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An Econometric Analysis of the Environmental Benefits Provided by the Conservation Reserve Program

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Over $1.7 billion has been spent on the Conservation Reserve Program (CRP) since 1985. The purpose of this study is to show that these expenditures have aided the environment. Rather than quantify changes in environmental variables, a spatial econometric model is used to test if CRP enrollments are greater in counties with poorer environmental quality. In seven of nine regions, CRP enrollments are higher in counties with an environmental concern. This positive finding justifies past expenditures by the CRP and supports continued funding as an environmental program. The CRP is targeting current environmental concerns that will lead to future improvement.

Key Words: Conservation Reserve Program, econometrics, environmental quality, soil erosion, spatial data, water quality, wildlife habitat

JEL Classifications: Q28, Q58, C31, Q24, Q25

This paper examines an important policy question—to what extent does crop acreage enrollment in the Conservation Reserve Program (CRP) aid the environment? The CRP was initiated by the 1985 Food Security Act for agricultural commodity supply control (Osborn). However, by the late 1980s supply control had become less important, and CRP enrollments increasingly reflected environmental and natural resource objectives. The 1996 Agriculture Improvement and Reform Act made the CRP the principal agriculture program designed for supply control via reduction in cropland availability. Nevertheless, the U.S. Department of Agriculture (USDA) made it clear that the CRP would also be administered to conserve and improve natural resources, including wildlife habitat, water quality, and soil.

The CRP is a voluntary program where the USDA agrees to pay agricultural landowners to idle highly erodible and/or environmentally sensitive cropland for 10 to 15 years (Osborn). Participants receive annual rental payments during the contract period. The rental payments are designed to reflect crop productivity (average annual per acre crop return) with a premium given to areas identified as highly erodible or environmentally sensitive (areas where the USDA wants to encourage enrollment). Participants also receive technical assistance from the Natural Resources Conservation Service (NRCS) and, at least, half the cost of establishing grass or trees on enrolled acreage.

According to the data used in this investigation, 34,404,006 acres across 2,544 U.S.

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counties have been enrolled in the CRP in 616,021 individual contracts since 1986. The average rental payment since 1986 across participating counties has been $57.79 per acre. Thus, the CRP has cost taxpayers $1,707,855,250 in farm payments alone.

Given the substantial investment in the CRP over the past 9 years, it is reasonable to ask if the program has, at minimum, improved soil erosion, water quality, and wildlife habitat. Studies designed to measure environmental benefits arising from the CRP are sparse. Most studies simply discuss potential environmental impacts of CRP (e.g., Ribaudo). This study is different in that it attempts to quantify potential environmental benefits arising from the CRP using an econometric model of CRP acreage enrollment that accounts for spatial correlation across U.S. farm resource regions. Nevertheless, this study is only a "first step" in determining the extent to which CRP enrollments have aided the environment. Specifically, this paper addresses the question, Is enrollment (thus expenditures) occurring in counties where improvement of the environment (signified by improvement in the program target areas including wildlife habitat, water quality, and soil) is needed? If higher enrollments are occurring in counties with poorer environmental quality, then it is more likely that CRP will have a positive impact on the environment.

Again, the purpose of this study is to show that CRP enrollments are greatest in counties where environmental quality improvement is most needed. If it is shown that enrollments match concerns, then one can conclude that the CRP benefits the environment. However, it is not the purpose of this study to establish the extent of environmental improvement (e.g., in pounds of reduced agricultural chemical runoff) or the value of improvements. This is left to further study. But before embarking on studies that measure the environmental benefits to society arising from the CRP, it is prudent to first establish if program moneys are being spent in areas with the greatest environmental needs. If so, then it is more likely that there is something to study in terms of extent of environmental improvement and the monetary benefit of the improvement.

Theoretical Development

This study develops a model to estimate the correlation between aggregate county CRP acreage, a set of agrienvironmental indicators that "indicate" level of environmental quality, and a set of county-level "control" variables. The agrienvironmental indicators used in this study are reported at the watershed or eight-digit hydrologic unit code (HUC) level of aggregation, while CRP acreage and other variables are reported at the county level of aggregation. Each U.S. county is identified according to Federal Information Processing Standards, or FIPS, code. Thus, the term "FIPS" is used in place of the term "county" throughout this paper.

The analysis presented in this paper was conducted at the FIPS level. This required that the agrienvironmental indicators be reaggregated to the FIPS level. Using the Geographic Information System (GIS) computer package ArcView, thematic FIPS and HUC maps for the lower 48 U.S. states were overlaid and areas calculated for each unique FIPS-HUC intersection. Intersections were defined using the "Union" tool in the "GeoProcessing Wizard" of ArcView. The area of each intersection was calculated using an ArcView "script" program obtained from the ESRI company website (ESRI is the company that produces ArcView). Next, using the statistical computer package SAS, the agrienvironmental data were linked to the FIPS-HUC intersection data and reaggregated to the FIPS level. Reaggregation was completed using a weighted mean where the weight was the percent of total FIPS area represented by the intersection area.

Each FIPS is attached to a Farm Resource Region (FRR) as defined by the USDA Economic Research Service (ERS) (Heimlich). The regions are derived from four sources: (1) the Farm Production Regions—Northern Plains, Delta, and so on; (2) a cluster analysis of farm characteristics in the United States; (3) the USDA Land Resource Regions; and (4) the National Agricultural Statistics Service's

(NASS's) Crop Reporting Districts (CRD). Regions were constructed based on the types of commodities grown, along with environmental and physiographic factors, such as soil, climate, and water. Regional boundaries conform to CRDs, but state boundaries were not a factor in the aggregation process. The nine regions are Heartland (FRR 1; H), Northern Crescent (FRR 2; NC), Northern Great Plains (FRR 3; NGP), Prairie Gateway (FRR 4; PG), Eastern Uplands (FRR 5; EU), Southern Seaboard (FRR 6; SS), Fruitful Rim (FRR 7; FR), the Basin and Range (FRR 8; BR), and Mississippi Portal (FRR 9; MP). The nine FRR as defined by ERS are depicted in Heimlich (see the Internet site).

