COST EFFECTIVENESS OF ALTERNATIVE SUBSIDY STRATEGIES FOR SOIL EROSION CONTROL

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Abstract

This article reports on analyses of the cost effectiveness of three soil erosion control policy alternatives, specifically 1) uniform-rate cost sharing, 2) variable-rate cost sharing, and 3) fixed subsidy payments per unit reduction in erosion. A brief discussion of the place of these alternative subsidy strategies within the context of the current policy environment is presented. Integer programming is employed to simulate adoption of "best management practices" (BMPs) on a set of representative farms in a case study watershed in response to these alternative subsidy strategies. Conclusions and policy implications are outlined.

Key words: cost effectiveness, subsidies, cost sharing, policy, soil erosion.

Soil erosion control policy in the United States has received much criticism in recent years, with the cost effectiveness of major programs being questioned (USGAO). A number of innovative changes in these programs have been introduced or suggested. This article reports on comparative analyses of the cost effectiveness of the traditional strategy of uniform-rate cost sharing to induce voluntary adoption of soil erosion control practices and two alternative subsidy strategies. One is variable-rate cost sharing, where rates depend on characteristics of the practice and the field to which it is applied. The other involves offering a fixed subsidy per ton of erosion reduction. The primary hypothesis tested is that cost effectiveness is improved in shifting from uniform- to variable-rate cost sharing to the fixed subsidy payment approach. What follows first is a discussion of the policy environment in which these alternatives arose

and the logic behind them. Second, best management practice (BMP) options and costs are specified for representative farm units in a case study area. Third, an integer programming model is employed to simulate the three subsidy strategies and allow comparison of their cost effectiveness. Finally, conclusions and implications are drawn with regard to soil erosion control policy.

THE SOIL EROSION CONTROL POLICY ENVIRONMENT

Though regulatory or tax policy approaches for gaining soil erosion control are often analyzed (Taylor and Frohberg; Boggess et al.; Walker and Timmons; Spurlock and Clifton; or Seale et al.) and calls for mandatory soil erosion control are increasingly heard (Cook; Epp and Shortle), subsidization to induce voluntary adoption of BMPs appears likely to be the general policy approach for the foreseeable future (Sharp and Bromley; AAEA Task Force). Subsidy programs have generally been designed to compensate farmers by an amount equal to or greater than their net BMP cost, that is, gross costs for BMP adoption less the economic return from on-site productivity benefits of soil erosion control, though Michalson and Brooks have argued for off-site damages as a basis for subsidy amounts. Cost effectiveness in the use of public funds for subsidization is a matter of concern because these funds are limited.

The question of how to define cost effectiveness with regard to soil erosion control has received a great deal of attention (USGAO). Ideally, cost effectiveness should be defined in terms of damages avoided, both on- and off-site. However, given the limitations on such information, the focus in this study is on cost effectiveness as reflected by cost per unit reduction in the annual average

erosion rate based on the Universal Soil Loss Equation (USLE).

The Agricultural Conservation Program (ACP), the primary federal effort to encourage soil erosion control, employs a cost-sharing approach for offering subsidies. Uniform cost sharing at a 50 percent rate was the rule until recently, regardless of the particular situation and characteristics of the farmer, the rate of erosion on the field to be treated, or the particular BMP to be applied. This is true even though the minimum percentage cost-share necessary to induce adoption of BMPs may vary greatly across farmers, fields, and practices (Mitchell et al.; Johnson et al.). As a result, under uniform cost sharing some farmers receive "rents," that is, cost-share payments in excess of their net BMP costs. Walker and Timmons found that under a uniform per acre subsidy approach these "rents" may be quite sizable.

In a more formal sense, the inability or unwillingness of ACP administrators to practice perfect price discrimination (i.e., eliminate all "rents") in their role as a monopsonist buyer of soil erosion control leads to total subsidy payment costs in excess of the minimum amount necessary to induce any particular level of soil erosion control. Rents could be reduced to zero if cost-sharing rates could be varied on a field-by-field basis as additional increments of erosion reduction were sought. Some studies have argued for this (Johnson et al.) or defined "optimal" cost-sharing rates in this way (Bouwes et al.). However, administrative costs and political constraints restrict the extent to which such price discrimination in cost-share rate offers can be employed (Walker and Timmons). Use of a bidding scheme, as in the 1983 Payment-in-Kind program or the Conservation Reserve Program of the Food Security Act of 1985, could be a way of reducing rents with relatively low transactions costs.

The ACP recently has been modified in several ways in an attempt to increase cost effectiveness. These efforts came in response to documentation that in recent years the bulk of cost-sharing funds has been directed toward slight erosion problems, where cost per unit of erosion reduction is relatively high. Only 28 percent of cost-sharing funds was allocated for BMPs on fields estimated to be eroding at an annual average rate of greater than 10 tons per acre, where cost per unit of erosion reduction is relatively low (USDA, 1980a). As a

result, some ACP funds are now being targeted to highly erosive watersheds and counties. In addition, a pilot Variable Cost-Share Level (VCSL) program is being implemented (USGAO).

