Agricultural Economics, 8 (1993) 173–185
Elsevier Science Publishers B.V., Amsterdam

Efficiency of U.S. conservation-compliance program

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(Accepted 31 March 1992)

ABSTRACT

Govindasamy, R. and Huffman, W., 1992. Efficiency of U.S. conservation compliance program. *Agric. Econon.,* 8: 173–185.

Under the conservation-compliance program, most of the individual producers are forced to cut their soil erosion to 7 t per acre annually irrespective of the marginal cost of controlling soil erosion. In a system where coupons to a ton of soil loss were issued to producers and traded, the marginal cost of controlling soil loss within each soil type and across different soil types would be equalized. An instrumental variable procedure was used to determine the effect of soil erosion on net profits. The results for Iowa show that there is considerable difference in the marginal opportunity cost of controlling soil erosion between soil types. By assigning one ton of erosion to Iowa soil type Downs (5–10% slope) instead of Clarion (2–5% slope), there is a savings of $5.00 per acre for the society as a whole. The tradable coupon system is not only efficient, but will also bring in more land under soil conservation.

INTRODUCTION

Although federal soil conservation policies have been evolving since the early 1930s, soil erosion on America's farmlands persists and is expected to intensify in the future if there are increased cropland demands (Crosson and Brubaker, 1982). Given the current state of knowledge, cropland erosion rates in the major crop-producing regions exceed the rate of top-soil genesis. About 44% of all crop-land in the United States is eroding at levels greater than the soil loss tolerance (Council for Agricultural Science and Technology, 1988). This positive net erosion will reduce the long-term productivity of the cropland resources. It also has greater impact on environmental quality and cropland resource for the future.

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These legitimate concerns led to the U.S. government's conservation-compliance program which requires that any land owner farming 'highly' erodible land should develop and apply a suitable conservation plant for that land by 1 January 1990. If this condition is not met, the land owner will not be eligible for most federal farm program benefits. Such a plan must be fully carried out by 1995. The producer is required to reduce the soil losses to no more than 7 tonnes per acre per year ($\mathrm{t\,a^{-1}\,y^{-1}}$). The 7 $\mathrm{t\,a^{-1}\,y^{-1}}$ is fixed for all farms irrespective of the present level of the erosion. Policy makers are searching for more effective methods of encouraging producers to practice greater conservation. In the absence of a comprehensive study about the relative cost–benefit analysis of a suitable conservation program, cross-compliance has been proposed as a first-step incentive strategy in this direction. With cross-compliance, a producer cannot have soil loss in excess of 7 $\mathrm{t\,a^{-1}\,y^{-1}}$ on cropland and qualify for the government farm program. The financial impacts of a hypothetical cross-compliance program were analyzed by Batie and Sappington (1986).

The cross-compliance program forces most of the producers to reduce the soil erosion to 7 $\mathrm{t\,a^{-1}\,y^{-1}}$ irrespective of the marginal cost of the reduction. The benefits from greater soil conservation under the farm program were estimated by McSweeny and Kramer (1986). The marginal cost of reducing soil erosion depends on the level of soil erosion and the type of soil. Those producers who have low soil erosion rates seem likely to have a different marginal cost of controlling soil erosion that producers who have high soil erosion rates. Thus, there may be some cost differences in controlling the soil erosion based on the initial level of soil erosion.

The objective of this study is to model soil loss under the conservation-compliance program and conduct an empirical analysis of the effects of soil erosion on net profits when different tillage practices, rotations, spacing for soybeans and soil erosion control measured were used. The second section of this paper models the conservation-compliance program, the third section models an efficient solution, and the fourth section deals with empirical analysis. The fifth section gives a summary of findings and drawn conclusions.

THEORETICAL MODEL

Consider only those lands which would come under the conservation-compliance program (CCP). The objective is to reduce aggregate total soil erosion to some constant level $C\sim$, which would have been brought about through CCP and minimize the cost involved in this process.

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1 acre = 0.4047 ha.