Given the grouped, spatial nature of the data, it was anticipated that groupwise heteroscedasticity would be an issue. Furthermore, there is no reason to believe that model coefficients would be same in each FRR. Hence, a model similar to seemingly unrelated regression is utilized to correct for spatial heterogeneity and to allow separate parameter estimates for each FRR.

Following Greene, each FRR is treated as a separate regression equation. The data constituting the nine FRRs are grouped and stacked by equation following Equation (1):

$$(1)\quad \begin{aligned} Y_1 &= X_1 b_1 + \varepsilon_1 \\ Y_2 &= X_2 b_2 + \varepsilon_2 \\ &\vdots \\ Y_9 &= X_9 b_9 + \varepsilon_9. \end{aligned}$$

In Equation (1), Y represents the dependent variable arranged in a column vector, X is a matrix comprised of a constant and relevant independent variables, b is a column vector of parameters or solution values, and ϵ is the unknown error term. Stacked and converted to matrix form, Equation (1) is expressed as Equation (2). The X matrix in Equation (2) has a special "block-diagonal" form. It is this form that allows estimation of separate parameter values for each FRR. Keeping track of the dimensions of this system is very important. As discussed here, each region possesses a unique number of observations, but there are 1,544 total observations (T). For each region, k parameters are estimated for a total of KR parameters (R represents regions of which there are nine). Thus, Y and ϵ are T by 1, X is T by KR, and b is KR by 1:

$$(2)\quad \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_9 \end{bmatrix} = \begin{bmatrix} X_1 & 0 & \cdots & 0 \\ 0 & X_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & X_9 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_9 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_9 \end{bmatrix}$$

$$Y = Xb + \varepsilon.$$

Each FRR contains a unique set of FIPS (or counties); thus, the FRRs represent unbalanced panel data. By region, there are 541 (R_1), 345 (R_2), 177 (R_3), 351 (R_4), 301 (R_5), 424 (R_6), 160 (R_7), 99 (R_8), and 146 (R_9) FIPS (or observations), respectively, in the H, NC, NGP, PG, EU, SS, FR, BR, and MP FRRs (see Tables 1–5).

With groupwise heteroscedasticity, each FRR is hypothesized to possess a unique variance term (σ_{ii}) that is grouped in a matrix Σ (Equation [3]). The issues of contemporaneous correlation and spatial autocorrelation are left to further study. Equation (3) also provides the derivation of Σ (Judge et al.). Note that e_i is the residual vector from a regression of X on Y for the ith cross section (or FRR). In Σ, I_{Ri} is an R_i by R_i identity matrix for the ith FRR (i = 1 to 9). Note that Σ is a square T by T, symmetric, positive definite matrix:

$$(3)\quad \sum = \begin{bmatrix} \sigma_{11} I_{R_1} & 0 & \cdots & 0 \\ 0 & \sigma_{22} I_{R_2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{99} I_{R_9} \end{bmatrix},$$

where $\sigma_{ii} = e_i e_i / R_i$. Following Judge et al. and given the definitions for σ_{ii} from Equation (3), the presence of groupwise heteroscedasticity is tested using a Lagrange multiplier statistic (Equation [4]). The null and alternative hypotheses for the Lagrange multiplier test are H_0, $\sigma_{11} = \sigma_{22} = \ldots = \sigma_{99} = 0$ (i.e., the disturbances of the regions are unrelated), and H_a, at least one variance term is not equal to the remaining variance terms. Asymptotically, λ is distributed according to a chi-square distribu-

Table 1. Total Cumulative Conservation Reserve Program (CRP) Acreage, 1986–2003, as a Function of Type of Enrollment, Environmental Variables, and Other Control Variables for the Heartland Farm Resource Region Counties Plus Means and Standard Deviations for All Modeled Farm Resource Regions and U.S. Counties[a]

	Estimate	Standard Error	Prob >|T|	Mean	Standard Deviation
All U.S. Counties and Farm Resource Regions				**2,544 Counties (observations)**	
Aggregate County CRP Acreage				13,523.59	28,381.15
Intercept					
Annual Rental Rate				57.79	29.71
Contracts				242.15	327.40
Farm Acreage				309,957.78	361,784.82
County Acreage				595,212.63	632,119.54
In CREP				0.19	0.40
In Non-CREP				0.77	0.42
In Wetland				0.42	0.49
In Pasture				0.48	0.50
In Timber				0.87	0.34
Erosion Index				13.28	14.03
Water Erosion				0.74	0.68
Wind Erosion				1.02	2.86
Pesticide Leaching				1.87	0.94
Agricultural Runoff				1.48	0.57
% Change in Wetland Acreage				55.37	19.00
Heartland Farm Resource Region				**541 Counties (observations)**	
Aggregate County CRP Acreage				11,687.48	13,156.07
Intercept	**5,263.78**	**2,633.26**	**0.05**		
Annual Rental Rate	**−144.78**	**12.49**	**0.00**	**94.09**	**23.91**
Contracts	**20.29**	**0.82**	**0.00**	**503.68**	**393.82**
Farm Acreage	0.00	0.00	0.44	256,004.05	113,770.51
County Acreage	**0.01**	**0.00**	**0.01**	**340,442.79**	**121,085.03**
In CREP	−564.22	599.63	0.35	0.25	0.43
In Non-CREP				1.00	0.06
In Wetland	−347.31	586.62	0.55	0.61	0.49
In Pasture	627.83	546.85	0.25	0.66	0.47
In Timber				0.99	0.10
Erosion Index	22.01	39.34	0.58	13.19	8.17
Water Erosion	**7,886.22**	**871.01**	**0.00**	**0.99**	**0.49**
Wind Erosion	**667.38**	**232.57**	**0.00**	**0.51**	**1.12**
Pesticide Leaching	**783.31**	**264.27**	**0.00**	**1.67**	**0.96**
Agricultural Runoff	236.08	1,159.99	0.84	1.95	0.21
% Change in Wetland Acreage	**−35.12**	**18.77**	**0.06**	**76.71**	**16.61**

[a] Adjusted $R^2 = 0.81$. Estimated values in bold type are statistically different from 0 with 90% confidence or better.