As initially designed, one of two forms of the VCSL option could be employed by counties. In one, cost-sharing rates were based on the initial erosion rate and the percentage reduction achieved in the erosion rate. This percentage erosion reduction (PER) form was later modified to consider differing soil loss tolerance or T-values across soils, reflecting the idea that a ton of erosion reduction is more valuable on some (generally shallow) soils than on other soils, due to the importance of on-site damages.[1] Percentage reduction, as estimated by pre- and post-practice application of the USLE, is multiplied by the appropriate "weighting" factor (Table 1) to arrive at the cost-sharing rate. The maximum cost-share rate allowed is 75 percent. For example, terraces which reduce the erosion rate on a field with T = 5 from 12 to 6 tons per acre per year (a 50 percent reduction) would qualify for 40 percent cost sharing (50 percent × 0.8 = 40 percent).

TABLE 1. WEIGHTING FACTORS FOR PERCENTAGE EROSION REDUCTION FORM OF VARIABLE COST-SHARE LEVEL OPTION IN THE AGRICULTURAL CONSERVATION PROGRAM, 1983

Prepractice erosion rate (tons per acre per year)	T-value			
	T = 2	T = 3	T = 4	T = 5
20 +	1.3	1.3	1.3	1.3
18 + thru 20	1.3	1.3	1.3	1.2
16 + thru 18	1.3	1.3	1.3	1.1
14 + thru 16	1.3	1.3	1.2	1.0
12 + thru 14	1.3	1.3	1.0	.9
10 + thru 12	1.3	1.1	.9	.8
8 + thru 10	1.3	1.0	.8	.7
6 + thru 8	1.1	.8	.7	.7
4 + thru 6	.9	.7	.7	.7[a]
4 or less	.7	.7	0	0

[a] If prepractice erosion rate is not in excess of T, the weighting factor is 0.

Source: U.S. Government Accounting Office.

Alternatively, participating counties could choose another form of the VCSL option that based cost-sharing rates on the land capability class (LCC) of the field to be treated. In this LCC form the cost-sharing rate was set at 45 percent for class I and II land, 55 percent for class III land, 65 percent for class IV land, and 75 percent for class VI and VII land. As under the other form of the VCSL option, no cost sharing was available where soil loss

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[1]According to the Soil Conservation Service, the T-value for a soil represents the maximum soil erosion rate permissible if the soil is to sustain a high level of economical crop productivity for the indefinite future (USGAO).

tolerance was already being met. However, the LCC form was eliminated as an option after the initial year of the program, apparently because of the limited number of counties employing this form and concern about its effectiveness.

The VCSL option can potentially improve public cost effectiveness in three ways: 1) by eliminating cost sharing where soil loss tolerance is already being met, 2) by encouraging some application of BMPs to highly eroding fields (where cost per unit of erosion reduction is relatively low) which would not have taken place with 50 percent cost sharing, and 3) by discouraging some application of BMPs to slightly eroding fields (where cost per unit of further erosion reduction is relatively high) which would have taken place with 50 percent cost sharing.[2] However, the VCSL option will not necessarily reduce rents as a percentage of total cost-sharing expenditures.

The shift from uniform-rate cost sharing to the PER form of the VCSL option represents a significant step in the direction of a strategy which would employ a fixed subsidy payment per unit of erosion reduction. This is because under this form of the VCSL option, generally speaking, the greater the erosion rate reduction, the higher the cost-sharing rate and subsidy payment. A fixed subsidy payment per ton (SPT) strategy would do so proportionally. The appeal of this Pigouvian subsidy strategy is in assuring that only BMPs with a public cost per ton of erosion reduction lower than the subsidy payment per ton would be adopted. As a result, a given amount of erosion reduction would be achieved at lowest total net BMP costs, though the potential for substantial "rents" would remain. An SPT strategy, referred to as the bonus contract approach, did appear on the list of alternatives developed in the recent Resources Conservation Act review and assessment of soil erosion control policy (Brubaker and Castle).

As noted earlier, a number of studies have compared efficiency, equity, and other attributes of tax, subsidy, and regulatory policies for soil erosion control. A few have focused on subsidies and addressed the question of principles for design of variable subsidies or cost-share rates (Walker and Timmons; Michalson and Brooks; Kugler). This study seeks to address soil erosion control policy as it has actually existed and evolved,

and as it could conceivably evolve in the future. This study estimates, for a particular watershed, how public cost effectiveness has been or could be affected by marginal changes within the subsidization approach.

BMP OPTIONS AND COSTS
FOR FARMS IN THE STUDY AREA

The North Fork Forked Deer (NFFD) Watershed in West Tennessee, where an ACP water quality project was initiated in 1979, served as the case study area for the analyses. The NFFD Watershed comprises 80,190 acres in the central portion of the Obion-Forked Deer River Basin. The project application indicates that of the 45,119 acres of cropland in the watershed, 20,150 acres were considered to have a critical erosion problem, as reflected by their average erosion rate of 47.5 tons per acre per year (USDA, 1980b). Analysis of yields for the major soil type in the watershed suggests that at such an erosion rate soybean yields may decline as much as three bushels per acre over a 10-year period (Hunter and Keller). Water quality data indicate that the NFFD River has experienced high levels of suspended solids and turbidity and that aquatic life and recreation criteria have been exceeded for several pollutants. Land damage from sediment deposition was estimated to amount to $175,383 annually for the watershed (USDA, 1980b).

