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# **The Economic, Environmental, and Fiscal Impacts of a Targeted Renewal of Conservation Reserve Program Contracts**

Bruce A. Babcock, P.G. Lakshminarayan, and JunJie Wu

*Working Paper 95-WP 129*

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## ABSTRACT

What to do with CRP contracts as they expire is one of the most pressing issues confronting U.S. agricultural policymakers in 1995. Because CRP renewal will compete in 1995 with other agricultural programs for funding, greater attention will be paid to improved targeting of payments to maintain a significant portion of existing environmental and farm benefits at a reduced program cost. We consider three alternative renewal criteria: (1) renewal of least expensive land first (cost-ranking), (2) renewal of most environmentally sensitive land first (benefit-ranking), and (3) renewal of land according to the cost per unit of environmental benefit offered (cost/benefit-ranking). Environmental indicators used to measure benefits include sheet and rill erosion, wind erosion, surface water quality, groundwater vulnerability to pesticide leaching, wildlife habitat, and an aggregate of the five individual indicators. Measures of these environmental attributes currently enrolled CRP land are from the 1992 National Resources Inventory. Estimates of the trade-offs between the number of acres enrolled in CRP and the level of specific environmental benefits from targeting environmental indicators for various limits on annual government expenditures are provided. We show that the degree of conflict between maximizing CRP acreage and maximizing environmental benefit is determined by the moments of joint distribution of land opportunity costs and land characteristics. In particular we show that conflicts increase as (1) land rental rates and the level of environmental benefits offered by individual tracts of CRP land become more positively correlated and (2) the distribution of environmental benefits across CRP land becomes less uniformly distributed. We estimate that renewing 49 percent of CRP acreage could provide 72 percent of aggregate environmental benefits while reducing costs by 55 percent. Greater cost savings will result, so policymakers want to target one or two specific environmental benefits.

## **THE ECONOMIC, ENVIRONMENTAL, AND FISCAL IMPACTS OF A TARGETED RENEWAL OF CONSERVATION RESERVE PROGRAM CONTRACTS**

Determining the best way to achieve multiple benefits from a renewal of the Conservation Reserve Program (CRP) is perhaps the most pressing policy issue that Congress will resolve in the 1995 Farm Bill. Support for a renewal is widespread because both farmers and the environment benefit from CRP. Environmental benefits include reducing soil erosion, increasing water quality, and enhancing wildlife habitat. Farmers benefit from supply reductions and direct rental payments offered by CRP. In 1995, CRP renewal will compete with other agricultural programs for funding, so greater attention will be paid to improved targeting of payments to maintain a significant portion of existing environmental and farm benefits at a reduced program cost. But the question of what should be targeted is open given the many benefits of CRP.

Previous analyses of CRP efficiency have demonstrated that specific CRP benefits could have been achieved at a lower cost. Heimlich and Osborn estimate that it would cost \$0.54 per ton to save soil in a five million acre CRP renewal if maximum soil erosion were targeted, compared with a cost of \$1.01 per ton if renewal were based on minimizing rental cost. Reichelderfer and Boggess demonstrate that the cost per ton for reducing erosion could be decreased by 15 percent if erosion benefits were maximized. They also estimate that the amount of supply control benefits would increase by 13 percent if supply control had been targeted. Ribaud shows how net water quality benefits from CRP land enrolled after the seventh sign-up in 1988 could have been increased by better targeting, particularly if the economic benefits of improved water quality were included.



A critical factor in determining the political optimality of a policy that targets a single objective is the extent to which other objectives are also achieved. Reichelderfer and Boggess show that there are significant trade-offs among the objectives of maximizing erosion benefits, supply control benefits, and the amount of acreage enrolled in CRP. Ribaud reports that there is a significant trade-off between wind and water erosion in current CRP land because land vulnerable to wind erosion is not vulnerable to water erosion. Both Reichelderfer and Boggess and Ribaud conclude that the characteristics of land initially enrolled are consistent with a CRP objective of maximizing the number of acres enrolled, rather than maximizing some environmental benefit or the amount of supply control offered by CRP.

In this paper we consider the benefit trade-offs under alternative CRP renewal policies. We demonstrate that the magnitude of the trade-offs between maximizing CRP acreage and maximizing environmental and supply control benefits is determined by the moments of the joint distribution of land opportunity costs and land characteristics. We estimate the extent to which the multiple CRP benefits are achieved under alternative renewal criteria and for varying budget constraint scenarios. The alternative renewal criteria include: (1) renew least expensive lands first; (2) renew most environmentally sensitive lands first; and (3) renew lands to maximize environmental benefits. Six indicators measure environmental benefits including water erosion, wind erosion, groundwater vulnerability to pesticide leaching, surface water quality, wildlife habitat potential, and an aggregate index that is a simple linear aggregate of the five individual indicators.

We describe how we constructed the five environmental benefit indexes, present the distribution of environmental benefits and enrollment costs of current contracts, and analyze the

extent to which efficiency can be increased by targeting. We discuss data and estimation procedure and report estimates of the percentage gains in efficiency under alternative targeting policies and scenarios.

### **Target Indicators**

The indicators selected for targeting CRP renewal to achieve greater environmental benefits, as indicated by multiple media (soil/water/wildlife habitat), may be classified into four broad categories: erodibility, groundwater quality, surface water quality, and wildlife habitat potential. More specifically, soil erosion from wind and water, groundwater vulnerability to pesticide leaching, surface water quality measured indirectly by the nearness of CRP to surface water bodies, and a potential wildlife habitat index were selected as the indicators for targeting CRP lands.

The Universal Soil Loss Equation (USLE) was used in estimating water erosion (sheet and rill erosion) (USDA 1978). The wind erosion estimates are the average annual soil loss as estimated by the wind erosion equation. A detailed explanation of factors entering the wind erosion equation is available in USDA 1988. Both wind and water erosion estimates used for targeting are the preenrollment values for the NRI point that is contracted under CRP. We use preenrollment rather than postenrollment estimates to indicate the likely erosion levels if the land were returned to production.

The groundwater vulnerability index (GWV index) for pesticide leaching are obtained from Kellogg et al. 1992. The GWV index is a function of soil leaching potential, pesticide leaching potential, precipitation, and chemical use. The GWV index can only provide relative

measures of the risk of shallow groundwater contamination by chemicals used in agriculture. It represents an extension to the national level of the State Pesticide Interaction Screening Procedure. Chemical use at each NRI point was inferred based on the crop grown and the crop specific chemical use assembled by Resources for the Future (RFF). The GWV index is based on the 1982 pesticide use and cropping patterns.

At present there is no direct or relative measure of risk to surface water from agricultural nonpoint source pollution at the national level. Therefore, we use the distance of a given NRI point from surface water bodies as a rough indicator of surface water quality (SWQ index). It is well documented that the closer cropland is to a surface water body the greater the chance of contamination from agricultural chemicals and soil sediment from field runoff. For example, the establishment of riparian buffer strip around water bodies buffers the zone between cropland and surface water, thereby reducing pollution caused by field runoff. The distance variable in the National Resource Inventory (NRI 1992) database measures actual distance (in feet) from the surface water body.

We constructed an index by assigning scores based on distance,  $d$ , from the surface water body: SWQ index = 100 if  $d < 100$  feet; SWQ index = 64 if the distance is between 100 feet and 165 feet; SWQ index = 32 if the distance is greater than 165 feet but less than 1/16 mile; SWQ index = 16 if the distance is between 1/16 and 1/8 mile; SWQ index = 8 if the distance is between 1/8 and 1/4 mile; and SWQ index = 0 if  $d > 1/4$  mile. The NRI collects and reports distances of 1/4 mile and less.

Site-specific ecological studies have shown that CRP has improved the abundance and distribution of wildlife habitat. Reproductive success of upland nesting species of waterfowl

such as mallard and blue-winged teal has been greater on CRP land than on cropped land (Kantrud 1993; Best et al. 1994). It is the general perception of wildlife biologists and ecologists that management decisions favoring species suited for expansive tracts of grass/hayland may conflict with those intended for species endemic to agricultural production landscapes.<sup>1</sup> Wildlife biologists and ecologists are quick to point out that critical wildlife habitat east of the Mississippi River differs from that west of the Mississippi.

East of the Mississippi, riparian land and wetlands are the critical wildlife habitat. Thus, we assign a value of 100 to CRP land within 100 feet of water bodies and to CRP land classified as wetlands. For CRP land farther than 100 feet from the surface water body the same discrete score as that of the surface water quality index was used. Even though land more than 1,320 feet away from a water source has some riparian value, the maximum distance reported in the NRI data is 1,320 feet.

For regions west of the Mississippi, both riparian lands and grasslands enhance the wildlife habitat. Values for wildlife habitat west of the Mississippi should compare with the index values for land east of the Mississippi. Riparian lands and wetlands west of the Mississippi have the same scores as those for land east of the Mississippi. To target grasslands west of the Mississippi, a score of 10 was assigned to all grasslands.

In addition to the specific environmental indicators targeted to protect soil, water, and wildlife habitat resources, a cumulative environmental benefits index (henceforth referred to as *multiple index*) was constructed as:

$$\text{Multiple Index} = f(\text{water/wind erosion, ground/surface water quality, wildlife habitat}).$$

Since the units of measurement as well as the range of each of these indicators are substantially different, we normalized them to a scale of 0 to 100. The ranking of CRP land for targeting under any given indicator is based on this normalized score. The specific equation used in constructing the multiple index is

$$\begin{aligned} \text{Multiple Index} = & \beta_1 * \text{Water Erosion} + \beta_2 * \text{Wind Erosion} + \beta_3 * \text{GWV Index} + \\ & \beta_4 * \text{SWQ Index} + \beta_5 * \text{WLH Index} \end{aligned}$$

where  $\beta_i$  is the weight assigned to each target indicator. Here we have assumed all target indicators are equally important; therefore, a value of 1 is assigned to each  $\beta_i$ . Alternatively, if the decision maker can assign different weights to these indicators or prefers a multiplicative relationship, then the multiple index can be constructed accordingly. Targeting CRP land for cumulative environmental benefits is based on the linear multiple index shown above.

### **Distribution of Current CRP Land**

About 34 million acres of U.S. cropland were enrolled in the CRP through the eleventh sign-up in 1991, at an annual cost of \$1.67 billion and an average annual rental value of \$49 per acre. Table 1 presents the distribution of CRP acres and total annual rental cost in the ten USDA farm production regions. Appendix B tables show the distribution of CRP land by USDA regions and specific environmental indicators used in this analysis. Appendix C contains maps that illustrate the locations of CRP land and different relevant characteristics at the county level. As can be seen in Table 1, the Corn Belt, Lake States, Northern and Southern Plains, and Mountain regions accounted for more than 85 percent of the cost and acres enrolled under CRP. The Northern Plains alone accounted for nearly 25 percent of total CRP acres. Average rental

Table 1. Distribution of CRP acres, total and average rental payments, and total soil loss by USDA region

USDA Region	Total CRP		Total Rent		Average Rent dollars per acre	Total Soil Loss <sup>a</sup>		Soil Savings Pre/Post	Erosion Rate tons per acre
	acres	percent	dollars	percent		Pre	Post		
Northeast	201,500	0.60	11,965,236	0.72	59.38	2,773,475	234,859	11.8	13.76
Appalachian	1,074,700	3.19	58,083,098	3.48	54.05	29,409,610	1,584,203	18.6	27.37
Southeast	1,522,100	4.52	64,882,210	3.88	42.63	23,622,095	1,698,329	13.9	15.52
Delta States	1,142,300	3.39	50,603,437	3.03	44.30	21,132,020	1,500,779	14.1	18.50
Corn Belt	5,125,500	15.21	379,131,181	22.68	73.97	97,183,476	6,128,435	15.9	18.98
Lake States	2,718,200	8.07	160,554,818	9.61	59.07	45,528,187	3,280,630	13.9	16.75
N. Plains	8,824,200	26.19	408,829,844	24.46	46.33	150,419,720	13,150,411	11.4	17.05
S. Plains	5,129,300	15.22	205,629,638	12.30	40.09	177,090,359	10,148,542	17.4	34.53
Mountain	6,246,200	18.54	247,031,124	14.78	39.55	133,171,578	13,229,226	10.1	21.32
Pacific	1,706,000	5.06	84,598,736	5.06	49.59	23,893,035	2,255,665	10.6	14.01
National	33,690,000	100	1,671,309,322	100	49.61	704,223,554	53,211,079	13.2	20.90

Note: CRP enrollment through the eleventh sign-up is included (end of 1991).

<sup>a</sup>Total soil loss is from sheet and rill erosion and wind erosion.

<sup>b</sup>Preenrollment

<sup>c</sup>Postenrollment

Source: National Resources Inventory database from USDA/SCS 1992.

cost per acre of CRP land ranged from \$39 in the Mountain region to \$74 in the Corn Belt. To indicate the magnitude of environmental benefits derived from CRP, Table 1 also shows that total annual soil loss from both sheet and rill erosion was reduced from 700 million tons to 53 million tons on the 34 million acres in 1992.

Figure 1 shows the three categories of established cover on CRP acres. Nationwide, 89 percent of CRP land has grass/legume cover, 7.7 percent has tree cover, and the remaining 3 percent was designated as a wildlife component. Evaluating the distribution of CRP acres among land capability classes (LCC)<sup>2</sup> indicates whether the program idles marginal land or more productive land (Figure 2). Land capability classes 4 to 8 are considered less productive than 1 to 3. The economic and environmental benefits from idling marginal land are significant if farmers apply more inputs to their marginal land than their more productive land. Nationwide

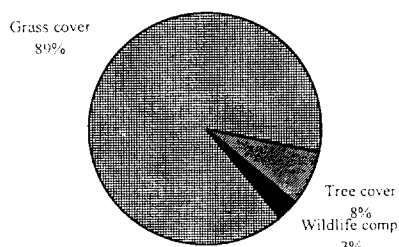


Figure 1. Established cover on CRP land

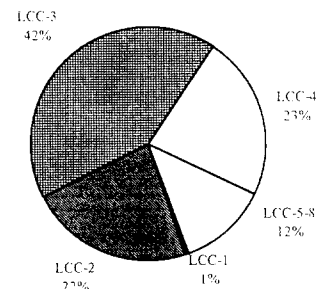


Figure 2. Land capability class on CRP land

1/3 of CRP land belonged to the land capability classes 4 to 8 and the remaining 2/3 were in categories 1 to 3.

Distribution of CRP land according to pre- and postenrollment levels of sheet and rill erosion is estimated (see Table B.1). Nearly 41 percent of CRP land had an average annual erosion (sheet and rill) of more than 20 tons per acre. Distribution of CRP land according to wind erosion rates is shown in Table B.2. The most wind erosive land is in the Great Plains and Mountain regions. About 27 percent of CRP land is within a 1/4 mile of a surface water body (Table B.3). The Northeast, the Southeast, and the Midwest had more than 50 percent of CRP land within a 1/4 mile of a surface water body.

CRP land was grouped into no-, low-, medium-, and high-risk classes for ground vulnerability to pesticide leaching as defined by Kellogg et al. (1992) (Table B.4). The high-risk land has a groundwater vulnerability score of 124 and above, medium-risk has a score of 30 to 124, and low-risk has a score of 0.1 to 30. Only about 17 percent of total CRP land is estimated to be in the high-risk class. This is not surprising because initial CRP enrollment targeted erosive land with high runoff potential. Thus, the leaching potential of this land is limited.

### **Efficiency Gains from Targeting**

More precise targeting of CRP payments can increase the efficiency of meeting some social objective. The trade-offs involved when moving from an objective of maximizing total CRP acreage to a program that directly targets some benefit offered by the CRP land are examined. The targeted program will select land to enroll based on some attribute other than cost of the land. Land will be enrolled until a budget constraint, which we denote as  $TC^*$ , is achieved. Let  $C$  denote the per acre annual cost of land,  $C_0 \leq C \leq C_I$ , and  $B$  the per acre annual targeted benefit offered,  $B_0 \leq B \leq B_I$ . Denote the joint density function of  $B$  and  $C$  as  $s(C, B)$ .



This joint density function can measure the share of land with desired attributes. For example, the share of current CRP land with  $C_A \leq C \leq C_B$  is given by

$$\int_{B_0}^{B_1} \int_{C_A}^{C_B} s(C, B) dC dB.$$

A targeted or selective renewal of CRP contracts corresponds to selecting a subset of the  $C$  and  $B$  values. For example, policymakers may want to renew only CRP land with  $C \leq C_s$  and  $B \geq B_s$ . Under this targeting scheme, the size of CRP, total annual CRP payment, and total environmental benefits are

$$TA(C_s, B_s) = TA_0 \int_{C_0}^{C_s} \int_{B_s}^{B_1} s(C, B) dB dC, \quad (1)$$

$$TC(C_s, B_s) = TA_0 \int_{C_0}^{C_s} \int_{B_s}^{B_1} s(C, B) C dB dC, \quad (2)$$

$$TB(C_s, B_s) = TA_0 \int_{C_0}^{C_s} \int_{B_s}^{B_1} s(C, B) B dB dC, \quad (3)$$

where  $TA_0$  is the total acreage of current CRP land. Reichelderfer and Boggess conclude that the characteristics of land initially enrolled are most consistent with a CRP objective of maximizing the number of acres enrolled. An alternative targeting scheme will trade decreases in  $TA$  for increases in  $TB$  and hold  $TC$  constant.

