New Conservation Initiatives in the 2002 Farm Bill[*]

Robert C. Johansson

Roger Claassen

Economic Research Service
United States Department of Agriculture

Mark Peters

Agricultural Marketing Service
United States Department of Agriculture

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ABSTRACT

The role of agri-environmental programs has taken on increased importance in the current Farm Bill debate with an eighty percent increase in Title II funding. However, little empirical evidence exists on the tradeoffs between economic costs and environmental benefits of new agri-environmental programs to assist policymakers in their designs. This paper illustrates some of the budgetary and environmental issues inherent in these initiatives. Several policy options are explored using an environmental simulation model and an economic spatial-equilibrium model for U.S. agriculture. Results indicate abatement levels of nitrogen and pesticides are higher under performance-based policies and those for wind erosion and soil productivity are higher under practice-based policies. Abatement of phosphorus discharge, soil erosion and carbon sequestration remains relatively constant regardless of policy type. A national performance-based conservation policy funded at the $1 billion level has the potential to improve the environmental performance of U.S. farmers by as much as ten percent.

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INTRODUCTION

The 2002 Farm Bill includes large increases in funding for conservation programs. The new funding will be largely devoted to subsidizing conservation efforts on land in production, rather than the more traditional approach of land retirement. While land retirement, largely through the Conservation Reserve Program (CRP; FSA, 2002), has lowered levels of soil erosion and provided other environmental benefits, the cost-effectiveness of retiring land to achieve these benefits has been questioned (Ribaudo et al., 1994, 2001). One method to increase the cost-effectiveness of conservation programs is to shift funding to agri-environmental incentive payments designed to encourage cleaner, less-polluting production practices (Ribaudo et al., 1999). Doing so capitalizes on the fact that it may not cost farmers much to alter current management practices to obtain modest environmental gains.

Two prominent conservation programs for working lands featured in the 2002 Farm Bill are the Conservation Security Program (CSP) and the Environmental Quality Incentives Program (EQIP; NRCS, 2002). The CSP, a new conservation program, provides a comprehensive, locally driven approach to agricultural conservation on lands in production and is flexible enough to include payments to "good actors"[1] (Harkin, 2001). While the funding level for the CSP is not capped, the Congressional Budget Office (CBO) estimates it will provide approximately $2 billion to farmers for conservation practices over the next ten years (CBO, 2002). EQIP, introduced in the 1996 Farm Bill, provides agri-environmental payments to crop and livestock producers to generate broadly defined environmental benefits in a cost-effective manner. The new funding level for EQIP has been set at $9 billion over the next ten years (CBO, 2002). Based on the importance and funding accorded these new conservation initiatives, there is an opportunity to illustrate potential benefits and costs under several different conservation programs reflective of those outlined in S. 1731 and H.R. 2646. Comparisons are useful when designing particular aspects of these programs, such as acreage restrictions, good-actor payments, and the like. Furthermore, cost-benefit analyses of any federal rule that may have an annual effect on the economy of $100 million is mandated by the Regulatory Improvement Act of 1999.

That said, while the design and cost-effectiveness of land retirement programs has often been examined, very little empirical data exist to assist in the design of conservation programs at the national-level (e.g., Heimlich, 1994; Cooper and Keim, 1996; Powell and Wilson, 1997; Cattaneo, 2001). In addition, the environmental achievements of such programs as EQIP have not been well studied, for the most part due to inadequate ex-post monitoring of relevant environmental parameters. Analysis of similar agri-environmental programs for national nitrogen and soil erosion policies including cost and benefits was recently conducted by Claassen et al. (2001). They illustrate how emphasis on rewarding good actors limits the incentives available for new conservation practices. This paper builds on the Claassen et al. analysis by focusing on the provisions found in current Farm Bill legislation: multiple pollutants, cost-plus or good-actor payments, and flexible or restricted practice eligibility. Further to advance the notion of cost-effectiveness in the provision of environmental benefits, we model these provisions in the context of practice-based versus performance-based payments.

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[1] Good-actor payments essentially are income transfer mechanisms designed to reward past environmental performance and to encourage a continuation of "good" management practices in the future.

The fiscal and environmental tradeoffs inherent in these initiatives are simulated using the Environmental Policy Integrated Climate Model (*EPIC*)[2] and the U.S. Regional Agricultural Sector Model (*USMP*).[3] Benefits are achieved by providing incentives (agri-environmental payments) to farmers to adopt improved or "best" management practices (BMPs), including alternative tillage, rotation, and fertilizer management practices. Furthermore, those farmers who have demonstrated adoption of BMPs in the past may receive good-actor payments. Section 2 develops the methodology used to estimate the costs and benefits of several potential conservation policies. These policies, which are described in Section 3, include various mechanisms for distributing agri-environmental payments to encourage the production of environmental benefits. Simulation results of these policies using *EPIC* and *USMP* are presented and discussed in Section 4. Section 5 concludes with summary comments.

METHODOLOGY

For a nationwide voluntary conservation policy to address the menu of externalities associated with U.S. agricultural production, it must address many potential pollutants and their relevant medium (air, water, and soil). This analysis tracks nine agricultural pollutants affecting four media: surface water (sheet and rill erosion, nitrogen, phosphorus, and pesticides), ground water (nitrogen and pesticides), air (wind erosion and carbon emissions), and soil (decreasing productivity). To facilitate the analysis and exposition the United States is separated into 90 production regions. Each of these production regions is treated as an economic agent who seeks

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[2] *EPIC* uses a daily time step to simulate weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, crop management and growth, and pesticide and nutrient movements with water and sediment (Mitchell et al., 1998).