Fifteen representative farms were developed on the basis of survey information from a random sample of 76 farm units (10 percent of the total in the NFFD Watershed) and a Soil Conservation Service study of the watershed (USDA, 1980b). The farms were differentiated on the basis of soil type (Grenada/Loring, Lexington-Ruston, Memphis), slope of fields (0–2 percent, 2–5 percent, 5–8 percent, 8–12 percent), tenure status (owner-operator or renter), crops (soybeans, wheat, corn), livestock (beef cattle or not), tillage practices (conventional, reduced, no), and ownership of earth-moving equipment (yes or no). There are clearly other factors which influence farmers' behavior with regard to adoption of BMPs, such as farmers' attitudes toward conservation and their current financial situation. However, the above factors are ones which 1) could be expected to substantially affect farmers' estimates of gross costs of BMPs and on-site productivity benefits and 2) were associated with several as opposed to a single

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[2]Cost effectiveness may also be affected to the extent that BMPs that would have been adopted at the uniform 50 percent rate are also adopted at either a lower or higher rate under the VCSL option.

farmer and thus allowed for a reasonably small number of representative farm situations.

To remain relatively consistent with the characteristics of the ACP water quality project, which required reduction of erosion rates to approximately soil loss tolerance, only BMP options which reduced erosion rates to less than eight tons per acre per year were considered. These BMP options were taken from the set available for cost sharing in the project.[3] Erosion rate reductions were estimated with the USLE and information specific to West Tennessee provided by Jent et al. Fields with 0–2 percent slope required no BMPs to achieve soil loss tolerance. Terraces with reduced tillage or no-till without winter cover were specified as BMP options for fields with 2–5 percent slope. Terraces with reduced tillage, no-till with winter cover, or establishment of permanent vegetative cover were specified as BMP options on fields with 5–8 percent slope. Establishment of permanent vegetative cover was the only BMP option considered available on fields with 8–12 percent slope.

Information from Hunter and Keller, Blisard and Keller, and Ray and Walch was used to develop estimates of gross costs for application of each BMP to each field for a 10-year period beginning in 1982, discounted to present value in 1982 dollars at 8 percent.[4] Based on discussion with local SCS personnel, the gross cost of terraces was estimated to be 20 percent lower if the operator owned earth-moving equipment and thus could be expected to contribute labor with an opportunity cost equal to zero during periods of inactivity. The gross cost of no-till varied by crop and the gross cost for winter cover varied by soil type. The gross cost of permanent vegetative cover establishment differed by livestock enterprise and by soil type, given the explicit consideration of forgone net returns from soybean production. Reduced tillage, which was required along with terraces on some fields, was assumed to involve zero cost, as enterprise budgets show little difference in expected net returns and many farmers are shifting to reduced tillage on their own.

The present value of on-site productivity benefits from reductions in erosion was estimated based on soil loss-productivity rela-tionships for major soils in the NFFD Watershed reported in Hunter and Keller. Normalized 1982 prices based on a 10-year trend of prices received by Tennessee farmers were employed. No assumptions were made with regard to the possible impact of future technological change. On-site benefits were subtracted from gross costs to arrive at net cost to the farmer for each BMP on each field. These productivity benefits differed by soil type, crop, and prior tillage practice, which influence the initial erosion rate and thus erosion reductions. Owner-operators were assumed to fully account for productivity benefits, while renters were assumed to recognize none. This is admittedly a somewhat arbitrary assumption. However, year-to-year lease arrangements are relatively common in West Tennessee, so renters' time horizons can be expected to be relatively short. This assumption is also consistent with the very limited participation of rental farm units in the ACP.

These gross cost and on-site productivity benefits allowed specification of net costs for each BMP, which indicates the minimum cost-share payment required to induce voluntary adoption. To arrive at what cost-share payment would be offered under uniform-rate cost sharing and the VCSL option, it was also necessary to specify the cost basis for cost sharing, which under the ACP may differ from gross BMP cost. The cost basis for cost sharing in the ACP generally takes into account only out-of-pocket expenses. However, for permanent vegetative cover establishment, gross cost must take into account not only out-of-pocket establishment expenses but also the differences between foregone net returns from row crop production and net returns from pasture (Ray and Walch). In some cases then, even 100 percent cost sharing of out-of-pocket establishment expenses would not induce voluntary adoption. For no-till, just the opposite occurred. The cost basis of $18 per acre established for cost sharing in the water quality project was somewhat above our gross cost estimate, which reflected increased out-of-pocket expenses for chemicals and equipment, but also reduced costs for labor and fuel (Ray and Walch). For fields where winter cover was required with

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[3]Cost effectiveness might be increased by allowing practices which do not meet this requirement. However, analyzing this particular constraint on cost effectiveness was not an objective of this study.