Maximizing CRP acreage is accomplished by ranking CRP tracts from low to high according to  $C$  and accepting bids until the total rental cost equals the budget constraint,  $TC^*$ ; in other words, the least expensive land is renewed first. The highest bid accepted under this targeting scheme,  $C^*$ , is defined by

$$TC(C^*, B_0) = TC^*. \quad (4)$$

Total acreage and total benefits from this targeting scheme are

$$TA_1(TC^*) = TA(C^*, B_0), \quad (5)$$

$$TB_1(TC^*) = TB(C^*, B_0). \quad (6)$$

An alternative targeting scheme is to rank land from high to low according to  $B$ ; that is, the most environmentally sensitive land is renewed first. The smallest per acre benefit accepted under this targeting scheme,  $B^*$ , is defined by

$$TC(C_I, B^*) = TC^*. \quad (7)$$

Total acreage of CRP land and the total environmental benefit from this targeting scheme equal

$$TA_2(TC^*) = TA(C_I, B^*), \quad (8)$$

$$TB_2(TC^*) = TB(C_I, B^*). \quad (9)$$

The last targeting scheme takes into account both costs and benefits, ranking land from low to high according to the marginal cost of providing  $B$ , which is measured by the ratio  $C/B$ . Here the land that provides an additional unit of environmental benefit at least cost is renewed first. The highest marginal cost under this targeting scheme,  $MC^*$ , is defined by

$$TC(C_I, C/MC^*) = TC^*. \quad (10)$$

Total acreage and the total benefit from this targeting scheme equal

$$TA_3(TC^*) = TA(C_I, C/MC^*), \quad (11)$$

$$TB_3(TC^*) = TB(C_I, C/MC^*). \quad (12)$$

It is easily shown that  $TA_1(TC_0) = TA_2(TC_0) = TA_3(TC_0)$  and  $TB_1(TC_0) = TB_2(TC_0) = TB_3(TC_0)$ , where  $TC_0$  is the current total annual CRP payment, which implies that if the budget

constraint is set high enough to renew all CRP acres, all three targeting schemes yield the same acreage and benefits. However, when the budget constraint is binding, these targeting schemes lead to different outcomes. Differentiating (4) through (12) shows that when total expenditures are reduced, total acreage and total benefits are reduced at different rates under the three targeting schemes:

$$\begin{aligned}
 dTA_1/dTC^* &= 1/C^*, & dTB_1/dTC^* &= E(B|C=C^*)/C^*, \\
 dTA_2/dTC^* &= 1/E(C|B=B^*), & dTB_2/dTC^* &= B^*/E(C|B=B^*), \\
 dTA_3/dTC^* &= 1/E(C|C/B=MC^*), & dTB_3/dTC^* &= 1/MC^*,
 \end{aligned} \tag{13}$$

where the expectations are appropriately defined conditional expectations. Before analyzing these derivatives further, Proposition 1 establishes some basic relationships between acreage and benefits under the three targeting schemes and will be referred to as *C-ranking*, *B-ranking*, and *C/B-ranking*.

**Proposition 1.**  $TA_1(TC^*) \geq TA_3(TC^*) \geq TA_2(TC^*),$   
 $TB_3(TC^*) \geq TB_1(TC^*),$  and  $TB_3(TC^*) \geq TB_2(TC^*).$

**Proof:** See Appendix A.

Proposition 1 simply establishes that acreage is maximized if land is accepted according to cost ( $C$ ) and benefits are maximized if land is accepted according to marginal cost ( $C/B$ ). (See Appendix A for a complete proof.) The marginal cost targeting scheme results in greater acreage and benefits than if land is ranked by  $B$ . Note that maximizing acreage may also result in greater total benefits than the  $B$ -ranking. Insight into the factors that determine the magnitude of the acreage and benefit trade-offs from the ranking schemes can be obtained

from the derivatives in (13). Acreage and benefit outcomes from the  $C$ -ranking scheme and the  $B$ -ranking scheme are compared first.

Using the derivatives in (13), note that

$$TA_1 - TA_2 = \int_0^{TC^*} \left( \frac{\partial TA_1}{\partial TC} - \frac{\partial TA_2}{\partial TC} \right) dTC = \int_0^{TC^*} \left( \frac{1}{C^*} - \frac{1}{E(C|B=B^*)} \right) dTC. \quad (14)$$

How the correlation between  $B$  and  $C$  affects this difference is illustrated in the two panels of Figure 3.

Suppose first that  $B$  and  $C$  are uncorrelated. Then  $E(C|B=B^*) = \bar{C}$ , where  $\bar{C}$  is the unconditional mean of  $C$ . When  $TC^*$  is the lowest level needed to purchase a single tract of land,  $C^*$  is the lowest cost for an available tract of land. At this low cost, let  $R$  equal the integrand in (14).  $R$  is positive unless  $B$  and  $C$  are perfectly negatively correlated, in which case  $R = 0$ . Let  $R'$  equal the integrand in (14) when  $TC^* = TC_0$ . At  $TC_0$ ,  $C^*$  is the highest cost tract of land and  $R'$  is negative.  $R$  and  $R'$  are shown in the top panel of Figure 3. Consider what happens to the integrand at the two cost extremes when  $B$  and  $C$  are negatively correlated. At the low cost extreme  $E(C|B=B^*) < \bar{C}$ . At  $TC^* = TC_0$ ,  $E(C|B=B^*) > \bar{C}$ . That is, negative correlation rotates the  $RR'$  curve in Figure 3 in a counterclockwise direction to the new curve  $SS'$ . Similarly, a positive correlation results in a clockwise rotation from  $RR'$  to  $TT'$  in Figure 3.

The three curves in the top portion of Figure 3 are the integrand in (14) under the three correlation scenarios assuming a single crossing as  $TC^*$  increases. Linearity is assumed for expositional purposes only. As shown in the bottom portion of Figure 3, the difference between  $TA_1$  and  $TA_2$  is maximized where the curves in the top panel intercept the horizontal axis. A single crossing is a sufficient condition for a monotonic relationship between the degree of

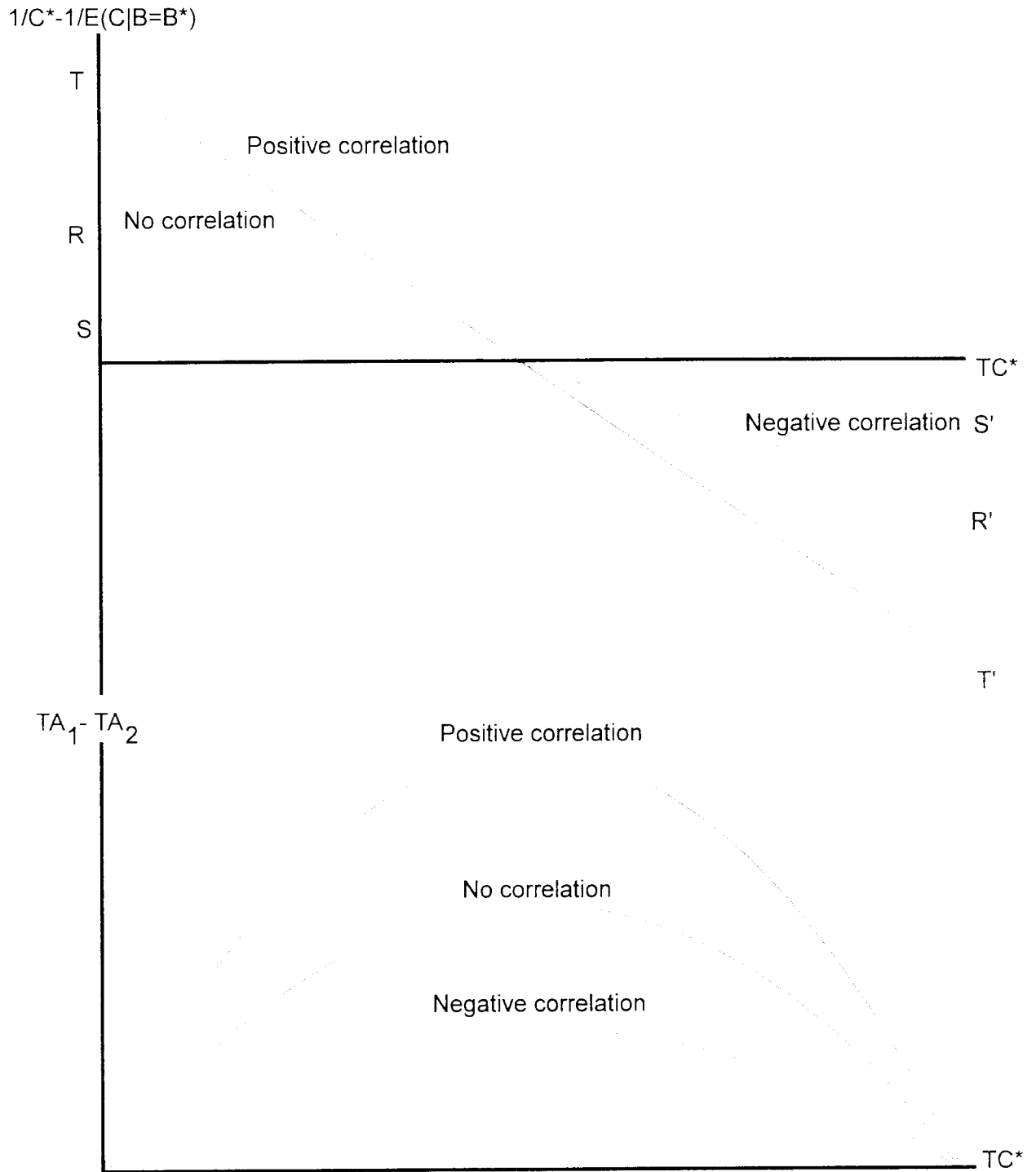


Figure 3. The effect of correlated  $B$  and  $C$  on the acreage cost of environmental targeting

correlation and  $TA_1 - TA_2$  because  $TA_1(TC_0) - TA_2(TC_0) = 0$  for all correlation coefficients (Rothchild and Stiglitz). With a single crossing, the more positively correlated  $B$  and  $C$  are, the greater the difference in acreage outcomes from targeting. The intuition behind this result is straightforward. Positive correlation between  $B$  and  $C$  implies that, on average, CRP acreage that offers large targeted benefits also costs more to enroll. Thus, on average under positive correlation, when the  $C$ -ranking scheme is accepting low-cost acreage, the  $B$ -ranking scheme is accepting high-cost acreage, and the size of CRP under the two schemes is likely to differ by a large amount. Negative correlation between  $C$  and  $B$  makes the two ranking schemes more consistent because, on average, the low-cost acreage will also yield the highest benefits. So when  $C$ -ranking is enrolling low-cost land,  $B$ -ranking is enrolling the same land because of its high  $B$ -value.

A similar result can be developed for an increase in the variability of  $C$  holding  $\bar{C}$  constant. When  $B$  and  $C$  are uncorrelated, a small variability in  $C$  implies that the integrand in (14) is relatively small for all  $TC^*$ . An increase in variability that affects all values of  $C$  increases (decreases) the integrand for low (high) values of  $TC^*$ . Such a rotation is similar to the rotation from  $RR'$  to  $TT'$  in Figure 3, which results in an increase in the difference between the two acreage outcomes. When  $B$  and  $C$  are positively correlated, an increase in variability also increases the difference in acreage outcomes but, as is shown for the bivariate normal distribution, a negative correlation will ameliorate some of the increase. Increasing the variability of  $B$  that does not alter the  $B$ -ranking will not affect  $TA_1 - TA_2$  because neither  $C^*$  nor  $E(C^*B^*)$  will change.

Now consider how aggregate benefits under the  $C$ -ranking scheme and the  $B$ -ranking scheme differ. Using the derivatives in (13),

$$TB_1 - TB_2 = \int_0^{TC^*} \left( \frac{\partial TB_1}{\partial TC} - \frac{\partial TB_2}{\partial TC} \right) dTC = \int_0^{TC^*} \left( \frac{E(B|C = C^*)}{C^*} - \frac{B^*}{E(C|B = B^*)} \right) dTC. \quad (15)$$

First note that Proposition 1 does not establish the sign of (15), even though we might assume that targeting  $B$  should result in greater total benefits. To see why this result cannot be established in general, note that the integrand of (15) for uncorrelated  $B$  and  $C$  becomes

$\frac{\bar{B}}{C^*} - \frac{B^*}{\bar{C}}$ . This expression is negative when  $\bar{B}\bar{C} - B^*C^* < 0$ . Consider the sign of this expression for low values of  $TC^*$ . Holding  $\bar{B}$  and  $\bar{C}$  constant, if the range of  $B$  relative to the range of  $C$  is large, then it is likely that  $\bar{B}\bar{C} < B^*C^*$ . However, if the range of  $B$  is small relative to the range of  $C$ , then the integrand is likely to be positive for low values of  $TC^*$ . If the integrand of (15) is negative for low values of  $TC^*$  and there is a monotonic relationship between the integrand and  $TC^*$ , then  $TB_1 - TB_2 < 0$  for all  $TC^*$ .

Now it is relatively simple to show what happens to the difference in benefits as the variability of  $B$  and  $C$  changes. When  $B$  and  $C$  are uncorrelated and  $TC^*$  is small, increasing the variability of  $C$  will not affect  $B^*$ , but  $C^*$  will decrease, thus increasing the integrand in (15). If  $TB_1 - TB_2 < 0$ , then this increase in variability lessens the difference (makes it less negative). If  $TB_1 - TB_2 > 0$ , then this increase in variability increases the difference. Conversely, increasing the variability of  $B$  will decrease the integrand in (15) for a low  $TC^*$ , and hence, will tend to increase the difference if  $TB_1 - TB_2 < 0$  (make it more negative). If  $TB_1 - TB_2 > 0$ , then an increase in variability of  $B$  will tend to decrease the difference. As is shown for the special case

of a bivariate normal distribution, making  $B$  and  $C$  correlated will not affect the direction of change from increases in variability, but it will affect the magnitude of change.

How an increase in the correlation between  $B$  and  $C$  affects  $TB_1 - TB_2$  can be seen by noting that  $E(C|B = B^*)$  for low  $TC^*$  increases with an increase in correlation (more positive or less negative) and that  $E(B|C = C^*)$  decreases with an increase in correlation. Thus both terms in the integrand of (15) decrease as the correlation between  $B$  and  $C$  increase and the net effect on the difference in total benefits is ambiguous.

Deriving analytical results when marginal costs are targeted is much more difficult because of the complexity of the joint distribution of  $C$  and the ratio  $C/B$ . However, some insight can be obtained by noting when  $C$  and  $B$  are negatively correlated,  $C$  and  $C/B$  are positively correlated. This positive correlation is a result of two factors. First, the ratio varies directly with  $C$  because  $C$  is the numerator. This direct relationship is reinforced by the negative correlation because when the ratio's numerator is large, the denominator is, on average, small. Thus, the more negatively correlated  $B$  and  $C$  are, the less conflict there is between  $C$ -ranking and  $B$ -ranking. And because there is an ambiguous effect of correlation on  $TB_1 - TB_2$ , one would expect this result to carry over to the case of  $C/B$ -ranking.

As illustrated in Figure 3, a positive correlation between  $B$  and  $C$  increases the trade-offs that must be made when moving from  $C$ -ranking to  $B$ -ranking. But a positive correlation between  $B$  and  $C$  does not necessarily imply large conflicts between  $C$ -ranking and  $C/B$  ranking. With a positive correlation, high (low) draws of  $C$  tend to increase (decrease) the ratio  $C/B$  because  $C$  appears in the numerator. But, on average, high (low) draws of  $C$  imply high (low) draws of  $B$  and tends to increase (decrease) the denominator. The indirect effect from correlation



works against the direct effect, thus making it difficult to derive any general statement about the magnitude of change as correlation increases. However, it is clear that there will be less conflict between  $C$ -ranking and  $C/B$  ranking under a positive correlation than between  $C$ - and  $B$ -ranking.

Additional insight into the trade-offs involved as one moves away from  $C$ -ranking can be obtained by assuming that  $C$  and  $B$  are bivariate normal random variables with means  $\bar{C}$  and  $\bar{B}$ , variances  $\sigma_1^2$  and  $\sigma_2^2$ , and correlation coefficient  $\gamma$ . The results under this assumption are presented below. Derivation of these results are also provided in Appendix A.

$$\frac{\partial(TA_1 - TA_2)}{\partial\gamma} = \frac{\sigma_1}{E(C|B=B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \geq 0. \quad (16)$$

where  $\varphi(\bullet)$  is the probability density function of the standard normal distribution.

Equation (16) is a formal statement of the result illustrated in Figure 3 that the more positive the correlation between  $B$  and  $C$  is the greater the change in total acreage when moving away from  $C$ -ranking.

$$\frac{\partial(TA_1 - TA_2)}{\partial\sigma_1} = \frac{1}{C^*} \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) + \frac{\gamma}{E(C|B=B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \quad (17)$$

When  $\gamma \geq 0$ , (16) is a restatement of the previously developed result that increases in the variability of  $C$  will increase the change in acreage when moving away from  $C$ -ranking. Note that a negative  $\gamma$  decreases the effect of a change in variance, whereas a positive  $\gamma$  increases the effects of variance. In fact, it cannot be shown in general that (17) is positive because an increase in  $\sigma_1$  when  $\gamma$  is negative increases both  $TA_1$  and  $TA_2$ , although (17) is nonnegative when  $\gamma = -1$  and when  $\gamma = 0$ .

$$\frac{\partial(TA_1 - TA_2)}{\partial\sigma_2} = 0. \quad (18)$$

Increases in  $\sigma_2$  do not affect  $TA_1$  because  $C$ -ranking ignores  $B$ . Also, changes in  $\sigma_2$  do not affect  $TA_2$  because the ranking and expected cost remain unchanged with increases in the variance of benefits.

$$\frac{\partial(TB_1 - TB_2)}{\partial \gamma} = -\sigma_2 \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) + \frac{B^* \sigma_1}{E(C|B=B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \quad (19)$$

As discussed above, the effect of increases in  $\gamma$  on the difference in benefits received cannot be signed because the two effects of  $\gamma$  work in opposition to each other.

$$\frac{\partial(TB_1 - TB_2)}{\partial \sigma_1} = \frac{E(B|C=C^*)}{C^*} \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) + \frac{B^* \gamma}{E(C|B=B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \quad (20)$$

When  $\gamma \geq 0$ , increases in the variability of  $C$  increase  $TB_1 - TB_2$ . Decreases in the correlation coefficient decrease the magnitude of the variance effect. And, as with (17), when  $\gamma < 0$  it is not possible to sign (20).

$$\frac{\partial(TB_1 - TB_2)}{\partial \sigma_2} = -\gamma \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) - \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \quad (21)$$

Equation (21) is the analogous result to (20). Note that increases in the correlation coefficient increase the impact of changes in the variability of benefits and that (21) cannot be signed when  $\gamma < 0$ .

## Data and Estimation

### Correlation and Variability Estimation

Estimation of the variability of  $B$  and  $C$  and the correlation between the two is crucial to determining the extent to which movement away from  $C$ -ranking (acreage maximization) affects the performance of CRP. Ideally, data measuring accepted CRP bids and attributes of specific

tracts of current CRP lands would be used. With these data the critical relationships could be determined by calculating the sample covariance matrix. The problem with implementing this procedure is that data measuring both the site-specific environmental attributes and the accepted rental rate bids of CRP land are not available in the same data set.