[3] *USMP* is an agricultural sector model, incorporating commodity supply, use and policy measures (House, Peters, and McDowell, 2001). This system has been developed at the USDA-ERS for analysis of policy, price, or demand shocks on U.S. agricultural production in a spatial equilibrium framework as described in McCarl and Spreen (1980).

to maximize profits given a policy environment in which to operate. Cropland enterprises are chosen from a set of crop rotations, residue management strategies, and fertilizer applications. Given the 90 regions (45 not highly-erodible and 45 highly-erodible regions) and various production management choices (tillage, rotation, and nitrogen fertilizer rate), more than 5000 agricultural production operations are available for simulation analysis. We use the environmental simulation model *EPIC* to generate crop yields and environmental externalities on a per acre basis for short-run production (7 years) and for long-run production (67 years) given historical climate and soils data from across the United States. The yield and externality data are combined and calibrated to current production patterns. Following Heimlich et al. (1997), Claassen et al. (1998, 2001), and Ribaudo et al. (2001), *USMP* is used to estimate the production shifts and price changes resulting from the environmental policy shocks.

Both CSP and EQIP provide agri-environmental payments to farmers for the provision of environmental enhancement, broadly defined to include a range of conservation practices. To reflect this definition of environmental enhancement, an aggregate benefits score (I_{ki}) is generated for each *USMP* production enterprise (subscript *k*) and region (subscript *i*). This aggregate benefits score is composed of the "relative damage estimate" (RDE_{kji}) for each of the environmental externalities (subscript *j*) based on the mass of each pollutant that potentially arrives at the appropriate medium from system (*i*) and region (*k*). The respective RDEs are the product of edge-of-field emissions and the corresponding transport factors:

$$RDE_{kji} = q_{kji} * t_{kj}, \tag{1}$$

where q represents edge-of-field emissions and t represents the relevant transport factor (Table 1). Transport factors are estimated from predicted agricultural emissions in the case of surface water pollutants and are assumed to be 100% for soil, air, and ground water media (i.e., there is no assumed loss in mass from the edge-of-field emissions to the relevant destination media).

Table 1. Relative Damage Estimates

Edge-of-field Emissions (*q*)			**Transport Factor (*t*)**
Externality	**Medium**	**Units ($acre^{-1}year^{-1}$)**	
Sheet and Rill Erosion	Surface Water	Tons	Same As Phosphorus
Nitrogen	Estuary	Lbs.	Derived from SPARROW[a]
Phosphorus	Surface Water	Lbs.	Derived from SPARROW
Pesticides	Surface Water	TPUs[b]	Same as Phosphorus
Nitrogen	Ground Water	Lbs.	100%
Pesticides	Ground Water	TPUs	100%
Wind Erosion	Air	Tons	100%
Carbon Emissions[c]	Air	Metric Tons	100%
Loss in Soil Productivity	Soil	$'s	100%

[a] The national sediment model relates in-stream measurements of sediment at approximately 400 long-term stream monitoring sites to upstream nitrogen sources and physical characteristics of the watersheds. The model empirically estimates the delivery of sediment to streams and the outlets of watersheds from point and nonpoint sources. Estimates of stream transport (dependent variable in the SPARROW models) are adjusted to reflect 1987 sediment inputs and long-term mean flow conditions (1970-1988), based on records of the concentration and flow for the period 1974 to 1989 (Smith et al., 1997). [b] TPUs refer to "toxicity persistence units" (Barnard et al., 1997). These refer to the sum of reference doses (maximum daily human exposure resulting in no appreciable risk) of the pesticides used for a particular cropping enterprise multiplied by the number of days each of those pesticides remain active in the environment. As a point of reference the number of TPUs in a pound of DDT = 4,443 million and in a pound of Borax = 103,872. [c] Carbon emissions are calculated according to the Intergovernmental Panel on Climate Change estimates (IPCC, 1996). The values indicate the amount of carbon emitted when converting land from native pasture.

The resulting relative damage estimates are a measure of the pollutant mass reaching the relevant environmental medium (Table 2). It should be noted that this table includes estimates from all available farming practices, not simply those practices currently observed. Had these estimates been weighted by current production levels, the mean values would have been significantly higher. Negative values for soil productivity indicate that most available farming practices actually increase soil productivity over time. Similarly, negative carbon emission values indicate practices that sequester more carbon than baseline pasture coverage.

Table 2. Descriptive Statistics

RDE_{kji}	Mean	Min	Max	Max - Min
Sheet and Rill Erosion	0.206	0.000	7.238	7.238
Nitrogen to Estuaries	0.164	0.000	4.350	4.350
Phosphorus to Surface Water	0.136	0.000	1.404	1.404
Pesticides to Surface Water	256.400	0.000	62,154.494	62,154.494
Nitrogen to Ground Water	5.694	0.000	65.828	65.828
Pesticides to Ground Water	189.405	0.000	6,638.688	6,638.688
Wind Erosion	3.968	0.000	749.651	749.651
Carbon Emissions	0.344	-0.509	0.687	1.195
Loss in Soil Productivity	-0.421	-64.421	46.886	111.306

Production systems having low relative damage estimates (RDEs) indicate cleaner practices; conversely those with high RDEs are those contributing higher quantities of pollutants to the environment. To characterize each crop production system (*i*) and its potential to generate environmental benefits in each region (*k*), the relative damage estimates (RDE_{kji}) are converted to a 0-1 benefit index (I_{kji}) for each pollutant (*j*):

$$(2) \qquad I_{kji} = \left(\frac{RDE_{kji} - \min(RDE_j)}{\max(RDE_j) - \min(RDE_j)} \right),$$

where $\min(RDE_j)$ and $\max(RDE_j)$ are the minimum and maximum damage estimates across all systems (*i*) and regions (*k*) for the *j*th environmental pollutant. For example, the potential to deliver nitrogen to groundwater is the highest for conventionally tilled, soybean-wheat rotations on non-highly erodible land in the Lake States production region (65.83 lbs./acre/year). Its benefit index value for nitrogen loading to ground water would be 1.0.

