# Assessing Cost-effectiveness of the Conservation Reserve Program and its Interaction with Crop Insurance Subsidies

Ruiqing Miao[a1], Hongli Feng[b], David A. Hennessy[b,c], and Xiaodong Du[d]

***Working Paper 14-WP 553***
November 2014

**Center for Agricultural and Rural Development**
**Iowa State University**
**Ames, Iowa 50011-1070**
***www.card.iastate.edu***



[a]Institute for Genomic Biology, University of Illinois at Urbana-Champaign, Urbana, IL 61801; [b]Department of Economics, Iowa State University, Ames, IA 50011; [c]Center for Agricultural and Rural Development, Iowa State University, Ames, IA 50011; [d]Department of Agricultural & Applied Economics, University of Wisconsin-Madison, Madison, WI 53706.

# Assessing Cost-effectiveness of the Conservation Reserve Program and its Interaction with Crop Insurance Subsidies

Ruiqing Miao

Hongli Feng

David A. Hennessy

Xiaodong Du

This draft: November 24, 2014

**Abstract:** Strong demand for agricultural commodities, high crop prices and pressure to reduce government budget deficits heighten the need for land retirement programs to be designed to maximize environmental benefits for any given budget outlay. The Conservation Reserve Program (CRP) is the largest land retirement program while the federal crop insurance program (FCIP) is the largest federal program supporting U.S. agriculture. We examine the environmental and budgetary implications of alternative CRP enrollment mechanisms in the context of the program's interactions with FCIP. We demonstrate that the current CRP enrollment mechanism is inconsistent with cost-effective targeting. We also identify a cost-effective targeting enrollment mechanism that maximizes total environmental benefits under a budget constraint. Since federal crop insurance subsidies will not be incurred when a tract of land is retired from agricultural production, we consider the impacts when avoided subsidies are accounted for in designing a land-retirement program. Based on contract-level CRP offer data in 2003 and 2011 across the contiguous United States, we find that adopting the cost-effective targeting enrollment mechanism can increase CRP acreage by up to 45% and total environmental benefits by up to 21% while leaving government outlay unchanged. Incorporating crop insurance subsidies into the land retirement design can increase avoided subsidies caused by CRP enrollment and environmental benefits obtained from CRP. The government can enroll significant acres at zero real cost. Under cost-effective targeting, CRP acreage and payments would increase in the Great Plains and the Southeastern states but would decrease in the Midwest.

**Significance:** The Conservation Reserve Program (CRP) is the largest land retirement program supported by the United States federal government, with 26 million acres enrolled as of May 2014 and an annual program outlay of about $2 billion. We show that the program's current land enrollment mechanism is not cost-effective. We identify an alternative enrollment mechanism that can increase CRP enrollment by up to 45% and environmental benefits by up to 21% for the same government outlay. We also show that a CRP land enrollment mechanism that accounts for interactions between the CRP and the federal crop insurance program, the largest program supporting U.S. agriculture, will reduce CRP outlays while improving environmental benefits.

**Keywords**: Conservation Reserve Program, Cost-effectiveness, Crop Insurance, Environmental Benefit Index

**Assessing Cost-effectiveness of the Conservation Reserve Program and Its Interaction with Crop Insurance Subsidies**

Conservation effectiveness when facing resource constraints is a central theme in the ecological conservation literature. Cost-benefit analysis has been advocated as a basic tool to enhance conservation effectiveness (1–3). This paper focuses on the Conservation Reserve Program (CRP), the largest land retirement program supported by the United States federal government, and shows that CRP's effectiveness can be significantly enhanced by appropriate use of cost-benefit targeting and by accounting for interactions between CRP and federal crop insurance program (FCIP), the largest U.S. agricultural commodity subsidy program.

CRP has about 26 million acres enrolled as of May 2014 at a program outlay of nearly $2 billion annually. It is a voluntary program that pays farmers to retire environmentally sensitive land from active production and plant it with grasses or trees for a contract period of 10–15 years (4, 5). Most CRP land is enrolled through a competitive bidding process during general signup periods—designated periods of a few weeks during which farmers are invited to submit applications to enroll their cropland. The program was first authorized in 1985 and by 1990 the enrollment reached 33.9 million acres, which accounted for about 8% of the country's total cropland. Enrollment in CRP ranged from 30 to 37 million acres between 1990 and 2011, but has declined to about 26 million acres in 2014. CRP is generally considered to be successful in providing multiple environmental benefits including soil, water, wildlife, and other natural resources (6-8).

Currently the CRP is faced with serious challenges. With strong demand for agricultural commodities and high crop prices, as well as pressure to reduce the federal budget deficit, the Agricultural Act of 2014 will gradually reduce the maximum amount of land that can be kept in CRP from the current 32 million acres to 24 million acres by 2018. High crop prices also mean that farmers will require higher rental payments to enroll their land into CRP, which will result in higher program outlays and hence dull the program's political appeal (9). These new challenges heighten the need for a CRP enrollment mechanism designed to achieve maximum environmental benefit for any given federal government budget outlay.

In this paper, we examine the environmental and budgetary implications of CRP enrollment in the context of the program's interactions with FCIP, as well as how these implications vary with different enrollment policy designs. FCIP insures more than 250 million acres of land with an annual average liability worth about $117 billion in 2011–2013 (10). It supports farmers mostly through premium subsidies, which have averaged about 60% of total premiums paid in recent years. FCIP is predicted to cost about $8.9 billion per year over 2013–2022, making it the most expensive agricultural commodity program (11). Large literatures have examined the efficiency of the CRP and FCIP separately. Specifically, efficiency studies on CRP have emphasized indirect effects while efficiency studies on FCIP have addressed participation and adverse selection issues (12–14). However, interactions between FCIP and CRP have received little attention.

CRP and FCIP can interact. CRP is targeted at removing cropland from production if the land performs sufficiently well according to the program's Environmental Benefits Index (EBI). Factors entering the EBI include wildlife impacts, water quality, air quality, erosion propensity, and carbon sequestration potential. Enrollment cost factors are also included where, ceteris paribus, land that commands higher rental payment will perform worse on the index and so is less likely to be accepted for enrollment. Omitted from the index, however, is the crop insurance subsidy reduction that would occur were the land removed from production. To underscore the omission's significance, in some regions average crop insurance premium subsidies are comparable to average CRP rents and cash rents. For North Dakota, Table 1 indicates that some land could be taken out of production at no budgetary cost to the government. That is, when crop insurance subsidies on a land tract are as large as its CRP rent the saved crop insurance subsidies through enrolling the land into CRP can completely offset its CRP payment. Although program fund sources differ, federal taxes spent and saved have equal weight when calculating the budget deficit. Moreover, were avoided crop insurance costs included in the index, then incentives for optimal land allocation would be strengthened because the inclusion would mitigate potential dissonance across the suite of agro-environmental policies.

In this study, we show first that the current EBI is not cost-effective and is a form of maximizing net benefit per acre targeting where benefits measured in index points are assumed to be commensurable with land rental rates. By contrast, a cost-effective enrollment criterion requires cost-benefit ratio targeting so that environmental benefit per dollar spent is maximized. Cost-benefit ratio targeting is widely used for analysis of programs and regulations (1, 3, 15). We identify a cost-effective EBI and examine how crop insurance savings can be included in the current EBI and also in this cost-effective EBI. We then compare empirically the environmental and budgetary consequences of four alternative EBI design scenarios by using contract-level CRP offer data for the contiguous United States obtained from the Farm Service Agency (FSA) of the U.S. Department of Agriculture (USDA). These four scenarios are: (*i*) the Baseline scenario under which EBI is kept at the status quo; (*ii*) Scenario 1, under which EBI in the Baseline is modified to include crop insurance subsidies; (*iii*) Scenario 2, under which cost-effective EBI is employed without including crop insurance subsidies; and (*iv*) Scenario 3, under which cost-effective EBI is employed and crop insurance subsidies are included. To facilitate exposition, we specify four comparisons. Comparisons I through III compare Scenarios 1 through 3 with Baseline, respectively; Comparison IV compares Scenarios 2 and 3.

## Results

Our analysis is based on actual enrollment data from Signups 26 and 41, two general signups that were conducted in 2003 and 2011, respectively. We select these two signups because crop prices, and hence crop insurance subsidies, were much higher in 2011 than in 2003. The large differences between insurance subsidies in these two years provide an opportunity to see the impacts of incorporating crop insurance subsidies over a wide range of values. In Table 2, we present summary simulation results where Baseline and Scenario 1 are constrained by the actual enrollment acreage that occurred under the two signups (2 million acres for Signup 26 and 2.8 million acres for Signup 41), while Scenarios 2 and 3 are constrained by the actual level of CRP real payment (defined as CRP rental payment minus saved crop insurance subsidies by CRP enrollment) that occurred under the two signups (i.e., $95.6 million for Signup 26 and $50.2 million for Signup 41). When comparing the scenario outcomes we focus on the following: (*a*) CRP enrollment acreage, program payment, and avoided crop insurance subsidies; (*b*) environmental benefits from CRP that are measured by environmental components of EBI (i.e., physical environmental benefits, labeled as EEBI); and, (*c*) geographic patterns in CRP enrollment changes under different designs.