[4]Alternative assumptions regarding planning horizon and discount rate would change the absolute cost estimates for BMPs. However, this would not be expected to substantially affect the relative comparison of alternative subsidy strategies, the primary focus of this paper.

no-till, it was assumed a wheat crop would be harvested, and gross BMP cost took this into account. However, based on ACP rules, no cost sharing was available for winter cover. Terrace costs estimated by Blisard and Keller were used to represent both gross BMP cost and the cost basis for cost sharing. No cost sharing was offered in the special ACP project for reduced tillage.

The Grenada-Loring soil combination is the dominant one in the watershed and has fields with all possible slopes and thus all possible BMPs. As such, representative information for this soil combination is provided in Table 2 to indicate how net cost per acre, net cost per ton of erosion reduction, and minimum cost-share rate (necessary to induce voluntary adoption) vary for the BMPs across field slopes and operator characteristics. A few illustrations of the significance of these figures may be helpful. The minimum cost-share rate necessary to induce voluntary adoption of no tillage with winter cover (NT/WC) on a 5–8 percent slope field is 95 percent for a renter, but 59 percent for an owner due to his recognition of on-site productivity benefits. The minimum cost-share rate for establishment of permanent vegetative cover (PVC) on a 5–8 percent slope field is 65 percent for an owner with livestock, but 177 percent for an owner without livestock due to the assumed lack of any net returns from use for either pasture or hay production. Enterprise budgets for the latter indicate negative returns given the prices and yields expected in this area (Ray and Walch). The minimum cost-share rate for reduced tillage with terraces (RT/T) on a 5–8 percent slope field is

decreased from 79 percent to 59 percent if an owner has earth-moving equipment. Also, net cost per ton generally decreases as slope increases using the most cost efficient BMP in each slope class, but BMP field combinations with lower net cost per ton do not always have lower minimum cost-share rates.

CHARACTERISTICS OF THE INTEGER PROGRAMMING MODEL

The information from the previous section was incorporated into an integer programming (IP) model designed to simulate BMP adoption in response to alternative subsidy strategies. BMP adoption was assumed to occur if the subsidy payment offered was equal to or greater than net BMP cost.

In general terms, the IP model was structured as follows:

$$(1) \quad \text{maximize:} \quad \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}X_{ij},$$

$$(2) \quad \text{subject to:} \quad \sum_{j=1}^{n} f_{1j}X_{1j} \le F_1,$$

$$\vdots$$

$$\sum_{j=1}^{n} f_{mj}X_{mj} \le F_m,$$

$$(3) \quad \sum_{i=1}^{m} \sum_{j=1}^{n} nc_{ij}X_{ij} \le NC,$$

TABLE 2. VARIATION IN COSTS FOR BMPs ON GRENADA-LORING SOILS IN THE NORTH FORK OF THE FORKED DEER WATERSHED OF WEST TENNESSEE, 1982

| Slope of field | BMP[a] | Renter | | | | | | | | | Owner | | | | | | | | |
| | | With neither livestock nor earth-moving equipment | | | With livestock but without earth-moving equipment | | | With earth-moving equipment but without livestock | | | With neither livestock nor earth-moving equipment | | | With livestock but without earth-moving equipment | | | With earth-moving equipment but without livestock | | |
		NCPA[d] ($)	MCSR[c] (%)	NCPT[d] ($)	NCPA ($)	MCSR (%)	NCPT ($)	NCPA ($)	MCSR (%)	NCPT ($)	NCPA ($)	MCSR (%)	NCPT ($)	NCPA ($)	MCSR (%)	NCPT ($)	NCPA ($)	MCSR (%)	NCPT ($)
2–5%	NT	81	67	0.79	45	37	0.83	81	67	0.79	71	59	0.70	39	32	0.72	71	63	1.49
	RT/T	125	100	1.16	125	100	2.23	100	80	0.93	114	91	1.06	114	91	1.08	89	71	0.83
5–8%	PVC	268	177	0.80	118	78	0.35	268	177	0.80	268	177	0.80	98	65	0.29	268	177	0.80
	NT/WC	115	95	0.43	115	95	0.43	115	95	0.43	71	59	0.27	71	59	0.27	71	59	0.27
	RT/T	220	100	0.81	220	100	0.81	176	80	0.65	174	79	0.64	174	79	0.64	130	59	0.48
8–12%	PVC	171	113	0.28	40	26	0.07	171	113	0.28	171	113	0.28	29	19	0.05	171	113	0.28

[a]Base situation is conventional tillage soybeans, except for 2–5% slope fields on farms with livestock where base situation is conventional tillage corn. NT = no tillage; RT = reduce tillage; T = terraces; PVC = permanent vegetative cover; and WC = winter cover.

[b]NCPA = net cost per acre.

[c]MCSR = minimum cost-share rate.

[d]NCPT = net cost per ton.