These individual indicators can be combined to generate an aggregate benefits index score (I_{ki}) specific to each production system and region that reflects the total management effects of that production system on the environment:

(2) $$I_{ki} = f(I_{kji}).$$

Several functional forms have been promoted to construct aggregate measures of environmental quality from individual indices (Heimlich, 1994; Cude, 2001). This paper uses a weighted sum of the individual environmental indicators as an aggregate environmental quality index:

(3) $$I_{ki} = \sum_{j} w_{kj} I_{kji},$$

where w_{kj} are weights on pollutant damages. This functional form implies that damages to the environment are continuous and linear in emissions. This is similar to other aggregate measures of environmental quality such as the Environmental Benefits Index (FSA, 2002) and the Index of Watershed Indicators (USEPA, 2002).[4] Ideally the weights chosen would reflect socio-economic preferences for mitigating the various pollutants (Heimlich, 1994). For the purposes of this analysis we simply let all weights equal one, which essentially serves to focus only on the physical mass of each externality potentially arriving at the respective medium from each system and region. Further, this weighting implies a point equivalency ratio between the nine pollutants:

(4) $$\max(RDE_m) - \min(RDE_m) : \max(RDE_n) - \min(RDE_n) \ \forall\, m \neq n \in j.$$

Given our weighting assumptions, the point equivalency values reflect equivalent amounts of each pollutant necessary to generate 1 unit of I_{ki} (Table 2). For example, the benefit to the environment from reducing aggregate nitrogen emissions to estuaries by 3 lbs. is approximately equal to reducing aggregate phosphorus emissions by 1 lb.

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[4] The assumptions of continuous and linear damages serve to illustrate the costs to producers in reducing the physical amounts of these pollutants from entering the environment. More complicated damage functions can be incorporated into future analysis by changing the form of the aggregate environmental indicator.

POLICY OPTIONS

Once the benefits and costs to each production enterprise are quantified, it is possible to design conservation policies that generate environmental benefits. The primary policy choice of interest is how to determine the payment base (i.e., practice-based or performance-based). Policymakers and producers use this payment base to calculate their agri-environmental payments for different ex-post production choices. In addition, the CSP contains provisions for "good actor" payments as a way to reward good environmental behavior in the past. How to incorporate these good-actor premiums is another question that we examine. Lastly, because different policies will induce producers to increase or decrease acreage in different regions, we constrain regional acreage to ex-ante levels to facilitate policy comparisons. This constraint is not all that unrealistic given explicit acreage restrictions in the CSP and preclusion of land retirement credits (with the exception of certain buffer practices).

Practice-Based Policy

Given that each production system can be assigned an aggregate environment quality score (I_{ki}), let the payment to each eligible practice be based on the difference between I_{ki} and some base environmental quality ($\bar{I}_{rl}$), or "reference level" (Claassen et al., 2001), such that $(\bar{I}_{rl} - I_{ki}) > 0$. The reference level is chosen by the policymaker and effectively limits the conservation practices that are eligible for program payments. If a producer is currently using an eligible practice or agrees to adopt one of these practices she will be eligible for program payments. This policy essentially focuses payments towards those farmers that are already farming in a less-polluting manner and depending on the reference level, may restrict some of the more-polluting farms from participating.[5]

There are two methods of implementing such a policy following the selection of a reference level. The policymaker can set a given price for each environmental quality point generated under the reference level (recall that a lower score indicates a less-polluting production system) and open the program for any and all interested producers. A second method of implementation is to declare the reference level to producers and then solicit bids for contracts. Each contract would specify the production practices to be used in production, the quantity of environmental benefits generated under the reference level, and the willingness-to-accept bid from the producer. This is similar to the current bid system for the CRP, which solicits willingness-to-accept bids from producers to engage in eligible BMPs. All bids would then be evaluated by the program manager, who would accept contracts on a cost-effective basis until the program budget was met.

We focus on this latter method of implementing a practice-based program, which will result in significantly lower aggregate costs than the former. The larger the budget the greater the value of payments and the more farmers willing to adopt cleaner management practices. The mapping between the budget and environmental benefits, or abatement cost curve, is expected to be convex in abatement levels. That is, program costs are increasing in abatement at an increasing rate.

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[5] Obviously those farmers that are already farming below the reference level will be automatically eligible for program payments. In this way, the “good actor” payment is endogenous to this policy. For those farmers that simply want to participate as good-actors they would list ex-ante levels of eligible practices that they intended to maintain ex-post. The generation of ex-post benefits by these producers would essentially be zero.

Performance-Based Policy

A second type of voluntary conservation policy examined is one where the government agency provides payments to farmers corresponding to any management or conservation practice change resulting in positive environmental benefits. Each producer that desires to participate in the program agrees to adopt cleaner methods of farming and submits a contract bidding on a payment plan for the provision of environmental benefits. These bids list the willingness-to-accept levels of the producer for a range of production practices and benefit levels. This is similar to optimal nonlinear tax and subsidy schedules to achieve first-best abatement solutions (Smith and Tomasi, 1999). Smith and Tomasi describe the process of inferring the optimal tax scheme to achieve a desired environmental goal as a two-stage subgame-perfect Bayesian-Nash Equilibrium. Here each producer is eligible to submit a bid stating her schedule of estimated costs and benefits. The policymaker then accepts bids seeking to maximize benefits subject to a fixed budget. Once again as the budget for this program increases, more contracts will be accepted resulting in more environmental benefits.