**CRP enrollment acreage, program payment, and avoided insurance subsidies.** Comparison II shows that when switching to the cost-effective targeting EBI design, enrolled acreage will increase significantly (42.3% and 26.6% for Signups 26 and 41, respectively) while keeping CRP real payments equal to that under Baseline. This shows the efficiency loss from using the current EBI, which is consistent with maximizing environmental benefits per acre instead of maximizing environmental benefits per dollar spent. Notice that the percentage change in acreage enrollment under Signup 26 is larger than that under Signup 41 (see Comparisons II and III in Table 2). An explanation is that the comparison outcomes depend on acceptance rate (i.e., acreage accepted over acreage offered) for CRP offers. Under the Baseline the acreage acceptance rates in Signups 26 and 41 are 48% and 75%, respectively (Table S1 in Supporting Information (SI)). A smaller acceptance rate in Signup 26 indicates a more competitive selection and so a larger space for acreage increase starting from the Baseline. As an extreme example, if all CRP offers are accepted under each of the four scenarios then scenario outcomes will not differ. Figure S1 in SI depicts the difference between the four scenarios when CRP real payment varies. Given the large magnitude of insurance subsidy in 2011 (see Table S1 in SI), it is not surprising that about 50% of the CRP acreage can be enrolled at zero real payment.

For Signup 41, when crop insurance subsidies are included in the current EBI design (i.e., Scenario 1), the total annual CRP real payment is about 8.1% less than that under Baseline while leaving CRP enrolled acreage the same. For Signup 26, including crop insurance subsidies in the current EBI design can reduce CRP real payment by 1%. The reduction in real CRP payment is much larger under Signup 41 than that under Signup 26 because subsidy per acre in 2011 (year of Signup 41) was almost quadruple that in 2003 (year of Signup 26) (see Table S1in SI).

Adopting cost-effective targeting EBI and incorporating insurance subsidies into EBI design have significant impacts on avoided subsidies. Under the Baseline for Signup 26, the total avoided crop insurance subsidies equaled about $16.9 million, which amounted to about 15% of total nominal CRP payment (i.e., CRP rental rents) for enrolled acres. If cost-effective targeting is applied then the avoided subsidies would increase by 41.1% when compared with Baseline (see Comparison II in Table 2). When insurance subsidies are incorporated into cost-effective targeting EBI design, then the avoided subsidies would increase by 47.3% for Signup 26 (see Comparison III in Table 3). Under the Baseline for Signup 41, the saved crop insurance subsidies are about 63% of nominal CRP payments whereas under Scenario 3 the percentage becomes 68%. The crop insurance savings are much larger under Signup 41 than those under Signup 26 because, as mentioned above, subsidy per acre in 2011 was much larger.

**Environmental benefits from CRP.** Larger environmental benefits from CRP, as measured by total EEBI, are achieved with cost-effective targeting EBI than the current EBI. For example, Comparison II shows that total EEBI of enrolled acres increases by 20.5% and 15.3% in Signup 26 and Signup 41, respectively. The increased total EEBI is largely from the increased enrolled acres under Scenario 2. Since enrolled acres increase more under Signup 26 than under Signup 41 (i.e., 42.3% versus 26.6%), the total EEBI increase under Signup 26 is larger than that under Signup 41. For the same reason, the EEBI per enrolled acre decreases under Scenario 2 when compared with the Baseline scenario, and the decrease is larger under Signup 26 than under Signup 41 (-15.3% versus -9%).

Table 2 also shows that incorporating crop insurance subsidies into the current EBI design will increase total EEBI of enrolled acres, average EEBI per enrolled acre, and average EEBI per dollar of CRP real payment (see Comparison I in Table 2). For Signup 26, the increases are small. For Signup 41, since an 8% decrease in CRP real payment occurs under Comparison I, we see a relative larger increase in EEBI per real payment dollar under Comparison I, namely 11.2%. The reason for the relatively small impacts when incorporating crop insurance subsidies into the current EBI is that the cost component has significantly fewer points available than the environmental component. For both Signups 26 and 41, maximum points available for the cost component are 150, whereas maximum points available for the environmental component are 395. Incorporating crop insurance subsidies by subtracting these subsidies from the rental rate only changes the cost component. When crop insurance subsidies are relatively low, as in 2003, they are a small fraction of the rental rate and so incorporating subsidies had little impacts.

**Geographic patterns in CRP enrollment changes.** When compared with Baseline scenario, Scenarios 1–3 result in noticeable geographical patterns for the changes in CRP enrollment (see Figures 1 and 2). The Great Plains and Southeastern United States would gain CRP acreage and payments while the Midwest will see reductions. Accordingly, the Midwest would gain more commodity revenues and crop insurance subsidies under Scenarios 1–3 than under Baseline. These regional differences in CRP enrollment are important because of implications for welfare distribution and regional politics, and also because spatially distinct environmental and natural resources are concerned.

Table 2 also presents the amount of acres that change status. That is, these acres either changed from being accepted to being rejected or vice versa. The largest differences are observed under Comparison III, under which a total of 46.8% and 24.5% of total offered acres would change enrollment status in Signups 26 and 41, respectively. Figures 1 and 2 shows changes in CRP acres under Comparisons I, III, and IV for Signups 26 and 41, respectively. The patterns of CRP acreage changes are similar. CRP enrollment will increase in areas with high subsidy-rent ratios, such as the Great Plains and Southeastern States. These are in the main marginal cropland regions where CRP enrollment costs are low and environmental benefits may be high. What makes these locations marginal for cropping and environmentally sensitive often also makes them poor crop insurance prospects, which indicates high insurance premiums and subsidies.

By contrast, under Scenarios 1–3, the Midwest would lose CRP acreage relative to the Baseline because cropland in this region requires higher CRP rental rates and receives lower crop insurance subsidies when compared with cropland elsewhere. For example, in Iowa the CRP rent and subsidies in 2011 are $128.1/acre and $32.4/acre, respectively, whereas in North Dakota these two numbers are $36.2/acre and $55.3/acre, respectively (Table 1). Notice that the CRP acreage change across regions is not significant in Comparison I because the total enrolled CRP acreage in Scenario 1 and Baseline is the same. However, large differences exist between cost effective targeting EBI and current EBI as shown by Comparison III (Figures 1 and 2).

Cost effective targeting would overwhelmingly favor low rent regions whether or not crop insurance subsidies are incorporated. Our analysis suggests that the central Corn Belt will have an even lower enrollment rate if cost effective targeting is used. Furthermore, the region along southern Iowa and northern Missouri will be less competitive compared to other regions based on EEBI points and rental cost information submitted in Signups 26 and 41. This may raise concerns that CRP enrollment under the cost-effective targeting criterion would de-emphasize productive regions with erodible land (e.g., southern Iowa and northern Missouri).

**Discussion**

Strong demand for food and biofuels in recent years has increased the pressure to draw more land into agricultural production. On the other hand, both CRP and crop insurance programs are receiving intensive scrutiny as legislators seek to tighten federal budget outlays. The intent of this article is to promote a better understanding of how EBI design affects the cost-effectiveness of CRP and interactions between CRP and the federal crop insurance subsidy program with a focus on the budgetary and environmental impacts. Given that the Agricultural Act of 2014 will gradually reduce total acreage enrolled in the CRP, it is likely that competition to enroll in the program will strengthen so long as CRP rental payments are not too low compared to cash rental rates. The enrollment mechanism used will likely play a more important role in future signups in order to ensure program cost-effectiveness. We show that there is significant potential to improve upon the CRP's enrollment mechanism and that large regional redistribution of enrolled CRP acres would result. We also illustrate how avoided crop insurance subsidy costs can be calculated for entry as a cost consideration in an environmental benefit index. The potential benefits of doing so are two-fold: to assist in managing total program tax dollar cost and to better screen land into its most efficient use. Based on CRP enrollment data from Signups 26 and 41, as well as crop insurance subsidy data in corresponding years, we simulate the impacts of including avoided crop insurance subsidies into EBI calculations under different EBI designs.

It is important to note that our results are based on the current environmental benefit scores for various factors. If the central Corn Belt provides benefits that are not captured in the current calculation, then integrating these benefits into EEBI would increase this region's competitiveness in CRP enrollment. One caveat is that the government also subsidizes crop insurance by paying the administration and operating (A&O) costs, which amounted to $1.4 billion in 2012, compared to $7.1 billion in premium subsidies (16). If enrolling land in CRP reduces some of these A&O costs, our results would underestimate the budgetary impacts of incorporating crop insurance subsidies into the CRP enrollment formula.