The approach in this study relates the 1992 National Resources Inventory (NRI), compiled by the Soil Conservation Service (SCS), with the county-level average CRP summary file for acres enrolled through the eleventh sign-up. These data were compiled by the Agricultural Stabilization and Conservation Service (ASCS) to examine the correlation between CRP bid statistics and the environmental characteristics of the enrolled land. The 1992 NRI is the latest in a series of inventories conducted by SCS and USDA. The NRI provides information on the status, condition, and trends of land, soil, water, and related resources on private U.S. land. The 1992 NRI is unique in that it is the first attempt to associate a randomly drawn sample of geographically based primary sampling units (PSUs) with both physical resource characteristics and the CRP participation information and has 5- to 10-year trends for natural resources and cropping history. The 1992 NRI is an extensive inventory that covers about 800,000 sample points representing 75 percent of U.S. land area. Sample locations for the NRI were chosen using a two-stage, stratified, area sampling scheme. Two-stage area samples were selected within each stratum. The first-stage sample unit (PSU) was an area of land, and the second stage contains one or more points within each PSU (Goebel, Riser, and Hickman 1982). The expansion factor associated with each PSU provides natural aggregation to the county, state, and national levels.

A sample of site-specific environmental attributes of CRP lands are available using the NRI-92 database. But this database does not include the CRP rental rate because of privacy concerns. Only county-average rental rates are available. County-average rental rates equal site-specific rental rates if land is homogeneous or if the CRP auction design resulted in a single price being paid for all CRP tracts in a county. There clearly is a large degree of variation in CRP land quality within many counties, so the first condition is not met for these counties. But, as pointed out by Taff and Runge (1988), USDA decided to set an upper limit on CRP bids in the early and middle rounds of bidding. As these caps became widely known, CRP bids within a county converged to the cap. Thus, county average bids during these sign-up periods serve as a good proxy for the site-specific bids. The degree of correlation between  $B$  and  $C$  is measured by the sample correlation matrix between county average bids and site-specific environmental factors.

The simplest way of determining the extent of variability of environmental benefits is to estimate Lorenz curves (Figure 4). The vertical axis measures the percentage of total environmental benefits. The horizontal axis measures the percentage of land enrolled in a targeted CRP. A 45-degree line implies a uniform distribution of environmental benefits. The greater the concavity of the curve, the greater the concentration of environmental benefits and the greater the environmental gains from environmental targeting.

### **Bias in Estimating the Effects of Targeting**

County-average rental rates are unbiased estimates of the tract-specific rental rates. Thus, when the tract-specific environmental attributes are used to rank CRP tracts, as is done with  $B$ -ranking, the estimated budget costs of different enrollment levels are unbiased. However, the

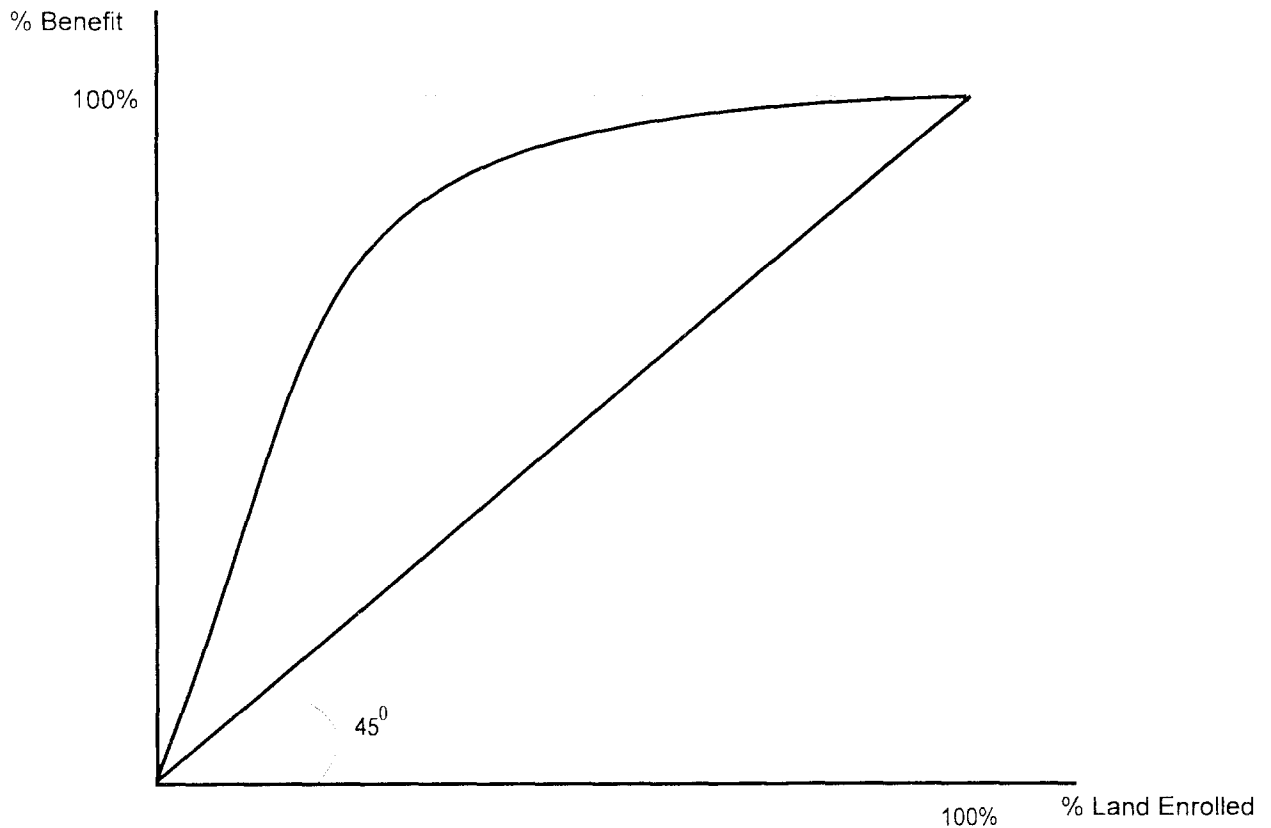


Figure 4. Measuring the concentration of environmental benefits with a Lorenz curve

lack of information about tract-specific CRP bids can bias the estimated impacts of the other two targeting schemes because use of county-average rental rates underestimates the variability of  $C$  and hence the ratio  $C/B$ . Consider the  $C$ -ranking scheme. Because land is accepted according to the bid level, increases in the variance of bids, holding the mean constant, increases the number of acres that can be purchased, because there are more “low” bid draws. Similarly, an increasing variance in  $C$  leads to an increased variance in  $C/B$ , which would allow additional acreage (and environmental benefits) to be purchased. Thus, use of county-average bids underestimates the amount of acreage and environmental benefits that could be purchased with these two schemes.

## Results

The critical factors that determine the extent to which targeting increases the efficiency with which environmental attributes of CRP land are purchased are the degree of correlation between  $B$  and  $C$  and the amount of variability in  $B$  and  $C$ . Figure 5 presents the sample correlation coefficients and Figure 6 presents Lorenz curves that measure how uniformly the various target indicators, including the multiple index, are distributed over current CRP lands. Wind erosion is negatively correlated with cost, which implies that moving away from acreage targeting ( $C$ -ranking) to targeting wind erosion should not greatly decrease the size of CRP for given budget outlays. When acreage targeting is enrolling low-cost land, environmental targeting based on wind erosion is also targeting the same land. Conversely, the water erosion, surface water quality, wildlife habitat, and the sum of all indicators (multiple index) are positively correlated with  $B$ , which implies that low-cost land offers, on average, low values for these indicators. Based solely on the correlation coefficient, we might conclude that moving away from acreage targeting would have a relatively large effect on CRP size and the amount of environmental attribute offered. The groundwater vulnerability index is essentially uncorrelated with cost.

As indicated by Figure 6, the distribution of benefits varies widely across the indicators.

The most concentrated indicator is surface water quality: more than 98 percent of total surface

water quality benefits on current CRP land are obtained by enrolling less than 27 percent of CRP

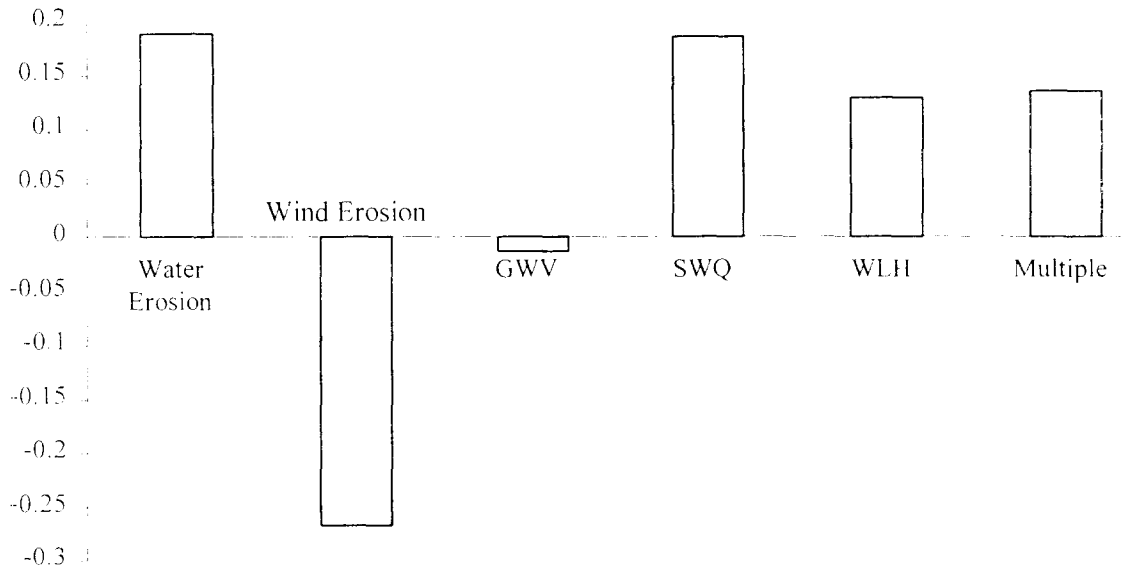


Figure 5. Correlation between CRP rent and the target indicator

land. Wind erosion and groundwater vulnerability are also fairly concentrated; enrollment of 32 percent of CRP land achieves about 90 percent of the total benefits from the two indicators. Water erosion is slightly less concentrated. To achieve 90 percent of the total water erosion benefits, nearly 43 percent of current CRP land has to be renewed. The wildlife habitat and the multiple index are the most uniformly distributed.

Combining the correlation and concentration estimates, we might expect that moving away from C-ranking (acreage targeting) would have the largest effects on surface water quality and water erosion because these indicators are positively correlated with cost and are highly concentrated. Because wind erosion is negatively correlated with cost and is also highly

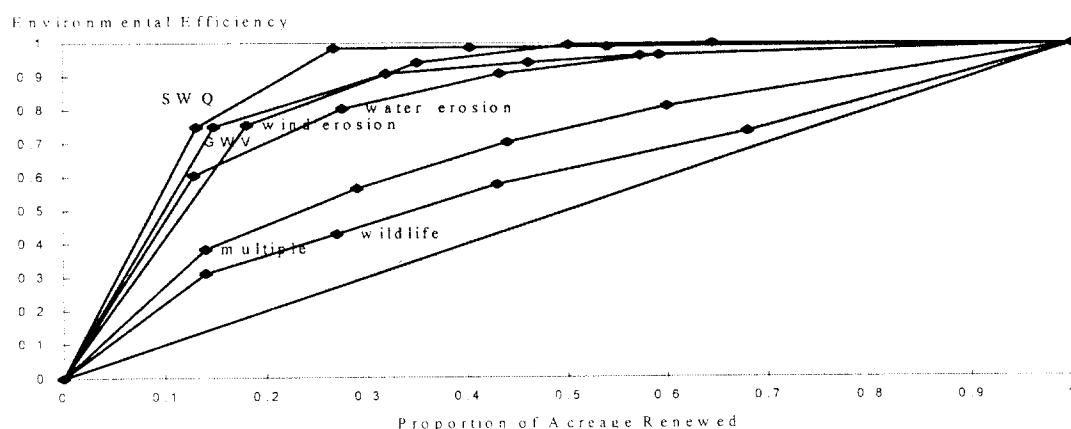


Figure 6. Trade-offs between environmental efficiency and CRP acres (Efficiency is measured by the level of target indicator)

concentrated, we might expect that acreage targeting does a fairly good job of achieving wind erosion benefits.

To better understand the magnitude of these trade-offs and to determine the extent to which environmental and economic gains can be obtained from targeting, we examine the overall cost and environmental implications of targeted renewal of current CRP land under alternative policy scenarios. In the absence of policy guidelines for the future of the CRP program we analyzed four different scenarios, based on CRP fiscal spending limits of \$250 million, \$500 million, \$750 million, and \$1 billion for each target indicator. These upper limits translate into 15, 30, 45, and 60 percent renewal of CRP outlay for the contracts entered through the eleventh sign-up. Tables 2 and 3 present the empirical results for our three targeting schemes: acreage targeting (*C*-ranking), environmental benefits targeting (*B*-ranking), and maximizing of environmental benefits (*C/B* ranking). The *B*-ranking and *C/B*-ranking were calculated for the



multiple index and also for individual environmental indicators: water erosion, wind erosion, groundwater vulnerability, surface water quality, and wildlife habitat.

Tables 2 and 3 present the number of acres enrolled, the proportion of CRP land renewed, the average rental rate paid for the enrolled acreage, and the total budget exposure under the three schemes. Table 2 presents the results for the multiple index and for acreage maximization. Table 3 presents the results for the individual environmental attributes.

The results in Table 2 indicate the degree to which moving away from acreage targeting to environmental targeting increases environmental benefits from targeting and the trade-off with regard to the number of acres enrolled. For example, at \$500 million, acreage targeting achieves only 21.5 percent of potential water erosion benefits of CRP, 37.6 percent of groundwater vulnerability benefits, 16 percent of surface water quality and wildlife habitat benefits, and about 31 percent of multiple environmental benefits. In contrast, targeting the multiple index almost doubles each of the indicators, except for wind erosion benefits. The trade-off for higher environmental benefit is a 10 percent reduction in CRP size. There is little difference in wind erosion benefits among these three targeting schemes because of the negative correlation between bid rate and wind erosion. Almost 69 percent of wind erosion benefits at the \$500 million level are from maximizing CRP size. The *C/B*-ranking gains 58 percent of the multiple environmental benefits, only about two percentage points more benefits than can be achieved by *B*-ranking, and enrolls 32 percent of CRP lands. Furthermore, *C/B*-ranking gains larger wind erosion and wildlife habitat benefits and smaller water erosion and groundwater benefits compared to purely *B*-ranking.

Table 2. Economic, environmental, and fiscal implications of the three ranking schemes: C-, B-, and C/B-ranking

Target/Scenario	Total Acres	Prop. of acres renewed	Rent \$/acre	Budget exposure	Multiple index <sup>a</sup>	Level of Selected Indicators				
						Water erosion <sup>b</sup>	Wind erosion <sup>b</sup>	GWV <sup>c</sup>	SWQ <sup>d</sup>	WLHI <sup>e</sup>
C-ranking										
Scenario 1: \$250 m CRP	6,815,600	0.20	36.68	0.15	0.172	0.109	0.434	0.177	0.077	0.077
Scenario 2: \$500 m CRP	13,090,400	0.39	38.19	0.30	0.314	0.215	0.692	0.376	0.166	0.165
Scenario 3: \$750 m CRP	18,815,800	0.56	39.86	0.45	0.465	0.379	0.827	0.456	0.338	0.336
Scenario 4: \$1000 m CRP	23,908,200	0.71	41.82	0.60	0.586	0.498	0.950	0.659	0.440	0.437
B-ranking of multiple index										
Scenario 1: \$250 m CRP	4,709,900	0.14	53.08	0.15	0.384	0.335	0.370	0.426	0.749	0.296
Scenario 2: \$500 m CRP	9,727,300	0.29	51.40	0.30	0.566	0.551	0.636	0.656	0.983	0.441
Scenario 3: \$750 m CRP	14,945,000	0.44	50.14	0.45	0.703	0.713	0.809	0.798	0.986	0.571
Scenario 4: \$1000 m CRP	20,054,800	0.60	49.86	0.60	0.812	0.796	0.910	0.874	0.989	0.700
C/B-ranking of multiple index										
Scenario 1: \$250 m CRP	5,360,700	0.16	46.61	0.15	0.400	0.288	0.475	0.441	0.768	0.310
Scenario 2: \$500 m CRP	10,902,200	0.32	45.81	0.30	0.584	0.508	0.742	0.630	0.983	0.468
Scenario 3: \$750 m CRP	16,442,600	0.49	45.60	0.45	0.721	0.661	0.879	0.779	0.988	0.615
Scenario 4: \$1000 m CRP	21,746,300	0.65	45.95	0.60	0.831	0.779	0.957	0.893	0.992	0.754

Note: Budget exposure refers to the proportion of current scenario expenditure to total expenditure (renewal CRP contracts) and environmental efficiency refers to the ratio of performance of the target indicator under the current scenario to its performance under the completed renewal of CRP.

<sup>a</sup>A nonweighted linear sum of normalized values of each of the five target indicators represent the multiple index.

<sup>b</sup>Water and wind erosion are the normalized (0 to 100) values of soil loss per acre based on preenrollment levels of soil erosion.

<sup>c</sup>Groundwater vulnerability is based on pesticide use and leaching potential index constructed by Kellogg et al. 1992.

<sup>d</sup>Surface water quality index is based on the distance of CRP land from water bodies.

<sup>e</sup>Wildlife habitat index is based on the riparian and grassland potential of CRP land and the location as to the east or west of the Mississippi.