The mapping between these two variables is also expected to be convex in abatement, and is expected to lie below the practice-based abatement cost curve. The reason for this is that all management practices are eligible for payments, excluding land retirement. As long as the producer is adopting a management practice that results in lower expected damages ex-post versus ex-ante, she will be eligible for program payments. It should be noted that under a performance-based policy, participating producers are penalized for reverting to more-polluting, ex-post practices. This is consistent with language currently included in the CSP and EQIP provisions, which exclude eligibility for practices "*that would tend to defeat the purposes of the program*." (e.g., H.R. 2646, Sec. 1240D.). In addition, good-actor payments are now decoupled from the provision of ex-post benefits. This allows the policymaker to decide upon different payment levels and distribution methods for this component of the conservation policy. To implement this policy it is necessary to evaluate both the ex-ante and ex-post management practices. It should be noted that the costs of acquiring this information from the producer might be high.

RESULTS

These policies will be evaluated based on how cost-effective they are in generating environmental benefits. Total environmental benefits (E) are given by:

$$(5) \qquad E = \sum_k \sum_i (xact_{ki}^0 - xact'_{ki}) \times I_{ki}\,,$$

where $xact_{ki}^0$ ($xact'_{ki}$) is the ex-ante (ex-post) production system activity level in acres. Total agri-environmental payments for the practice-based and performance-based policies are respectively given by:

$$(6a) \qquad C^P = \sum_k \sum_i [xact'_{ki} \times P(\bar{I}_{rl} - I_{ki})]\,,$$

$$(6b) \qquad C^E = \sum_k \sum_i [(xact_{ki}^0 - xact'_{ki}) \times PI_{ki} + GAP_{ki}]\,.$$

Here P is the payment for benefits generated from activity $xact_{ki}$ and GAP_{ki} represents the decoupled good-actor payments for the performance-based policy. It is also important under these to constrain acreage to ex-ante levels, or unintended adverse environmental consequences may result from increases in production acres ex-post. The policymaker's problem (J) is written:

$$(7) \qquad J \equiv \max_{P,GAP} E \text{ subject to } C \leq B \text{ and } \sum_{\mathrm{k}} \sum_{\mathrm{i}} xact'_{ki} = \sum_k \sum_i xact_{ki}^0\,,$$

where B is the finite budget allocated to the program.[6]

To estimate the aggregate cost curves for two policies, the payment (P) for each benefit point was allowed to increase. Producer participation under each policy includes both a price and income effect. The income effect encourages farmers to adopt and implement cleaner production practices. As one might expect, the higher the payment is, the more producers will participate. However, the price effect is not quite as transparent. Because we are using a spatial equilibrium model encompassing more than eighty percent of the primary and secondary agricultural production in the United States, it is possible to evaluate medium-run effects of these policies on the agricultural sector. As producer participation in conservation programs increases (i.e., a movement towards less-polluting crop systems) there will be an offsetting price effect for those crops produced under the more-polluting systems due to the decreased production of those crops. This effect is not expected to swamp the income effect, but will nevertheless temper producers' marginal willingness-to-accept conservation contracts.

Practice-Based Policy

For the practice-based policy the policymaker sets the reference level at the beginning of the program period and accept bids from interested farmers who would list all ex-post practices that would be eligible for program payments and the expected benefits generated. For those farmers that simply want to participate as good-actors they would list ex-ante levels of eligible practices that they intended to maintain ex-post. All bids would be then be evaluated by the program manager who would set payment levels ex-ante for each eligible practice such that the expected participation would not exceed the program budget.

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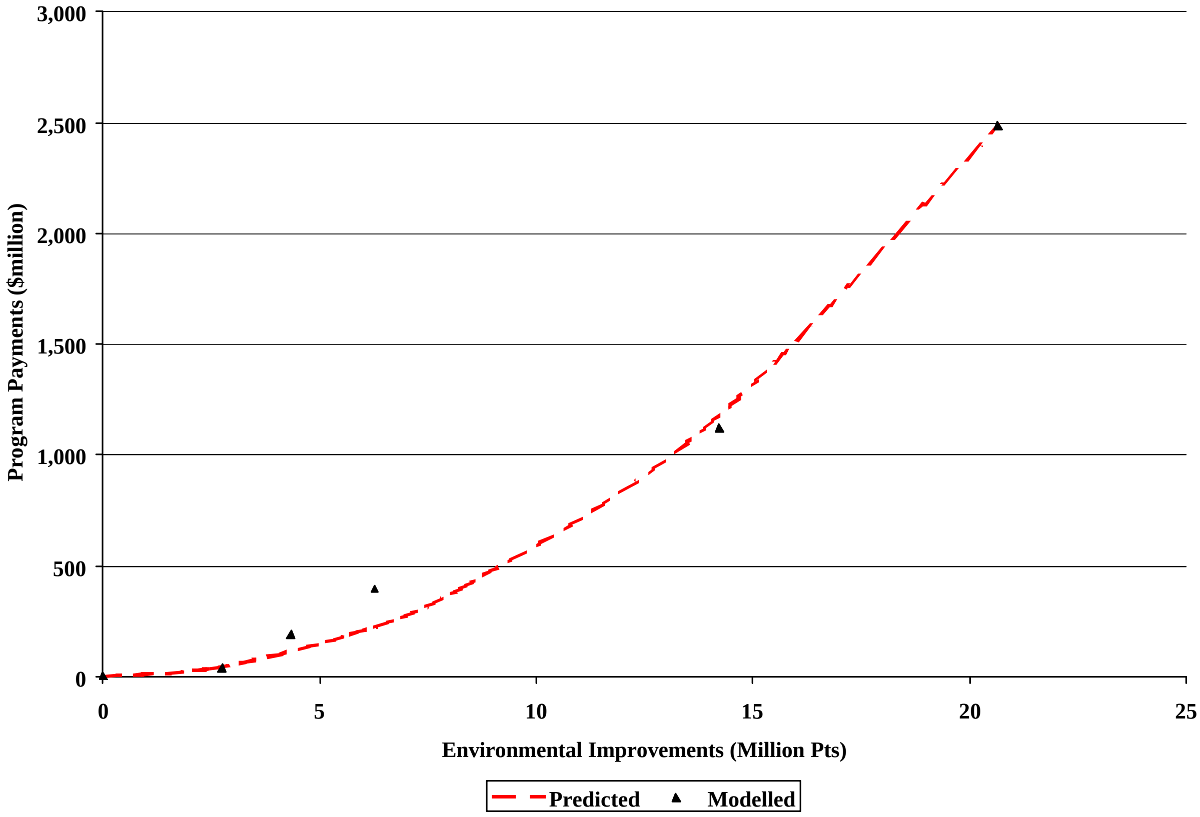
[6] Note that we are implicitly assuming that 100% of the foregone revenue incurred by farmers to implement best management practices are covered by the program.