**Methods**

**Conceptual Framework**. In this section, we model CRP's enrollment mechanism. Most CRP land is enrolled through a competitive bidding process during general signup periods. FSA assign an EBI to each offer based on the offer's environmental benefits and rental payment requested by the landowner. Then all offers are ranked according to EBI and offers with EBI no less than the cut-off EBI will be enrolled into CRP. Let EEBI denote environmental benefits of an offer and $r_k$ denote the rent per acre requested in an offer for land tract *k*. The formulation of EBI under the current CRP is as follows:

$$\text{EBI} = \text{EEBI} + f(r_k) + \text{extra bonus points}, \quad [1]$$

where $f(r_k)$ is a function of the requested rental rate; and the extra bonus points are a relatively small number reflecting whether the offer requests cost share or how much the requested rental rate is below the weighted average soil rental rate (WASRR) of the offered land. Under current CRP administration, $f(r_k)$ is set to be

$$f(r_k) = a \times \left(1 - \frac{r_k}{b}\right), \qquad [2]$$

where parameters $a$ and $b$ are program administrator determined. Table S2 in SI presents values of these two parameters, the maximum possible points for the cost components, EEBI, EBI, and the cut-off EBI points for acceptance in some signups over 1997–2011.

A notable feature of the EBI in equations [1] and [2] is that it is a linear combination of costs and environmental benefits. We refer this form of benefit targeting as “pseudo cost-effective targeting.” The term “pseudo” is used here to emphasize that benefits and costs are not necessarily measured in a common unit and the EBI is not necessarily a true measure of net benefits. Before demonstrating that “pseudo cost-effective targeting” is consistent with an optimization problem to be described below, we first introduce some notation. Define by $k \in \Omega \equiv \{1, 2, \ldots, K\}$ the *k*th parcel of land. Let $a_k$ denote the size of parcel *k*. The set of all subsets of $\Omega$ is written as $\mathscr{P}(\Omega)$. Environmental benefits arising from land retirement amount to $e_k$ per acre for parcel *k*. Therefore, if set $\boldsymbol{\hbar} \subseteq \mathscr{P}(\Omega)$ is placed in CRP then net environmental benefits amount to $\sum_{k \in \boldsymbol{\hbar}} e_k a_k$. Then the optimization problem that induces “pseudo cost-effective targeting” can be written as:

**Optimization Problem 1** (OP1, pseudo cost-effective targeting**)**: maximize environmental benefits with a linear adjustment of costs, subject to an acreage constraint. That is,

$$\begin{aligned} &\max_{\boldsymbol{\hbar} \subseteq \mathscr{P}(\Omega)} \sum_{k \in \boldsymbol{\hbar}} a_k \times \left[e_k + f(r_k)\right], \\ &\text{s.t.} \qquad \sum_{k \in \boldsymbol{\hbar}} a_k \le \bar{A}, \end{aligned} \qquad [3]$$

where $\bar{A}$ denotes the cap for total acreage enrollment. Let $\lambda_1$ denote the Lagrange multiplier representing the shadow value of acreage. Then the enrollment criterion for the *k*th parcel is

$$\begin{cases} \text{enroll if} & e_k + f(r_k) \geq \lambda_1; \\ \text{do not enroll if} & e_k + f(r_k) < \lambda_1. \end{cases} \quad [4]$$

Comparing [4] with [1] and [2], we find that $e_k + f(r_k)$ is the same as the EBI (except for the minor extra bonus points) if we treat EEBI as $e_k$.

OP1 assumes that benefits $e_k$ and the transformation of rental rate, $f(r_k)$, are measured on comparable units such that summing the two terms is a meaningful operation. However, in the case of the current CRP, $e_k$ is represented by EEBI, an index based on points assigned to physical environmental benefits, and $f(r_k)$ is a linear transformation of rental rate. Thus, in general, $e_k$ and $f(r_k)$ will not be measured in a common unit.

In contrast with OP1, a standard optimization problem that is associated with maximizing environmental benefits for a given monetary budget can be formulated as follows:

**Optimization Problem 2** (OP2, cost effective targeting**)**: maximize environmental benefits subject to a budget constraint:

$$\begin{aligned} &\max_{\mathscr{k} \subseteq \mathscr{P}(\Omega)} \sum_{k \in \mathscr{k}} a_k e_k, \\ &\text{s.t.} \quad \sum_{k \in \mathscr{k}} a_k r_k \leq \bar{M}, \end{aligned} \quad [5]$$

where $\bar{M}$ denotes the CRP budget constraint. With $\lambda_2$ denoting the Lagrange multiplier for the shadow value of budget, the enrollment criterion for the *k*th parcel is

$$\begin{cases} \text{enroll if} & e_k / r_k \geq \lambda_2; \\ \text{do not enroll if} & e_k / r_k < \lambda_2. \end{cases} \quad [6]$$

In [6] the criterion is the ratio of benefit over cost. For any given budget, enrollment based on [6] will maximize benefits achievable. Equivalently, for any given amount of benefits achieved, the required cost will be minimized. So we refer to selection based on this criterion as "cost effective targeting." In contrast with the criterion in [4], that in [6] does not require $e_k$ and $r_k$ to be measured in a common unit, and should be a meaningful measure to use when comparing the cost effectiveness of the parcels in providing environmental benefits. OP2 is also commonly used in economic analyses with direct policy implications (17, 18). To our knowledge, no study has considered the nature of pseudo cost-effective targeting embedded in the current CRP enrollment procedure.

Now we study how saved crop insurance subsidy can be incorporated into the EBI. Let $s_k$ be the dollar amount of premium subsidies per acre for land parcel *k*. If we value a dollar that would have been paid in premium subsidies the same as a dollar spent on CRP rental payments, then we can subtract $s_k$ from $r_k$ when making enrollment decisions. Thus, if crop insurance subsidies are to be taken into account, then equations [3] and [4] of OP1 would be adjusted as follows.

**Optimization Problem 1′** (OP1′, adjusted pseudo cost-effective targeting**)**: maximize environmental benefits with a linear adjustment of costs and crop insurance subsidies, subject to an acreage constraint. That is,

$$\begin{aligned} &\max_{\mathcal{h}\subseteq\mathcal{P}(\Omega)} \textstyle\sum_{k\in\mathcal{h}} a_k \times [e_k + f(r_k - s_k)], \\ &\text{s.t.} \quad \textstyle\sum_{k\in\mathcal{h}} a_k \le \bar{A}'. \end{aligned} \qquad [7]$$

Then the adjusted enrollment criterion is

$$\begin{cases} \text{enroll if} & e_k + f(r_k - s_k) \ge \lambda_1'; \\ \text{do not enroll if} & e_k + f(r_k - s_k) < \lambda', \end{cases} \qquad [8]$$

where $\lambda_1'$ is the Lagrange multiplier representing acreage shadow value. Including $s_k$ will not change the program’s acreage constraint (i.e., $\bar{A} = \bar{A}'$ ), but will change the CRP enrollment criterion. What may also change is the budget required to pay for enrolled acres. Integrating crop insurance subsidies will also change equations [5] and [6] of OP2 as follows.

**Optimization Problem 2′** (OP2′, adjusted cost effective targeting**)**: maximize environmental benefits subject to a budget constraint, when rental cost is offset by crop insurance subsidies:

$$\max_{\hbar \subseteq \mathcal{P}(\Omega)} \sum_{k \in \hbar} a_k e_k, \quad \text{s.t.} \quad \sum_{k \in \hbar} a_k (r_k - s_k) \le \bar{M}', \qquad [9]$$

where $\bar{M}'$ is the government's real CRP payment. The adjusted enrollment criterion is

$$\begin{cases} \text{enroll if} & e_k / (r_k - s_k) \ge \lambda_2'; \\ \text{do not enroll if} & e_k / (r_k - s_k) < \lambda_2'. \end{cases} \qquad [10]$$

where $\lambda_2'$ is the Lagrange multiplier for the shadow value of budget. All else equal, inclusion of $s_k$ in OP1′ and OP2′ will render a parcel with larger insurance subsidy per acre more competitive for CRP acceptance because its "net cost" is smaller. However, how the inclusion of $s_k$ will affect the order of CRP offers based on adjusted EBI depends on the function $f(\cdot)$ and the relationship among $r_k$, $s_k$, and $e_k$. In an extreme case, if $f(r_k - s_k) - f(r_k)$ is a constant for all $k$, then inclusion of $s_k$ in OP1′ has no effect on CRP enrollment. Similarly, if $s_k$ is a constant proportion of $r_k$ for all $k$, then each parcel's relative competitiveness based on [10] will be the same as that based on [6].

**Data and Simulation Approach**. We obtained information on each CRP offer for Signups 26 and 41 from FSA for the contiguous United States. The signup data include variables such as EBI for each land tract offered to CRP, rental rate offered by land owners, and whether an offer was accepted. Since the CRP offer dataset does not include crop insurance information, a matching mechanism is developed to map insurance subsidies to each CRP offer. County-level insurance subsidies for the contiguous United States in 2003 and 2011 were obtained from the USDA's Risk Management Agency (http://www.rma.usda.gov/data/sob.html). This dataset includes information on each insured crop such as insurance type, coverage level, insured acres, total premiums, and total subsidies. We first remove crops that are ineligible for CRP enrollment and then take the weighted average (using net insured acres as weights) of total subsidies to obtain each county's average subsidy per acre. Table S1 in SI presents summary statistics for the CRP and crop insurance data.