Table 3. Acres, average rent, and level of benefits obtained by targeting selected environmental indicators using B- and C/B-ranking

Target Scenario	CRP Acres Renewed		Proportion of Total CRP		Annual Rent		Target Indicator Level		Multiple Index Level <sup>a</sup>	
	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking
<b>Water Erosion Benefits Ranking<sup>b</sup></b>	number of acres				dollars per acre					
Scenario 1: \$250 m CRP	4,336,600	4,704,300	0.13	0.14	57.64	53.14	0.604	0.604	0.189	0.201
Scenario 2: \$500 m CRP	9,270,900	9,806,300	0.28	0.29	53.92	50.99	0.804	0.804	0.341	0.359
Scenario 3: \$750 m CRP	14,561,700	15,017,800	0.43	0.45	51.50	49.94	0.908	0.908	0.496	0.511
Scenario 4: \$1 billion CRP	19,956,900	20,332,200	0.59	0.60	50.10	49.18	0.963	0.963	0.637	0.649
<b>Wind Erosion Benefits Ranking<sup>b</sup></b>										
Scenario 1	6,088,600	6,243,500	0.18	0.19	41.05	40.03	0.754	0.759	0.242	0.245
Scenario 2	11,809,500	12,056,400	0.35	0.36	42.33	41.47	0.939	0.942	0.390	0.393
Scenario 3	16,891,900	17,046,800	0.50	0.51	44.40	43.99	0.994	0.995	0.512	0.513
Scenario 4	21,733,100	22,682,400	0.65	0.67	46.01	44.08	1.000	1.000	0.634	0.641
<b>Groundwater Vulnerability Ranking<sup>c</sup></b>										
Scenario 1	4,983,700	5,288,500	0.15	0.16	50.15	47.16	0.749	0.754	0.241	0.241
Scenario 2	10,767,200	10,835,500	0.32	0.32	46.43	46.14	0.908	0.908	0.363	0.363
Scenario 3	15,538,800	16,765,700	0.46	0.50	48.26	44.72	0.941	0.948	0.502	0.521
Scenario 4	19,303,300	21,583,700	0.57	0.64	51.80	46.33	0.962	0.974	0.641	0.709
<b>Surface Water Quality Benefits Ranking<sup>d</sup></b>										
Scenario 1	4,408,900	4,855,100	0.13	0.14	56.68	51.49	0.749	0.768	0.312	0.324
Scenario 2	9,004,900	9,107,300	0.27	0.27	55.52	54.88	0.983	0.983	0.438	0.444
Scenario 3	13,574,500	15,799,600	0.40	0.47	55.22	47.46	0.986	0.988	0.534	0.625
Scenario 4	18,184,800	21,926,500	0.54	0.65	54.99	45.60	0.989	0.992	0.629	0.759

Table 3. Continued

Target Scenario	CRP Acres Renewed		Proportion of Total CRP		Annual Rent		Target Indicator Level		Multiple Index Level <sup>a</sup>	
	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking	B-ranking	C/B-ranking
<b>Wildlife Habitat Benefits Ranking<sup>e</sup></b>										
Scenario 1	4,673,900	5,807,000	0.14	0.17	53.46	43.05	0.312	0.328	0.320	0.320
Scenario 2	8,948,000	12,053,600	0.27	0.36	55.87	41.47	0.429	0.503	0.420	0.497
Scenario 3	14,357,200	17,769,300	0.43	0.53	52.23	42.20	0.577	0.665	0.547	0.646
Scenario 4	20,175,300	22,960,000	0.68	0.68	49.56	43.55	0.736	0.804	0.681	0.774

Note: The environmental efficiency represented by the level of target indicator measures the ratio of value of target indicator under the current scenario to its value under complete renewal of CRP.

<sup>a</sup>A nonweighted linear sum of normalized values of each of the five target indicators represent the multiple index

<sup>b</sup>Water and wind erosion are the normalized (0 to 100) values of soil loss per acre based on preenrollment levels of soil erosion.

<sup>c</sup>Groundwater vulnerability is based on pesticide use and leaching potential index constructed by Kellogg et al. 1992.

<sup>d</sup>Surface water quality index is based on the distance of CRP lands from water.

<sup>e</sup>Wildlife habitat index is based on the riparian and grassland potential of CRP land and the location east or west of the Mississippi River.

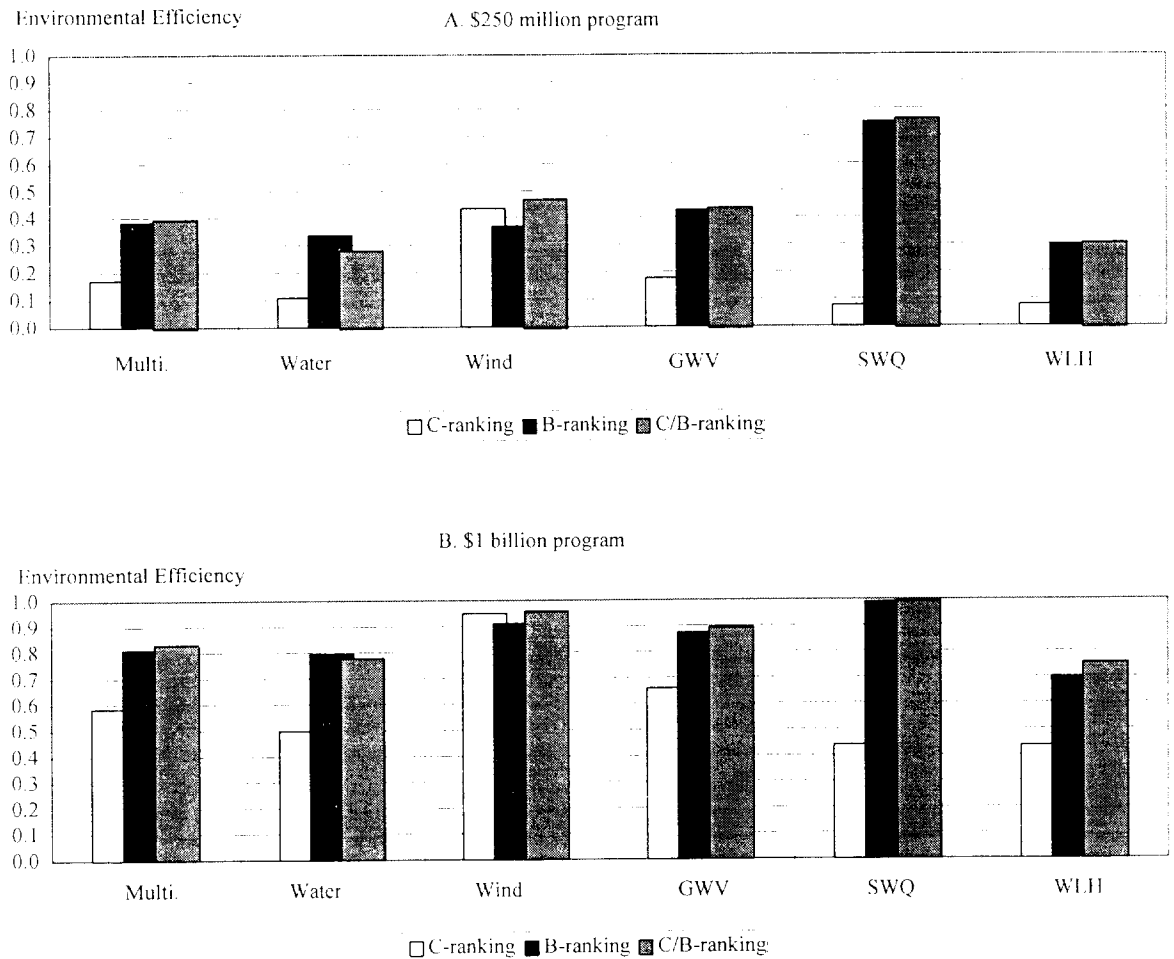


Figure 7. Environmental efficiency of the three ranking schemes: C-, B-, and C/B-ranking

Figure 7 compares the environmental benefits under these three alternative schemes for two budget constraints: \$250 million and \$1 billion. Two key observations can be made. First, with only \$250 million to spend, a significant portion of environmental benefits can be achieved by targeting. Second, more than 75 percent of the environmental benefits can be achieved by renewing only 50 to 60 percent of current CRP contracts. The policymaker can redirect the

remaining 40 to 50 percent of the current annual CRP budget (assuming that Congress will approve 100 percent of the budget) to enroll new land that is environmentally sensitive.

Results from targeting the five environmental indicators independently under the two alternative schemes (*B*- and *C/B*-ranking) are presented in Table 3. The environmental efficiency of these targeting schemes is estimated both by the levels of the target indicator and the level of multiple index. The correlation between the environmental attribute and the bid level plays an important role in determining the number of acres that can be enrolled under the different options. For example, under a \$500 million program selecting land based solely on water erosion benefits (water erosion benefits ranking), which is positively correlated with cost, will reduce CRP size from 13 million acres under *C*-ranking to about 9.3 million acres. But when wind erosion is targeted, it is negatively correlated with bids, so the program size is reduced by one million acres, despite the greater concentration of wind erosive lands relative to water erosive.

How the average bid changes as more land is enrolled indicates whether the sign and magnitude of the correlation between *C* and *B* changes as enrollment increases. These estimates are illustrated in Figure 8. For water erosion and surface water quality, the average bid monotonically decreases, suggesting that the correlation remains positive. For wind erosion, the average bid monotonically increases as enrollment increases, suggesting that the correlation remains negative. However, the correlation coefficient for the groundwater vulnerability index is first negative, and then becomes positive, and the correlation coefficient for wildlife habitat is first positive (since riparian land, which is more expensive, is enrolled first), and then becomes negative as more grassland is enrolled.

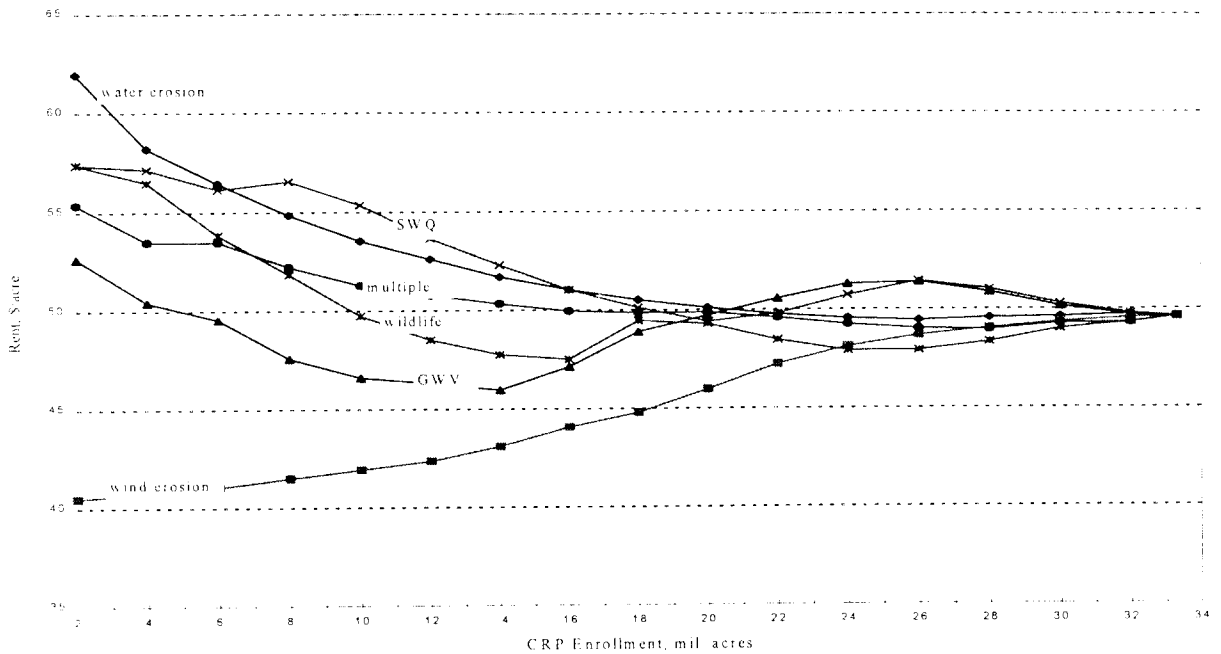


Figure 8. Average rent under selected environmental ranking

Table 3, column titled Level of Target Indicator, lists the percentage of the total benefits from targeting a given indicator. What is striking is that maximization of environmental benefits by enrolling land according to low values of the  $C/B$  ratio leads to essentially the same level of environmental benefits as does enrolling land according to high  $B$  values. Perhaps this should not be too surprising given the degree of concentration of many of the indicators: if we want to purchase environmental quality, we should seek land with significant environmental amenities. In addition, use of county-average bids underestimates the environmental benefits that can be derived from  $C/B$ -ranking. The largest difference between the two targeting schemes is for the wildlife habitat indicator. As diagramed in Figure 6, this is the most uniformly distributed indicator. Marginal cost targeting thus allows more choice of where to purchase the

environmental amenity. Again, these results indicate that the more the attribute is concentrated and negatively correlated, the greater the proportion of the total attribute obtained at the various funding levels. For example, 80.4 percent of potential water erosion in CRP land can be eliminated at just 30 percent of current expenditures (\$500 million). But, for the negatively correlated wind erosion, 94.2 percent of wind erosion can be eliminated at 30 percent of current cost. Almost 100 percent of benefits from the surface water quality index and 91 percent of the land vulnerable to pesticide leaching can be purchased with \$500 million funding. But if wildlife habitat is targeted, \$500 million buys just 43 to 50 percent of total benefits, as measured by our wildlife habitat index that depends on *B*-ranking or *C/B*-ranking.

The last two columns of Table 3 shows the percentage of the multiple index that can be obtained by targeting individual environmental attributes. The more the individual targets are positively correlated with the multiple index, the greater the percentage of multiple index. Surface water quality and wildlife habitat indexes are most correlated with the multiple index: The correlation coefficients are 0.89 and 0.92. At the \$500 million budget constraint, 32 percent of potential multiple benefits are achieved if surface water quality and wildlife habitat benefits are maximized. Of course, policymakers may assign far different weights when constructing their own indicator of multiple environmental benefits, which could greatly modify the environmental benefits from these targeting schemes. Figure 9 traces the Lorenz curve for the multiple index benefits under *B*-ranking, which maximizes benefits from each of the environmental indicators.



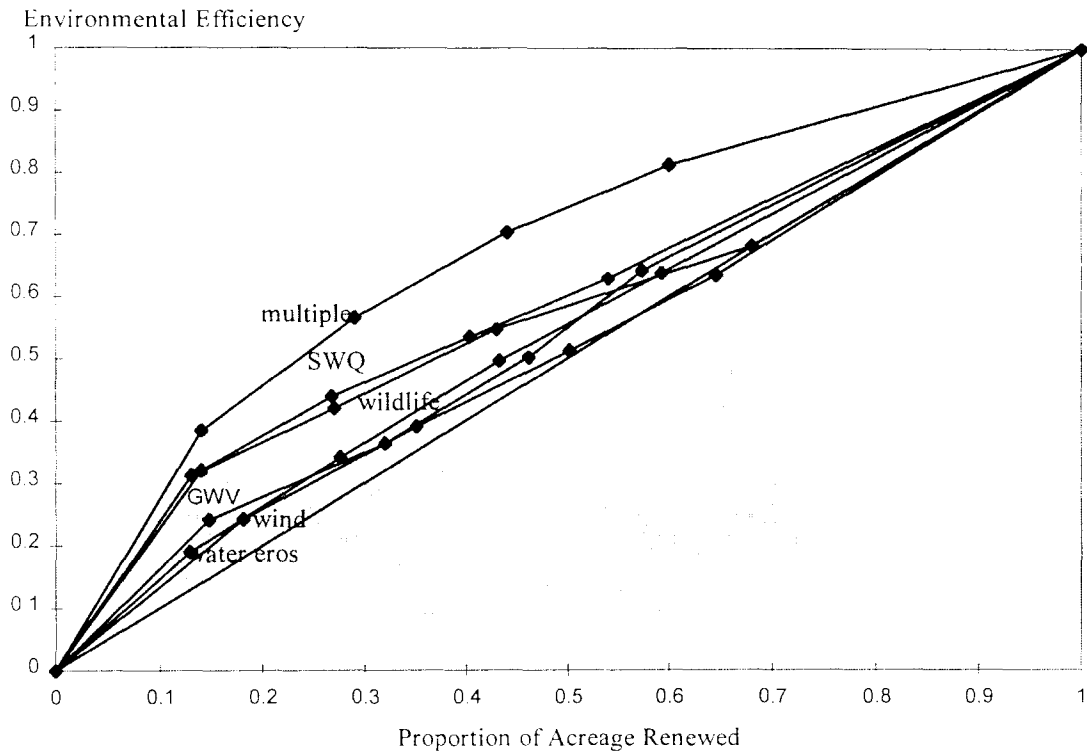


Figure 9. Trade-offs between environmental efficiency and CRP acreage (Efficiency is measured by the level of the multiple index)

Appendix D maps show the county-level distribution of CRP at the \$250 million budget level. There are clear distributional implications of the various targeting schemes. Wind erosion targeting and wildlife targeting result in land concentrated in the Great Plains. Water erosion targeting results in concentration in the Mississippi and Missouri River valleys, as does surface water quality. Targeting for groundwater vulnerability results in concentration in the High Plains region overlying the Ogallala aquifer.

The preceding analysis estimates the tradeoffs involved from targeting different environmental objectives for land that is currently enrolled in CRP. One important point that the

focus on current CRP land neglects is the proportion of environmentally sensitive U.S. lands that are currently enrolled in CRP. For example, if only a small fraction of lands vulnerable to groundwater contamination are currently enrolled in CRP, does it make sense to target this environmental indicator at the expense of others? Perhaps so, if the marginal social benefits from enrolling these lands decrease at a significant rate. But if the marginal benefits are constant or decrease slowly, then the payoff from enrolling these lands is likely low. If, on the other hand, a large portion of environmentally sensitive lands are enrolled, then it is more justifiable to target such lands because a significant portion of the total land available can be obtained. This is particularly true if marginal payoffs are constant or decrease slowly.

For this paper's indicators, the proportion of groundwater sensitive lands and lands that offer wildlife benefits that are currently in CRP is quite low because of the way that these two indexes are defined. Groundwater vulnerability is highest on lands that grow crops that use a lot of fertilizer and pesticides, such as corn, soybeans, wheat and cotton. CRP does not and never will, enroll a significant proportion of lands that grow these crops. Furthermore, there is no reason to believe that marginal benefits decline rapidly from enrolling more groundwater vulnerable lands. And our wildlife index is constructed such that all nonriparian land west of the Mississippi provides equal wildlife habitat. Thus, a small proportion of wildlife habitat will ever be enrolled in CRP. But, it still might make sense to target wildlife habitat because the marginal returns to wildlife habitat west of the Mississippi might decline fairly rapidly. That is, there are likely very large payoffs from converting riparian lands and some grasslands from agriculture uses. But, additional grasslands are likely to have significantly lower values because society

generally places a large weight on saving species and much lower weight on expanding populations of nonthreatened species.