tion with R (or nine) degrees of freedom. In Equation (4), σ^2 is equal to $e'e/T$, where e represents the residual vector from a regression of X on Y for all T (2,544) observations:

$$(4) \quad \lambda = \frac{T}{2}\left[\sum_{i=1}^{R} \frac{\sigma_{ii}^2}{\sigma^2} - 1\right]^2 \Rightarrow \chi_R^2.$$

If the outcome of the Lagrange multiplier test is to reject H_0, then given Σ the solution values (or parameters) of Equation (2) (i.e., b) are determined using feasible generalized least squares (GLS) (Equation [5]). Here b_{GLS} is more efficient than ordinary least squares regression by equation or regression using an

Table 2. Total Cumulative Conservation Reserve Program (CRP) Acreage, 1986–2003, as a Function of Type of Enrollment, Environmental Variables, and Other Control Variables for the Northern Crescent and Northern Great Plains Farm Resource Region Counties, Including Means and Standard Deviations[a]

	Estimate	Standard Error	Prob >|T|	Mean	Standard Deviation
Northern Crescent Farm Resource Region				**345 Counties (observations)**	
Aggregate County CRP Acreage				4,144.24	6,943.17
Intercept	**1,886.63**	**951.30**	**0.05**		
Annual Rental Rate	**−22.90**	**8.38**	**0.01**	**55.47**	**22.68**
Contracts	**21.48**	**0.71**	**0.00**	**191.94**	**300.10**
Farm Acreage	**0.01**	**0.00**	**0.00**	**147,530.29**	**109,132.54**
County Acreage	0.00	0.00	0.70	621,407.67	519,596.53
In CREP	**−674.14**	**388.98**	**0.08**	**0.37**	**0.48**
In Non-CREP	−198.55	416.04	0.63	0.82	0.38
In Wetland	−15.11	336.40	0.96	0.48	0.50
In Pasture	271.33	332.30	0.41	0.56	0.50
In Timber	−18.18	507.29	0.97	0.88	0.32
Erosion Index	13.08	17.47	0.45	11.32	10.02
Water Erosion	**631.07**	**323.51**	**0.05**	**0.76**	**0.65**
Wind Erosion	88.88	147.79	0.55	0.61	1.08
Pesticide Leaching	−138.71	243.10	0.57	1.92	0.69
Agricultural Runoff	−545.25	417.09	0.19	1.58	0.55
% Change in Wetland Acreage	−13.45	11.39	0.24	52.10	13.28
Northern Great Plains Farm Resource Region				**177 Counties (observations)**	
Aggregate County CRP Acreage				53,305.45	54,488.92
Intercept	**51,706.03**	**15,613.27**	**0.00**		
Annual Rental Rate	**−783.36**	**196.33**	**0.00**	**35.48**	**8.53**
Contracts	**130.41**	**5.44**	**0.00**	**469.84**	**417.70**
Farm Acreage	**−0.01**	**0.01**	**0.08**	**900,913.50**	**582,481.15**
County Acreage	**0.01**	**0.01**	**0.01**	**1,056,037.27**	**678,016.23**
In CREP	637.15	5,165.50	0.90	0.08	0.28
In Non-CREP	2,901.88	5,160.08	0.57	0.95	0.22
In Wetland	−2,484.43	2,981.55	0.40	0.79	0.41
In Pasture	165.11	2,682.99	0.95	0.35	0.48
In Timber	−33.09	4,741.52	0.99	0.92	0.28
Erosion Index	**1,175.81**	**370.51**	**0.00**	**9.04**	**3.82**
Water Erosion	**17,407.47**	**7,146.01**	**0.01**	**0.32**	**0.18**
Wind Erosion	1,087.36	802.24	0.18	2.90	2.21
Pesticide Leaching	3,124.88	2,076.63	0.13	0.99	0.62
Agricultural Runoff	**−11,467.46**	**3,879.03**	**0.00**	**1.02**	**0.34**
% Change in Wetland Acreage	**−1,215.58**	**267.96**	**0.00**	**39.30**	**6.57**

[a] Adjusted $R^2 = 0.81$. Estimated values in bold type are statistically different from 0 with 90% confidence or better.

alternative estimation technique like fixed or random effects. Presence of groupwise heteroscedasticity, thus the appropriateness of this regression model, is demonstrated in the results. In Equation (5), Y is T by 1, X is T by KR, and Σ is T by T, which yields the T by 1 solution vector b:

$$b_{GLS} = \left[X' \overset{-1}{\Sigma} X\right] X' \overset{-1}{\Sigma} Y. \tag{5}$$

Data

To estimate the correlation between CRP acreage enrollment and environmental vari-

Table 3. Total Cumulative Conservation Reserve Program (CRP) Acreage, 1986–2003, as a Function of Type of Enrollment, Environmental Variables, and Other Control Variables for the Prairie Gateway and Eastern Uplands Farm Resource Region Counties, Including Means and Standard Deviations[a]

