is used as a cap, we call the CAC policy “equal cost enlightened CAC.”

Profile of CRP Land under Alternative Policies

The *ex ante* optimal CRP policy enrolls land with the lowest costs. Therefore, this policy is able to enroll the most land into CRP. The acreage enrolled is X^1 =1,288,641 acres, 17.6 percent more than the acreage of the actual CRP.

Land enrolled in the actual CRP accounted for about 15.8 percent of cropland with an EI greater than 8 (i.e., highly erodible land) in Iowa. This percentage number is used as a basis for the strict CAC policy. More specifically, each county enrolls the same percentage, 15.8 percent of its highly erodible land into CRP, which implies that the total enrolled land under the strict CAC is equal to the total acreage of the actual CRP.

The average EI of the actual CRP (20.1) is much lower than the average EI of the CAC policies (56.4 for the equal acreage enlightened CAC). The equal acreage enlightened CAC has an annual cost of about B^3 = $84,600,000, which is lower than that of the actual CRP, B^0. Conversely, the equal cost enlightened CAC is able to enroll more land (X^4 = 1,174,300 acres). This is because land with a higher EI tends to have lower values than land with a lower EI. While the average EI is highest under the enlightened CRP with equal acreage constraint, the total EI is higher under the enlightened CRP with equal costs.

The distribution of CRP land under the different policies, as shown in Figures 1 through 5, is one way to illustrate their different implications. Figure 1 indicates that land enrolled in the actual CRP is fairly evenly distributed around the state. By construction, land enrolled in the strict CAC program is also evenly scattered in the state. However, the *ex ante* optimal CRP program would enroll land predominantly in southern Iowa and a few counties along the Missouri River, where land in general is cheaper than in other parts of the state. The CRP land under the two enlightened CAC policies comes mainly from counties in the south and along the Mississippi and Missouri Rivers on the state boundary. The two policies have similar CRP land distributions because they have the same criterion for enrollment, and the only difference lies in how the total CRP acreage is set.

It is interesting that both the *ex ante* optimal CRP and the two enlightened policies move land away from a uniform distribution across the state to more acreage enrolled in