We employ a simple polynomial curve fitting to map the county-level insurance subsidies to each CRP offer. To capture heterogeneous relationships between CRP rent and crop insurance subsidy across states, we fit a polynomial curve state by state. For each state in the dataset, we first regress county-level crop insurance subsidy on county-level WASRR using data available in a specific state. New Mexico data are pooled with Texas data while Wyoming data are pooled with Nebraska data because New Mexico and Wyoming have few counties enrolled in CRP. Here we use WASRR instead of CRP rental payment because WASRR is a better measure of land productivity and hence a better measure of the land's insurance prospects. Suppose we estimate

$$\ln(S^{ij}) = \sum_{n=0}^{N} \hat{\beta}_n^j [\ln(R^{ij})]^n, \qquad [11]$$

where $S^{ij}$ and $R^{ij}$ are county-level insurance subsidy and county-level WASRR in county *i* of state *j*, respectively; and $\hat{\beta}_n^j$, $n \in \{0, ..., N\}$, is the estimated coefficients for state *j*. In this study we set $N = 4$. Setting $N = 3$ or $N = 5$ only yields a negligible difference in terms of predicted insurance subsidies. Upon obtaining [11] for each CRP offer we then insert its WASRR into equation [11] and estimate the offer's projected insurance subsidy. In order to avoid negative insurance subsidy predictions for a CRP offer, we utilize the natural logarithm transformation of the dependent variables and independent variables in equation [11]. This matching approach is similar to that used in (19) to obtain daily weather data from monthly weather information. To test for matching approach robustness, we also performed an alternative matching approach in which unit-level, instead of county-level, insurance subsidy information obtained from RMA are used. We show in SI that insurance subsidy predictions and simulation results from these two different approaches are close.

In line with the four optimization problems discussed in the conceptual framework section, we differentiate four scenarios in the simulation. We calculate the EBI under each scenario based on each problem's enrollment criteria, that is,

$$\begin{aligned}
&\text{Baseline (OP1)}: && \text{EBI}_0 = \text{EEBI} + a \times \left(1 - \frac{r_k}{b}\right) + c, \\
&\text{Scenario 1 (OP1}'\text{)}: && \text{EBI}_1 = \text{EEBI} + a \times \left[1 - \frac{(r_k - s_k)}{b}\right] + c, \\
&\text{Scenario 2 (OP2)}: && \text{EBI}_2 = \frac{\text{EEBI} + c}{r_k}, \\
&\text{Scenario 3 (OP2}'\text{)}: && \text{EBI}_3 = \frac{\text{EEBI} + c}{r_k - s_k},
\end{aligned} \tag{12}$$

where $a$ and $b$ are cost parameters as in equation [2]; and $c$ represents extra bonus points.

Once we have calculated EBI points for each scenario, the offered CRP parcels can be enrolled into CRP in descending order by each parcel's EBI until the acreage or budget constraint is reached. For Baseline and Scenario 1, the acreage constraint for Signup 26 (respectively, 41) is the actual acreage enrolled under Signup 26 (respectively, 41). For Scenarios 2 and 3, the budget constraint for a signup is the actual payment that occurred under the signup. In the simulation, we do not constrain CRP enrollment in a county to be no more than 25% of cropland, a constraint that is imposed by FSA. This constraint is omitted from our simulation because we only focus on two signups and CRP offers in these two signups are only a small fraction of CRP acreage stock. We are interested in the environmental benefits, acreage, payments, and saved crop insurance subsidies obtained from CRP under each scenario. Specifically, when $\boldsymbol{\hbar}^* \subseteq \mathcal{P}(\Omega)$ is the selected set of parcels under a scenario then total environmental benefits are $\sum_{k \in \boldsymbol{\hbar}^*} a_k e_k$ , total acres enrolled are $\sum_{k \in \boldsymbol{\hbar}^*} a_k$, total savings of insurance subsidies are $\sum_{k \in \boldsymbol{\hbar}^*} a_k s_k$ , total CRP nominal payment is $\sum_{k \in \boldsymbol{\hbar}^*} a_k r_k$, and total CRP real payment is $\sum_{k \in \boldsymbol{\hbar}^*} a_k (r_k - s_k)$. That is, we refer to real payment as the different between total CRP nominal payments and total avoided crop insurance subsidies.

**Acknowledgements.** This research was partially supported by Ducks Unlimited.

## References


1. Ando, A.W. and M.L. Mallory. 2012. "Optimal Portfolio Design to Reduce Climate-Related Conservation Uncertainty in the Prairie Pothole Region." *Proc Natl Acad Sci USA* 109(17): 6484-6489.
2. Murdoch, W., J. Ranganathan, S. Polasky, and J. Regetz. 2010. "Using Return on Investment to Maximize Conservation Effectiveness in Argentine Grasslands." *Proc Natl Acad Sci USA* 107(49): 20855-20862.
3. Arrow, K.J., M.L. Cropper, G.C. Eads, R.W. Hahn, L.B. Lave, R.G. Noll, P.R. Portney, M. Russell, R. Schmalensee, V.K. Smith, R.N. Stavins. 1996. "Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?" *Science*. 272(5259): 221-222.
4. Farm Service Agency at United States Department of Agriculture. (2014) Monthly Active CRP Contract Reports, May 2014. Available at https://arcticocean.sc.egov.usda.gov/CRPReport/monthly_report.do?method=displayReport&report=May-2014-ActiveContractsSummaryByProgramYearNational-00. Accessed August 16, 2014.
5. Stubbs, M. 2013. "Conservation Reserve Program (CRP): Status and Issues." Congressional Research Service Report for Congress, NO. R42783, March 18.
6. Feather, P., D. Hellerstein, and L. Hansen. 1999. "Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP." Agricultural Economic Report No. 778, Economic Research Service, U.S. Department of Agriculture, Washington, DC, April.

7. Food and Agricultural Policy Research Institute at University of Missouri-Columbia (FAPRI-UMC). 2007. "Estimating Water Quality, Air Quality, and Soil Carbon Benefits of the Conservation Reserve Program." Report #01-07.
8. Wu, J. and B. Weber. 2012. "Implications of a Reduced Conservation Reserve Program." The Council on Food, Agriculture & Resource Economics, July. Available at http://issuu.com/c-fare/docs/implicationsofareducedconservationreserveprogram. Accessed on August 16, 2014.
9. Hellerstein D. and S. Malcolm. 2011. "The Influence of Rising Commodity Prices on the Conservation Reserve Program." USDA, ERS, Economic Research Report number 110, February.
10. Risk Management Agency of United States Department of Agriculture. 2014. Summary of Business Reports and Data. Available at http://www3.rma.usda.gov/apps/sob/current_week/sobrpt2011-2014.pdf. Accessed on August 16, 2014.
11. United States Government Accountability Office. 2012. Crop Insurance: Savings Would Result from Program Changes and Greater Use of Data Mining. March, GAO-12-256. Available at http://www.gao.gov/assets/590/589305.pdf. Accessed on August 16, 2014.
12. Jacobson, S. 2014. "Temporal Spillovers in Land Conservation." *Journal of Economic Behavior & Organization*. In press. DOI: 10.1016/j.jebo.2014.04.013.
13. Wu, J. 2000. "Slippage Effects of the Conservation Reserve Program." *American Journal of Agricultural Economics*, 82(4): 979–992.
14. Glauber, J.W. 2013. "The Growth Of The Federal Crop Insurance Program, 1990–2011." *American Journal of Agricultural Economics*, 95(2): 482–488.
15. Mishan, E.J. and E. Quah. 2007. *Cost-Benefit Analysis* (5th edition). Routledge, New York, NY.

16. Shields, D. 2013. “Federal Crop Insurance : Background.” CRS Report for Congress, Congressional Research Service, 7-5700, R40532. Washington, DC.
17. Babcock, B.A., P.G. Lakshminarayan, J. Wu, and D. Zilberman. 1996. “The Economics of a Public Fund for Environmental Amenities: A Study of CRP Contracts.” *American Journal of Agricultural Economics* 78(4):961–971.
18. Feng, H., L.A. Kurkalova, C.L. Kling, and P.W. Gassman. 2006. “Environmental Conservation in Agriculture: Land Retirement vs. Changing Practices on Working Land.” *Journal of Environmental Economics and Management* 52(2):600–614.
19. Schlenker, W. and M.J. Roberts. 2009. “Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields under Climate Change.” *Proc Natl Acad Sci USA* 106(37): 15594-15598.