	Estimate	Standard Error	Prob >|T|	Mean	Standard Deviation
Prairie Gateway Farm Resource Region				**351 Counties (observations)**	
Aggregate County CRP Acreage				28,816.50	43,390.73
Intercept	63.65	7,578.79	0.99		
Annual Rental Rate	**−329.53**	**94.88**	**0.00**	**40.35**	**11.83**
Contracts	**113.95**	**5.06**	**0.00**	**254.43**	**271.85**
Farm Acreage	0.00	0.01	0.85	554,443.36	325,619.67
County Acreage	0.01	0.01	0.41	643,230.92	378,921.20
In CREP	468.54	3,834.12	0.90	0.04	0.20
In Non-CREP	1,197.07	2,008.80	0.55	0.71	0.45
In Wetland	123.97	1,557.01	0.94	0.47	0.50
In Pasture	544.50	2,030.52	0.79	0.21	0.41
In Timber	**−5,319.43**	**1,999.21**	**0.01**	**0.60**	**0.49**
Erosion Index	8.03	154.23	0.96	11.65	5.06
Water Erosion	**−7,855.97**	**2,776.14**	**0.00**	**0.58**	**0.34**
Wind Erosion	**800.32**	**161.91**	**0.00**	**3.19**	**5.98**
Pesticide Leaching	1,334.69	1,106.89	0.23	1.76	0.72
Agricultural Runoff	1,385.76	1,980.21	0.48	1.23	0.48
% Change in Wetland Acreage	**191.98**	**101.10**	**0.06**	**51.05**	**7.67**
Eastern Uplands Farm Resource Region				**301 Counties (observations)**	
Aggregate County CRP Acreage				1,059.57	2,564.42
Intercept	−7.12	219.17	0.97		
Annual Rental Rate	−4.59	3.01	0.13	52.54	12.43
Contracts	**29.80**	**1.11**	**0.00**	**32.80**	**67.23**
Farm Acreage	0.00	0.00	0.47	132,203.48	103,397.60
County Acreage	0.00	0.00	0.15	323,486.52	157,081.91
In CREP	32.15	118.57	0.79	0.13	0.34
In Non-CREP	16.61	76.08	0.83	0.72	0.45
In Wetland	237.43	199.96	0.24	0.09	0.29
In Pasture	−96.57	74.54	0.20	0.59	0.49
In Timber	−0.10	83.83	1.00	0.85	0.36
Erosion Index	**−2.71**	**1.47**	**0.07**	**18.76**	**17.68**
Water Erosion	−68.25	53.41	0.20	0.63	0.67
Wind Erosion				0.00	0.00
Pesticide Leaching	−39.08	36.96	0.29	2.12	0.89
Agricultural Runoff	**141.39**	**66.64**	**0.03**	**1.47**	**0.52**
% Change in Wetland Acreage	1.70	1.88	0.37	62.92	17.40

[a] Adjusted $R^2 = 0.81$. Estimated values in bold type are statistically different from 0 with 90% confidence or better.

ables, data from various sources are used. The dependent variable and independent variables representing type of CRP enrollment and annual rental rate were obtained from the Natural Resource Conservation Service (NRCS). "Control" variables, including total county acreage and total crop acreage from the 2000 Census of Agriculture, were obtained from the NASS. Environmental variables were obtained from the NRCS and the U.S. Environmental Protection Agency (EPA).

Table 4. Total Cumulative Conservation Reserve Program (CRP) Acreage, 1986–2003, as a Function of Type of Enrollment, Environmental Variables, and Other Control Variables for the Southern Seaboard and Fruitful Rim Farm Resource Region Counties, Including Means and Standard Deviations[a]

	Estimate	Standard Error	Prob >|T|	Mean	Standard Deviation
Southern Seaboard Farm Resource Region				**424 Counties (observations)**	
Aggregate County CRP Acreage				3,190.27	4,939.03
Intercept	−679.16	757.68	0.37		
Annual Rental Rate	0.57	8.07	0.94	45.79	18.52
Contracts	**32.45**	**1.58**	**0.00**	**92.16**	**141.85**
Farm Acreage	**0.01**	**0.00**	**0.00**	**100,427.40**	**71,644.94**
County Acreage	0.00	0.00	0.78	381,200.46	323,018.61
In CREP	**−885.24**	**302.56**	**0.00**	**0.24**	**0.43**
In Non-CREP	−159.77	188.73	0.40	0.53	0.50
In Wetland	**637.80**	**207.29**	**0.00**	**0.27**	**0.45**
In Pasture	253.04	193.62	0.19	0.37	0.48
In Timber	202.43	631.97	0.75	0.98	0.14
Erosion Index	**−7.77**	**4.27**	**0.07**	**14.36**	**21.97**
Water Erosion	−105.52	95.07	0.27	0.88	1.03
Wind Erosion	−112.45	634.48	0.86	0.02	0.14
Pesticide Leaching	8.64	95.80	0.93	2.47	0.77
Agricultural Runoff	−56.93	153.19	0.71	1.46	0.50
% Change in Wetland Acreage	**11.94**	**6.32**	**0.06**	**41.20**	**12.30**
Fruitful Rim Farm Resource Region				**160 Counties (observations)**	
Aggregate County CRP Acreage				13,927.27	31,589.72
Intercept	721.94	3,511.24	0.84		
Annual Rental Rate	**−31.89**	**13.77**	**0.02**	**60.68**	**52.69**
Contracts	**127.37**	**7.03**	**0.00**	**103.13**	**210.12**
Farm Acreage	**0.00**	**0.00**	**0.09**	**411,559.32**	**522,659.75**
County Acreage	0.00	0.00	0.72	1,213,177.45	1,040,678.33
In CREP	778.26	1,843.25	0.67	0.26	0.44
In Non-CREP	−182.17	1,091.68	0.87	0.53	0.50
In Wetland	**−4,612.02**	**1,282.61**	**0.00**	**0.20**	**0.40**
In Pasture	**3,561.11**	**2,008.61**	**0.08**	**0.45**	**0.50**
In Timber	−981.55	1,881.83	0.60	0.74	0.44
Erosion Index	6.58	10.57	0.53	11.99	21.67
Water Erosion	−1,421.86	1,926.83	0.46	0.45	0.41
Wind Erosion	**417.34**	**195.32**	**0.03**	**2.04**	**3.86**
Pesticide Leaching	**−1,424.61**	**732.50**	**0.05**	**1.48**	**0.97**
Agricultural Runoff	1,625.76	1,269.60	0.20	0.96	0.45
% Change in Wetland Acreage	7.81	43.73	0.86	46.15	17.69

[a] Adjusted R^2 = 0.81. Estimated values in bold type are statistically different from 0 with 90% confidence or better.

The Dependent Variable

The dependent variable of this investigation is aggregate county CRP enrollment (CRP_AC). Annual enrollment figures were obtained from the NRCS for every U.S. county from 1986 to 2003. Total county CRP enrollment was determined by summing up annual enrollments across each year for each county. Of 3,111 counties in the lower 48 states, 2,544 counties enrolled at least one tenth of an acre of farmland in the CRP over the 8-year period studied.