Tables 4 and 5 present the amount of croplands that has wind or water erosion rates greater than 20 tons per acre (Table 4), that is within 100 feet of a surface water body (Table 5), and that has a high risk of groundwater vulnerability. The fraction of total U.S. cropland meeting these criteria can be calculated by comparing these estimates with the amount of CRP land meeting these criteria reported in Tables B.1. to B.4. USDA did a surprisingly good job enrolling land subject to water erosion rates greater than 20 tons per acre. CRP contains 68 percent of total U.S. cropland that has water erosion rates 20 tons or greater. In the Northern and Southern Great Plains, fully 90 percent of cropland with erosion rates greater than 20 tons is enrolled in CRP. But in the Corn Belt, only 40 percent cropland with this erosion rate is enrolled. Thus, if reducing water erosion is a top priority, then targeting existing CRP land will be productive at achieving significant national benefits. If additional highly erosive land in the Corn Belt is desired, it is available, but it will be expensive. As indicated in the fifth column of Table 4, the average cost of these lands, as estimated by the county-average CRP rental rates is more than \$76/ac. which is substantially greater than land in the Great Plains.

Currently, CRP land contains 33 percent of the nation's cropland that has wind erosion rates greater than 20 tons per acre and about 7 percent of the land within 100 feet of a surface water body. The wind erosion estimate suggest that targeting wind erosive cropland would achieve significant national benefits. And, if the marginal social benefit from retiring cropland close to surface water bodies is quite high, then targeting these lands would also result in significant social benefits.

Table 4. Highly erodible non-CRP cropland and the cost of enrollment under CRP

USDA Region	Cropland with >20 tons water erosion per acre					Cropland with >20 tons wind erosion per acre				
	acres	percent	cost, dollars	percent	Rent, \$/acre	acres	percent	cost, dollars	percent	Rent, \$/acre
Northeast	348,600	5.36	20,403,651	4.84	58.53	0	0.00	0	0.00	NA
Appalachian	1,086,200	16.69	55,092,568	13.06	50.72	1,800	0.02	106,047	0.03	58.92
Southeast	278,400	4.28	11,952,045	2.83	42.93	0	0.00	0	0.00	NA
Delta States	211,200	3.24	9,132,589	2.16	43.24	0	0.00	0	0.00	NA
Corn Belt	2,995,800	46.03	229,636,532	54.44	76.65	8,400	0.09	758,110	0.21	90.25
Lake States	442,700	6.80	30,369,637	7.20	68.60	656,800	7.28	31,775,838	8.67	48.38
N. Plains	676,700	10.40	43,649,103	10.35	64.50	530,400	5.88	22,854,740	6.24	43.09
S. Plains	83,400	1.28	2,803,337	0.66	33.61	4,136,700	45.84	170,473,971	46.52	41.21
Mountain	133,700	2.05	5,758,450	1.37	43.07	3,294,400	36.50	121,665,425	33.20	36.93
Pacific	252,200	3.87	13,051,120	3.09	51.75	396,300	4.39	18,809,636	5.13	47.46
National	6,508,900	100	421,849,032	100	64.81	9,024,800	100	366,443,767	100	40.60

Note: Cost is imputed from county level average bid price of current CRP contracts.

Table 5. Non-CRP cropland affecting surface water and groundwater quality the most and the cost of enrollment under CRP

USDA Region	Cropland within 100 feet of surface water body					Cropland with high groundwater vulnerability risk				
	acres	percent	cost, dollars	percent	Rent, \$/acre	acres	percent	cost, dollars	percent	Rent, \$/acre
Northeast	490,100	9.02	24,685,438	8.62	50.37	0	0.00	0	0.00	NA
Appalachian	761,100	14.00	32,855,179	11.47	43.17	0	0.00	0	0.00	NA
Southeast	404,900	7.45	6,885,770	2.40	17.01	0	0.00	0	0.00	NA
Delta States	525,300	9.67	20,050,076	7.00	38.17	604,800	1.36	28,599,427	1.24	47.29
Corn Belt	1,461,500	26.89	110,220,657	38.49	75.42	6,889,100	15.45	495,183,168	21.42	71.88
Lake States	650,400	11.97	41,793,009	14.59	64.26	291,300	0.65	19,997,309	0.87	68.65
N. Plains	336,400	6.19	19,096,541	6.67	56.77	15,925,000	35.72	921,835,266	39.88	57.89
S. Plains	216,500	3.98	8,500,296	2.97	39.26	9,958,900	22.34	397,978,311	17.22	39.96
Mountain	285,500	5.25	10,225,169	3.57	35.81	4,947,000	11.10	189,363,489	8.19	38.28
Pacific	303,300	5.58	12,078,158	4.22	39.82	5,960,700	13.37	258,485,149	11.18	43.36
National	5,435,000	100	286,390,293	100	52.69	44,576,800	100	2,311,442,119	100	51.85

Note: Cost is imputed from county level average bid price of current CRP contracts.

As can be calculated from Tables 5 and B.4, CRP currently has 11 percent of cropland rated as having a high risk of contaminating groundwater. Thus, unless the marginal benefit from retiring these lands is initially very large and declines rapidly, significant groundwater benefits may not be obtained from targeting this environmental indicator. If marginal benefits are fairly constant, then a less costly program may be to induce farmers to alter their production practices so that nutrients and pesticides are used more efficiently.

### **Concluding Remarks**

This study estimates the trade-offs from three CRP targeting options for renewal of CRP contracts. The three options are (1) CRP acreage maximization, (2) enrolling land solely on the level of environmental benefits offered, and (3) maximizing environmental benefits offered by CRP. We provide estimates of the trade-offs between the number of acres enrolled in CRP and the level of specific environmental benefits from targeting environmental attributes for various limits on annual government expenditures. Estimates of these trade-offs are made for the environmental targets of water erosion, wind erosion, surface water quality, groundwater vulnerability to pesticides, wildlife habitat, and a simple average of the five individual targets. The degree to which environmental targeting conflicts with an objective of maximizing CRP size is shown to depend on the degree of negative correlation between rental rates and the level of environmental attribute offered by individual tracts of CRP land and on the degree of concentration of the environmental targets.

This study reports outcomes for the simple average weighting schemes and weighting schemes that assign a weight of one to individual targets and zero weights to all others. It should

be noted that a weighting scheme other than a simple linear average weighting scheme will yield different results. Without knowing policymakers' level preferences on these individual environmental indicators, the best approach is a simple average multiple index. Because of spatial heterogeneity in the importance of these environmental indicators (that is, the sensitivity of these indicators varies with the underlying site-specific physical characteristics), it is difficult to develop a defensible multiple index that could be applied uniformly to all regions of the United States. So it is important to perform sensitivity analyses of alternatively constructed multiple indexes. With this note of caution, we highlight the two key findings of this analysis. First, under a smaller and tighter CRP renewal program, it pays to target the environmental indicators. Second, by renewing only 50 to 60 percent of the current CRP land, nearly 75 percent of the environmental benefits can be purchased by targeting. The remaining CRP fiscal resources could be used to purchase environmental benefits from new land that is environmentally sensitive.



## Appendix A. Mathematical Proofs

### A. Proof of Proposition 1

$$\begin{aligned}
TA_1(TC^*) - TA_2(TC^*) &= \int_{C_0}^{C^*B_1} \int_{B_0} s(C, B) dC dB - \int_{C_0}^{C_1} \int_{B^*} s(C, B) dC dB = \int_{C_0}^{C^*B^*} \int_{B_0} s(C, B) dB dC - \int_{C^*B^*}^{C_1} \int_{B_0} s(C, B) dB dC \geq \\
&\int_{C_0}^{C^*B^*} \int_{B_0} s(C, B) \frac{C}{C^*} dB dC - \int_{C^*B^*}^{C_1} \int_{B_0} s(C, B) \frac{C}{C^*} dB dC = \frac{1}{C^*} \left[ \int_{C_0}^{C^*B^*} \int_{B_0} s(C, B) C dB dC - \int_{C^*B^*}^{C_1} \int_{B_0} s(C, B) C dB dC \right] - \\
&\frac{1}{C^*} \left[ \int_{C_0}^{C^*B_1} \int_{B_0} s(C, B) C dB dC - \int_{C_0}^{C_1} \int_{B^*} s(C, B) C dB dC \right] = \frac{1}{C^*} (TC^* - TC^*) = 0.
\end{aligned}$$

$$\begin{aligned}
TA_1(TC^*) - TA_3(TC^*) &= \int_{C_0}^{C^*B_1} \int_{B_0} s(C, B) dC dB - \int_{C_0}^{C_1} \int_{MC^*}^{B_1} s(C, B) dC dB = \int_{C_0}^{C^*C/MC^*} \int_{B_0} s(C, B) dB dC - \int_{C^*C/MC^*}^{C_1} \int_{MC^*}^{B_1} s(C, B) dB dC \geq \\
&\int_{C_0}^{C^*C/MC^*} \int_{B_0} s(C, B) \frac{C}{C^*} dB dC - \int_{C^*C/MC^*}^{C_1} \int_{MC^*}^{B_1} s(C, B) \frac{C}{C^*} dB dC = \frac{1}{C^*} \left[ \int_{C_0}^{C^*C/MC^*} \int_{B_0} s(C, B) C dB dC - \int_{C^*C/MC^*}^{C_1} \int_{MC^*}^{B_1} s(C, B) C dB dC \right] - \\
&\frac{1}{C^*} \left[ \int_{C_0}^{C^*B_1} \int_{B_0} s(C, B) C dB dC - \int_{C_0}^{C_1} \int_{MC^*}^{B_1} s(C, B) C dB dC \right] = \frac{1}{C^*} (TC^* - TC^*) = 0.
\end{aligned}$$

$$\begin{aligned}
TA_3 - TA_2 &= \int_{C_0}^{C_1} \int_{MC^*}^{B_1} s(C, B) dB dC - \int_{C_0}^{C_1} \int_{B^*} s(C, B) dB dC = \int_{C_0}^{C_1} \int_{C/MC^*}^{B^*} s(C, B) dB dC = \\
&\int_{C_0}^{MC^*B^*} \int_{C/MC^*}^{B_1} s(C, B) dB dC - \int_{MC^*B^*}^{C_1} \int_{B^*} s(C, B) dB dC \geq \frac{1}{MC^*B^*} \left[ \int_{C_0}^{C_1} \int_{C/MC^*}^{B^*} s(C, B) C dB dC \right] = \\
&\frac{1}{MC^*B^*} \left[ \int_{C_0}^{C_1} \int_{C/MC^*}^{B^*} s(C, B) C dB dC - \int_{C_0}^{C_1} \int_{B^*} s(C, B) C dB dC \right] = \frac{1}{MC^*B^*} (TC^* - TC^*) = 0.
\end{aligned}$$



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### B. Derivation of the bivariate normal results (16) through (21)

Let  $s_1(C)$  and  $s_2(B)$  denote the marginal density functions of  $C$  and  $B$ . Under the assumption of normality

$$s_1(C) = \frac{1}{\sigma_1} \varphi\left(\frac{C - \bar{C}}{\sigma_1}\right), \quad s_2(B) = \frac{1}{\sigma_2} \varphi\left(\frac{B - \bar{B}}{\sigma_2}\right),$$

where  $\varphi(\cdot)$  is the probability density function of the standard normal distribution. The sizes of CRP under acreage and environmental targeting can be rewritten as

$$TA_1 = \int_{-\infty}^{C^*} s_1(C) dC = \Phi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) \quad (\text{A.1})$$

and

$$TA_2 = \int_{B^*}^{+\infty} s_2(B) dB = 1 - \Phi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \quad (\text{A.2})$$

where  $\Phi(\cdot)$  is the distribution function of the standard normal distribution.

Similarly, the total environmental benefits under the two targeting schemes can be rewritten as

$$\begin{aligned} TB_1 &= \int_{-\infty}^{C^*} \int_{-\infty}^{+\infty} s(C, B) B dB dC = \int_{-\infty}^{C^*} s_1(C) \int_{-\infty}^{+\infty} \frac{s(C, B)}{s_1(C)} B dB dC = \\ &= \int_{-\infty}^{C^*} \frac{1}{\sigma_1} \varphi\left(\frac{C - \bar{C}}{\sigma_1}\right) \left[ \bar{B} + \gamma \left( \frac{\sigma_2}{\sigma_1} \right) (C - \bar{C}) \right] dC = \bar{B} \Phi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) - \gamma \sigma_2 \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right). \end{aligned} \quad (\text{A.3})$$

$$\begin{aligned} TB_2 &= \int_{B^*}^{+\infty} \int_{-\infty}^{+\infty} s(C, B) B dB dC = \int_{B^*}^{+\infty} \frac{1}{\sigma_2} \varphi\left(\frac{B - \bar{B}}{\sigma_2}\right) B dB = \\ &= \int_{B^*}^{+\infty} \sigma_2 \varphi\left(\frac{B - \bar{B}}{\sigma_2}\right) \frac{B - \bar{B}}{\sigma_2} \frac{dB}{\sigma_2} + \int_{B^*}^{+\infty} \varphi\left(\frac{B - \bar{B}}{\sigma_2}\right) \frac{\bar{B}}{\sigma_2} dB = \sigma_2 \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) + \bar{B} [1 - \Phi\left(\frac{B^* - \bar{B}}{\sigma_2}\right)]. \end{aligned} \quad (\text{A.4})$$

The total CRP payment under the acreage targeting can be rewritten as

$$TC^* = \int_{-\infty}^{C^*} s_1(C) C dC = \bar{C} \Phi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) - \sigma_1 \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right). \quad (\text{A.5})$$

Differentiating (A.5) with respect to  $\sigma_1$ ,  $\sigma_2$ , and  $\gamma$  gives

$$\frac{\partial C^*}{\partial \sigma_1} = \frac{C^* - \bar{C}}{\sigma_1} + \frac{\sigma_1}{C^*}, \quad \frac{\partial C^*}{\partial \sigma_2} = 0, \quad \frac{\partial C^*}{\partial \gamma} = 0. \quad (\text{A.6})$$

The total CRP payment under the environmental targeting can be written as

$$\begin{aligned} TC^* &= \int_{-\infty}^{+\infty} \int_{B^*}^{+\infty} s(C, B) C dB dC = \int_{B^*}^{+\infty} s_2(B) \int_{-\infty}^{+\infty} \frac{s(C, B)}{s_2(B)} C dB dC \\ &= \int_{B^*}^{+\infty} \frac{1}{B^* \sigma_2} \varphi\left(\frac{B - \bar{B}}{\sigma_2}\right) [\bar{C} + \gamma\left(\frac{\sigma_1}{\sigma_2}\right) + (B - \bar{B})] dB = [1 - \Phi\left(\frac{B^* - \bar{B}}{\sigma_2}\right)] \bar{C} + \gamma \sigma_1 \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right). \end{aligned} \quad (\text{A.7})$$

Differentiating (A.7) with respect to  $\sigma_1$ ,  $\sigma_2$ , and  $\gamma$  gives

$$\frac{\partial B^*}{\partial \sigma_1} = \frac{\gamma \sigma_2}{E(C|B = B^*)}, \quad \frac{\partial B^*}{\partial \sigma_2} = \frac{B^* - \bar{B}}{\sigma_2}, \quad \frac{\partial B^*}{\partial \gamma} = \frac{\sigma_1 \sigma_2}{E(C|B = B^*)} \quad (\text{A.8})$$

Differentiating the difference of equations (A.1) and (A.2) with respect to  $\sigma_1$ ,  $\sigma_2$ , and  $\gamma$  and using equations (A.6) and (A.8) gives

$$\begin{aligned} \frac{\partial(TA_1 - TA_2)}{\partial \gamma} &= \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \frac{1}{\sigma_2} \frac{\partial B^*}{\partial \gamma} = \frac{\sigma_1}{E(C|B = B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \geq 0, \\ \frac{\partial(TA_1 - TA_2)}{\partial \sigma_1} &= -\varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) \frac{C^* - \bar{C}}{\sigma_1^2} + \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) \frac{1}{\sigma_1} \frac{\partial C^*}{\partial \sigma_1} + \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \frac{1}{\sigma_2} \frac{\partial B^*}{\partial \sigma_1} = \\ &= \frac{1}{\sigma_1} \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) \left(\frac{\partial C^*}{\partial \sigma_1} - \frac{C^* - \bar{C}}{\sigma_1^2}\right) + \frac{1}{\sigma_2} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \frac{\partial B^*}{\partial \sigma_1} = \\ &= \frac{1}{C^*} \varphi\left(\frac{C^* - \bar{C}}{\sigma_1}\right) + \frac{\gamma}{E(C|B = B^*)} \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right), \\ \frac{\partial(TA_1 - TA_2)}{\partial \sigma_2} &= -\varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \frac{B^* - \bar{B}}{\sigma_2^2} + \varphi\left(\frac{B^* - \bar{B}}{\sigma_2}\right) \frac{1}{\sigma_2} \frac{\partial B^*}{\partial \sigma_2} = 0. \end{aligned}$$

Similarly, differentiating the difference of equations (A.3) and (A.4) with respect to  $\sigma_1$ ,  $\sigma_2$ , and  $\gamma$  and using equations (A.6) and (A.8) gives

$$\frac{\partial(TB_1-TB_2)}{\partial\gamma} = -\sigma_2\varphi\left(\frac{C^*-\bar{C}}{\sigma_1}\right) + \frac{B^*\sigma_1}{E(C|B=B^*)}\varphi\left(\frac{B^*-\bar{B}}{\sigma_2}\right),$$

$$\frac{\partial(TB_1-TB_2)}{\partial\sigma_1} = \frac{E(B|C=C^*)}{C^*}\varphi\left(\frac{C^*-\bar{C}}{\sigma_1}\right) + \frac{B^*\gamma}{E(C|B=B^*)}\varphi\left(\frac{B^*-\bar{B}}{\sigma_2}\right).$$

$$\frac{\partial(TB_1-TB_2)}{\partial\sigma_2} = -\gamma\varphi\left(\frac{C^*-\bar{C}}{\sigma_1}\right) - \varphi\left(\frac{B^*-\bar{B}}{\sigma_2}\right).$$



**APPENDIX B.**  
**REGIONAL DISTRIBUTION OF CRP LAND**



Table B.1. Distribution of CRP land by pre- and postenrollment sheet and rill erosion level

USDA Region	Soil loss < 5 tons/ac		Soil loss 5-10 tons/ac		Soil loss 10-20 tons/ac		Soil loss 20-30 tons/ac		Soil loss > 30 tons/ac	
Preenrollment Sheet and Rill Erosion										
	Acres	%	Acres	%	Acres	%	Area	%	Area	%
Northeast	900	0.64	78,700	3.89	105,400	0.59	16,500	0.17	0	0.00
Appalachian	300	0.21	4,700	0.23	390,400	2.19	406,500	4.16	272,800	6.98
Southeast	0	0.00	76,600	3.79	1,247,500	6.99	176,400	1.80	21,600	0.55
Delta States	5,900	4.20	196,000	9.69	478,400	2.68	375,100	3.84	86,900	2.22
Corn Belt	19,800	14.08	204,300	10.10	2,931,000	16.43	1,781,900	18.23	183,500	4.70
Lake States	18,000	12.80	123,200	6.09	2,015,200	11.29	561,800	5.75	0	0.00
N. Plains	76,900	54.69	618,200	30.57	6,028,800	33.79	1,622,900	16.61	477,400	12.22
S. Plains	18,000	12.80	8,000	0.40	337,600	1.89	2,786,200	28.51	1,979,000	50.66
Mountain	800	0.57	448,500	22.18	2,868,800	16.08	2,043,100	20.91	885,000	22.66
Pacific	0	0.00	263,800	13.05	1,439,400	8.07	2,800	0.03	0	0.00
National	140,600	100	2,022,000	100	17,842,500	100	9,773,200	100	3,906,200	100
% of row total	0		6		53		29		12	
Postenrollment Sheet and Rill Erosion										
Northeast	201,500	0.60	0	0.00	0	0	0	0	0	0
Appalachian	1,074,700	3.22	0	0.00	0	0	0	0	0	0
Southeast	1,522,100	4.57	0	0.00	0	0	0	0	0	0
Delta States	1,142,300	3.43	0	0.00	0	0	0	0	0	0
Corn Belt	5,120,500	15.36	0	0.00	0	0	0	0	0	0
Lake States	2,718,200	8.15	0	0.00	0	0	0	0	0	0
N. Plains	8,824,200	26.47	0	0.00	0	0	0	0	0	0
S. Plains	5,110,600	15.33	18,200	5.20	0	0	0	0	0	0
Mountain	5,914,600	17.74	331,600	94.80	0	0	0	0	0	0
Pacific	1,706,000	5.12	0	0.00	0	0	0	0	0	0
National	33,334,700	100	349,800	100	0	0	0	0	0	0.00
% of row total	99		1		0		0		0	

Note: CRP enrollment through eleventh sign-up (end of 1991) is included.