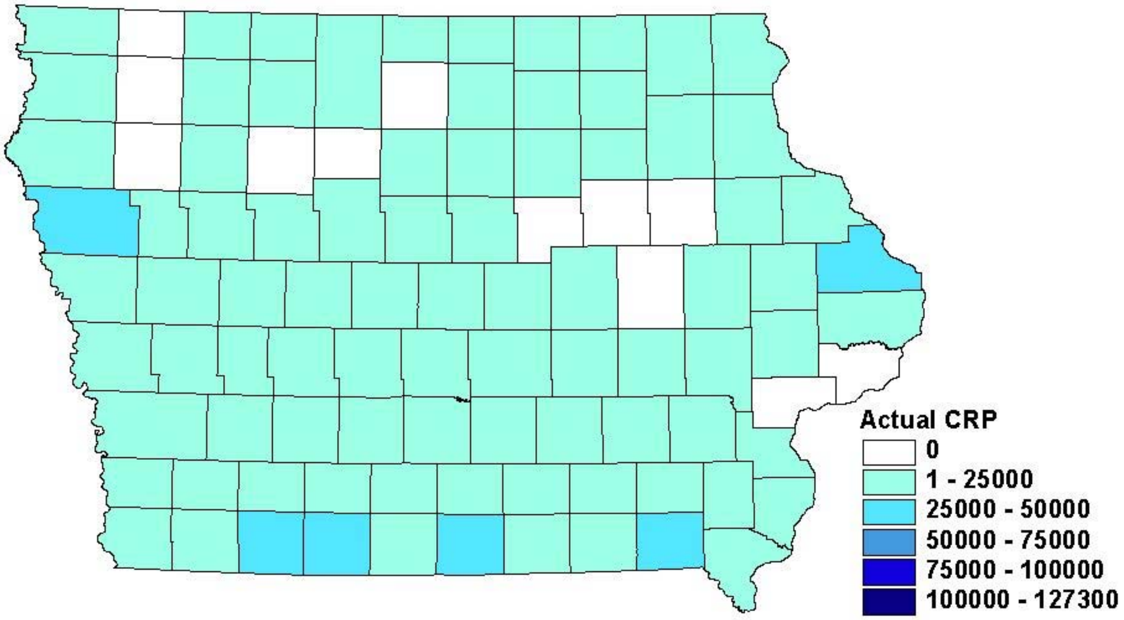

FIGURE 1. The distribution of CRP acres: the actual CRP

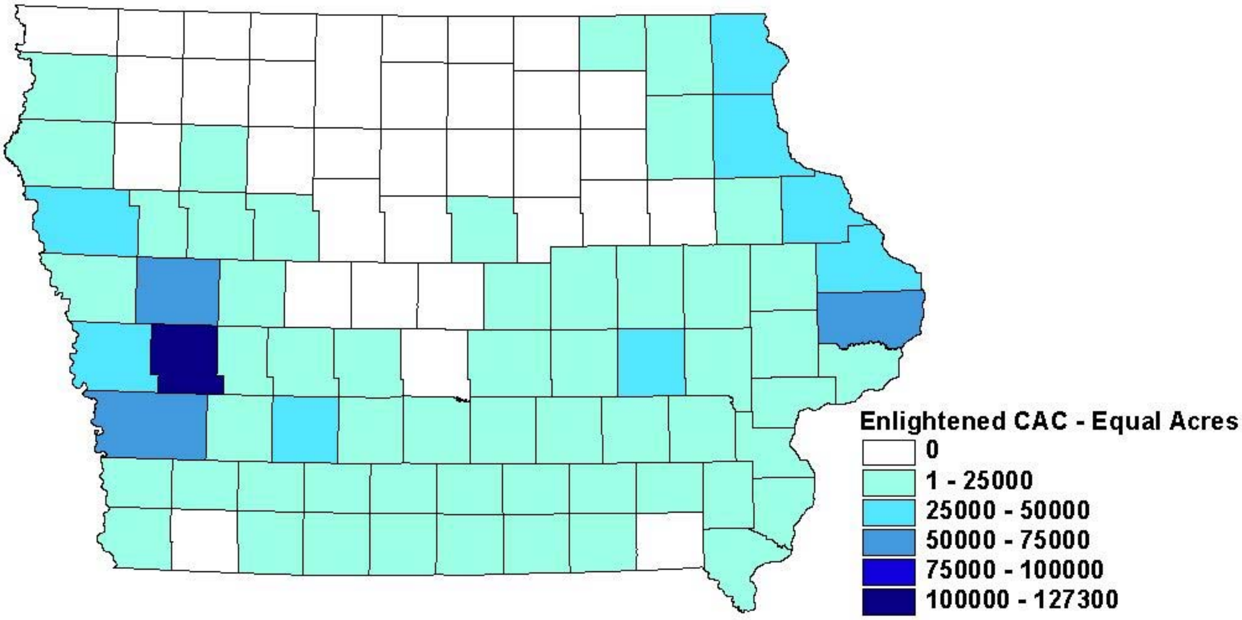

FIGURE 2. The distribution of CRP acres: the enlightened CAC—equal acres

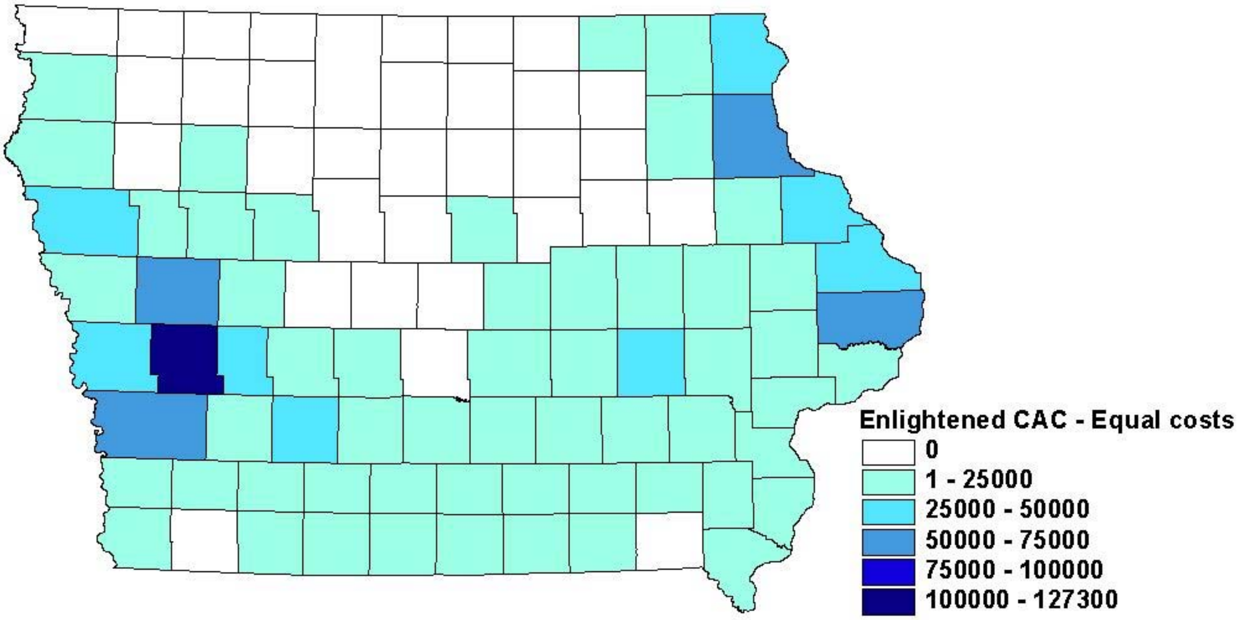

FIGURE 3. The distribution of CRP acres: the enlightened CAC—equal costs

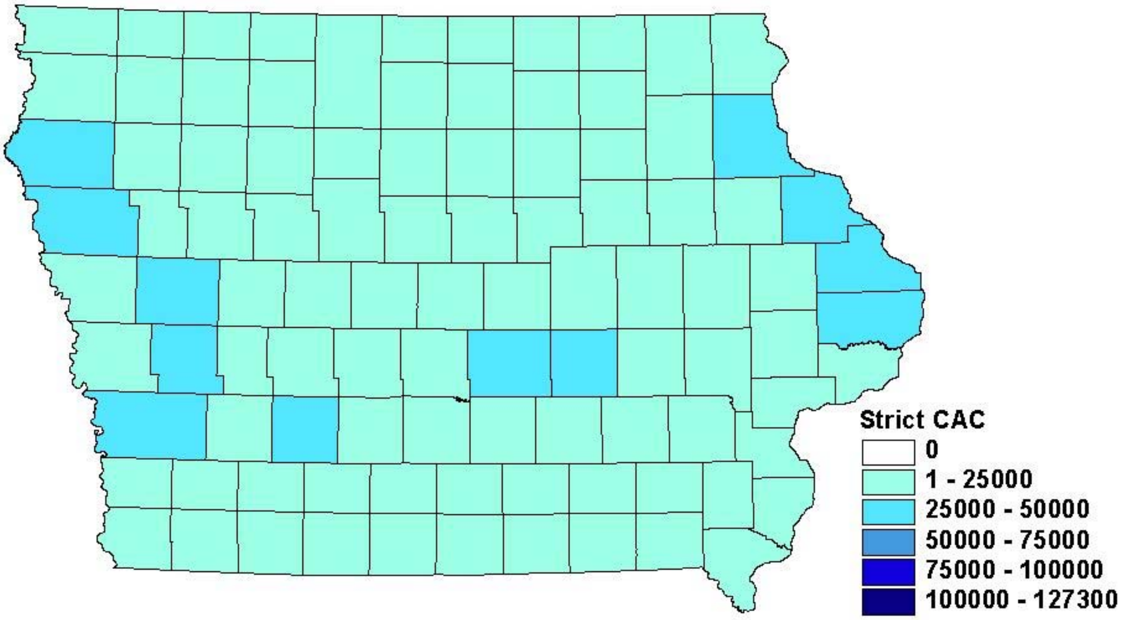

FIGURE 4. The distribution of CRP acres: the strict CAC

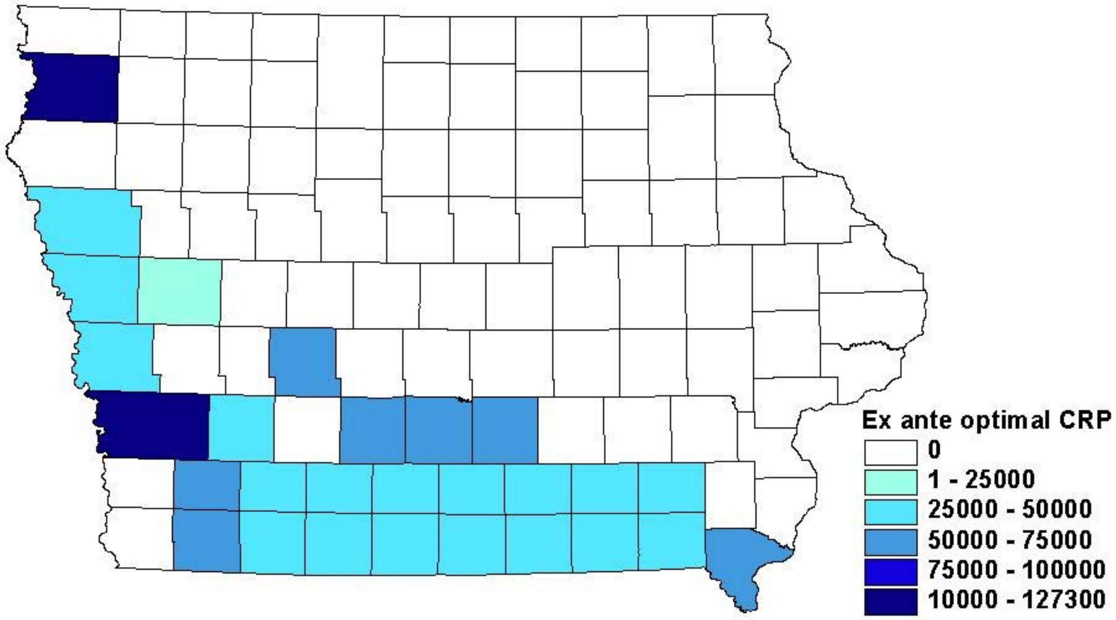

FIGURE 5. The distribution of CRP Acres: The *ex ante* optimal

the south and along the two rivers. At first blush, this is surprising given that the criteria used to identify the plots of land enrolled are different: costs in the cases of the *ex ante* CRP and the erodibility index in the case of the CAC policies. But, as Babcock et al. (1997a) note, this result is expected when there is a strong negative correlation between an environmental amenity (EI in this case) and the cost of the land.

Another way to illustrate the difference between the actual CRP and a counterfactual policy alternative is to identify which parcels would be enrolled in a CRP program whether the parcel selection was made as it actually was (the actual CRP program) or had it been made