Table 5. Total Cumulative Conservation Reserve Program (CRP) Acreage, 1986–2003, as a Function of Type of Enrollment, Environmental Variables, and Other Control Variables for the Basin and Range and Mississippi Portal Farm Resource Region Counties, Including Means and Standard Deviations[a]

	Estimate	Standard Error	Prob >|T|	Mean	Standard Deviation
Basin and Range Farm Resource Region				**99 Counties (observations)**	
Aggregate County CRP Acreage				17,558.76	29,095.38
Intercept	9,909.00	7,284.53	0.17		
Annual Rental Rate	**−149.23**	**84.63**	**0.08**	**44.13**	**18.89**
Contracts	**98.32**	**10.74**	**0.00**	**113.58**	**217.81**
Farm Acreage	**0.01**	**0.00**	**0.03**	**709,333.65**	**581,716.41**
County Acreage	0.00	0.00	0.28	1,940,160.95	1,416,864.74
In CREP	**22,460.18**	**5,247.06**	**0.00**	**0.15**	**0.36**
In Non-CREP	4,028.05	5,572.14	0.47	0.71	0.46
In Wetland	−4,828.66	3,619.34	0.18	0.19	0.40
In Pasture	−1,106.29	4,163.18	0.79	0.59	0.50
In Timber	0.19	6,067.90	1.00	0.72	0.45
Erosion Index	−112.88	86.22	0.19	15.53	14.84
Water Erosion	−1,901.49	4,978.31	0.70	0.31	0.49
Wind Erosion	825.91	593.51	0.16	1.43	2.16
Pesticide Leaching	569.87	3,215.15	0.86	0.64	0.68
Agricultural Runoff	−1,127.26	3,418.14	0.74	0.60	0.49
% Change in Wetland Acreage	−92.41	96.90	0.34	40.74	15.60
Mississippi Portal Farm Resource Region				**146 Counties (observations)**	
Aggregate County CRP Acreage				10,023.13	9,479.88
Intercept	4,993.62	3,865.40	0.20		
Annual Rental Rate	16.12	40.56	0.69	49.43	11.65
Contracts	**49.71**	**3.63**	**0.00**	**192.80**	**182.63**
Farm Acreage	0.00	0.01	0.41	181,939.75	98,833.58
County Acreage	0.00	0.00	0.62	395,755.70	126,286.62
In CREP	592.52	2,034.81	0.77	0.03	0.18
In Non-CREP	−176.66	1,262.84	0.89	0.90	0.30
In Wetland	**2,132.41**	**775.01**	**0.01**	**0.58**	**0.50**
In Pasture	853.87	836.94	0.31	0.55	0.50
In Timber	442.84	1,731.37	0.80	0.97	0.16
Erosion Index	−22.65	48.73	0.64	12.73	7.69
Water Erosion	−903.76	650.49	0.16	1.09	0.79
Wind Erosion				0.00	0.00
Pesticide Leaching	435.36	877.35	0.62	2.77	0.44
Agricultural Runoff	22.39	1,001.61	0.98	1.86	0.35
% Change in Wetland Acreage	**−119.40**	**48.87**	**0.01**	**59.59**	**8.47**

[a] Adjusted $R^2 = 0.81$. Estimated values in bold type are statistically different from 0 with 90% confidence or better.

The Independent Variables

The independent variables are grouped as follows: (1) "control" variables that are included to capture the variation in the dependent variables that cannot be attributed to the environmental variables and (2) the environmental variables. Continuous control variables include the annual rental rate (ARR), total number of contracts (CONTRACTS), total county acreage (TCA), and total farm acreage (TFA). ARR and CONTRACTS are explained in the following. TCA and TFA are included to control for, respectively, size of the county and the supply of agricultural land in the county. It is anticipated that larger counties and counties with more agricultural land will enroll more acreage in the CRP.

ARR is the amount per acre paid to landowners for acreage enrolled in the CRP. This price varies by location and reflects the native productivity of the land as well as the importance of the acreage in meeting specific conservation goals. This price also varies by year. In this investigation ARR is the average of the rental rates paid from 1986 to 2003. It might be expected that the higher the ARR, the more acreage will be enrolled in CRP. However, the program is designed such that higher ARRs are paid in areas of higher productivity, thus higher per acre returns. As a result, higher ARRs will lead to higher levels of enrollment only if the ARR exceeds (or is at least close to) average per acre return.

The variable CONTRACTS represents the total number of CRP contracts signed by county farmers from 1986 to 2003. Note that one farmer can sign more than one contract. Also, contracts within the data represented as little as one tenth of an acre. However, it is anticipated that a greater number of contracts is associated with more county CRP acreage.

A series of dichotomous (or dummy) control variables were included in the model to capture variation in the dependent variable due to type of acreage enrolled in CRP. The types of acreage identified in this study follow those identified by the NRCS and include Conservation Reserve Enhancement Program (CREP) acreage, non-CREP acreage (NCREP), acreage in historic wetlands areas (WETLANDS), pasture acreage (PASTURE), and naturally occurring timber acreage or acreage planted to timber (TIMBER). In all cases, the appropriate variable was assigned the value of 1 if the associated acreage in that county exceeded 0 and was 0 otherwise. Note that a county could have all CRP acreage in one category or some CRP acreage in all categories. The relationship between the dichotomous control variables and acreage enrolled in CRP (CRP_AC) cannot be determined *a priori.*

The study uses nine environmental variables to test if larger aggregate county CRP acreage enrollments are occurring in counties with greater need of environmental improvement. Note that the nine environmental variables are consistent with three defined CRP priority concerns: wildlife habitat, water quality, and soil. Derivation of and other details concerning the environmental variables can be found on the World Wide Web. What follows is the title of each variable, a brief description, and the name of the agency from which the data were obtained.

The "Erosion Index" (EI) was included with the CRP data obtained from the NRCS. EI is a measure of potential, combined wind and water erosion of soil in a county. This is an important variable because the EI is used by administrators of the CRP to establish priority areas and rental rates. In general, the program is designed such that higher levels of EI are associated with higher rental rates. The EI is a continuous variable with higher values of EI representing a greater potential for soil erosion (i.e., a poorer environment).