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$$(4) \qquad \sum_{j=1}^{n} cs_{1j}X_{1j} \le CS_1,$$

$$\vdots \qquad \vdots$$

$$\sum_{j=1}^{n} cs_{mj}X_{mj} \le CS_m,$$

$$(5) \qquad \sum_{j=1}^{n} pt_{1j}X_{1j} \le PT_1,$$

$$\vdots \qquad \vdots$$

$$\sum_{j=1}^{n} pt_{mj}X_{mj} \le PT_m,$$

where:

$i = 1, \ldots, m$ refers to field number;

$j = 1, \ldots, n$ refers to practice number;

$X_{ij} =$ a (0,1) variable representing application of BMP j to field i;

$C_{ij} =$ the erosion reduction resulting from application of BMP j to field i;

$f_{ij} = 1;$

$F_i = 1;$

$nc_{ij} =$ the net cost for application of BMP j to field i;

$NC =$ a limit on total net cost;

$cs_{ij} =$ net cost as a percentage of the cost basis for cost sharing for application of BMP j to field i, representing the minimum cost-share percentage necessary to induce voluntary adoption;

$CS_i =$ the cost-share percentage offered on field i;

$pt_{ij} =$ the net cost per ton of erosion reduction for application of BMP j to field i, representing the minimum payment per ton of erosion reduction necessary to induce voluntary adoption; and

$PT_i =$ the payment per ton of erosion reduction offered on field i.

The objective function (1) involves maximization of total erosion reduction for the NFFD Watershed as a whole. Each BMP-field combination, the (0,1) variable X_{ij}, was specified for an amount of acreage which depended upon the amount of acreage in the watershed represented by the farm unit in which the field was included. For example, consider application of a BMP to a 20-acre field on a 100-acre farm unit. If this farm unit represented 1,000 acres in the watershed, this BMP-field combination would be specified in the IP model for 200 acres. Erosion reduction, C_{ij}, and net cost, c_{ij}, in constraint set (3) would thus be calculated for a 200-acre application of this BMP. The set of constraints labeled (2) limits each field to one BMP. As discussed below, only one of the constraint sets (3), (4), and (5) is in effect at one time. If more than one BMP satisfies the constraint for any particular field, the one which maximizes erosion reduction is selected.

The need for the IP approach can be demonstrated by illustrating how constraint set (4) must function to simulate cost sharing. If 40 percent uniform cost sharing is to be simulated, CS_1 for field 1 would be specified as .40. If the lowest minimum cost-share percentage among the BMPs applicable to field 1 is 80 percent for BMP 1, cs_{11} would be specified as .80. If X_{11} were not a (0,1) activity, X_{11} could enter on a half-field basis to satisfy the constraint. Thus, an integer programming framework with erosion reductions and costs on a whole-field rather than a single-acre basis was required.

EMPIRICAL ANALYSIS OF ALTERNATIVE SUBSIDY STRATEGIES

The IP model was initially employed to establish the "perfect price discrimination" or "no rents" baseline. Simulation of BMP adoption in order of increasing net cost per ton of erosion reduction was accomplished by parametrically varying the right-hand side of the net cost constraint (3) by $100,000 increments up to $2.6 million, at which point all 37 fields were treated. Results are presented

in Table 3 and the total cost curve is labeled "BASELINE" in Figure 1. Twenty "different" BMPs were represented, that is, the three basic BMPs (no-till, terraces, and permanent vegetative cover) differentiated by soil, slope, prepractice crop and tillage, tenure, livestock, and equipment characteristics. Generally speaking, the order of BMP application was permanent vegetative cover on higher slopes, followed by no-till, and then terraces with reduced tillage on lower slopes.

TABLE 3. RESULTS OF BASELINE[a] SIMULATION OF BMP ADOPTION IN THE NORTH FORK OF THE FORKED DEER WATERSHED IN WEST TENNESSEE, 1982

Erosion reduction	Net costs	Cost per ton
(1,000's of tons)	($1,000)	($/ton)
1,522	200	.13
2,212	400	.18
2,755	600	.22
3,206	800	.25
3,609	1,000	.28
3,988	1,200	.30
4,329	1,400	.32
4,629	1,600	.35
4,892	1,800	.37
5,136	2,000	.39
5,371	2,200	.41
5,603	2,400	.43
5,783	2,600	.45

[a]The BASELINE simulation implicitly assumes perfect discrimination or no rents and BMP adoption in order of increasing net cost per ton of erosion reduction.

Uniform-Rate Cost Sharing

Next, the model was employed to simulate alternative rates of uniform cost sharing. The right-hand sides for the minimum cost-share constraints (4) were varied parametrically by 10 percent increments from 10 to 90 percent. The resulting total *public* (taxpayer) cost curve for uniform-rate cost sharing is labeled "UNIFORM" in Figure 1, with individual points on the curve identified by cost-share rate. No BMPs were applied until the cost-share rate reached 30 percent. Information on net costs, erosion reductions, cost-share payments, public cost per ton, and rents as a percentage of cost-share payments is provided in Table 4.
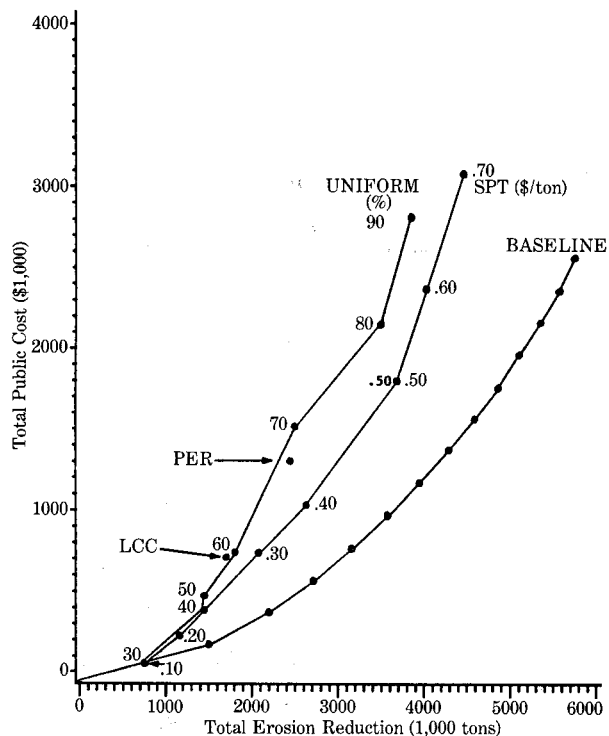