using the decision criteria of a counterfactual policy. Table 3 lists such overlapping acres between the actual CRP and the counterfactual polices examined in this paper. It is clear that the extent of overlap is quite small in all cases; thus, the alternative decision criteria may have significant environmental consequences.

The different location of CRP points under the different policies also implies that different people may benefit from the CRP policies. For example, the benefit of improved soil productivity from reduced erosion is mainly enjoyed by local land owners. On the other hand, some environmental benefits are more regional; for example, the reduction of nutrient runoff in Iowa may help relieve the hypoxia situation downstream in the Gulf of

TABLE 3. Common land enrolled both by the counterfactual CRP and by the actual CRP

Policies	Acres	% (of the total actual CRP acres)
The *ex ante* optimal CRP	35,100	3.20%
The strict CAC CRP	12,100	1.10%
The enlightened CRP—equal acres	8,500	0.78%
The enlightened CRP—equal costs	9,600	0.88%

Mexico. In this case, the different CRP land distributions may be less significant, although the spatial location of the CRP points may have significant regional consequences as well. In any case, it is important to know the relative magnitude of each dimension of environmental benefits in order to assess the overall implication of CRP. Extensively validated bio-physical models, such as EPIC, can provide information on such relative magnitudes.

Quantitative Differences in Environmental Benefits Shown by Simulations

After the points for alternative policies were selected, we ran EPIC simulations on them to obtain quantitative information on environmental indicators, including soil erosion, nutrient loss, and carbon sequestration. For land under all policies, either the actual CRP or the counterfactual CRP policies, we ran two sets of EPIC simulations: simulation assuming the land is under CRP practices and simulation assuming the land is under non-CRP practices.[16] We obtained the amount of environmental gain (or loss, if negative) by taking the difference between these two sets of simulations. For example, the number in the first row and the first column of the data in Table 4 indicates that the actual CRP policy achieved an annual erosion reduction of about 3,394,129.88 tons, as compared to the non-CRP situation. The results of the simulations are reported in Tables 4 and 5 and Figures 6 and 7.