Five of the nine environmental variables were obtained from NRCS sources not directly related to the CRP (specifically, the Resource Assessment Division of the NRCS). For greater detail, refer to Clark. These variables include "Potential Nitrogen Fertilizer Loss from Farm Fields, Based on Production of 7 Major Crops" (nitfert) (USDA, NRCS 1996a), "Average Annual Soil Erosion by Water on Cultivated Cropland as a Proportion of the Tolerable Rate" (e_h2o) (USDA, NRCS 2001a), "Average Annual Soil Erosion by Wind on Cultivated Cropland as a Proportion of the Tolerable Rate" (e_air) (USDA, NRCS 2001b), "Pesticide Leaching Potential by Watershed for 13 Crops" (p_lea) (USDA, NRCS 1996c), and "Pesticide Runoff Potential by Watershed for 13 Crops" (p_roff) (USDA, NRCS 1996b). Note that the variables nitfert, e_h2o, and e_air hold continuous values (the higher the value, the worse the condition), while the variables p_roff and p_lea are discrete index values that range from 1 to 3 (best to worse).

The remaining three environmental variables were obtained from the EPA. The first, "Agricultural Runoff" (a_roff), is a composite measure of the potential for surface and groundwater contamination arising from agricultural production activities. The variable a_roff holds discrete index values that range from 0 to 3 (best to worse). The second, "Nitrogen Exported" (n_exp), is a composite measure of the potential for all sources of agricultural nitrogen (fertilizer, animal manure, and so on) to contaminate surface and groundwater. The variable n_exp holds discrete index values that range from −1 to 2 (best to worse). The final variable, pc_wet, is continuous and holds the percentage change in historic wetland acreage within a county. The larger pc_wet, the greater the loss in wetland acreage within the county.

Again, the nine environmental variables are consistent with CRP priority environmental quality concerns that include wildlife habitat, water quality, and soil. Environmental quality concerns related to soil are represented in the model by the variables EI, e_h2o, and e_air. Environmental quality concerns related to water quality are represented in the model by the variables nitfert, p_roff, p_lea, a_roff, and n_exp. Note that the soil variables EI and e_roff might also represent water to the extent that soil-laden (or muddy) water is of poorer quality. Finally, environmental quality concerns related to wildlife habitat are represented in the model by the variable pc_wet. But, again, note that improvement in wildlife habitat may depend on improvements in soil and water quality.

For EI, e_h2o, e_air, nitfert, p_roff, p_lea, a_roff, and n_exp, the larger the value of the environmental variable, the worse the environmental quality. This is also the case for pc_wet, the variable representing wildlife habitat, but interpretation is less direct. The larger the value of pc_wet, the greater the loss of wetland acreage within the county, thus the worse the wildlife habitat. It is also important to note that pc_wet measures the historical change (usually a reduction) in wetland acreage, not the change in wetland acreage since inception of CRP.

Results

The "Factor" procedure in SAS was used to determine the degree of collinearity between the independent variables. Four environmental variables (all related to water quality)—nitrogen fertilizer loss (nitfert), pesticide runoff potential (p_roff), agricultural runoff (a_roff), and nitrogen exported (n_exp)—are highly correlated. Each of these variables concern releases of agricultural chemicals into the environment, specifically surface waters. To avoid issues associated with multicollinearity, especially within each cross section, the variable a_roff was selected to represent the group. Again, a_roff measures agricultural runoff from all sources (manure, fertilizer, pesticides, and so on); thus, it best represents the group of runoff-related environmental variables.

First-round OLS estimation using Equation (6) for each region was conducted to test for data issues including infinite error variance (IEV), heteroscedasticity (within the region), and autocorrelation (also within the region). Results indicate that the data from six regions (NGP, H, NC, MP, SS, and EU) suffers from IEV. However, because IEV is most problematic in small samples, this problem was ignored. First-order autocorrelation (FOA; within a region) was detected, and the data were corrected for this problem in all regions. Within the cross section, heteroscedasticity was detected and the data corrected for this problem in all regions:

$$
\begin{aligned}
(6)\quad \mathrm{CRP\_AC}_{ij} = {} & b_{j0} + b_{j1}\mathrm{ARR}_{ij} \\
& + b_{j2}\mathrm{CONTRACTS}_{ij} \\
& + b_{j3}\mathrm{TFA}_{ij} + b_{j4}\mathrm{TCA}_{ij} \\
& + b_{j5}\mathrm{CREP}_{ij} + b_{j6}\mathrm{NCREP}_{ij} \\
& + b_{j7}\mathrm{WETLANDS}_{ij} \\
& + b_{j8}\mathrm{PASTURE}_{ij} \\
& + b_{j9}\mathrm{TIMBER}_{ij} \\
& + b_{j10}\mathrm{EI}_{ij} + b_{j11}\mathrm{e\_h2o}_{ij} \\
& + b_{j12}\mathrm{e\_air}_{ij} + b_{j13}\mathrm{p\_lea}_{ij} \\
& + b_{j14}\mathrm{a\_roff}_{ij} \\
& + b_{j15}\mathrm{pc\_wet}_{ij},
\end{aligned}
$$

where i = 1 to R_j observations within a region, j = 1 to 9 regions, and variables are defined previously.

Results of the Lagrange multiplier test for groupwise heterogeneity (Equation [4]) indicated rejection of the null hypothesis that the disturbances across the regions are uncorrelated. Given estimation of Σ (Equation [3]) and appropriate data corrections for FOA and heteroscedasticity in each region, the parameters of this investigation are estimated using the model specified as Equation (7). Note that estimation of Equation (7) yields the same number of parameter estimates as in Equation (5):

$$(7) \qquad P_{ii}y\_var_i = \sum_{j=1}^{R} P_{ii} \begin{pmatrix} b_{j0} + b_{j1}ARR_i \\ + b_{j2}CONTRACTS_i \\ + b_{j3}TFA_i + b_{j4}TCA_i \\ + b_{j5}CREP_i \\ + b_{j6}NCREP_i \\ + b_{j7}WETLANDS_i \\ + b_{j8}PASTURE_i \\ + b_{j9}TIMBER_i \\ + b_{j10}EI_i \\ + b_{j11}e\_H2O_i \\ + b_{j12}e\_air_i \\ + b_{j13}p\_lea_i \\ + b_{j14}a\_roff_i \\ + b_{j15}pc\_wet_i \end{pmatrix} R_{ij}.$$

In Equation (7), the subscript i ranges from 1 to T = 2,544, the total number of observations (FIPS or counties). The variable R_{ij} is a dummy variable that retains the value of 1 if the ith observation resides in region j and is 0 otherwise. Use of R_{ij} generates the stacked X matrix illustrated in Equation (2). It is important that the i observations in Equation (7) be ordered by region. P_{ii} is the square root of the individual elements in Σ^{-1} (the inverse of Σ; Equation [3]). Using P_{ii}, the data are weighted to correct for groupwise heteroscedasticity.