By mapping increasing levels of the payment for benefits points ($/pt) and the resulting level of abatement it is possible to trace the abatement versus program payment curve. A simple quadratic function was fit to the policy simulations (Figure 2) to represent aggregate program payments: $C(A^P) = 0.00000505(A^P)^2$, where the superscript P represents “practice-based”. A given policy with a finite budget of approximately $1 billion annually (roughly equivalent to proposed EQIP funding over the next decade) could potentially generate approximately 14 million environmental quality points.

Figure 2. Aggregate Abatement Costs for a Practice-Based Policy

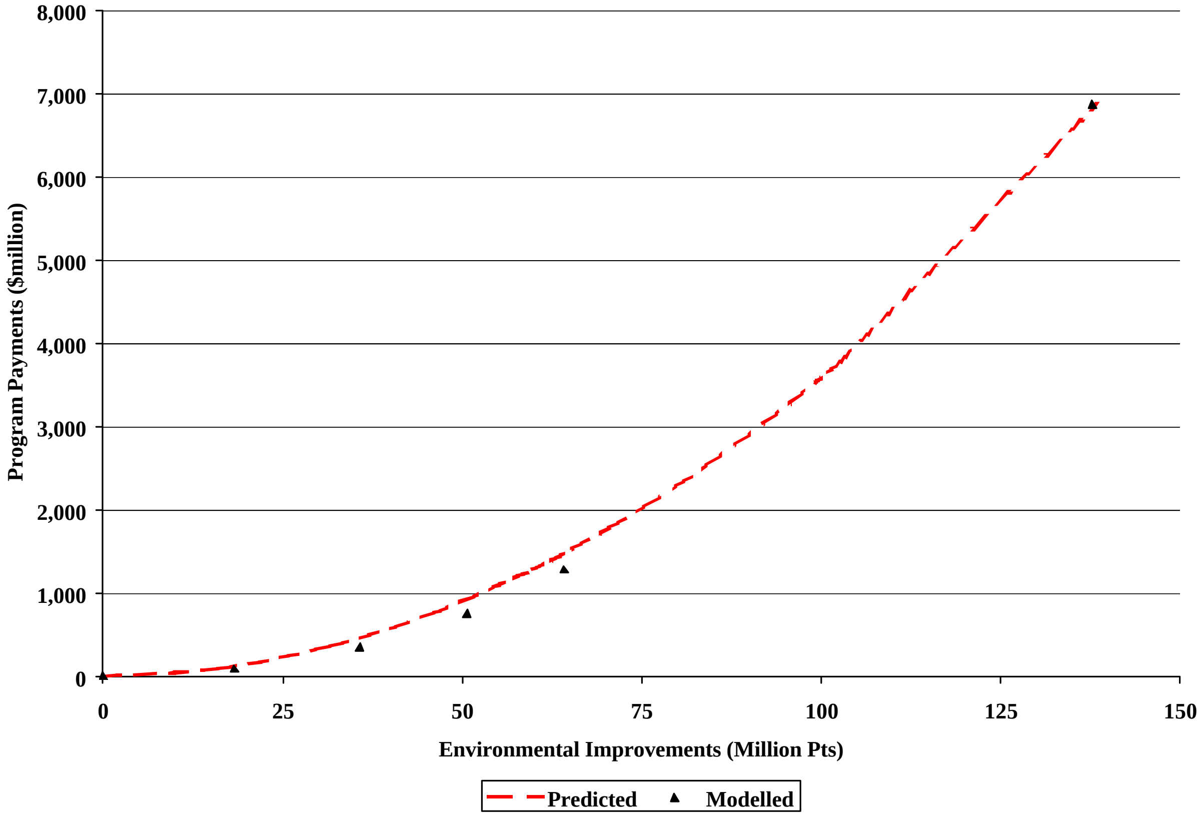


Keep in mind, though, that a large share of the practice-based budget is used to pay good actors; i.e., those producers that were producing ex-ante at eligible levels. In this case the percentage of funds allocated to good-actor payments is approximately 60% of the program. While changing the reference-level may shift this percentage, so that more of the budget is used to generate environmental quality and less is used to reward past efforts, the net effect of raising or lowering the reference-level is surprisingly small. When the bar is raised, so to speak, fewer good-actors are rewarded, however those practices that are now eligible for payments are harder and more expensive to implement especially for the more polluting farmers. Conversely by lowering the bar, more dollars are spent on good-actor payments, but it is relatively inexpensive for the high level polluters to participate.