From Table 4, we see that the *ex ante* optimal CRP does not necessarily have better environmental performance in all aspects, even though it enrolls significantly more (17.6 percent) land. In fact, there is a clear non-uniformity of ranking among the different environmental indicators. For example, the actual CRP policy results in less water erosion reduction but more NO_3 leaching reduction and more carbon sequestration than

TABLE 4. Comparison of the actual CRP with the *ex ante* CRP (environmental changes over all acres as a result of enrolling land into CRP)

	Actual CRP land	**Optimal CRP land**	**Difference**	**Difference in %**
Water erosion (t)	-3,394,129.88	-3,622,011.51	227,881.63	-6.7
Wind erosion (t)	-362,429.39	-262,276.83	-100,152.57	27.6
N loss sediment (kg)	-6,314,530.63	-6,678,850.69	364,320.06	-5.8
NO_3 loss runoff (kg)	-434,079.44	-535,168.49	101,089.05	-23.3
NO_3 loss subsurface (kg)	-230,951.67	-266,576.43	35,624.77	-15.4
NO_3 leaching (kg)	-1,519,514.95	-688,070.70	-831,444.25	54.7
P loss runoff (kg)	27,989.73	43,403.39	-15,413.65	-55.1
P loss sediment (kg)	-1,026,896.99	-953,521.93	-73,375.06	7.1
C sequestration (kg)	181,537,365.55	87,579,066.77	93,958,298.77	51.8

TABLE 5. Environmental performances (per acre) under alternative CRP policies

	The actual CRP	Ex ante optimal	Enlightened CAC-equal acres	Enlightened CAC-equal cost	Strict CAC
Water erosion (t)	-7.754	-7.114	-8.695	-8.431	-8.691
Wind erosion (t)	-0.830	-0.517	-0.416	-0.398	-0.486
N loss sediment (kg)	-14.443	-13.129	-15.645	-15.239	-16.105
NO3 loss runoff (kg)	-0.994	-1.053	-0.952	-0.949	-1.034
NO3 loss subsurface (kg)	-0.527	-0.523	-0.756	-0.727	-0.744
NO3 leaching (kg)	-3.475	-1.354	-1.187	-1.256	-1.349
Labile P loss runoff (kg)	0.056	0.080	0.065	0.053	0.065
P loss sediment (kg)	-2.348	-1.874	-2.134	-2.178	-2.128
C sequestration (kg)	410.304	169.304	-95.709	-92.956	-55.426

Note: As in Table 4, performances are relative to the pre-enrollment situation.