**Table 1. Average Crop Insurance Premium for Corn, Premium Subsidy for Corn, CRP Rental Rate, and Cropland Cash Rental Rate in North Dakota and Iowa** (unit: $/acre)

| | North Dakota | | | | Iowa | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Premium | Premium Subsidy | CRP Rent | Cash Rent | Premium | Premium Subsidy | CRP Rent | Cash Rent |
| 2002 | 18.7 | 11.0 | 33.1 | 36.5 | 14.9 | 8.0 | 100.8 | 120 |
| 2003 | 22.8 | 13.3 | 33.1 | 36.5 | 16.2 | 8.7 | 101.9 | 122 |
| 2004 | 28.7 | 16.7 | 33.0 | 37.5 | 20.8 | 11.3 | 103.4 | 126 |
| 2005 | 30.8 | 17.9 | 33.1 | 39.0 | 17.2 | 9.4 | 104.3 | 131 |
| 2006 | 55.6 | 32.3 | 33.1 | 39.0 | 20.8 | 11.2 | 105.3 | 133 |
| 2007 | 55.6 | 32.3 | 33.2 | 41.0 | 36.7 | 19.7 | 106.2 | 150 |
| 2008 | 78.5 | 45.9 | 33.7 | 42.5 | 49.0 | 26.4 | 110.9 | 170 |
| 2009 | 66.6 | 43.6 | 34.0 | 45.5 | 42.3 | 24.3 | 115.8 | 175 |
| 2010 | 56.4 | 37.5 | 34.9 | 46.5 | 33.4 | 19.5 | 120.1 | 176 |
| 2011 | 82.6 | 55.3 | 36.2 | 51.5 | 56.6 | 32.4 | 128.1 | 196 |
| 2012 | 76.5 | 52.8 | 37.6 | 58.0 | 48.7 | 28.2 | 131.6 | 235 |

Data source: All data are obtained from public datasets of USDA agencies. Premium and subsidy data are from RMA, CRP rent from FSA, and cash rent from NASS.

**Table 2. Pairwise Comparisons Between the Scenarios Regarding Budgetary and Environmental Outcomes of CRP**

| | | Comp. I | Comp. II | Comp. III | Comp. IV | |
|---|---|---|---|---|---|---|
| | | Percentage change from Baseline (%) | | | | |
| | Baseline Absolute values | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 2 Absolute values | Scenario 3: percentage change from Scenario 2 (%) |
| **Signup 26** | | | | | | |
| Total acres enrolled (million acres) | 2.0 | - | 42.3 | 45.4 | 2.8 | 2.2 |
| Total annual CRP real payment (million $)* | 95.6 | -1.0 | - | - | 95.6 | 0 |
| Total annual CRP nominal payment (million $) | 112.5 | -0.5 | 6.2 | 7.1 | 119.5 | 0.9 |
| Crop insurance subsidy saved per year (million $) | 16.9 | 1.8 | 41.1 | 47.3 | 23.9 | 4.5 |
| Total EEBI of enrolled acres (million) | 417.0 | 0.5 | 20.5 | 20.9 | 502.5 | 0.4 |
| Average EEBI per enrolled acre | 210.1 | 0.5 | -15.3 | -16.8 | 177.9 | -1.8 |
| Average EEBI per dollar of CRP real payment | 4.4 | 1.4 | 20.5 | 21.0 | 5.3 | 0.4 |
| Acres that change status (million acres)† | - | 4.7 | 43.0 | 46.8 | 1.8 | 8.7 |
| **Signup 41** | | | | | | |
| Total acres enrolled (million acres) | 2.78 | - | 26.6 | 28.6 | 3.52 | 1.5 |
| Total annual CRP real payment (million $)* | 50.2 | -8.1 | - | - | 50.2 | 0 |
| Total annual CRP nominal payment (million $) | 134.3 | -0.9 | 16.3 | 17.5 | 156.1 | 1.1 |
| Crop insurance subsidy saved per year (million $) | 84.1 | 3.4 | 26.0 | 28.0 | 105.9 | 1.6 |
| Total EEBI of enrolled acres (million) | 498.0 | 2.2 | 15.3 | 15.5 | 574.0 | 0.2 |
| Average EEBI per enrolled acre | 179.1 | 2.2 | -9.0 | -10.2 | 163.0 | -1.3 |
| Average EEBI per dollar of CRP real payment | 9.9 | 11.2 | 15.3 | 15.5 | 11.4 | 0.2 |
| Acres that change status (million acres)† | - | 10.4 | 22.5 | 24.5 | 0.8 | 9.0 |

Note: * Calculated by using total annual CRP nominal payment minus crop insurance subsidy saved per year. † Under Comparisons I to III, the percentage change from Baseline is calculated by using acres that changes status when compared with Baseline divided by total acres *offered* in a signup. Under Comparison IV, percentage change from Scenario 2 is calculated by *i*) obtaining the difference between "acres that change status when compared with Baseline" under Scenarios 3 and 2; and *ii*) divide the difference by "acres that change status when compared with Baseline" under Scenario 2.

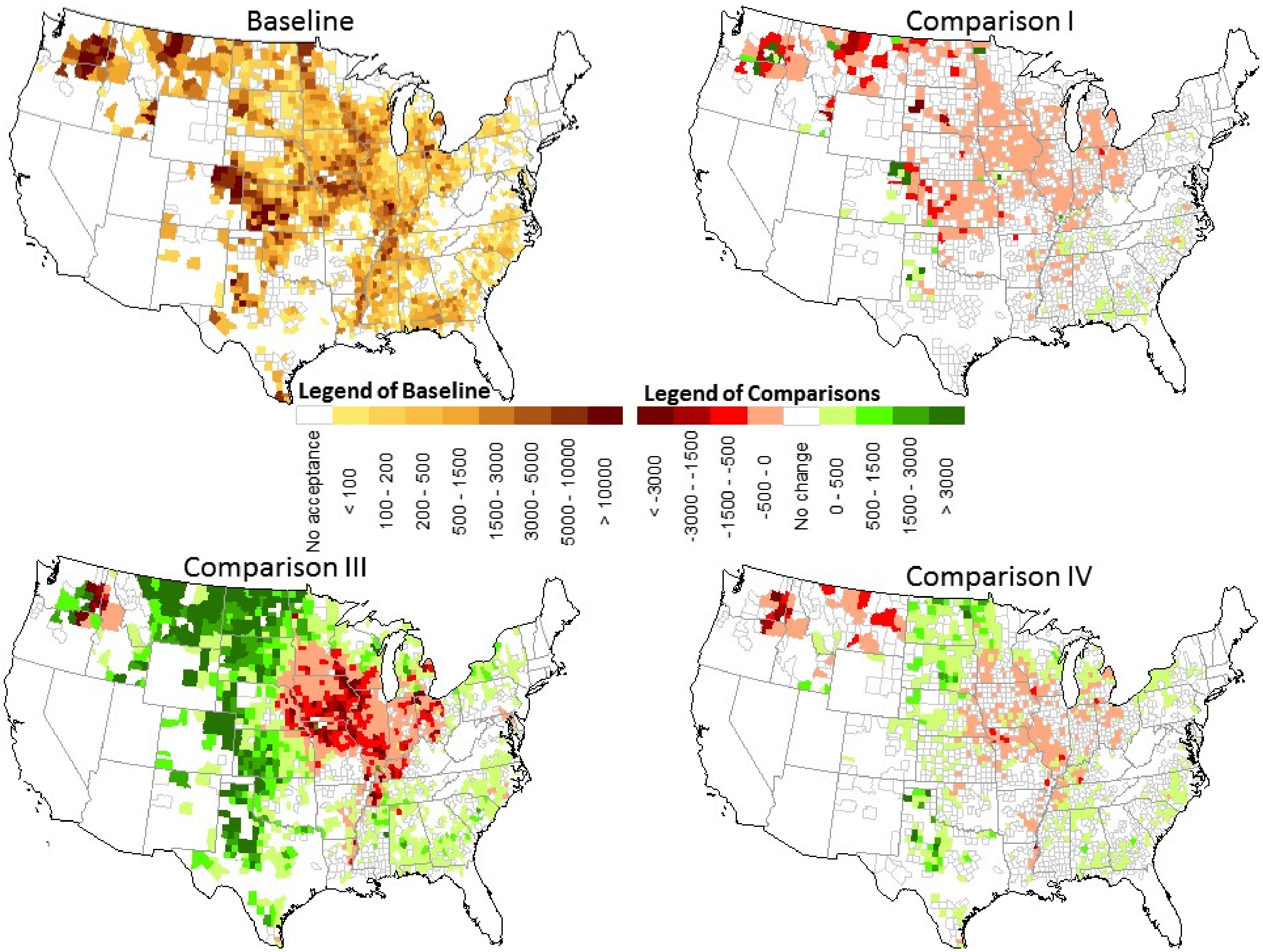


**Figure 1. Acres enrolled into CRP in Baseline and CRP acreage changes under Comparisons I, III, and IV (Singup 26).** Note: in the map of Baseline, counties with gray border but without color are counties that have CRP offers but none of these offers are accepted. Counties with neither border nor color are counties that have no CRP offers. In the three maps of comparisons, counties with gray border but without color are counties that have no enrollment changes.