Source: National Resources Inventory database, USDA/SCS, 1992.



Table B.2. Distribution of CRP land by pre- and postenrollment wind erosion level

USDA Region	Soil loss < 5 tons/ac		Soil loss 5-10 tons/ac		Soil loss 10-20 tons/ac		Soil loss 20-30 tons/ac		Soil loss > 30 tons/ac	
Preenrollment Wind Erosion										
	Acres	%	Acres	%	Acres	%	Area	%	Area	%
Northeast	201,500	0.88	0	0.00	0	0.00	0	0.00	0	0.00
Appalachian	1,074,700	4.68	0	0.00	0	0.00	0	0.00	0	0.00
Southeast	1,522,100	6.64	0	0.00	0	0.00	0	0.00	0	0.00
Delta States	1,142,300	4.98	0	0.00	0	0.00	0	0.00	0	0.00
Corn Belt	4,981,900	21.72	112,800	2.92	23,500	0.61	2,300	0.15	0	0.00
Lake States	1,742,800	7.60	313,400	8.12	492,800	12.80	137,100	8.97	32,100	2.13
N. Plains	5,690,100	24.80	1,543,500	40.00	1,154,200	29.99	237,000	15.50	199,400	13.22
S. Plains	2,900,400	12.64	507,100	13.14	615,300	15.99	401,600	26.27	704,400	46.71
Mountain	2,225,600	9.70	1,202,700	31.17	1,512,000	39.29	740,900	48.46	565,000	37.47
Pacific	1,458,900	6.36	179,300	4.65	50,700	1.32	10,100	0.66	7,000	0.46
National	22,940,300	100	3,858,800	100	3,848,500	100	1,529,000	100	1,507,900	100.00
% of row total	68		11		11		5		4	
Postenrollment Wind Erosion										
Northeast	201,500	0.68	0	0	0	0	0	0	0	0.00
Appalachian	1,074,700	3.6	0	0.35	0	0	0	0	0	0.00
Southeast	1,522,100	5.11	0	0	0	0	0	0	0	0.00
Delta States	1,142,300	3.84	0	0	0	0	0	0	0	0.00
Corn Belt	5,119,500	16.96	1,000	3.62	0	4.19	0	2.86	0	0.16
Lake States	2,677,500	8.67	28,700	2.88	12,000	3.22	0	4.56	0	3.53
N. Plains	8,662,100	25.75	119,700	49.34	40,300	37.27	600	30.7	1,500	18.61
S. Plains	4,884,900	15.27	128,400	17.04	55,300	6.01	10,000	14.69	50,200	17.67
Mountain	5,387,500	14.64	490,200	26.28	254,500	46.54	30,500	41.86	83,500	58.75
Pacific	1,685,400	5.47	16,000	0.49	4,600	2.76	0	5.32	0	1.29
National	32,357,500	100	784,000	100	366,700	100	41,100	100	135,200	100.00
% of row total	96		2		1		0		0	

Note: CRP enrollment through eleventh sign-up (end of 1991) is included.

Source: National Resources Inventory database, USDA/SCS, 1992.

Table B.3. Distribution of CRP land by distance to surface water body

USDA Region	> 1/4th of a mile		1/8-1/4th of a mile		1/16-1/8th of a mile		1/32-1/16th of a mile		<1/32th of a mile	
	Acres	%	Acres	%	Acres	%	Area	%	Acres	%
Northeast	112,300	0.49	60,300	1.21	22,400	0.9	4,000	0.39	2,500	0.61
Appalachian	270,000	1.17	352,600	7.06	251,800	10.08	141,500	13.71	58,800	14.38
Southeast	787,700	3.42	381,100	7.63	250,900	10.05	78,700	7.62	23,700	5.79
Delta States	420,700	1.83	374,500	7.5	223,500	8.95	91,800	8.89	31,800	7.78
Corn Belt	2,199,800	9.54	1,507,600	30.18	870,100	34.85	402,100	38.96	145,900	35.67
Lake States	1,837,200	7.97	453,100	9.07	255,700	10.24	111,600	10.81	60,600	14.82
N. Plains	6,969,700	30.24	1,233,500	24.69	431,700	17.29	132,100	12.8	57,200	13.99
S. Plains	4,603,200	19.97	395,100	7.91	104,300	4.18	18,200	1.76	8,500	2.08
Mountain	5,849,900	25.38	237,500	4.75	86,600	3.47	52,200	5.06	20,000	4.89
Pacific	1,577,300	6.84	80,700	1.62	35,000	1.4	11,200	1.09	1,800	0.44
<b>National</b>	<b>24,627,800</b>	<b>100</b>	<b>5,076,000</b>	<b>100</b>	<b>2,532,000</b>	<b>100</b>	<b>1,043,400</b>	<b>100</b>	<b>410,800</b>	<b>100.00</b>
<b>% of row total</b>	<b>73</b>		<b>15</b>		<b>8</b>		<b>3</b>		<b>1</b>	

Source: National Resources Inventory database. USDA/SCS, 1992.

Table B.4. Distribution of CRP land by groundwater vulnerability risk classes

USDA Region	No risk		Low risk		Medium risk		High risk	
	Acres	%	Acres	%	Area	%	Acres	%
Northeast	201,500	0.62	0	0	0	0	0	0.6
Appalachian	1,074,700	2.98	0	1.71	0	9.41	0	10.86
Southeast	1,522,100	4.54	0	1.63	0	1.7	0	13.63
Delta States	1,081,000	2.56	57,700	12.12	2,400	27.32	1,200	13.33
Corn Belt	3,765,200	14.91	624,800	7.65	533,100	24.98	197,400	32.53
Lake States	2,696,300	8.16	10,500	8.53	9,200	3.89	2,200	8.48
N. Plains	3,877,900	26.45	927,900	28.16	1,946,100	20.79	2,072,300	11.43
S. Plains	2,033,200	15.63	1,273,700	6.73	1,585,500	7.23	236,400	7.44
Mountain	1,394,800	19	241,600	23.83	2,156,200	3.57	2,453,600	1.7
Pacific	309,800	5.14	125,900	9.63	507,700	1.12	762,600	0
<b>National</b>	<b>17,956,500</b>	<b>100</b>	<b>3,262,100</b>	<b>100</b>	<b>6,740,200</b>	<b>100</b>	<b>5,725,700</b>	<b>100</b>
<b>% of row total</b>	<b>53</b>		<b>10</b>		<b>20</b>		<b>17</b>	

Note: Groundwater vulnerability for pesticide leaching is based on groundwater vulnerability index developed by Kellogg et al. 1992.

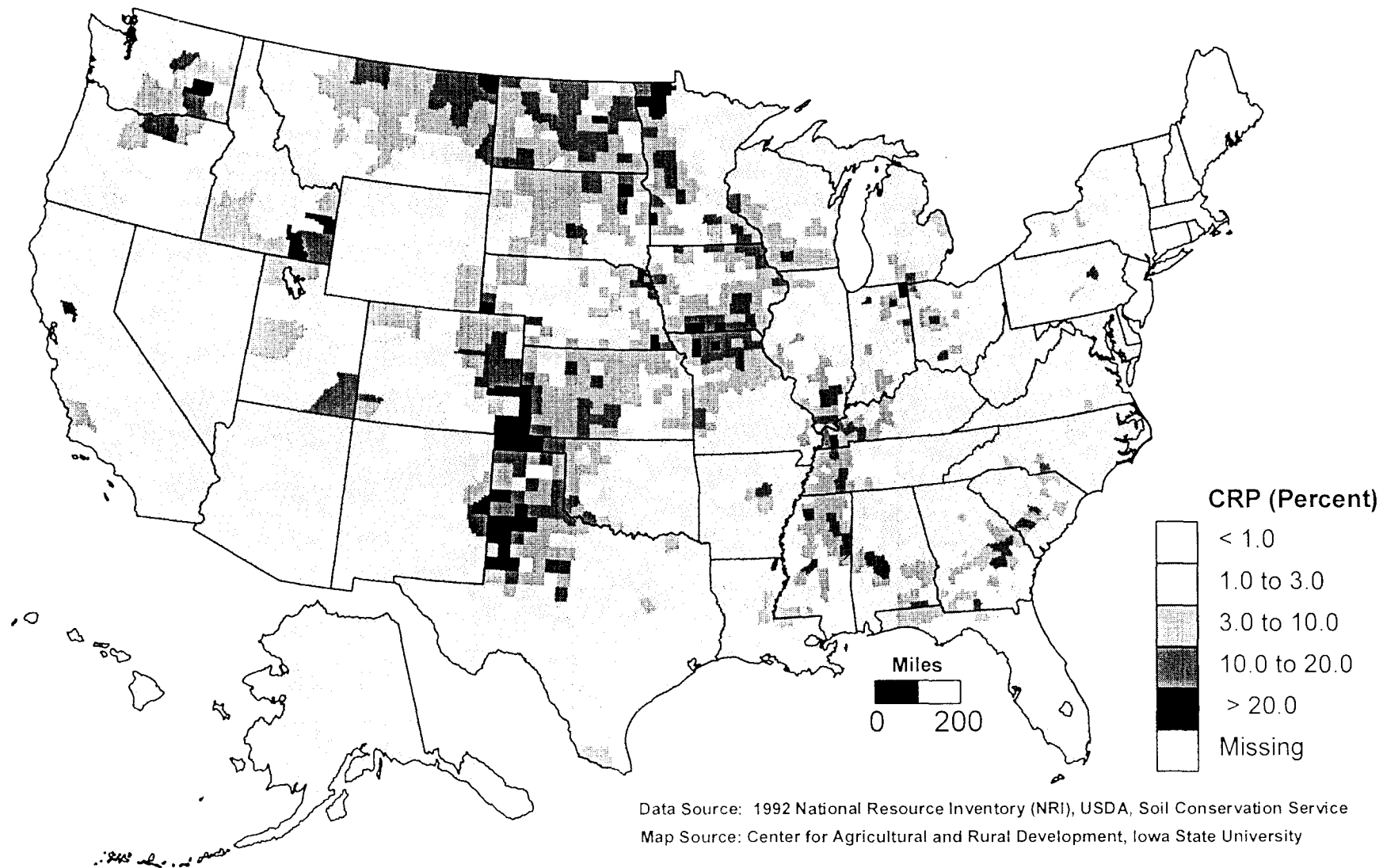


**APPENDIX C.**

**COUNTY-LEVEL DISTRIBUTION OF CRP LAND**

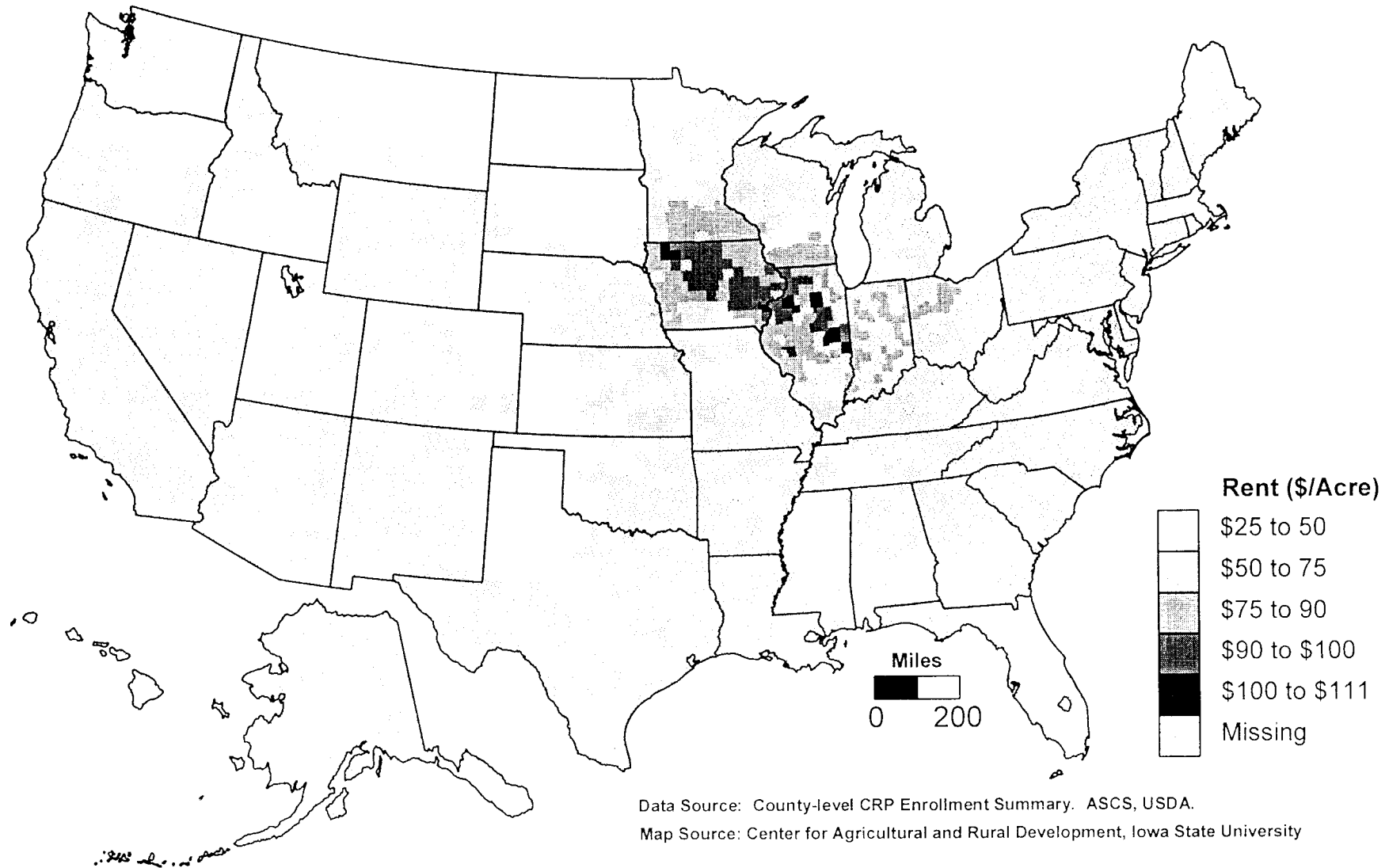


**Figure C.1. Percentage of CRP to total cropland, by county**





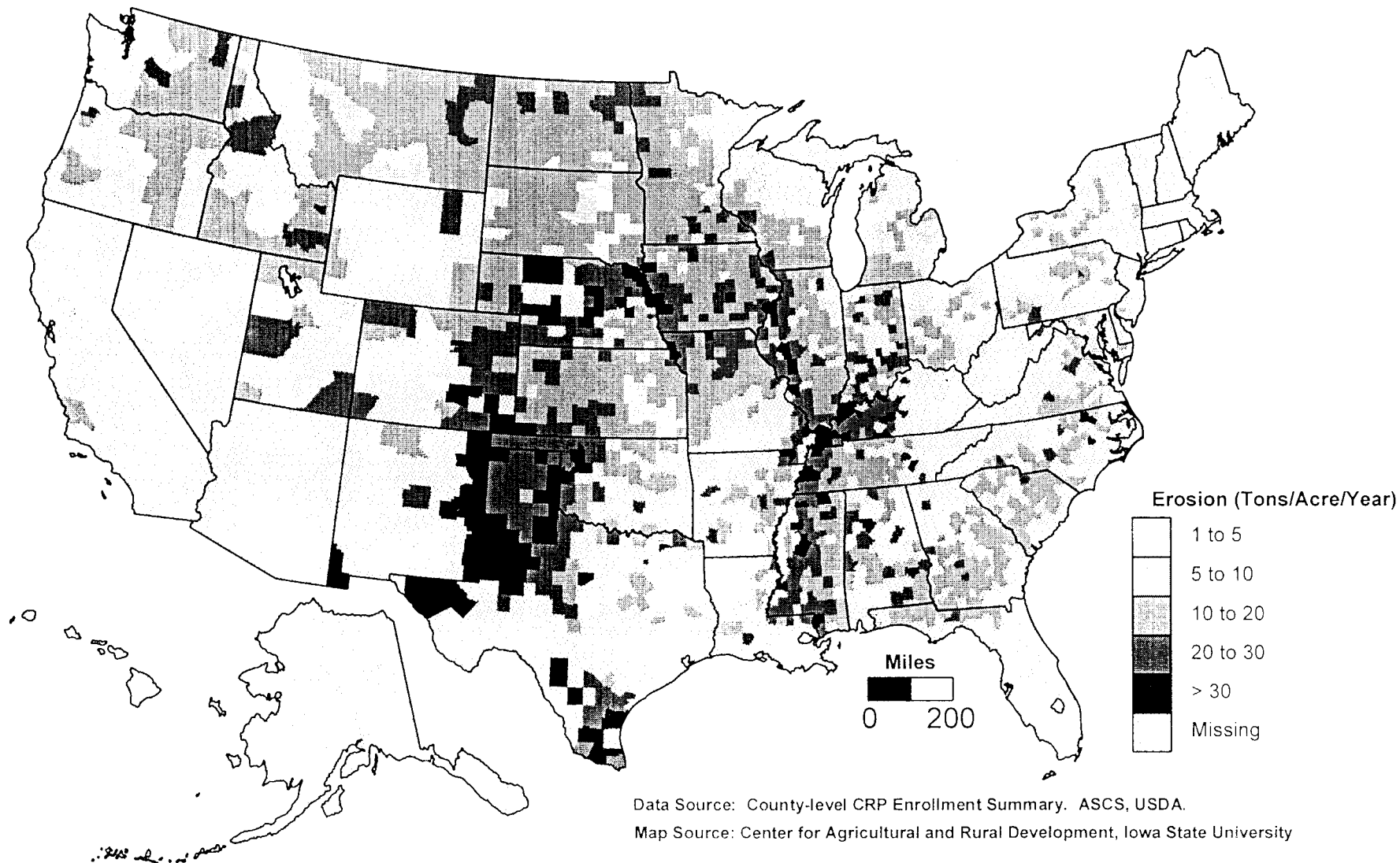
## Figure C.2. Cost of CRP land rent, by county