Figure 1. Comparison of the Public Cost Effectiveness of Alternative Subsidy Strategies for BMP Adoption in the NFFD Watershed of West Tennessee, 1982.

TABLE 4. RESULTS OF UNIFORM COST-SHARING (UNIFORM) SIMULATION OF BMP ADOPTION IN THE NORTH FORK OF THE FORKED DEER WATERSHED OF WEST TENNESSEE, 1982

Cost-share rate	Erosion reduction	Net costs	Cost-share payments	Public cost per ton[a]	Rents as a percentage of cost-share payments[b]
(%)	(1,000's of tons)	($1,000)	($1,000)	($/ton)	(%)
10	0	0	0	—	—
20	0	0	0	—	—
30	797	64	73	.09	12
40	1,487	322	402	.27	20
50	1,487	322	502	.34	36
60	1,849	489	772	.42	37
70	2,495	1,105	1,551	.62	29
80	3,515	1,613	2,207	.63	27
90	3,844	2,000	2,845	.74	30

[a]Represents Cost-Share Payments ÷ Erosion Reduction.

[b]Represents [Cost-Share Payments − Net Costs] ÷ Cost-Share Payments.

The "UNIFORM" curve lies above the "BASELINE" curve for two distinct reasons. First, as the uniform cost-share rate is increased, rents are paid in cases where BMPs would have been adopted at a lower cost-share rate. For example, rents represent 30 percent ($845,000) of cost-share payments at the 90 percent cost-share rate. Second, uniform-rate cost sharing results in two types of *social* cost inefficiencies. These inefficiencies account for the additional amount by which UNIFORM lies above BASELINE, almost $900,000 at the 90 percent cost-share rate, for example.

The first type of social cost inefficiency associated with uniform-rate cost sharing stems from the order of BMP adoption. Net cost per ton, an estimate of social cost, is not perfectly correlated with minimum cost-share rate across BMPs. For example, adoption of no-till (from conventional till) corn by an owner-operator on Grenada-Loring soil with 2–5 percent slope has the 15th highest net cost per ton among the 20 BMPs in the BASE-LINE solution but is adopted third in the UNIFORM solution with a minimum cost-share rate of 32 percent. This result is due primarily to the fact that the cost basis for cost sharing is well above gross cost as estimated for this study, though such a divergence is not necessary for uniform-rate cost sharing to generate an inefficient order of BMP adoption in terms of social cost. In addition, renting leads to this type of social cost inefficiency if on-site benefits assumed to be unrecognized by renters are considered a social benefit. That is, less cost efficient BMPs will be adopted by owner-operators before most cost efficient BMPs by renters.

The second type of social cost inefficiency associated with uniform-rate cost sharing stems from adoption of a BMP which is not the socially cost efficient BMP for the field; that is, it is not in the BASELINE set of 20 with lowest net cost per ton. Consider the case of an owner-operator with livestock and earth-moving equipment growing reduced tillage soybeans on Grenada-Loring soil with 5–8 percent slope. Although net cost per ton for permanent vegetative cover is $0.55 compared to $1.00 for terraces, the minimum cost-share rate is 78 percent for permanent vegetative cover compared to 69 percent for terraces. This is due primarily to the lack of accounting for foregone soybean revenue in the cost basis for cost sharing on permanent vegetative cover. This type of social cost inefficiency could also occur without a divergence between the cost basis for cost sharing and gross cost.

The Variable Cost-Share Level Option

To simulate the Variable Cost-Share Level (VCSL) option, the right-hand sides for the minimum cost-share constraints (4) were set at levels dictated by each of the two forms (PER and LCC). The simulation of the percentage erosion reduction (PER) form resulted in just one point in terms of total public cost and erosion reduction, rather than a curve. The same was the case for the land capability class (LCC) form. (See Table 5 and Figure 1.) Based on extrapolation between the 60 percent and 70 percent cost-share levels on UNIFORM, total public cost under the PER form of the VCSL option was 10.6 percent lower than under a 69.4 percent uniform cost-share rate. This increased cost effectiveness was primarily due to cost-share rates under the PER form of only 59 percent for no-till (from conventional till) corn on Grenada soil with 2–5 percent slope, which was still high enough to induce adoption. Public cost under the LCC form was 6.6 percent higher than under a 57 percent uniform cost-share rate. The reduced cost effectiveness in this case was primarily due to cost-share rates under

TABLE 5. RESULTS FROM SIMULATIONS OF BMP ADOPTION UNDER THE VCSL OPTION IN THE NORTH FORK OF THE FORKED DEER WATERSHED OF WEST TENNESSEE, 1982

Form of VCSL option	Erosion reduction	Net costs	Cost-share payments	Public cost per ton[a]	Rents as a percentage of cost-share payments[b]
	(1,000's of tons)	($1,000)	($1,000)	($/ton)	(%)
PER[c]	2,457	945	1,346	.55	30
LCC[d]	1,742	414	738	.42	44

[a]Represents Cost-Share Payments ÷ Erosion Reduction.