Results from the estimation of Equation (7) (parameter estimates, standard errors, and probability values for the t-statistic) are reported by region in Tables 1 through 5. These tables also report variable means and standard deviations for all U.S. counties (Table 1) and for each FRR (Tables 2–5). Note that estimation results are not reported for NCREP and TIMBER in FRR 1 (Heartland; Table 1), for e_air in the FRR 5 (Eastern Uplands; Table 3), and for e_air in the FRR 9 (Mississippi Portal; Table 5) because of perfect collinearity or because the data are 0. The estimated model explains 81% of the variation in aggregate county CRP acreage. The independent variables of the model, as a group, contribute to our understanding of aggregate county CRP acreage with 95% confidence.

The independent variables ARR, CONTRACTS, TFA, and TCA were included to control for variation in aggregate county CRP acreage not explained by the environmental variables. When statistically different from 0, CONTRACTS, TFA, and TCA all have the anticipated sign (i.e., all are positive), meaning that an increase in one or more of these variables is associated with an increase in aggregate county CRP acreage. Recall, however, that the sign of the estimate for annual rental rate (ARR) could not be determined *a priori.* The results of this investigation indicate that, when statistically different from 0, the parameter estimate for ARR is negative. Thus, the higher the ARR, the less acreage was enrolled in the CRP.

A series of dichotomous (or dummy) variables were also included in the model to control for variation in the dependent variable due to type of acreage enrolled in CRP. The sign of the parameter estimates for these variables could not be determined *a priori.* Results indicate that the five enrollment types were not statistically different from 0 in the Heartland, Northern Great Plains, and Eastern Uplands farm resource regions (FRRs). Also, in none of the nine FRRs was the parameter estimate for non-CREP enrollment statistically different from 0.

The parameter estimate on the dichotomous variable CREP was statistically different from 0 in the Northern Crescent, Southern Seaboard, and Basin and Range FRRs. In the Northern Crescent and Southern Seaboard regions, increased enrollment in the CREP is associated with fewer enrollments in the CRP. In the Basin and Range, the opposite was true.

The CRP and CREP are similar programs but different in that the CREP is designed to offer greater enrollment incentives in areas of special ecological importance. Generally, acreage that qualifies for CREP qualifies for CRP, but the converse is not true. Nevertheless, qualified acreage in a county is fixed. Thus, it is not surprising that increased CREP enrollment is associated with lower CRP enrollment. Apparently, in the Basin and Range counties, there is sufficient qualified acreage such that enrollments in both programs have increased since 1986.

The parameter estimate for wetlands enrollment (WETLANDS) was statistically different in the Southern Seaboard, Fruitful Rim, and Mississippi Portal farm resource regions. In the Southern Seaboard and Mississippi Portal regions, wetlands enrollments were associated with higher acreage enrollment in CRP. In the Fruitful Rim FRR, the opposite is true.

Finally, timber enrollments were statistically different from 0 in the Prairie Gateway FRR and pasture enrollments were statistically different from 0 in the Fruitful Rim FRR. Timber enrollments are negatively correlated with aggregate county CRP enrollment, and pasture enrollments are positively correlated.

Again, the purpose of this study is to show that CRP enrollments are greatest in counties with poor environmental quality. Initially, nine environmental variables consistent with three defined CRP priority concerns (wildlife habitat, water quality, and soil) were included in the model. However, testing revealed that the four water quality variables nitfert, p_roff, a_roff, and n_exp were collinear. Further testing indicated that only a_roff should be included in the model, as it best represented the group. In this manner, the model was reduced to six total environmental variables, where EI, e_h2o, and e_air capture environmental quality concerns related to soil; p_lea and a_roff capture environmental quality concerns related to water quality; and pc_wet captures environmental quality concerns related to wildlife habitat. In all cases, the larger the value, the worse the environmental quality. Thus, the null hypothesis consistent with the purpose of this study is that an increase in aggregate county CRP acreage is associated with a one-unit increase in an environmental variable.

Only in the Basin and Range FRR did results indicate that aggregate county CRP enrollments are not related to any of the six environmental variables (see Tables 1–5). With respect to soil concerns, evidence in support of the null hypothesis was indicated if any one of the parameter estimates for EI, e_h2o, and e_air was statistically different from 0 and positive. This finding was true in all but the Eastern Uplands, Southern Seaboard, Basin and Range, and Mississippi Portal FRRs. In the Eastern Uplands and Southern Seaboard regions, the parameter estimates for EI were statistically different from 0, but they were negative. In the Basin and Range and Mississippi Portal region, none of the parameters related to soil were statistically different from 0.

In the regions where results were consistent with the null hypothesis, the parameter estimate for EI was positive and statistically different from 0 in the Northern Great Plains region. This result is interesting given the previously stated assertion that EI is used by NRCS to establish priority areas and payment levels. Parameter estimates for e_h20 are statistically different from 0 and positive in the Heartland, Northern Crescent, and Northern Great Plains. In the Prairie Gateway region, the parameter estimates for e_h20 are statistically different from 0 but positive. However, this result is offset by a positive result for e_air. Parameter estimates for e_h20 are statistically different from 0 and positive in the Heartland, Northern Crescent, and Northern Great Plains. In the Prairie Gateway region, the parameter estimates for e_h20 are statistically different from 0 but negative. However, in the Prairie Gateway region, the negative result associated with e_h2o is offset by a positive result for e_air (the Prairie Gateway region is the only region where the signs of statistically significant parameter estimates for the soil variables conflicted). Parameter estimates for e_air are statistically different from 0 and positive in the Heartland, Prairie Gateway, and Fruitful Rim regions. Finally, note that the parameter estimates for e_h2o and e_air are statistically different from 0 and positive in the Heartland and that the parameter estimates for EI and e_h2o are statistically different from 0 and positive in the Northern Great Plains.