Performance-Based Policy

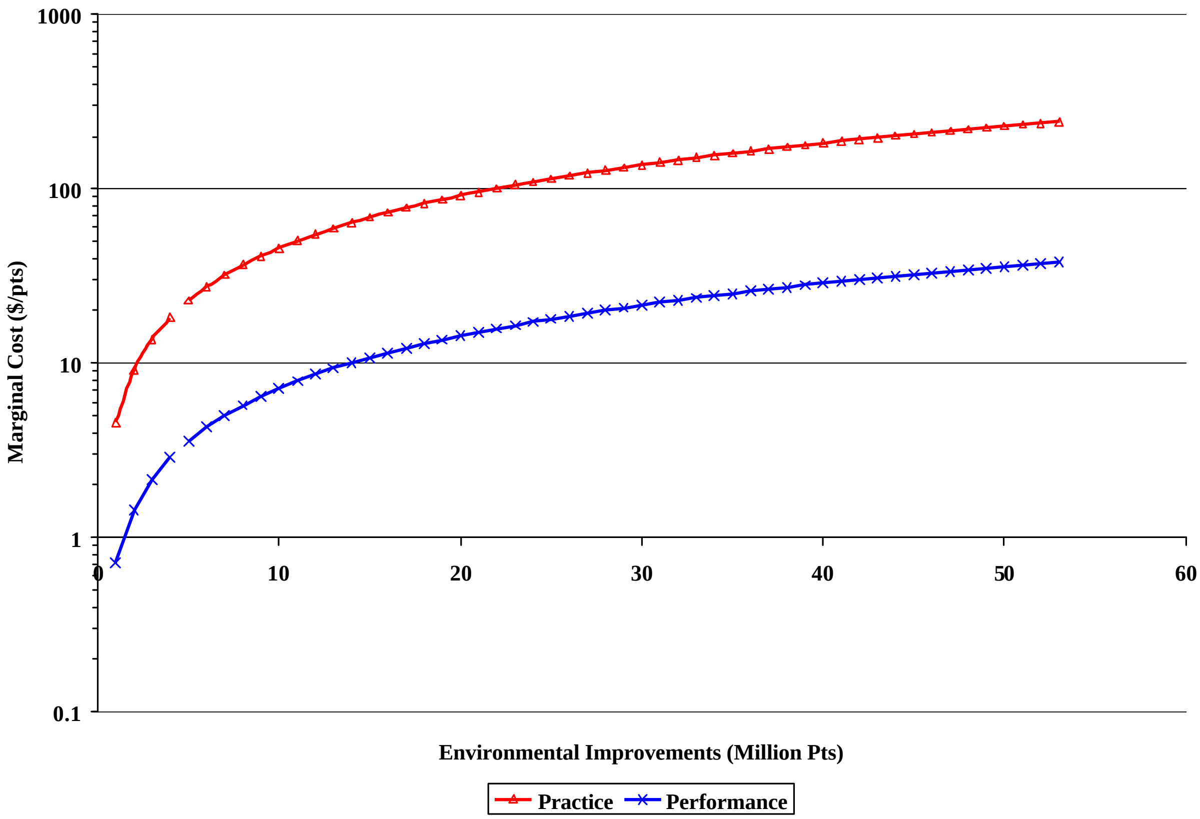
When there is no reference-level in effect and agri-environmental payments are available for all production practices, aggregate payments for the same level of abatement obviously are much lower. To estimate the abatement versus program payment curve for a voluntary participation policy that decouples benefits payments from good-actor payments once again it is necessary to solicit bids from all producers for the provision of ex-post benefits. Here each producer is eligible to submit a bid stating her schedule of estimated costs and benefits. The policymaker then accepts bids seeking to maximize benefits subject to a fixed budget. The estimated curve for the performance-based policy is $C(A^E) = 0.000000359(A^E)^2$, where superscript E represents “performance-based”. Such a policy with a budget of $1 billion could potentially generate 52.7 million environmental quality points. However, this does not include the cost of paying good-actor premiums. In addition, while all management practices are available to producers who wish to participate in the program, the payments are based on net environmental effects so that adoption of more-polluting practices will result in a lower net payment to the producer.

Figure 3. Aggregate Abatement Costs for a Performance-Based Policy



In order to compare the cost-effectiveness of each program, good-actor payments were subtracted from aggregate program payments under the practice-based policy and another abatement versus payment curve was estimated: $C'(A^P) = 0.00000229(A^P)^2$. This insures that the comparison of program payments is based solely on the generation of environmental quality points. The cost-effectiveness at achieving environmental benefits for these policies can then be compared in terms of the marginal program cost to achieve environmental benefits (Figure 4). Clearly the more flexible the policy is, the lower the marginal costs will be. Practice-based programs that restrict payments on the basis of acceptable management practices are not as cost-effective at achieving broadly defined environmental benefits as are performance-based programs.

Figure 4. Marginal Abatement Costs



However, under more efficient programs, farms that have been "bad" actors in the past will receive the majority of the agri-environmental payments, which is deemed unfair by some. A compromise between the two might evolve to resemble something like a performance-based policy with good-actor payments. Under such a policy an exogenously determined reference-level is chosen to define good actors. Once this determination is made these farms receive a premium for being a good actor corresponding to their level of past benefit production. The main difference between this policy and the practice-based policy is that once you are determined *not* to be a good actor in the past, you are not eligible to receive good-actor premiums even if your future production practices lie above the reference-level. Good-actor premiums notwithstanding, all producers are eligible for performance-based agri-environmental payments.