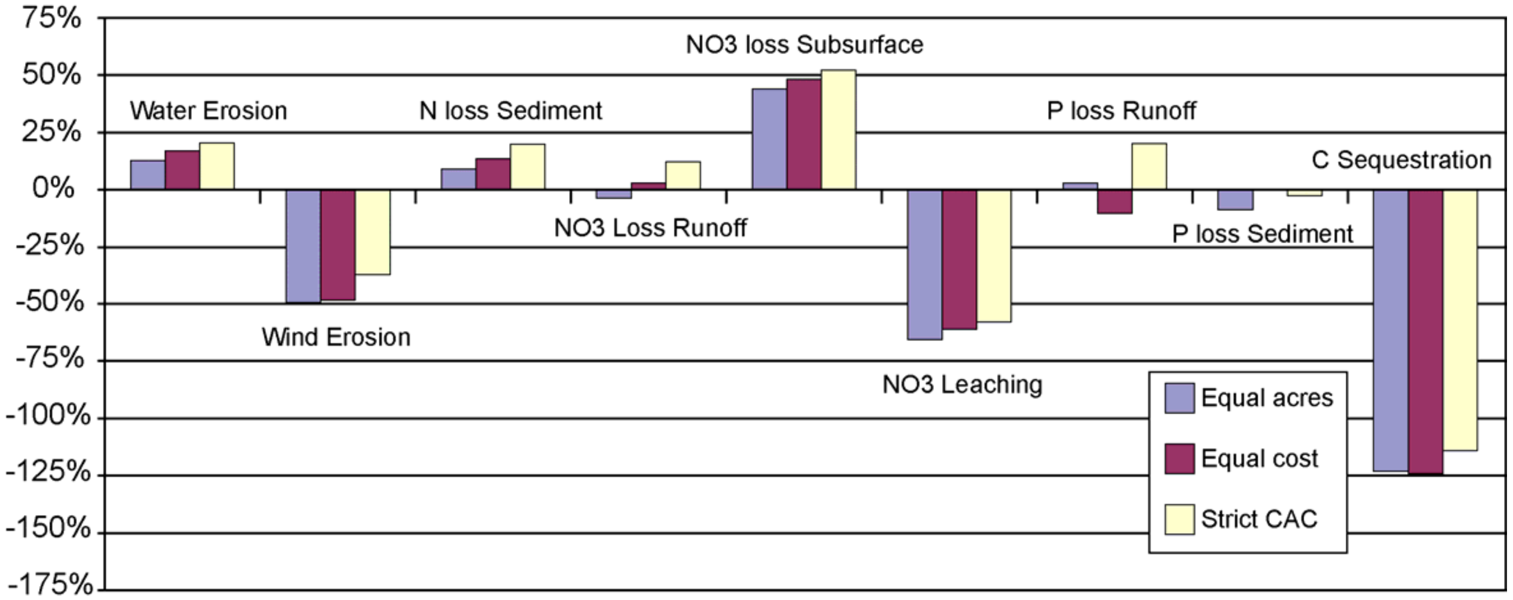

FIGURE 6. The actual versus the CAC policies

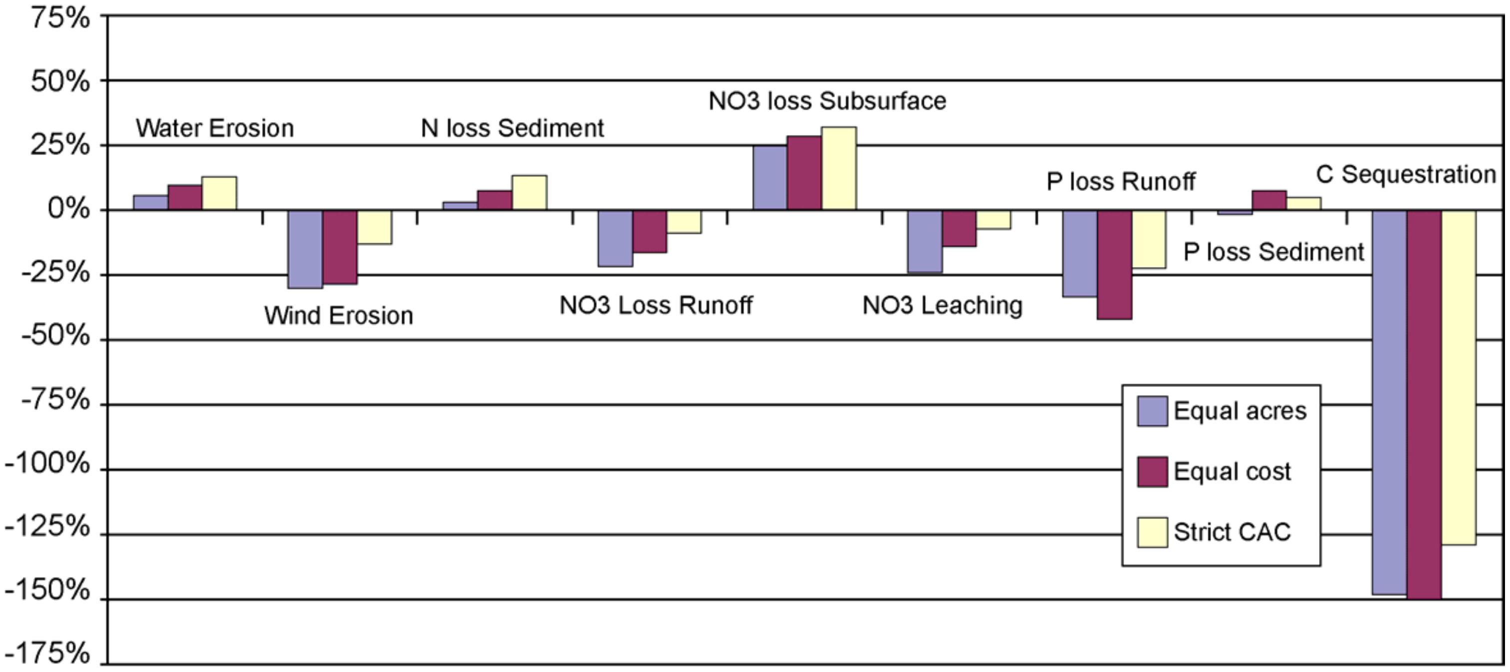

FIGURE 7. The optimal versus the CAC policies

the *ex ante* optimal policy. This implies that, on a per unit of land basis, carbon sequestration and reduction in NO_3 leaching is much lower under the *ex ante* optimal CRP than under the actual CRP. This is illustrated in the first two columns of Table 5.