Water quality was represented by the variables p_lea and a_roff. The parameter estimates for at least one of these variables were statistically different from 0 and positive in two of the nine FRRs (Heartland and Eastern Uplands). In no case were the parameter estimates for these two variables both statistically different from 0 and positive in the same region (which also implies that there was never a case where the signs of the parameter estimates disagreed). However, the parameter estimate for a_roff was statistically different from 0 and negative in the Northern Great Plains, and the same was true of the parameter estimate for p_lea in the Fruitful Rim.

Again, environmental quality concerns related to wildlife habitat were represented by the variable pc_wet. The parameter estimate for pc_wet is statistically different from 0 and positive in two of nine regions (Prairie Gateway and Southern Seaboard regions). In the Heartland, Northern Great Plains, and Mississippi Portal regions, pc_wet is statistically different from 0 but negative. It is also possible that wildlife habitat can be improved by increased enrollment in wetland, pasture, and timber acreage. This was the case in the Southern Seaboard (wetlands), Fruitful Rim (pasture), and Mississippi Portal (wetlands) regions. However, results suggest no relationship between aggregate county CRP enrollment and enrollment in wetland, pasture, and timber acreage in the majority of regions (Heartland, Northern Crescent, Northern Great Plains, Eastern Uplands, and Basin and Range), and in two regions the relationship is negative (timber in the Prairie Gateway and wetlands in the Fruitful Rim).

While some environmental variables are correlated with aggregate county CRP enrollment, the total effect might depend on the amount of acreage enrolled. Average aggregate county CRP acreage as a percent of average county acreage is ordered by FRR as follows: Eastern Uplands (0.3%), Northern Crescent (0.7%), Southern Seaboard (0.8%), Basin and Range (0.9%), Fruitful Rim (1.1%), Mississippi Portal (2.5%), Heartland (3.4%), Prairie Gateway (4.5%), and Northern Great Plains (5.0%). In terms of average aggregate county CRP acreage as a percent of average farm acreage, the FRR are ranked as follows: Eastern Uplands (0.8%), Basin and Range (2.5%), Northern Crescent (2.8%), Southern Seaboard (3.2%), Fruitful Rim (3.4%), Heartland (4.6%), Prairie Gateway (5.2%), Mississippi Portal (5.5%), and Northern Great Plains (5.9%).

Discussion and Conclusions

Since inception of the CRP program in 1985, $1.7 billion has been spent in farm payments alone. Given this substantial investment, it is reasonable to ask if the program has improved soil erosion, water quality, and wildlife habitat. The purpose of this study is to show that expenditures on the CRP program have aided the environment. This study makes no attempt to establish the extent of environmental improvement (e.g., in pounds per unit reduction) or the dollar value of improvements. This is left to further study.

While the environmental variables are the focus of the paper, some interesting results concerning the control variables were noted. The results of this investigation indicate that, when statistically different from 0, the parameter estimate for the average annual rental rate (ARR) is negative. This result suggests that in counties with higher productivity and thus higher per acre returns, the rental rate is not high enough to encourage enrollment in the CRP.

This study demonstrates that expenditures on the CRP program have aided the environment by demonstrating that CRP enrollments are greatest in counties with poorer environmental quality. Six environmental variables consistent with three defined CRP priority concerns (wildlife habitat, water quality, and soil) were included in the model. Variables related to general soil erosion (EI), soil erosion by water (e_h2o), and soil erosion by wind (e_air) capture environmental quality concerns related to soil. Variables related to pesticide leaching potential (p_lea) and general agricultural chemical runoff (a_roff) capture environmental quality concerns related to water quality. Finally, the percent change (usually a loss) in historic wetland acreage (pc_wet) was included to capture environmental quality concerns related to wildlife habitat. In all cases, the larger the value, the worse the environmental quality.

The null hypothesis consistent with the purpose of this study is that an increase in aggregate county CRP acreage is associated with a one-unit increase in an environmental variable (i.e., the parameter estimates for the environmental variables are positive). Parameter estimates were determined using an econometric model that corrects for issues related to the grouped, spatial nature of the data.

Only in the Basin and Range FRR did results indicate that aggregate county CRP enrollments are not related to any of the six environmental variables (see Tables 1–5). This surprising result suggests that CRP expenditures in the Basin and Range will have little impact on the environment. Note, however, that this result does not suggest that micro or local impacts will be of little importance.

In no case did all six environmental variables have a statistically significant, positive relationship with aggregate county CRP enrollment. In fact, there was never a case where at least one variable from each concern (soil, water quality, and wildlife habitat) was statistically significant and positive. Worse yet, in seven of nine regions the relationship between at least one of the environmental variables and aggregate county CRP enrollment was statistically different from 0 but negative (wetlands in the Heartland, agricultural runoff and wetlands in the Northern Great Plains, water erosion in the Prairie Gateway, erosion index in the Eastern Uplands, erosion index in the Southern Seaboard, pesticide leaching in the Fruitful Rim, and wetlands in the Mississippi Portal). Thus, the results are at best mixed and at worst opposite of expectations (see the Mississippi Portal, where all the environmental parameter estimates are insignificant or significant and negative).

Yet even if mixed, the results of this investigation indicate that in seven of nine regions, CRP expenditure are going to counties with at least one environmental concern. The results indicated the following priority concerns being addressed by region: soil erosion and water quality in the Heartland region, soil erosion in the Northern Crescent region, soil erosion in the Northern Great Plains, soil erosion by wind in the Prairie Gateway, water quality in the Eastern Uplands, wildlife habitat in the Southern Seaboard, and soil erosion by wind in the Fruitful Rim.

In conclusion, expenditures on the CRP program have aided or will aid the environment across much of the lower 48 U.S. states (in seven of nine regions). This is a positive finding that justifies past expenditures by the CRP and supports continued funding as an environmental improvement program. Some attention should be given by the administrators of the CRP as to why positive results were not noted in the Basin and Range and Mississippi Portal regions. Further investigation should reveal the extent of soil, water, and/or wildlife habitat improvement in the seven regions where expenditures were going to identified areas of concern. Once the extent of improvement has been documented, it will be possible to assess the economic value of the improvements and social value of the conservation reserve program.

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