[b]Represents [Cost-Share Payments − Net Costs] ÷ Cost-Share Payments.

[c]Percentage erosion reduction.

[d]Land capability class.

LCC of 75 percent for permanent vegetative cover on 8–12 percent sloping fields of farms with livestock, when only 26 percent to 31 percent cost-share rates were required to induce adoption.

It is of interest to note that public cost under the PER form of the VCSL option would have been lower and thus even more cost effective relative to uniform-rate cost sharing, had the weighting factors in the cost-share rate formula not been modified to reflect differing T-values. An initial set of simulations was done prior to this T-value modification, which essentailly increased cost-share rates for soils with T-values of less than five. This modification led to BMP application on several fields with slopes of 2–5 percent, as well as higher cost-share rates on several fields on which BMPs were applied at the original rates before the modification. Total erosion reduction increased by 17 percent as a result of the modification, but at a marginal cost of $1.187 per ton erosion reduction, almost three times the average cost of $.441 for the erosion reduction gained with the original weighting factors of the PER form.

Another basis for evaluating the VCSL option is to compare public cost per ton of erosion reduction under the PER and LCC forms with that of 75 percent uniform cost sharing (as indicated by the point labeled "75" in Figure 1), which is the rate generally paid in targeted water quality projects. Given the maximum 75 percent cost-share rate in the VCSL option, PER and LCC would be viewed as offering reduced rates of cost sharing for BMP application on less highly erosive land. Though erosion reduction would be 18 percent lower under PER as compared to 75 percent uniform-rate cost sharing, public cost per ton of erosion reduction for PER would be 13 percent lower, $.55 compared to $.63. Though erosion reduction would be 42 percent lower under LCC as compared to uniform-rate cost sharing, public cost per ton of erosion reduction for LCC would be 33 percent lower, $.42 compared to $.63. Similar comparisons could be made with the typical 50 percent uniform-rate cost sharing of the ACP.

Points representing both forms of the VCSL option lie well above the BASELINE curve in Figure 1 for the same reasons that UNIFORM lies above BASELINE. Rents account for 30 percent of public cost under PER and 44 percent under LCC. In addition, the socially

cost efficient order of BMP application is not followed. Under both forms, the top three ranked BMPs from the BASELINE set are included but the next most highly ranked BMP under either form is the 12th one.

A Fixed Subsidy Payment Per Unit Reduction

Finally, to simulate a strategy offering a fixed subsidy payment per unit reduction in erosion, the right-hand sides of the net cost per ton constraint set (5) were varied parametrically from $.10 per ton of erosion reduction to $1.50 in increments of $.10. Results are presented in Table 6 for the simulations up to $1.00.[5] The curve representing this strategy is labeled SPT in Figure 1, with individual points identified by the subsidy payment per ton of erosion reduction. The SPT strategy secures the same erosion reduction as 50 percent uniform-rate cost share rates at 20.3 percent lower public cost, the same erosion reduction as 75 percent uniform-rate cost sharing at 29.2 percent lower public cost.

The lower costs under SPT result exclusively from elimination of the social cost inefficiencies in terms of the BMP set and order of adoption. Rents are actually 16 percent greater under SPT than with 50 percent uniform-rate cost sharing and 17 percent greater under SPT than with 75 percent uniform-rate cost sharing. The reason for the higher rents is illustrated by the following comparisons. Total erosion reduction with a 30 percent uniform cost-share rate and total erosion reduction with a $.10 per ton fixed subsidy payment are approximately equal, as are total erosion reduction with a 90 percent uniform cost-share rate and total erosion reduction with a $.60 per ton fixed subsidy payment (Figure 1). Thus, to secure the higher of these two levels of total erosion reduction under UNIFORM by inducing additional BMP adoption with a 90 percent cost-share rate, farmers who would have participated at the lower 30 percent cost-share rate would receive three times the minimum payment necessary to induce adoption. On the other hand, to secure this higher level of total erosion reduction under SPT, some farmers would receive six times ($.60 versus $.10) the minimum payment necessary to induce adoption.

Comparisons of SPT with the VCSL option are also of interest. For achievement of the same total erosion reductions, SPT requires expenditure of 29 percent less in public funds

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[5]Payment levels above $1.00 per ton resulted in very small additional reductions in erosion.

than PER and 38 percent less than LCC. Rents under SPT are 17 percent higher than under PER and 26 percent lower than under LCC. As in the comparison with uniform-rate cost sharing, most of the increased public cost effectiveness from SPT derives from elimination of social cost inefficiencies regarding the set of BMPs adopted.