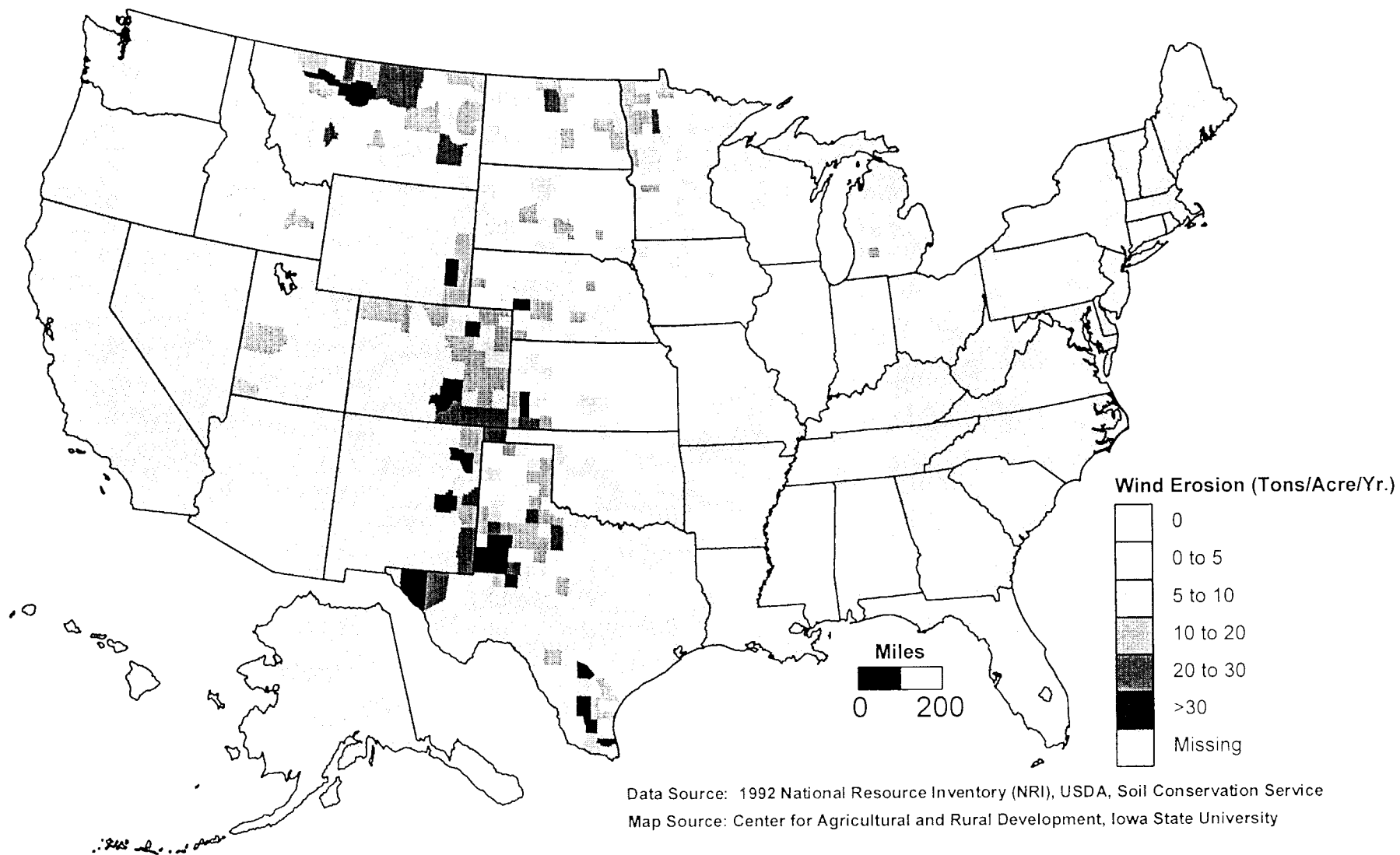


**Figure C.3. Water erosion rates for CRP land, by county**



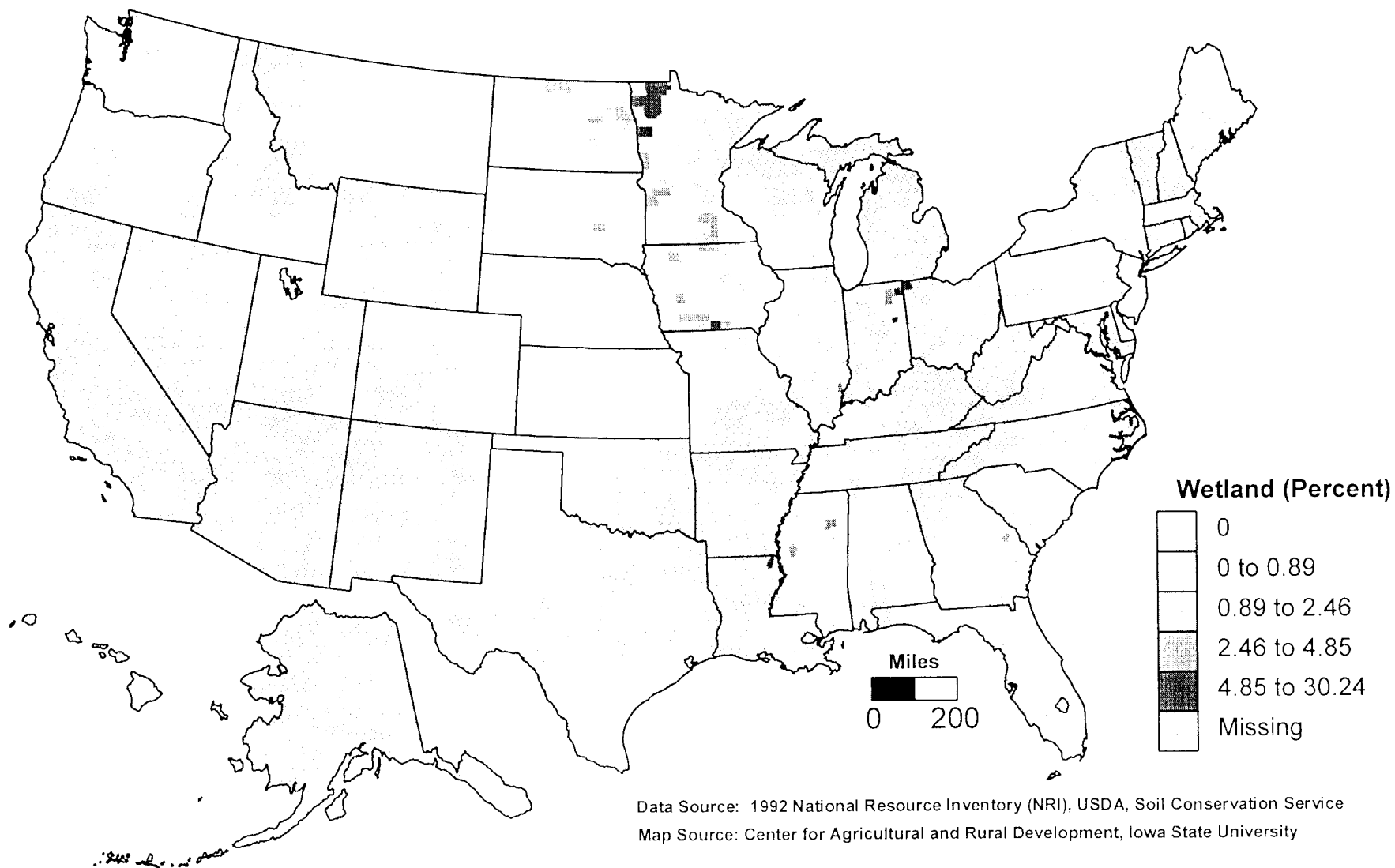


# Figure C.4. Wind erosion rates for CRP land, by county



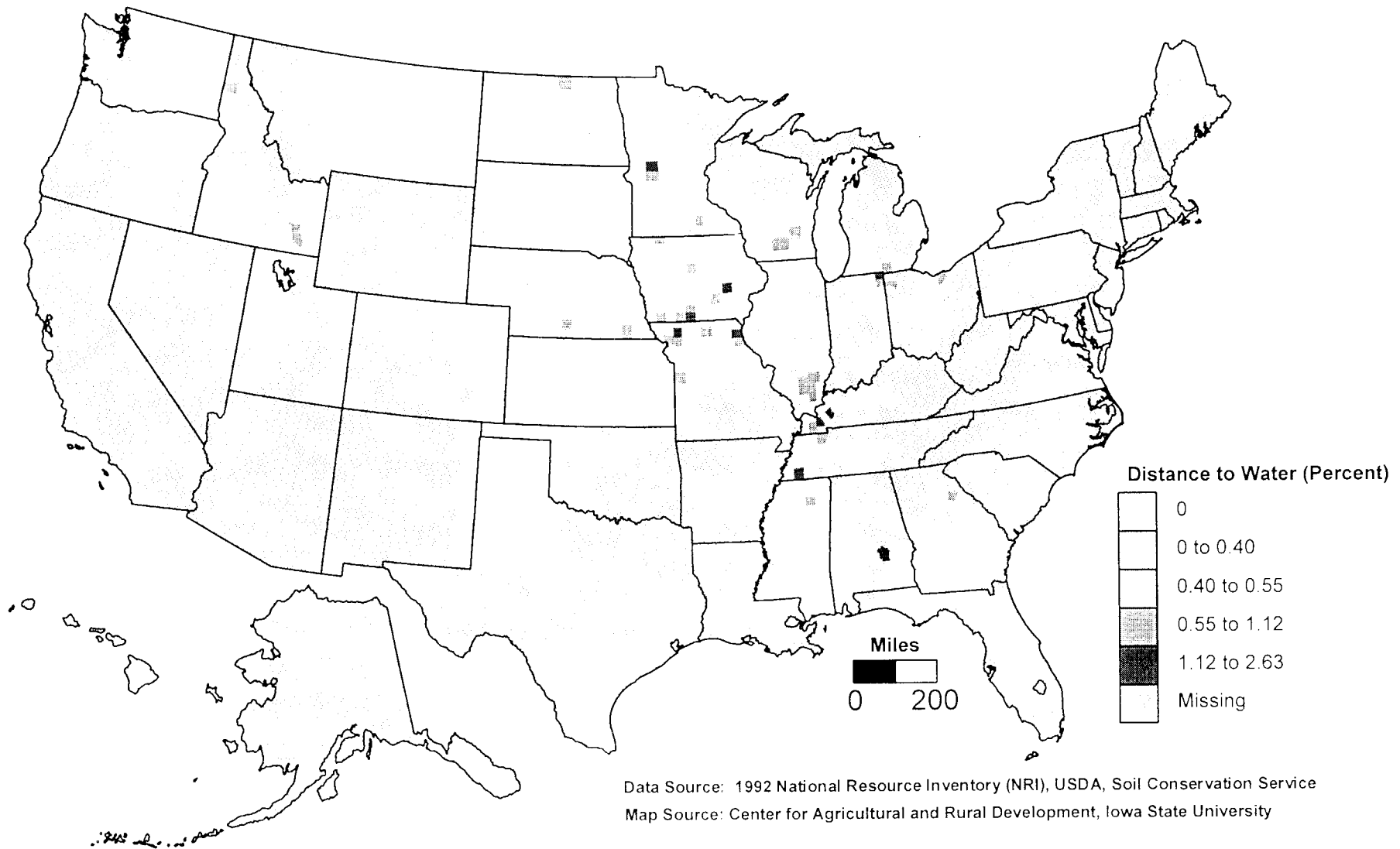


# Figure C.5. Percentage of CRP land designated as wetlands





**Figure C.6. Percentage of CRP land less than 100 feet from water**





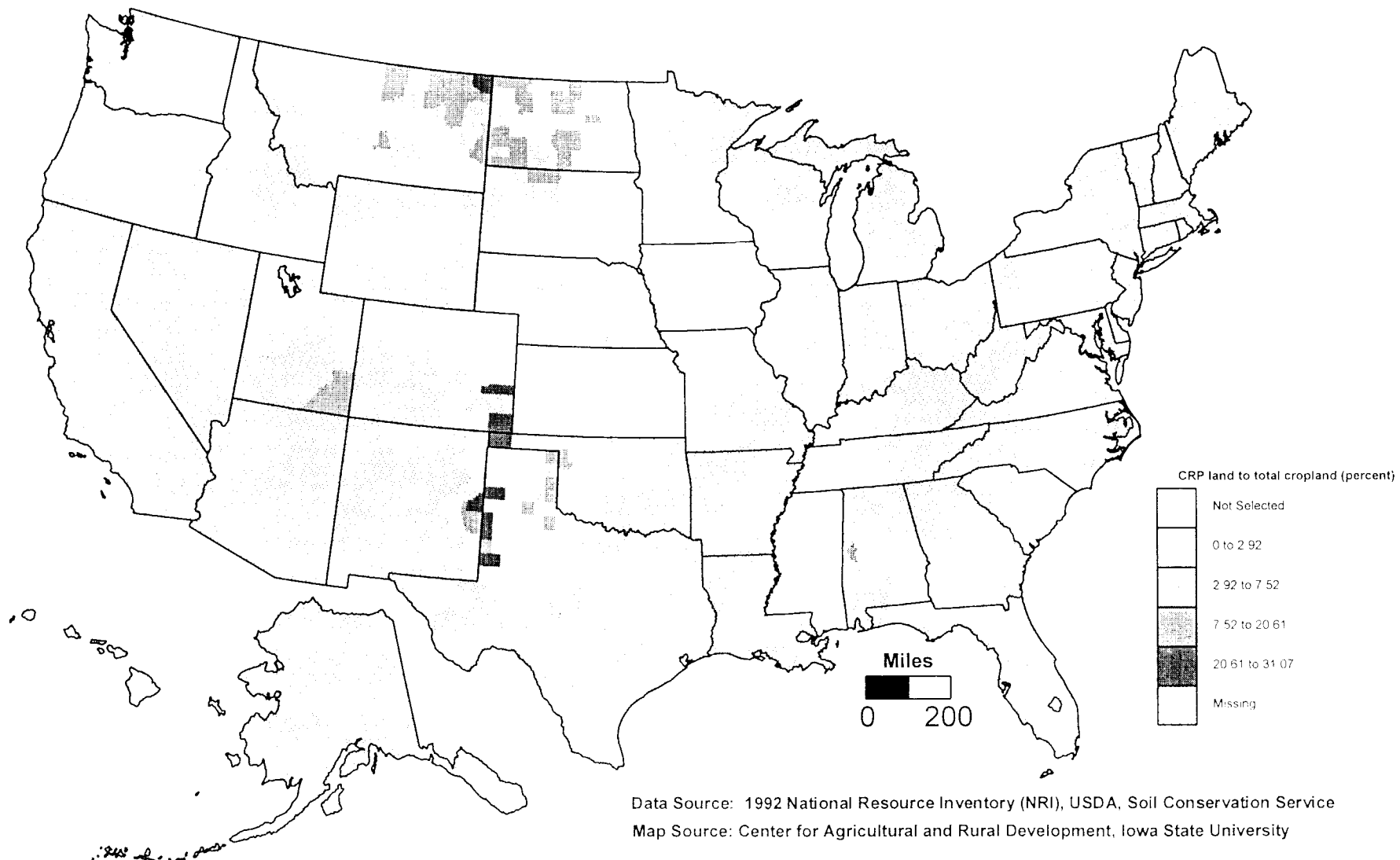


**APPENDIX D.**

**RESULTS FROM THE \$250 MILLION PROGRAM**

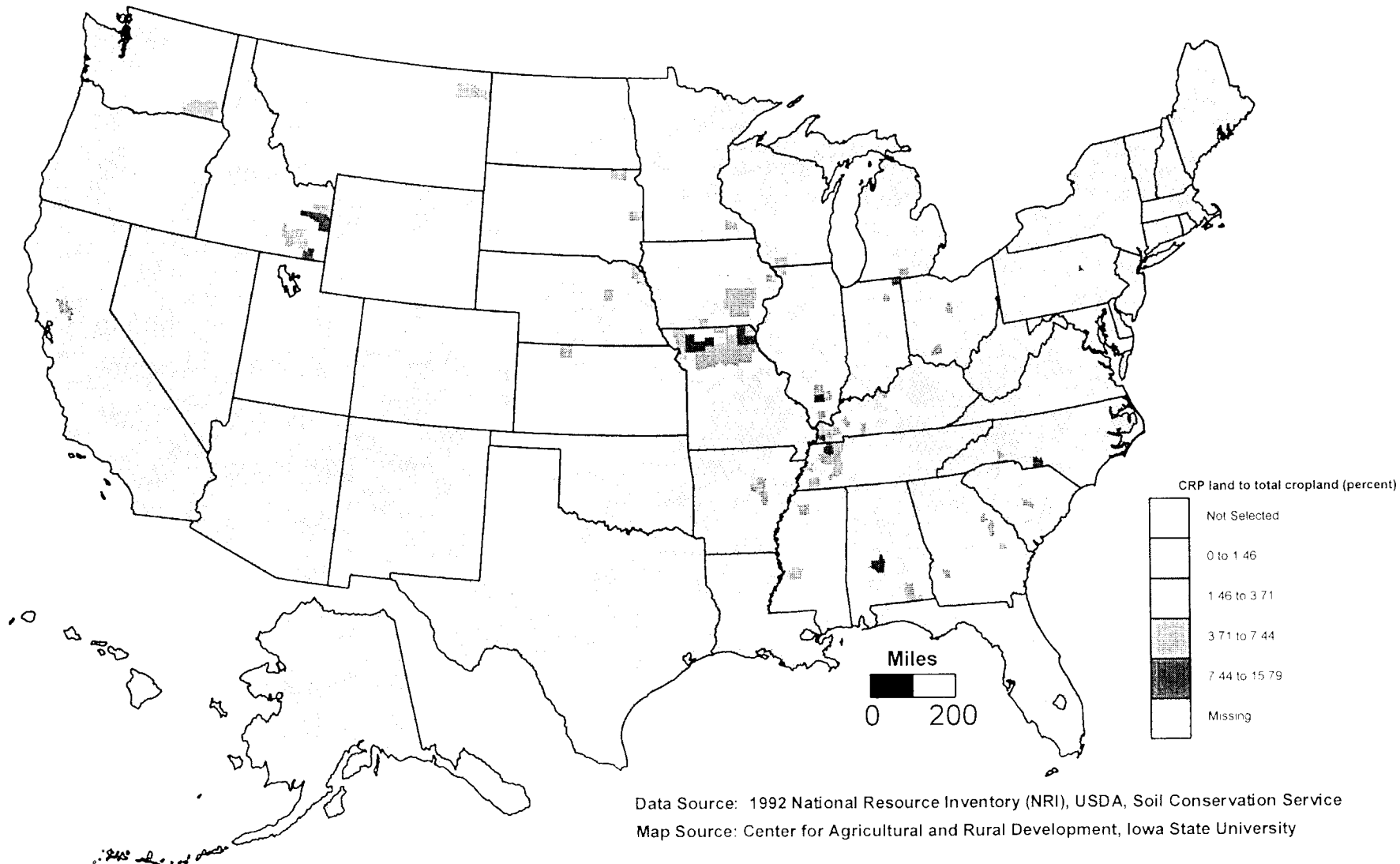


**Figure D.1. CRP land renewed by acreage targeting, \$250m program**



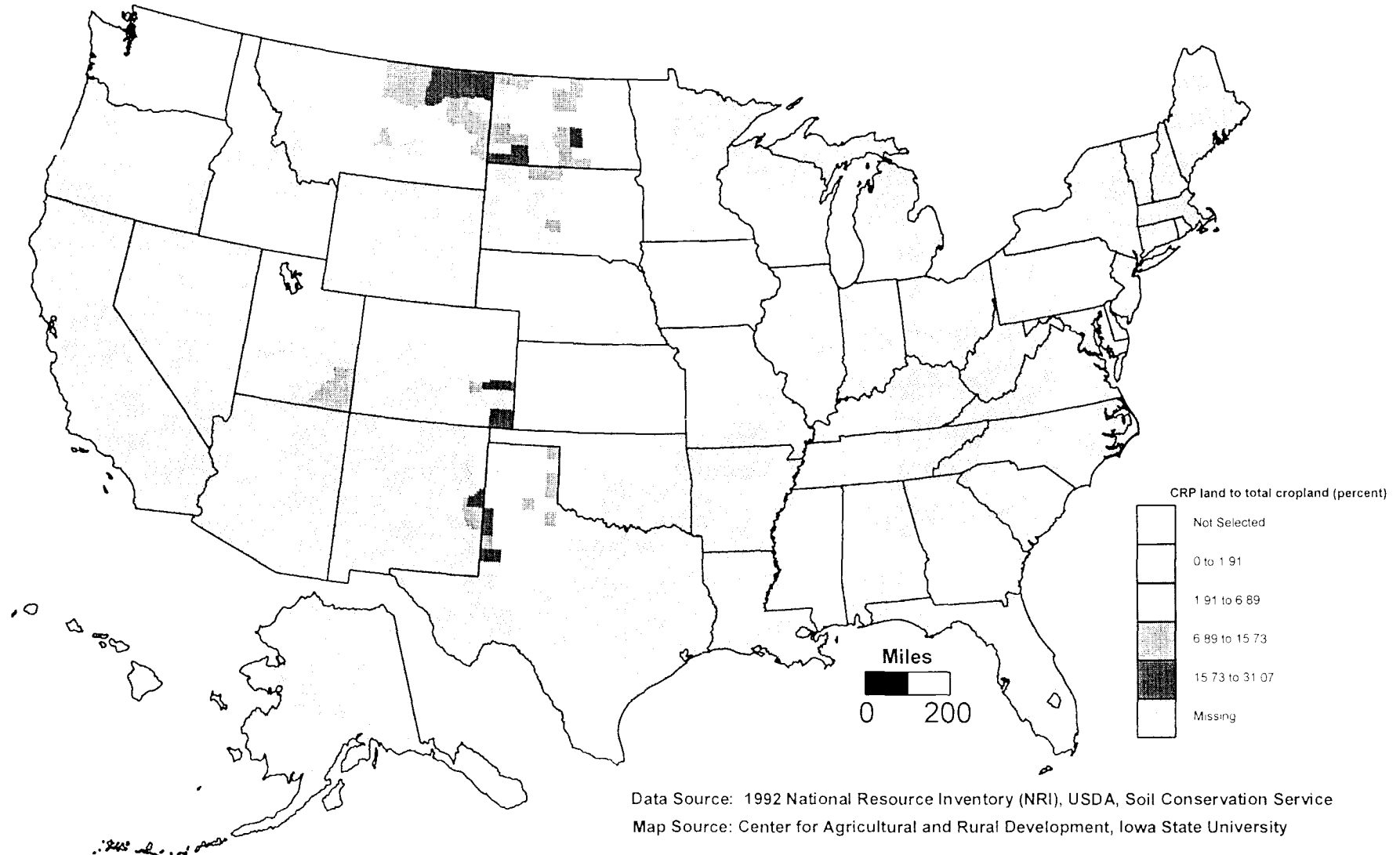


**Figure D.2. CRP land renewed by water erosion targeting,  
\$250m program**





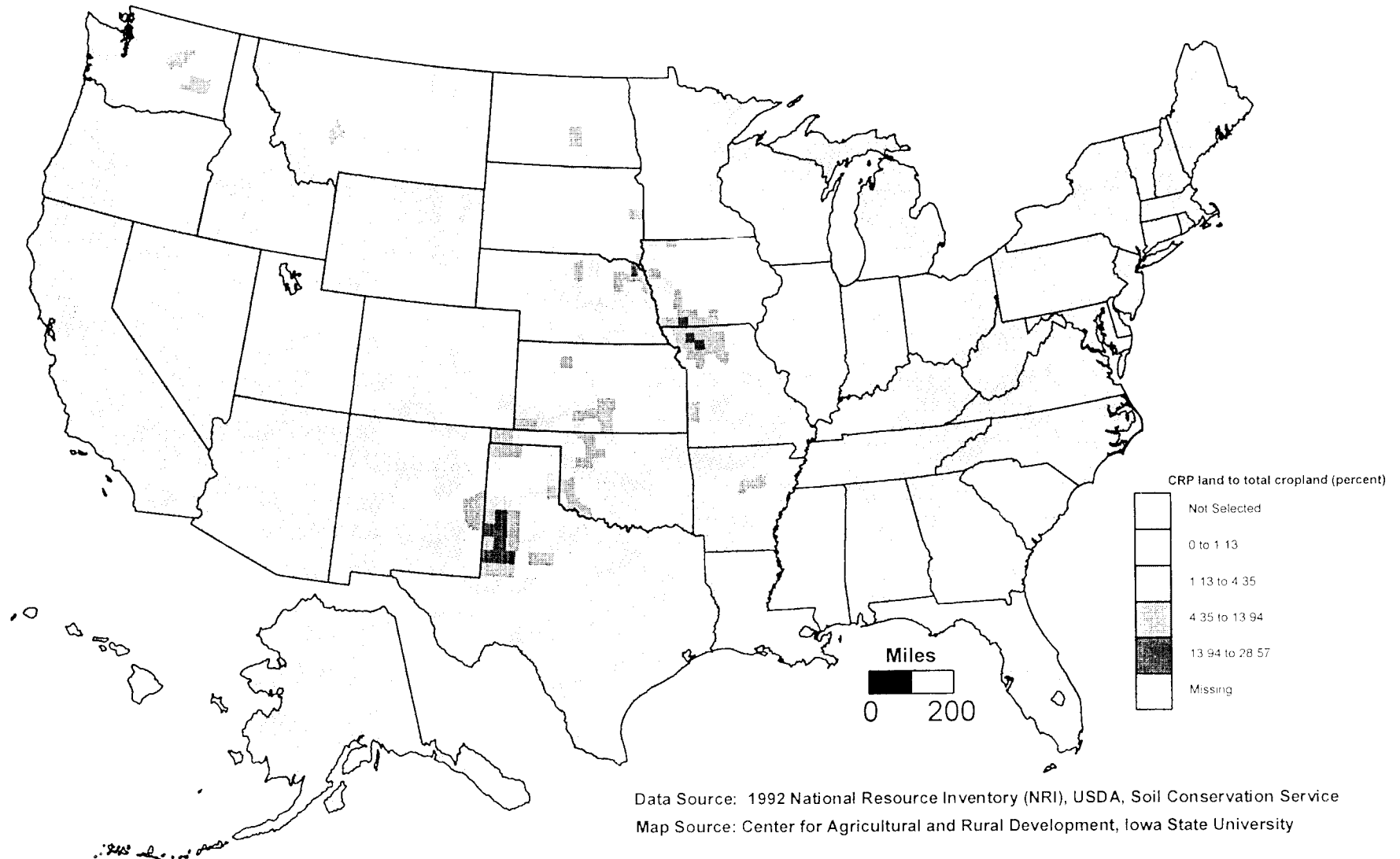
**Figure D.3. CRP land renewed by targeting wildlife habitat potential,  
\$250m program**





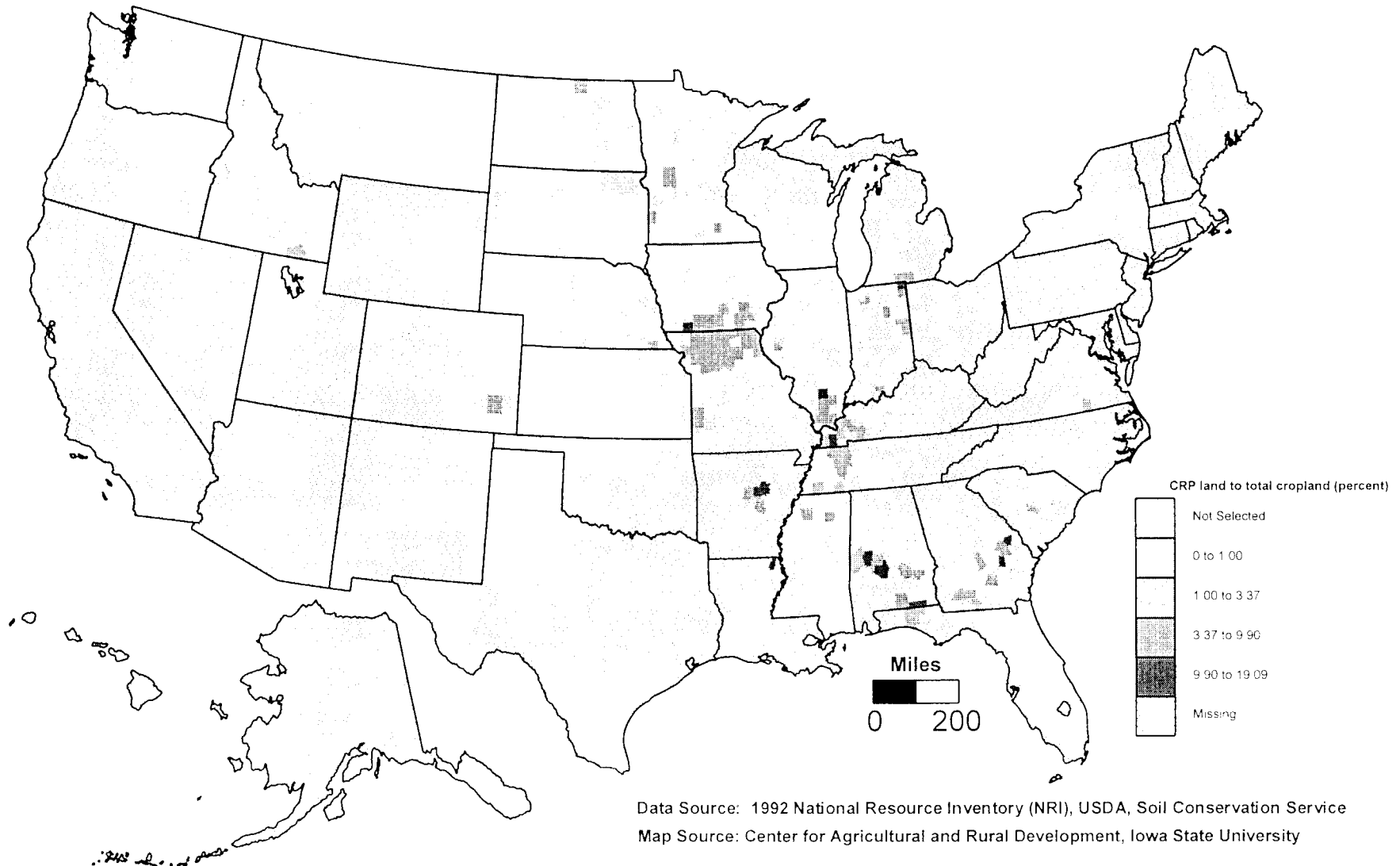


**Figure D.4. CRP land renewed by targeting groundwater vulnerable areas,  
\$250m program**