How a policymaker might distribute good-actor payments under an efficient policy framework is unclear. One possible method for combining good-actor payments and efficient conservation initiatives is to first decide on the percentage of the budget to be used as agri-environmental payments for the provision of ex-post benefits and the percentage to be used to reward good actors. Let the weights a and (1- a) describe which portion of the budget will go to generating future environmental benefits and which portion will be used to reward past performance, respectively. Once these weights are determined a hurdle rate is chosen to determine which farms are to receive good-actor payments. Because the good-actor payment is not linked to ex-post production decisions the distribution of these payments will not change the marginal costs of achieving environmental benefits. The total cost curve (Figure 3) for the performance-based policy will not change in slope, but its intercept shifts up depending on a and (1- a). For example, suppose that weights a and (1- a) were chosen to be 0.4 and 0.6. In such a case with a $1 billion budget, approximately $400 million would be available for generating performance-based environmental benefits. Such a policy would potentially yield 33.4 million benefit points, roughly 58% more than under the practice-based policy with a similar budget.

Environmental Benefits

When comparing these policies, we have used benefits points to compare aggregate abatement costs. What comprises an equivalent level of abatement is also of interest for it describes changes in aggregate benefits across the U.S. Because certain policies offer different incentives for different management practices the shifts in production practices in response to such conservation programs may not be identical for a given environmental goal. To evaluate all the regional changes in externalities under the various policies considered would be difficult in a parsimonious manner. National changes resulting from a practice-based and a performance-based policy are provided to illustrate how these policies under certain circumstances result in different levels of abatement for the individual externalities for a given level of aggregate abatement (Table 3). A benefit payment level of $10 per point results in aggregate abatement of approximately 7 million points under the practice-based policy. Including good-actor premiums, this program would entail aggregate payments of $395 million. A payment level of $1.50 per point results in similar aggregate abatement under the performance-based policy with aggregate payments of $10.8 million (excluding good-actor premiums).

Table 3. Composition of Environmental Benefits (7 Million Benefit Points)

Annual Externality Base[a]		Practice-Based Abatement[b]		Performance-Based Abatement	
Nitrogen Estuary	(38.89 lbs.)	1.79	4.59 %	1.73	4.44 %
Nitrogen Ground	(1,706.03 lbs.)	18.46	1.08 %	31.73	1.86 %
Phosphorus	(44.22 lbs.)	2.46	5.57 %	2.35	5.32 %
Sheet and Rill Erosion	(47.63 tons)	2.43	5.09 %	2.19	4.59 %
Wind Erosion	(717.59 tons)	57.13	7.96 %	9.74	1.36 %
Loss in Soil Productivity	($372.35)	274.80	73.80 %	156.10	41.92 %
Carbon Emissions	(114.19 metric tonnes)	1.02	0.90 %	0.98	0.86 %
Pesticides Surface	(140,625.26 TPUs)	296.85	0.21 %	559.87	0.40 %
Pesticide Ground	(36,321.81 TPUs)	324.65	0.89 %	700.41	1.93 %

[a] The annual externality base was calculated by summing the potential pollutant mass (in millions of units) arriving at the relevant medium across all current production systems and regions. [b] Abatement levels are shown not in benefits points, but in the decreased mass of each pollutant (in millions of units) arriving at the relevant medium due to the adoption of new conservation practices.

Given that these two policies generate approximately the same effect on the aggregate environment it is interesting to note how the individual amounts of the pollutants are different. Under the performance-based policy, a greater percentage of environmental benefits are achieved by reducing the amount of nitrogen to ground water and pesticide discharges. The practice-based policy generates a greater percentage of benefits via increasing soil productivity and reducing wind erosion.

Obviously these results are a function of many complex policy and environmental parameters. It may be possible to simplify the policy approach by focusing on a more narrow set of pollutants. If certain externalities were highly correlated it might be feasible to remove them from the aggregate environmental index without loss in environmental cost-effectiveness. One way to identify key variables in a reduced form for the environmental quality index is to examine the correlation matrix of the nine pollutants (Table 4).

Table 4. Environmental Correlation Matrix[a]

Correlation	Sheet	Nitr_G	Nitr_E	Phos	Prod	Carbon	Wind	Pest_S	Pest_G	Sum
Sheet	1.00									
Nitr_G	-0.04	1.00								
Nitr_E	0.32	0.08	1.00							
Phos	0.56	0.21	0.35	1.00						
Prod	0.01	-0.10	0.04	0.04	1.00					
Carbon	0.17	-0.01	0.05	0.12	-0.20	1.00				
Wind	0.17	-0.06	-0.04	-0.03	-0.04	0.09	1.00			
Pest_S	0.10	-0.02	0.01	0.14	-0.03	-0.06	0.03	1.00		
Pest_G	-0.02	0.31	0.04	0.15	-0.03	-0.14	-0.04	0.04	1.00	
Sum	0.55	0.55	0.54	0.72	0.11	0.35	0.14	0.12	0.38	1.00

[a] Sheet = sheet and rill erosion, Nitr_G = nitrogen discharge to ground water, Nitr_E = nitrogen discharge to estuaries, Phos = phosphorus discharge to surface water, Prod = loss in soil productivity, Carbon = carbon emissions, Wind = wind erosion, Pest_S = pesticide discharge to surface waters, Pest_G = pesticide discharge to ground water, Sum = aggregate environmental index (equation 3).

This matrix indicates the correlation between the externalities across all possible management choices. For example, changes in management practices resulting in reduced levels of sheet and rill erosion (*Sheet*) are associated with increased nitrogen loading to groundwater (*Nitr_G*), when weighted by the respective RDEs for these two pollutants. Abatement of all the pollutants is obviously related to positive movement in aggregate environmental quality (*Sum*). In addition it appears that phosphorus abatement has the largest positive correlation nationally with environmental quality and soil productivity the least. There are very few externalities that are highly correlated with each other, excluding that between soil erosion and phosphorus. However, phosphorus discharge to surface water is positively correlated with all pollutants with the exception of wind erosion. Despite the relatively low cross-correlations, a national policy of simply paying for phosphorus abatement may generate positive levels of abatement for all the other pollutants with the exception of wind erosion, which may actually increase slightly.