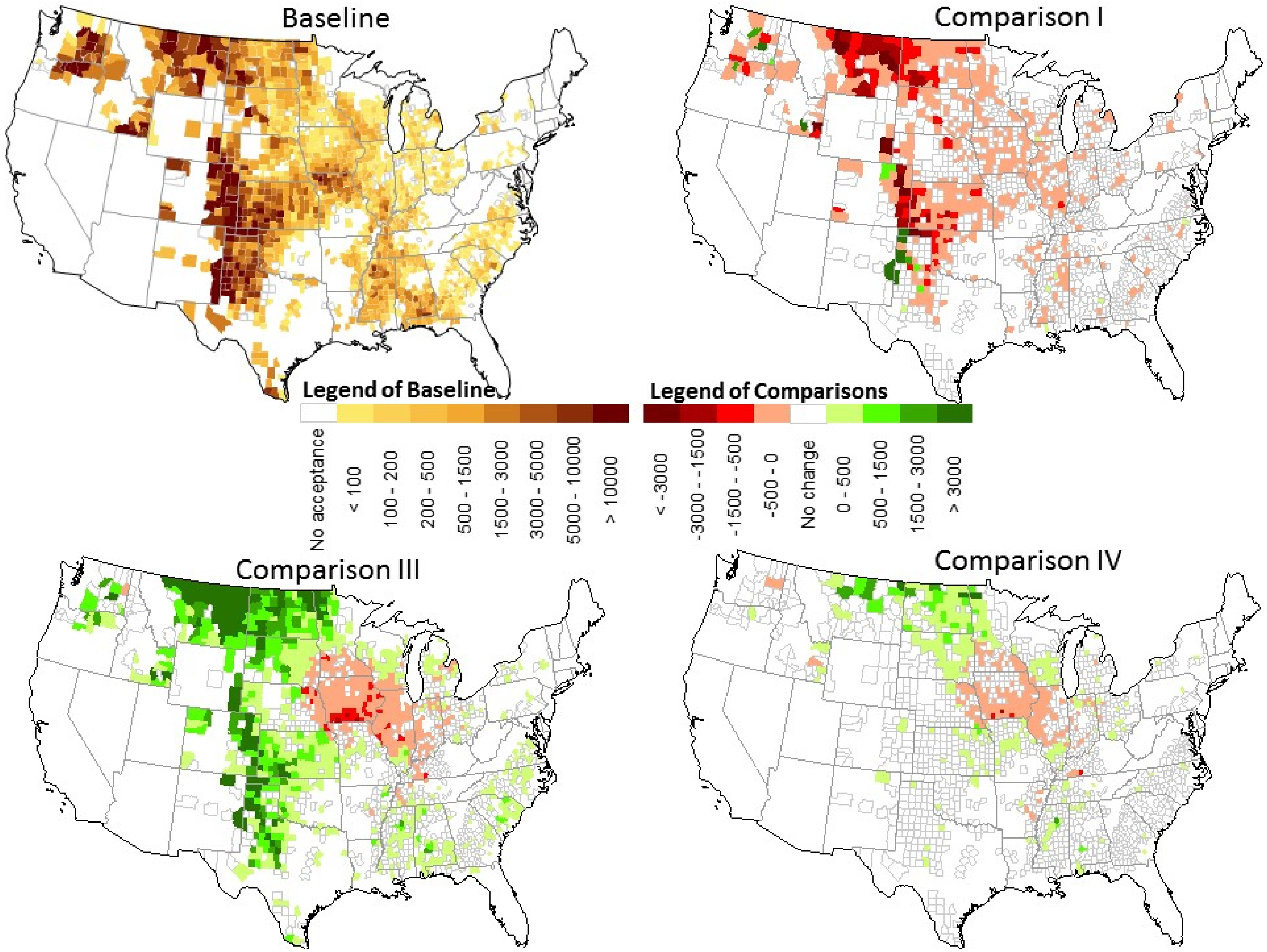


**Figure 2. Acres enrolled into CRP in Baseline and CRP acreage changes under Comparisons I, III, and IV (Singup 41).** Note: in the map of Baseline, counties with gray border but without color are counties that have CRP offers but none of these offers are accepted. Counties with neither border nor color are counties that have no CRP offers. In the three maps of comparisons, counties with gray border but without color are counties that have no enrollment changes.

**Supporting Information for "Assessing Cost-effectiveness of the Conservation Reserve Program and Its Interaction with Crop Insurance Subsidies"**

In what follows we show that the two matching approaches described in the "Data and Simulation Approach" section yield very similar crop insurance subsidy and final simulation result predictions. We first describe the data for insurance subsidy at insured-unit level and then the alternate matching approach, named quantile matching, which utilizes these data. An insured unit can be a single field or several fields on a farm. At the end we compare the results from quantile matching and those from the matching approach utilized in the main text, which is labeled as regression matching hereafter.

The two matching approaches utilize the same CRP data. The difference in data between the two approaches lies in data for crop insurance subsidies. Unit-level crop insurance subsidy data for corn, soybean, and wheat in 2003 and 2011 and in 12 Midwestern states are obtained from Risk Management Agency (RMA) at USDA. These states are: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. This dataset includes rate yield (yield expected for a crop unit), insurance type, coverage level, premium, and premium subsidy of each insured unit. Table S3 in this Supporting Information (SI) shows corn, soybean, and wheat insurance data summary statistics for each of the 12 states. In 2011, in total 2.4 million insured units covered 186 million acres of corn, soybean, and wheat within the 12 states. Crop insurance premiums and subsidies more than tripled between 2003 and 2011, largely due to increases in crop prices over that period. Moreover, like CRP rental rates, premiums and premium subsidies varied significantly across states. On average, premium subsidies accounted for about 50–65% of premiums across the states for the two years.

Even though both CRP offer data and the RMA datasets for corn, soybean, and wheat were contract unit-level data, the location of each contract unit within a county is not released for either type of dataset. Thus, we cannot directly link these datasets by land parcels and have to seek an alternative approach. The rate yield variable in the RMA data indicates an insured unit's yield potential. Similarly, the weighted average soil rental rate (WASRR) in the CRP data represents the parcel's productivity potential. To identify crop insurance subsidy for each parcel offered to CRP, we also develop a quantile-matching approach to establish a link between land parcels in CRP and RMA datasets using rate yield and WASRR as linkage variables. More specifically, for each county we estimate cumulative distribution functions (CDF) for corn rate yield, soybean rate yield, wheat rate yield, and WASRR, respectively. To match a CRP parcel with units in RMA corn, soybean, and wheat datasets, we first identify the CDF value of this parcel's WASRR, and then the matched RMA units will be the corn, soybean, and wheat units that have the same CDF values based on the estimated rate yield distributions. Since we expect that land offered to CRP is usually less fertile, in the matching we only consider RMA units that have rate yield less than a certain percentile (the 30th percentile in this study) within a county. Below is the specific matching procedure.

**Step 1**. For each crop (corn, soybean, and wheat) in each county, we identify RMA units that have rate yield less than the 30th percentile. Note that in this step we view all the rate yield observations for one crop within one county as the population.

**Step 2**. Based on the RMA units obtained from Step 1, for each crop in each county, we estimate an empirical yield distribution. The empirical distributions are estimated using kernel density estimation which is implemented by MATLAB function "ksdensity." Let $G_k^c(\cdot)$, $G_k^s(\cdot)$, and $G_k^w(\cdot)$ denote, respectively, estimated CDFs for corn, soybean, and wheat in county $k$.

**Step 3**. Based on CRP offer data, for each county, we estimate an empirical distribution of WASRR. Let $R_k(\cdot)$ denote the estimated CDF of WASRR in county *k*.

**Step 4**. Suppose the parcel *j* WASRR in county *k* is $x_{jk}$. Based on the estimation result in Step 3 we can obtain $R_k(x_{jk})$. Then an RMA corn unit that matches with this parcel *j* will be the RMA corn unit that minimizes $|G_k(y_{ck}) - R_k(x_{jk})|$, where $y_{ck}$ is the rate yield of a corn unit in county *k*. Following the same method we can match parcel *j* with a soybean unit and a wheat unit.

**Step 5**. Based on matching results in Step 4, parcel *j*'s estimated crop insurance subsidy will be the weighted average subsidy of the matched corn, soybean, and wheat units. The weights are reported acres for the matched units. This completes our description of the quantile matching procedure.

Table S4 summarizes the mean and standard deviation of the matched insurance subsidies for each state based upon the two matching approaches. We can see that on average the two matching approaches yield very close mean values of insurance subsidies. For Signup 26 the mean of predicted insurance subsidies from the two approaches are almost the same (differ only after the hundredths decimal place). For Signup 41, the subsidy means from the regression matching and quantile matching approaches are \$30.81/acre and \$30.52/acre, respectively. Since aggregate insurance subsidy data (i.e., county-level average) are used in regression matching, it is not surprising that the standard deviation of insurance subsidies obtained from the regression-matching approach is smaller than that from the quantile-matching approach.