Symbolically the relationship between target and actual soil erosion can be represented as:

$$C\sim = \beta + \Sigma_{i=1}^{K}(a_i - e_i) \tag{1}$$

where $C\sim$ is the steady state, target level soil erosion per year in the entire cultivated land and non-cultivated land in the U.S.; a_i is the steady state soil erosion in the ith acre, i.e., without any erosion control measure; e_i is amount of soil erosion reduction per acre per year in the ith acre brought about by changes in crop rotation, cultivation practices, tillage practices etc.; β is the soil erosion per year in uncultivated uncontrollable areas like natural hills, stream beds etc., and erosion in cultivated land which will not come under CCP; K is total number of acres which would come under CCP; $(a_i - e_i)$ is the soil erosion in the ith acre after adopting erosion control measures; and $\Sigma_{i=1}^{K}(a_i - e_i)$ is the total soil erosion per year in those lands which would come under CCP after adoption of soil erosion control measures.

Let $C_i(a_i, e_i)$ be a continuous cost function for reducing the soil erosion rate from a_i by e_i. Two assumptions are made for the cost function:

(1) cost involved in reducing the soil erosion by one more unit increases as e_i increased, i.e.

$$(\partial C_i/\partial e_i) > 0$$

$$(\partial^2 C_i/\partial e_i^2) > 0$$

(2) cost involved in reducing the soil erosion by one more unit depends on the level of total soil erosion, i.e.

$$(\partial C_i/\partial a_i) \neq 0$$

$$(\partial^2 C_i/\partial a_i^2) > 0$$

The objective of the social welfare maximizer is to minimize the cost involved in reducing the soil erosion subject to the aggregate total target level of soil erosion. This can be represented as:

$$\underset{e_i}{\text{Min}} \sum_{i=1}^{K} C_i(a_i, e_i)$$

subject to

$$C\sim \geqslant \beta + \sum_{i=1}^{K} (a_i - e_i)$$

and

$$e_i \geqslant 0 \qquad \text{for} \quad i = 1, 2, \ldots, K$$

This problem can be solved using the Lagrangian as follows:

$$\underset{e_i}{\operatorname{Min}} L = \sum_{i=1}^{K} C_i(a_i, e_i) + \mu\left[\beta + \sum_{i=1}^{K} (a_i - e_i) - C\sim\right] \tag{2}$$

Cost effectiveness can be defined as the allocation of erosion rates among the K sources which meets the erosion target $C\sim$ at minimum social cost. First-order conditions are:

$$e_i\colon (\partial L/\partial e_i) = [(\partial C_i(a_i, e_i)/\partial e_i) - \mu] \geqslant 0 \tag{3}$$

$$\mu\colon (\partial L/\partial \mu) = \left\{\left[\beta + \sum_{i=1}^{K} (a_i - e_i)\right] - C\sim\right\} \leqslant 0 \tag{5}$$

where complimentary slackness conditions are:

$$\{e_i[(\partial C_i(a_i, e_i)/\partial e_i) - \mu]\} = 0 \tag{4}$$

$$\mu\left\{\left[\beta + \sum_{i=1}^{K} (a_i - e_i)\right] - C\sim\right\} = 0 \tag{6}$$

$$e_i \geqslant 0,\ \mu \geqslant 0 \qquad \text{for all} \quad i = 1, 2, \ldots, K \tag{7}$$

The shadow price μ is the amount of soil erosion control cost saved by allowing the soil to erode one more unit. It is a measure of the marginal difficulty of meeting the standard $C\sim$.

Since μ is the same for all acres, it implies that the marginal cost of controlling one more unit of soil erosion should be the same for all acres. If in a cost-effective allocation, the marginal cost of controlling the first unit of soil erosion in that acre is higher than μ (higher than the marginal cost of controlling non zero amount of soil erosion in all other acres), then that particular acre will not be assigned any erosion control responsibility; μ is positive as long as some control is active. If $\mu = 0$, it implies:

$$C\sim > \left[\beta + \sum_{i=1}^{K} (a_i - e_i)\right]$$

or no erosion control is necessary. If the erosion target is fixed for each acre (or each farm) rather than for the whole farming sector, then the marginal cost of controlling soil erosion will be different for each acre (farm). This implies that $\mu_i \neq \mu_j$. The efficiency condition for interior solution, $(\partial C_i(a_i, e_i)/\partial e_i) = \mu$, will not be met under the above situation.