Suppose that this is the case and policymakers implement a national performance-based policy paying producers to reduce phosphorus discharge to surface waters. An example payment per point of phosphorus abatement is chosen to be $5.00, which would entail $8 million in agri-environmental payments (Table 5). Such a policy would result in positive reductions in all the externalities including wind erosion. Comparing the abatement levels across all the externalities reveals that this phosphorus-based performance policy would generate a total of 3.56 million environmental benefits points, or $2.25 per environmental point generated.

Table 5. Simplified Performance-Based Policy

Annual Externality Base		Abatement	
Nitrogen Estuary	(38.89 lbs.)	1.55	3.98 %
Nitrogen Ground	(1,706.03 lbs.)	4.55	0.27 %
Phosphorus	(44.22 lbs.)	2.25	5.09 %
Sheet and Rill Erosion	(47.63 tons)	2.03	4.27 %
Wind Erosion	(717.59 tons)	3.80	0.53 %
Loss in Soil Productivity	($372.35)	122.26	32.84 %
Carbon Emissions	(114.19 metric tons)	0.13	0.11 %
Pesticides Surface	(140,625.26 TPUs)	250.23	0.18 %
Pesticide Ground	(36,321.81 TPUs)	251.30	0.69 %

While comparisons are not easily made for many of the reasons discussed earlier, if we compare the average cost per point under this policy (Table 5) to the performance-based policy (Table 3) it can be seen that the phosphorus-based performance policy is less efficient than the performance-based policy ($1.50 per point), but more efficient than the practice-based policy ($10 per point).

Using a similar approach it is possible to examine the correlation matrices for each of the USDA Farm Production Regions in the United States (Corn Belt, Lake States, Northeast, Applachia, Southeast, Delta States, Southern Plains, Northern Plains, Mountain and Pacific Regions). This might assist in catering agri-environmental policies to the most relevant pollutant(s) for each region. As an example, in Appalachia the pollutant having the largest correlation with environmental quality remains phosphorus (Table 6a).

Table 6a. Environmental Correlation Matrix: Appalachia

Correlation	Sheet	Nitr_G	Nitr_E	Phos	Prod	Carbon	Wind	Pest_S	Pest_G	Sum
Sheet	1.00									
Nitr_G	-0.08	1.00								
Nitr_E	0.50	-0.37	1.00							
Phos	0.75	0.15	0.14	1.00						
Prod	0.24	-0.06	-0.04	0.20	1.00					
Carbon	0.44	0.02	0.13	0.38	-0.19	1.00				
Wind	0.31	0.38	-0.09	0.43	-0.07	0.02	1.00			
Pest_S	0.07	-0.07	0.02	0.17	-0.33	0.25	-0.04	1.00		
Pest_G	-0.19	0.05	-0.13	0.18	-0.15	-0.16	0.17	0.19	1.00	
Sum	0.46	0.49	0.13	0.71	0.17	0.33	0.39	0.14	0.53	1.00

However, in the Corn Belt sheet and rill erosion feature more prominently in aggregate environmental quality (Table 6b).

Table 6b. Environmental Correlation Matrix: Corn Belt

Correlation	Sheet	Nitr_G	Nitr_E	Phos	Prod	Carbon	Wind	Pest_S	Pest_G	Sum
Sheet	1.00									
Nitr_G	-0.10	1.00								
Nitr_E	0.28	0.01	1.00							
Phos	0.54	-0.23	-0.09	1.00						
Prod	0.04	-0.08	0.01	0.19	1.00					
Carbon	0.25	-0.03	0.17	0.18	-0.26	1.00				
Wind	0.03	-0.11	-0.13	0.12	0.23	0.08	1.00			
Pest_S	0.22	-0.11	-0.08	0.36	0.20	-0.06	0.04	1.00		
Pest_G	0.12	0.10	0.15	-0.01	0.27	-0.16	-0.08	0.14	1.00	
Sum	0.75	0.09	0.59	0.59	0.21	0.48	0.04	0.22	0.25	1.00

CONCLUSIONS

These results are sensitive to the weights placed on the various externalities and the functional form chosen to represent aggregate environmental quality. However, there are some general conclusions to be drawn from these policy simulations. First is that agri-environmental payments for the provision of broadly defined environmental benefits requires a measure of aggregate environmental quality, without which measuring the effects of such policies is impossible. It is also possible to simplify analysis by identifying the key pollutant or pollutants by region that have the greatest effect on aggregate environmental quality and that are positively correlated with the majority of the other variables. Nationally it appears that phosphorus discharge to surface waters is most highly correlated with environmental quality (as defined above). When this effect is examined at smaller scales, such as farm production regions the externality having the highest correlation with environmental quality is less clear.

A second conclusion is that practice-based policies that limit eligible production practices are less cost-effective than performance-based policies. The magnitude of efficiency gains is dependent on the exogenous budget, the chosen reference-level and the distribution of “bonus” or “good-actor” payments. However, we show that for a $1 billion policy that provides generous payments to good actors, a performance-based policy generates nearly 60% more environmental benefits than does a practice-based policy.

Lastly, it is unclear what shape these new conservation initiatives will eventually take. Results suggest that the level, type and geographic distribution of environmental benefits will depend significantly on both program design and the level of funding. For example, the new Conservation Security Program has an estimated annual funding level of $200 million annually over the next decade. Suppose that policymakers use fifty percent of this budget for new conservation incentives and fifty percent to reward past behavior in the form of good-actor payments. Such a funding level coupled with a performance-based policy has the potential to improve aggregate environmental quality (as defined earlier) by 3.5%. A similar policy with a $1 billion budget could improve aggregate environmental quality by 10.2%.

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