Table S5 presents simulation results such as total CRP acres enrolled, total annual CRP real payment, etc., within the 12 Midwestern States under the four scenarios based on data obtained from the two matching approaches. Results show that these two matching approaches yield negligible differences. For example, the total acres enrolled under Scenarios

2 and 3 simulated by using the data from regression matching are almost the same as those simulated by using the data from quantile matching (may differ after the hundredths decimal place). The payments (including real, nominal, and saved insurance subsidy payments) differ slightly between the simulation results based on the alternative matching approaches. The difference is because the predicted insurance subsidies from the two approaches are slightly different.

**Table S1. Summary Statistics for CRP Offer Data of Signups 26 and 41 as well as Crop Insurance Data in 2003 and 2011**

| | Signup 26 (Year 2003) | | Signup 41 (Year 2011) | |
|---|---|---|---|---|
| | Offered | Accepted | Offered | Accepted |
| Total number of offers | 71,073 | 38,619 | 38,677 | 29,861 |
| Total acres (million acres) | 4.15 | 2.00 | 3.75 | 2.82 |
| Average rent ($/acre) | 48 | 52 | 47 | 48 |
| Average WASRR ($/acre)* | 50 | 54 | 50 | 51 |
| Average EBI | 271 | 302 | 270 | 286 |
| Average EEBI | 177 | 210 | 161 | 179 |
| Average crop insurance premium ($/acre)† | 14.7 | | 50.1 | |
| Average crop insurance subsidy ($/acre)† | 8.6 | | 31.2 | |

Note: * WASRR stands for weighted average soil rental rate. † Crop Insurance premium and subsidy for insured acres growing crops that are not eligible for CRP enrollment are excluded from calculation.

**Table S2. CRP Environmental Benefits Index (EBI)--Points for Components**

| sign-up number (sign-up year) | 15 (1997) | 16 (1997) | 18 (1998) | 20 (1999) | 26 (2003) | 29 (2004) | 33 (2006) | 39 (2010) | 41 (2011) |
|---|---|---|---|---|---|---|---|---|---|
| Cost component parameter: *a* | 190 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Cost component parameter: *b* | 165 | 165 | 165 | 165 | 185 | 185 | 204 | 220 | 220 |
| Maximum of cost components | 200 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| Maximum of EEBI | 400 | 410 | 410 | 410 | 395 | 395 | 395 | 395 | 395 |
| Maximum of EBI | 600 | 560 | 560 | 560 | 545 | 545 | 545 | 545 | 545 |
| Cut-off EBI for acceptance | 259 | 247 | 245 | 246 | 269 | 248 | 242 | 200 | 221 |

*Note*: Cost component = a×(1-(rental rate/b)) + extra bonus points. Specifically, these extra bonus points are "N6b" and "N6c" in CRP signups. In Signup 26, N6b equaled 0 if a CRP offer required cost share and equaled 10 if not. N6c was the lower of 15 and the difference between rental rate and maximum payment rate. In Signup 41, N6c was eliminated while N6b measures how much the offered CRP rent was lower than the maximum payment rate. See links www.fsa.usda.gov/Internet/FSA_File/crpebi03.pdf and www.fsa.usda.gov /Internet/FSA_File/crp_41_ebi.pdf for details. EEBI is the sum of the scores for environmental factors, and EBI = EEBI + cost components.

**Table S3. Summary Statistics for RMA Insurance Data of the 12 Midwestern States in 2003 and 2011**

| | | Corn | | | | Soybean | | | | Wheat | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | States | Number of Units | Reported Acres | Premium ($/acre) | Subsidy ($/acre) | Number of Units | Reported Acres | Premium ($/acre) | Subsidy ($/acre) | Number of Units | Reported Acres | Premium ($/acre) | Subsidy ($/acre) |
| **2003** | Illinois | 148,562 | 10,833,809 | 12 | 6 | 141,909 | 9,210,779 | 6 | 3 | 11,275 | 472,270 | 8 | 5 |
| | Indiana | 62,740 | 4,088,162 | 15 | 8 | 60,025 | 3,677,722 | 9 | 5 | 4,066 | 170,899 | 7 | 4 |
| | Iowa | 167,339 | 13,526,638 | 12 | 7 | 154,663 | 11,989,988 | 7 | 4 | 131 | 8,814 | 12 | 7 |
| | Kansas | 45,458 | 3,761,712 | 12 | 6 | 54,671 | 3,089,506 | 8 | 5 | 176,867 | 15,234,345 | 7 | 4 |
| | Michigan | 19,316 | 1,266,461 | 14 | 8 | 17,726 | 1,086,768 | 10 | 6 | 7,178 | 338,192 | 9 | 5 |
| | Minnesota | 85,188 | 7,443,395 | 15 | 9 | 91,101 | 8,215,170 | 9 | 5 | 18,121 | 2,045,047 | 12 | 7 |
| | Missouri | 42,348 | 3,305,906 | 13 | 8 | 65,532 | 5,448,817 | 8 | 5 | 10,467 | 626,953 | 6 | 4 |
| | Nebraska | 132,763 | 10,214,861 | 14 | 7 | 93,401 | 5,845,373 | 9 | 5 | 34,643 | 2,507,902 | 8 | 5 |
| | North Dakota | 18,584 | 1,678,414 | 18 | 11 | 35,358 | 3,934,778 | 10 | 5 | 108,686 | 11,475,508 | 9 | 5 |
| | Ohio | 42,692 | 2,470,580 | 15 | 8 | 48,006 | 2,971,164 | 10 | 5 | 10,771 | 422,095 | 6 | 4 |
| | South Dakota | 63,143 | 5,395,230 | 15 | 9 | 60,952 | 5,457,440 | 10 | 5 | 33,595 | 3,865,914 | 10 | 6 |
| | Wisconsin | 36,780 | 2,049,808 | 19 | 11 | 21,064 | 1,092,798 | 10 | 6 | 2,045 | 71,018 | 12 | 7 |
| | **12 States** | 864,913 | 66,034,975 | 14 | 7 | 844,408 | 62,020,302 | 8 | 4 | 417,845 | 37,238,957 | 8 | 5 |
| **2011** | Illinois | 165,720 | 13,437,896 | 38 | 22 | 151,798 | 9,753,491 | 23 | 13 | 14,341 | 633,482 | 31 | 20 |
| | Indiana | 70,306 | 4,936,483 | 48 | 28 | 70,276 | 4,358,936 | 33 | 19 | 6,081 | 281,279 | 32 | 19 |
| | Iowa | 176,911 | 15,875,033 | 43 | 25 | 140,707 | 11,085,629 | 26 | 15 | 244 | 8,705 | 40 | 24 |
| | Kansas | 74,988 | 6,578,764 | 40 | 25 | 71,810 | 4,650,846 | 30 | 19 | 144,258 | 12,870,889 | 21 | 13 |
| | Michigan | 30,019 | 1,787,419 | 51 | 35 | 25,250 | 1,380,584 | 39 | 25 | 9,692 | 479,259 | 31 | 20 |
| | Minnesota | 107,444 | 8,927,060 | 49 | 31 | 95,452 | 7,922,207 | 33 | 20 | 17,209 | 1,746,336 | 44 | 30 |
| | Missouri | 52,575 | 4,063,231 | 49 | 32 | 77,997 | 6,059,521 | 28 | 18 | 10,806 | 680,467 | 23 | 15 |
| | Nebraska | 146,215 | 12,052,479 | 42 | 25 | 92,018 | 6,194,190 | 30 | 18 | 25,911 | 2,049,950 | 21 | 12 |
| | North Dakota | 39,143 | 3,276,239 | 69 | 46 | 56,882 | 5,265,896 | 38 | 24 | 117,137 | 11,553,909 | 35 | 23 |
| | Ohio | 52,388 | 3,045,180 | 52 | 32 | 64,379 | 3,867,055 | 39 | 23 | 14,790 | 566,906 | 27 | 16 |
| | South Dakota | 86,722 | 6,851,722 | 55 | 37 | 78,141 | 5,497,352 | 32 | 21 | 34,034 | 3,586,358 | 35 | 23 |
| | Wisconsin | 54,207 | 2,806,803 | 67 | 44 | 27,950 | 1,225,292 | 44 | 28 | 6,037 | 213,181 | 37 | 24 |
| | **12 States** | 1,056,638 | 83,638,309 | 46 | 28 | 952,660 | 67,260,999 | 30 | 19 | 400,540 | 34,670,720 | 29 | 18 |