ACHIEVING THE EFFICIENT SOLUTION

A socially efficient solution can be achieved by issuing erosion permits based on the target erosion control. Each coupon allows a person who holds it to erode 1 $t\,a^{-1}\,y^{-1}$ of soil. Then the number of coupons issued can be arrived as follows. Let

$$N = \sum_{i=1}^{K} (a_i - e_i) = C\sim -\beta \tag{8}$$

where N is the number of coupons issued. Therefore, the actual soil erosion is the loss on the land that comes under CCP target soil erosion rate. When these coupons are issued, they will have a positive price, as long as some soil erosion control is needed to meet the target. The owner of the land will attempt to acquire the number of coupons consistent with minimizing his or her cost of soil erosion control.

Let each acre be given m_i^0 coupons, i.e. if $m_i^0 = 7$, a person who owns one acre has the right to erode 7 $t\,a^{-1}\,y^{-1}$. When the number of coupons are summed across all acres belonging to all individuals, it will be equal to N, i.e. $\Sigma_{i=1}^{K} m_i^0 = N$ in order to ensure compliance with $C\sim$.

With the issue of coupons, the minimization problem can be modified as follows. Faced with the need to choose a non-negative level of soil erosion, ith acres choice can be characterized as:

$$\underset{e_i}{\mathrm{Min}}\, L = C_i(e_i, a_i) + p\left(a_i - e_i - m_i^0\right) \tag{9}$$

where p is the price the source would pay for an acquired coupon or receive for a coupon sold to another source. First-order conditions are:

$$e_i\colon \left[(\partial C_i(e_i, a_i)/\partial e_i) - p\right] \geqslant 0 \tag{10}$$

$$p\colon a_i - e_i - m_i^0 \leqslant 0 \tag{13}$$

where complimentary slackness conditions are:

$$e_i\left[(\partial C_i(e_i, a_i)/\partial e_i) - p\right] = 0 \tag{11}$$

$$e_i > 0 \qquad\qquad i = 1, 2, \ldots, K \tag{12}$$

$$p\left[a_i - e_i - m_i^0\right] = 0 \tag{14}$$

The market solution is exhibited in (10) which is in accordance with a socially cost-effective solution. According to (8) the number of coupons issued is compatible with $C\sim$ which implies that the erosion control target is attained. Assuming interior solution,

– from (3):

$$(\partial C_i(a_i, e_i)/\partial e_i) = \mu$$

– from (10):

$$(\partial C_i(e_i, a_i)/\partial e_i) = p$$

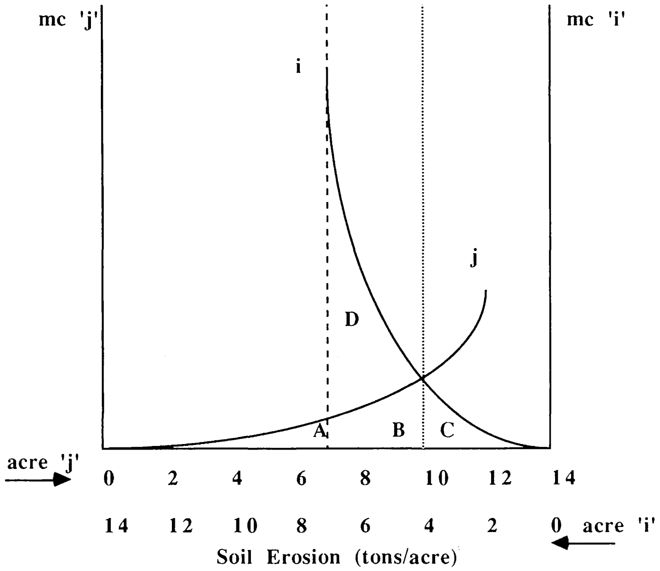

Fig. 1. Graphical representation of cost efficiency.