In Table 5, we present the per acre environmental gain (or loss) under all CRP policy alternatives we have discussed. Just as in Table 4, the gain (or loss) is relative to the non-CRP situation. For example, the number in the last row and last column of Table 5 indicates that the strict CAC policy actually would result in less carbon sequestered in the soil in the amount of 55.426 kg, relative to the non-CRP situation. Such per unit performance measures can help explain the underlying reason that one policy performs better than another policy. Again, comparing the actual CRP and the *ex ante* optimal, the former has a higher per acre water erosion reduction than the latter; however, the opposite is true when all acres under the policies are considered. This is because of the larger amount of land enrolled. Moreover, although both policies have similar per acre reduction in NO_3 loss subsurface, the *ex ante* CRP turns out to be better when all acres are taken into account.

From the last three columns in Table 5, we see that the three CAC policies have very similar environmental performances: the numbers not only have the same sign for each indicator but also are comparable in terms of magnitude. This similarity is likely because of the fact that the EI is used as a targeting tool in all three CAC policies. As Table 2 shows, all of them enroll land with high and similar average EIs.

Two interesting results emerge from Table 5. First, in environmental policies (including the actual CRP), the EI is often used as an indicator for the potential of environmental benefit. By definition, the EI indicates the potential of a soil to erode based on climatic factors and the physical and chemical properties of the soil. However, results in Table 5 show that, on average, higher EIs do not necessarily mean a higher erosion reduction upon conversion to CRP. In particular, a higher erosion reduction is achieved under the actual CRP, not the *ex ante* optimal, although the latter has a higher average EI. However, compared to the actual CRP or the *ex ante* optimal CRP, the three CAC policies (with much higher average EIs) do have higher erosion reductions.

Second, higher EIs do not necessarily imply higher performance in other environmental indicators. Carbon sequestration provides a good example: all three CAC policies actually obtain less carbon storage in the soil than do conventional agricultural uses. In fact, the best carbon sequestration is obtained through the actual CRP, which has the lowest average EIs among all of the policies studied.

Figures 6 and 7 illustrate how the environmental performances of the three CAC policies compare to those of the actual CRP and the *ex ante* optimal policy. In both figures, the bars indicate the environmental performance differences in percentages. A positive percentage indicates better performance under the CAC policies and a negative percentage indicates better performance under the actual CRP (in Figure 6) or the *ex ante* optimal (in Figure 7).

Note that the two figures look similar to each other. Both graphs show that, compared to the CAC alternatives, the actual CRP and the *ex ante* optimal CRP obtain a higher reduction in wind erosion and NO_3 leaching, higher carbon sequestration, a lower reduction in water erosion, N loss through sediment, and subsurface NO_3 loss. The major difference comes from P loss runoff and NO_3 loss runoff. The similarity of the two figures suggests that for most indicators we would get similar conclusions whether we compare the CAC alternatives with the actual CRP or with the *ex ante* optimal.

Discussion and Conclusion

Based on these simulations, the evidence is at best unclear as to the relative advantage of MBI and CAC policies as applied in the case of CRP. More HEL acreage with a higher average EI could have been enrolled in the subsidy program than actually was accomplished, implying that the MBI could have achieved greater efficiency. This is consistent with the findings of Smith (1995). In terms of overall environmental benefits from the program, there is no clear winner between the *ex ante* optimal MBI and the actual CRP.

Compared to a CAC alternative, the market-based instrument of CRP yielded less enrolled HEL acreage for a given budget outlay. When the acreage totals are held constant, the budget outlay is lower and the average EI is higher with the CAC alternatives. However, from the perspective of environmental gains, for the same program cost, the actual MBI policy as implemented seems to be preferred to an enlightened CAC policy (i.e., the equal-cost enlightened CRP) in some environmental aspects (e.g., carbon sequestration and wind erosion) but not in others (e.g., water erosion and subsurface NO_3 loss).

There are many CAC policy alternatives. In our study of CRP, the EI forms the basis for all of the CAC policies. Our results concerning the efficiency of CAC relative to the MBI are undoubtedly highly influenced by this choice; with a different method for implementing the CAC, the policy would be more or less attractive relative to the MBI. The use of the EI to form the basis for the CAC policy is intuitive and consistent with a long history of agricultural conservation policy, making it a natural choice for study. Alternative choices could be an interesting topic for future study.