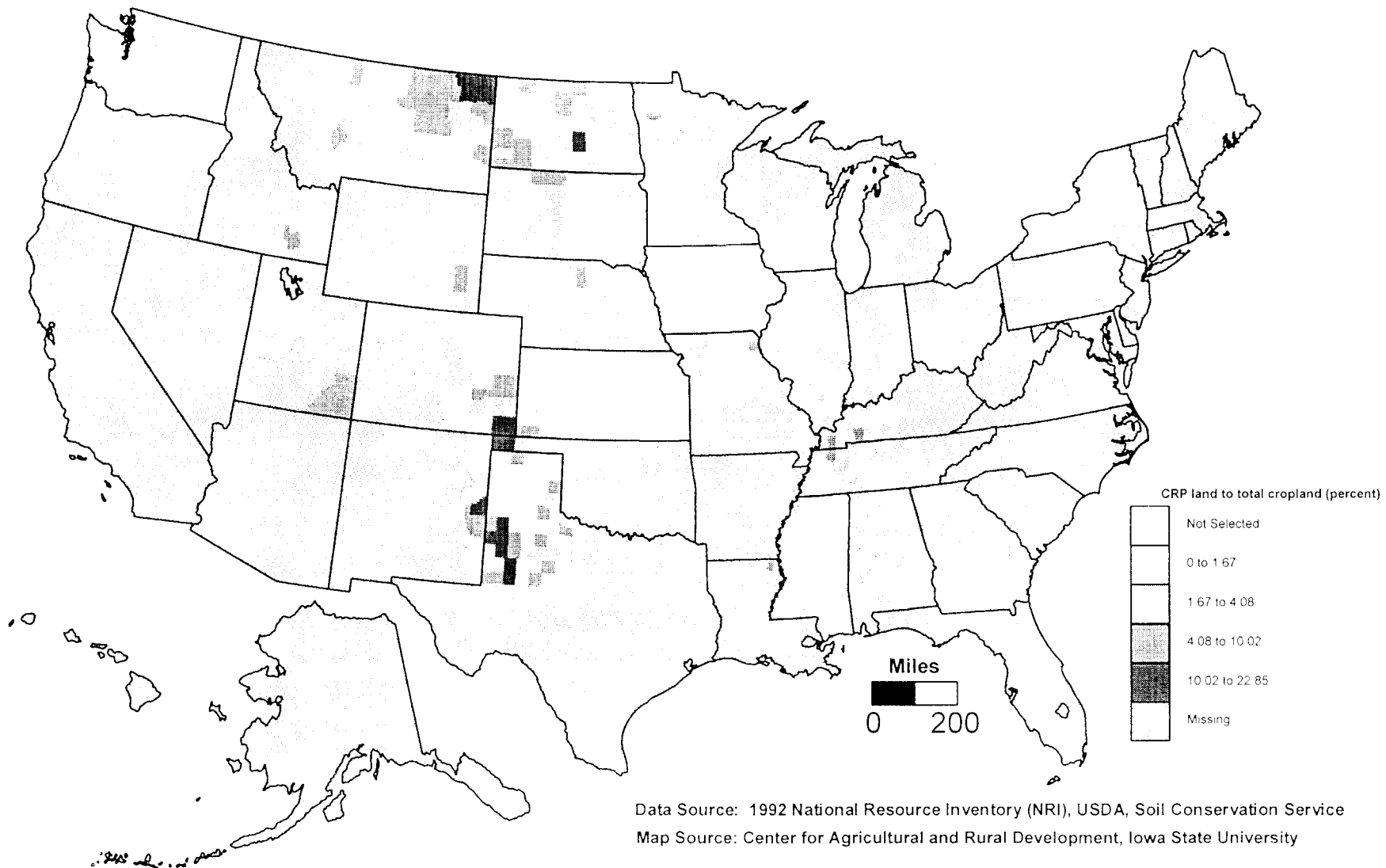


**Figure D.5. CRP land renewed by targeting surface water quality index,  
\$250m program**





**Figure D.6. CRP land renewed by targeting multiple index,  
\$250m program**





**ENDNOTES**

1. Allen (1993) classifies the majority of agricultural ecosystems suitable for wildlife habitat into two broad groups, namely (1) the species suitable for agricultural landscapes which contain a high degree of interspersed land use and vegetation associations and (2) the species indigenous to grassland ecosystems.
2. Klingbeil and Montgomery developed the LCC system for soil. Land classes 1 through 8 denote the degree to which the factors such as erosion, climate, soil characteristics, and moisture condition interfere with crop production. Land capability class 1 has no interference whereas LCC 8 has extensive problems.





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