**Table S4. Mean and Standard Deviation of Matched Insurance Subsidies per Acre from Regression Matching and Quantile Matching**

| | **Signup 26** | | | | **Signup 41** | | | |
|---|---|---|---|---|---|---|---|---|
| | mean ($/acre) | | standard deviation | | mean ($/acre) | | standard deviation | |
| State | regression | quantile | regression | quantile | regression | quantile | regression | quantile |
| Illinois | 8.00 | 8.08 | 1.09 | 3.20 | 32.13 | 31.41 | 4.30 | 14.57 |
| Indiana | 9.32 | 7.92 | 2.04 | 2.87 | 34.44 | 30.58 | 4.19 | 12.07 |
| Iowa | 7.43 | 7.19 | 1.44 | 2.74 | 29.07 | 29.05 | 2.52 | 9.87 |
| Kansas | 7.15 | 8.50 | 0.76 | 2.72 | 27.90 | 26.50 | 2.46 | 8.90 |
| Michigan | 8.54 | 7.93 | 0.55 | 3.54 | 30.11 | 27.89 | 1.79 | 9.83 |
| Minnesota | 8.96 | 8.58 | 0.86 | 3.40 | 33.14 | 35.94 | 3.12 | 13.37 |
| Missouri | 8.24 | 8.82 | 1.33 | 3.11 | 35.06 | 35.05 | 7.62 | 12.14 |
| Nebraska | 9.26 | 9.76 | 1.03 | 2.88 | 27.15 | 26.28 | 4.59 | 7.35 |
| North Dakota | 7.73 | 7.43 | 1.96 | 2.91 | 29.53 | 29.49 | 5.71 | 11.11 |
| Ohio | 8.04 | 7.40 | 0.72 | 2.59 | 34.08 | 28.54 | 2.19 | 8.02 |
| South Dakota | 8.30 | 8.23 | 1.15 | 2.53 | 30.51 | 32.06 | 6.08 | 10.24 |
| Wisconsin | 9.56 | 9.33 | 0.95 | 3.99 | 36.73 | 37.54 | 2.62 | 15.59 |
| average | 8.21 | 8.21 | 1.42 | 3.15 | 30.81 | 30.52 | 5.46 | 11.85 |

**Table S5. Comparing Simulation Results based on Regression Matching and Quantile Matching**

| | Regression matching | | | | Quantile matching | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Scen. 1 | Scen. 2 | Scen. 3 | Baseline | Scen. 1 | Scen. 2 | Scen. 3 |
| **Signup 26** | | | | | | | | |
| Total acres enrolled (million acres) | 1.1 | 1.1 | 1.5 | 1.6 | 1.1 | 1.1 | 1.5 | 1.6 |
| Total annual CRP real payment (million $) | 62.5 | 62.3 | 62.5 | 62.5 | 62.2 | 61.6 | 62.2 | 62.2 |
| Total annual CRP nominal payment (million $) | 71.5 | 71.3 | 75.0 | 75.2 | 71.5 | 71.1 | 75.2 | 75.7 |
| Crop insurance subsidy saved per year (million $) | 9.0 | 9.0 | 12.4 | 12.7 | 9.3 | 9.5 | 13.0 | 13.4 |
| Total EEBI of enrolled acres (million) | 237 | 237 | 278 | 278 | 237 | 237 | 279 | 279 |
| Average EEBI per enrolled acre | 213 | 213 | 181 | 179 | 213 | 213 | 181 | 179 |
| Average EEBI per CRP real payment dollar | 3.8 | 3.8 | 4.4 | 4.5 | 3.8 | 3.8 | 4.5 | 4.5 |
| Acres that change status when compared with Baseline (million acres) | - | 0.04 | 0.85 | 0.92 | - | 0.05 | 0.85 | 0.92 |
| **Signup 41** | | | | | | | | |
| Total acres enrolled (million acres) | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 | 0.9 | 1.1 | 1.1 |
| Total annual CRP real payment (million $) | 31.9 | 32.1 | 31.9 | 31.9 | 31.9 | 31.4 | 31.9 | 31.9 |
| Total annual CRP nominal payment (million $) | 57.0 | 57.3 | 63.5 | 64.4 | 57.0 | 57.1 | 63.6 | 64.7 |
| Crop insurance subsidy saved per year (million $) | 25.1 | 25.2 | 31.6 | 32.5 | 25.1 | 25.7 | 31.8 | 32.8 |
| Total EEBI of enrolled acres (million) | 156 | 156 | 173 | 174 | 156 | 156 | 173 | 174 |
| Average EEBI per enrolled acre | 181 | 181 | 160 | 157 | 181 | 181 | 160 | 157 |
| Average EEBI per CRP real payment dollar | 4.9 | 4.9 | 5.4 | 5.4 | 4.9 | 5.0 | 5.4 | 5.5 |
| Acres that change status when compared with Baseline (million acres) | - | 0.02 | 0.27 | 0.32 | - | 0.04 | 0.27 | 0.31 |

*Note*: Baseline scenario and Scenario 1 are under acreage constraints, which are 1,111,714 acres and 860,445 acres, respectively, for Signups 26 and 41. Scenarios 2 and 3 are under real-payment constraints. Regarding data from regression matching, the real payment constraints are $62,517,849 and $31,865,548, respectively, for Signups 26 and 41. Regarding data from quantile matching, the real payment constraints are $62,218,752 and $31,870,389, respectively, for Signups 26 and 41. The real payment constraints from the two matching approaches differ slightly because the predicted crop insurance subsidies under these two approaches differ slightly.

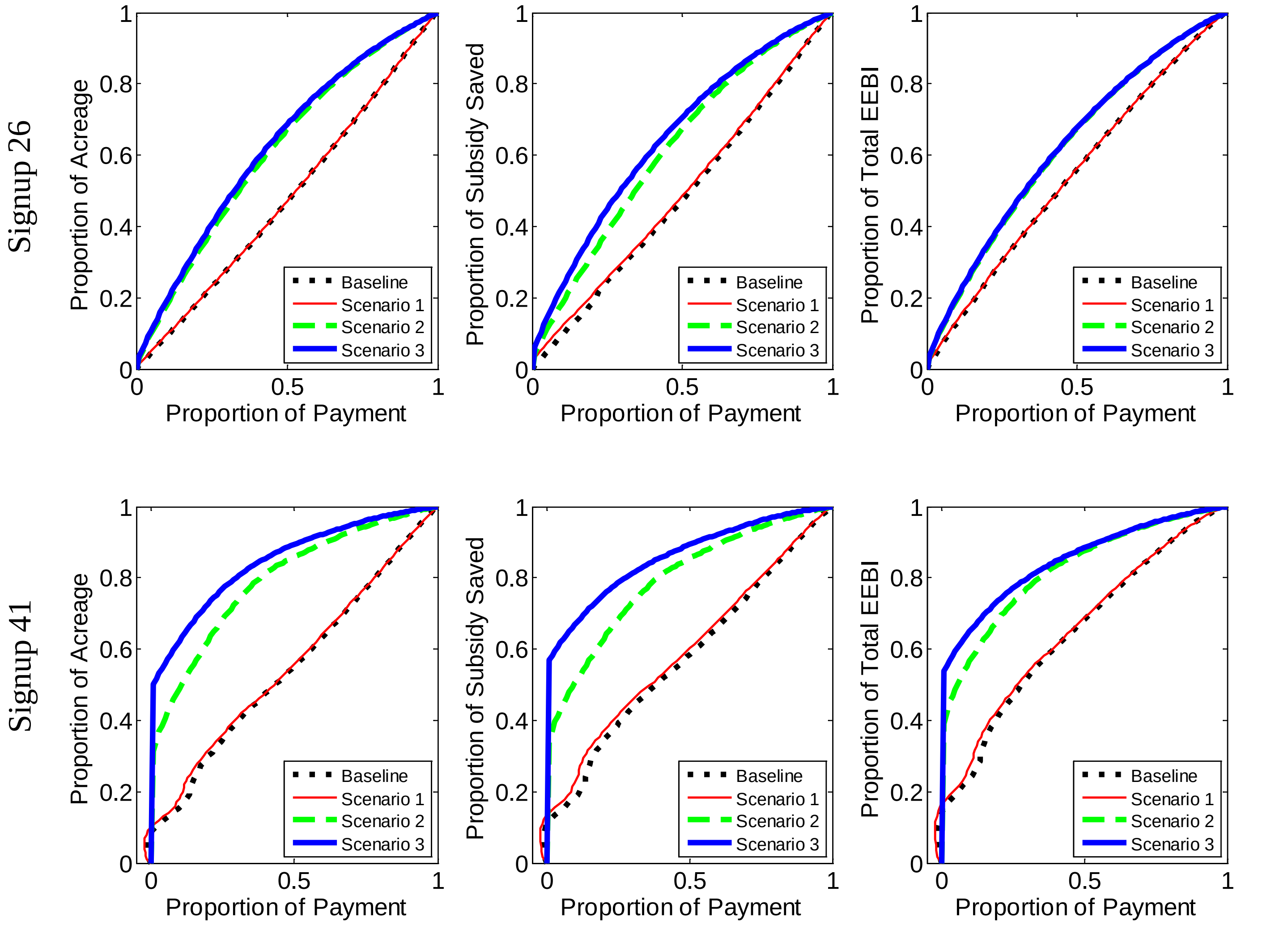


**Figure S1. Proportion of Acreage, Subsidy Saved, and EEBI when CRP Real Payment Varies**

Note: Recall that CRP real payment is defined as CRP nominal payment minus saved crop insurance subsidies. The large magnitude of insurance subsidy in 2011 made it possible that about half of the CRP acreage can be enrolled at zero real payment. Since Baseline and Scenario 1 are constrained by acreage cap and for some regions insurance subsidies are larger than CRP rent, the real payment can be negative when acreage caps are small.