As our results show, even if a policy is intended to reduce erosion, EI may not be the best targeting tool. Of course, if policymakers intend to reduce multiple adverse environmental effects, the EBI might be employed. Our ongoing research involves examining how the application of EBI will change the effectiveness of different policies.

Endnotes

1. A few examples include Oates, Portney, and McGartland 1989; Hahn 1989; and Kling 1994. Tietenberg 1985 provides an excellent table and summary of this literature.

2. Kolstad's (1986) work is an important, early exception.

3. The motivation for adopting a subsidy was likely due more to its voluntary nature than any efficiency property associated with its market-based price information.

4. This is an example of the more general case known in the literature as a "closed" class; see Holderness 1989.

5. While maximizing acreage was not the stated goal of the program, analysts have concluded that the implementation was largely consistent with a maximum acreage objective.

6. As Kathy Segerson noted when discussing this paper, an alternative approach to achieving least-cost land retirement would have been to issue land use permits for farming on HEL and to allow them to be traded. This would have retained the voluntary nature of the program with a much lower total program cost.

7. Specifically, the points associated with the three remaining factors are enduring benefits for up to 50 points, air quality for up to 35, and location in a Conservation Priority Area for up to 25. More information on the computation of the EBI is available in USDA-ERS 1997.

8. As long as the budget is large enough, the constraint on total acreage described above will not be binding, and if the budget is not large enough, no solution is feasible.

9. The CRP also limited the number of acres that could be enrolled within any county, but this limit was rarely reached and appears to have provided only minimal real constraint on program participants or regulators.

10. Throughout the paper, we use "*" to indicate optimized values.

11. As noted in the introduction, if the social cost of funds is greater than the private costs, the total program costs will underestimate the full social costs.

12. As with the model (1)-(2), as long as the budget is large enough, the constraint on total acreage previously described will not be binding, and if the budget is not large enough, no solution is feasible.

13. Note that the budget constraint is used to identify how many parcels can be enrolled, that is, how far down the rank ordered list the authority can afford to go. But unlike the optimal environmental CRP, the cost of enrolling parcels is not used to rank the parcels.

14. Earlier versions of EPIC were called Erosion Productivity Impact Calculator (Williams 1990).

15. EI is a number that indicates the potential of a soil to erode based on climatic factors and the physical and chemical properties of the soil. A higher index indicates that a greater investment is needed to maintain the sustainability of the soil resource base if intensively cropped; thus, a higher index for enrolled land indicates more program erosion benefits.

16. Non-CRP practices, which are obtained from the NRI data, include various farming alternatives, e.g., a piece of land may be under corn-soybean rotation with reduced tillage.

Appendix

Estimation of the CRP Rental Rate Function

To estimate the function relating the per acre CRP rental rate to the parcel location and its suitability for agricultural use, we used the data on all the actual CRP contracts enrolled in the program in Iowa in 1987 (USDA-FSA 2003). Out of the 15,270 records available, 15,221 were complete and used in estimation.

The rental rate function model is described as

$$rent_i = \alpha_0 + \sum_{j=1}^{98} \alpha_{ji}\delta_{ji} + \beta class_i + \varepsilon_i$$

Here the subscript i refers to the *i*th contract (i=1,…,15,221), subscript j refers to the *j*th Iowa county, $rent_i$ is the CRP rental rate in dollars per acre, δ_{ji} is the county indicator, i.e., $\delta_{ji} = 1$ if parcel i is located in county j and zero otherwise, and $class_i$ is the land-use capability classification of the parcel. The land-use capability classification system evaluates land according to its limitations for agricultural use with the land of classes 1 to 3 suitable for cultivation, land of class 4 suitable for limited cultivation, and land of classes higher than 4 not suitable for cultivation (Troeh and Thompson 1993). The ε_i is an error term, and the α 's and β are the parameters of interest. Summary statistics for the data are presented in Table A.1.

Estimation of model (A.1) on the data resulted in good fit ($R^2 = 0.852$). As expected, the estimate of β is negative and statistically significant meaning that land better suited for agricultural production requires higher CRP rental rate. For the sake of brevity, the estimates of the parameters are not reported here but are available from the authors upon request.

TABLE A.1. Summary statistics for the data used in estimation of CRP rental rate function

Variable	Mean	St. Dev.	Min	Max
CRP rental rate, $ per acre	78.40	8.40	35.0	90.0
Land-use capability class	3.36	0.96	2.0	8.0

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