CONCLUSIONS AND POLICY IMPLICATIONS FOR SOIL EROSION CONTROL POLICY

In drawing conclusions from the findings of this study, important assumptions and limitations, particularly those regarding factors influencing farmers' perceptions of net BMP cost and decision rules for BMP adoption, must be recognized. However, the primary purpose of the study was not to estimate the actual cost of gaining particular amounts of erosion control, but rather to estimate the relative cost effectiveness of alternative subsidy strategies. Violation of assumptions could affect absolute magnitudes of costs greatly, but relative cost differences to a much lesser degree. As such, the following conclusions and policy implications appear appropriate.

Uniform-rate cost sharing imposes a substantial limitation on the cost effectiveness of federal soil erosion control policy because minimum cost-share rates necessary to induce BMP adoption differ widely by BMP and across land and operator characteristics. At the typical 50 percent rate of cost sharing, the combination of rents and social inefficiencies in the BMP set served to more than double public cost per ton of erosion reduction relative to the theoretical minimum, ignoring administrative costs. The social cost inefficiencies resulted primarily from using out-of-pocket expenses as the cost basis for cost sharing.

The PER form of the VCSL option modestly increased public cost effectiveness relative to uniform-rate cost sharing, supporting the primary hypothesis of the study, while the discontinued LCC form actually reduced public cost effectiveness. The increase in public cost effectiveness with the PER form would have been greater with the original weighting factors, as the T-value modifications resulted in relatively high marginal costs for reductions in erosion on fields with T-values less than five and slight erosion problems. Whether this trade-off is justified depends upon the value of on-site damages

TABLE 6. RESULTS OF SUBSIDY PAYMENT PER TON (SPT) SIMULATION OF BMP ADOPTION IN THE NORTH FORK OF THE FORKED DEER WATERSHED OF WEST TENNESSEE, 1982

Payment per unit	Erosion reduction	Net costs	Subsidy payments	Public cost per ton[a]	Rents as a percentage of subsidy payments[b]
($/ton)	(1,000's of tons)	($1,000)	($1,000)	($/ton)	(⁵)
.10	797	64	80	.10	20
.20	1,228	120	246	.20	51
.30	2,118	367	777	.30	53
.40	2,653	556	1,061	.40	48
.50	3,682	1,036	1,841	.50	44
.60	4,023	1,225	2,414	.60	49
.70	4,476	1,531	3,133	.70	51
.80	5,008	2,189	4,006	.80	45
.90	5,497	2,612	4,947	.90	47
1.00	5,869	2,988	5,869	1.00	49

[a]Represents Subsidy Payments ¾ Erosion Reduction.

[b]Represents [Subsidy Payments—Net Costs] ¾ Subsidy Payments.

relative to off-site damages. However, a comprehensive evaluation of the PER form would require consideration of the increased administrative costs incurred in estimating erosion rates and erosion reductions. Conclusions about the advisability of expanding variable cost sharing within the ACP must await evaluation of actual field experience in participating counties. Whether variable cost sharing can develop and maintain acceptability is uncertain because it appears to "reward" those farmers who practice less erosion control. In addition, its effectiveness may be limited because both farmers and SCS technicians may have some incentive to see a higher initial erosion rate generated or to err on the high side in the judgments necessary in specifying factors in the Universal Soil Loss Equation (USLE). A high research priority is, thus, analysis of the VCSL option with actual program participation data.

The SPT strategy offering a fixed subsidy payment per ton of erosion reduction resulted in substantial increases in public cost effectiveness relative to uniform-rate cost sharing and the VCSL option, supporting the primary hypothesis of the study. This occurred primarily due to elimination of social-cost inefficiencies in the BMP set rather than from a reduction in rents. Thus, the SPT strategy may be viewed as a way of dealing with the out-of-pocket expense problem. The feasibility of such a strategy has been increased by implementation of, and several years experience with, the VCSL option, which broke the "uniformity" barrier, both philosophically and administratively, and relies on estimation of erosion rates with the USLE. However, the cost "sharing" approach surely maintains a good deal of sanctity even yet.

An SPT strategy clearly has attractive features if cost effectiveness is measured strictly in terms of public cost per ton of erosion reduction. The T-value modifications in the weighting factors for the PER form of the VCSL option reflect the idea that cost effectiveness should be defined more broadly. Differing on-site damages could be reflected similarly in an SPT strategy by specifying higher payment levels for soils with lower T-values.

The establishment of the Conservation Reserve Program for retirement of highly eroding cropland by the Food Security Act of 1985 suggests that a bidding approach for cost sharing on all BMPs could be politically viable. If farmers' bids approached their minimum cost-share rate required to induce voluntary BMP adoption, rents in total public costs for erosion reduction could be largely eliminated. Research on the expected performance of such a bidding scheme within the ACP would be useful.

The evident willingness on the part of ACP administrators to consider and even experiment with innovative subsidy strategies portends well for future improvements in the cost effectiveness of federal soil erosion control policy. As could be expected, the growing demand for accountability with regard to the product of programs like the ACP and the increasing scarcity in real terms of the basic resource in this particular production process, funds for technical assistance and cost sharing, together are serving to induce significant institutional change in this policy area.

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