This implies that $\mu = p$ which assures that the coupon system yields the socially cost-effective allocation. This model can be applied to any program like pollution (McGarland and Oats, 1985) which fixes a target for individual units, if marginal cost of control is not the same across all units.

The same idea can also be explained using graphical analysis as shown in Fig. 1. The graph shows the marginal cost (MC) of controlling soil erosion for two different soils i and j. As the theory says, in a cost-effective allocation, if the MC of controlling soil erosion in soil type i is greater than soil type j to control X (for example, 7) $t\,a^{-1}\,y^{-1}$, then soil type j will be assigned to control more erosion to achieve the target level of soil erosion. Using the graph, if the target level of soil erosion is 14 $t\,a^{-1}\,y^{-1}$, fixing 7 $t\,a^{-1}\,y^{-1}$ for each soil type would involve a total cost area of:

$$TC_{s1} = A + B + C + D = \left[(TC_j = A) + (TC_i = B + C + D)\right] \tag{15}$$

where TC_{s1} is the cost to control 14 t of soil erosion under situation 1, TC_j is the cost to control 7 t of soil erosion in jth soil type, and TC_i is the cost to control 7 t of soil erosion in ith soil type. With tradable coupons for soil erosion to achieve the target of 14 $t\,a^{-1}\,y^{-1}$ soil erosion control, the ith soil type's producer will control 4 $t\,a^{-1}\,y^{-1}$ and the jth soil type's producer will control 10 $t\,a^{-1}\,y^{-1}$. Now the total cost involved in achieving the target level of soil erosion is:

$$TC_{s2} = A + B + C = \left[(TC_j = A + B) + (TC_i = C)\right] \tag{16}$$

where TC_{s2} is the cost to control 14 t of soil erosion under situation 2. For the society as a whole, the cost of reducing the target level of soil erosion is reduced by:

$$\Delta TC = TC_{s1} - TC_{s2} = D \tag{17}$$

Therefore, given that the $MC_{s1} \neq MC_{s2}$, the cost efficiency can be achieved through tradable coupons.

EMPIRICAL ANALYSIS

The marginal cost of controlling soil erosion will be reflected in the profitability of farming. If the marginal cost of controlling soil erosion is not the same either at different levels of soil erosion or across different soil types, the coupon system will be more efficient than a government mandated uniform erosion rate for all soils and conditions. The same concept can be stated in terms of net profits. When the marginal change in the net profit due to one unit change in soil erosion is not the same at different levels of soil erosion or across different soil types, the coupon system will be efficient. Soil characteristics, including the tendency to erode have been shown to have a significant effect on farmland prices (Miranowski and Hammes, 1984). Crosson and Stout (1983) also showed that the effect of soil erosion on yield depends on the level of soil erosion.

Twelve major types of soils in the state of Iowa, U.S.A., were selected and the Universal Soil Loss Equation (USLE) was used to estimate soil erosion. Components of USLE are rainfall (R), soil erodability (K), slope and length (LS), support practice (P) and crop (C). The USLE can be written as:

$$A = R * K * LS * P * C \tag{18}$$

where A is the soil loss in $\mathrm{t\,a^{-1}\,y^{-1}}$. In estimating soil loss, R, K, and LS were treated as given and C and P were used to control the soil erosion. The P was used based on the soil erosion control measures (SECM) – base, contour, alternate strips of row crop and grass and permanent grass strip covering 20% of the field. Four different rotations, corn–soybean (CB), corn–corn–soybean (CCB). corn–soybean–oats (CBO) and corn–soybean–oats–meadow–meadow (CBOMM), were considered. Within each rotation, seven tillage practices were considered; fall plow, spring plow, no till with 50% crop residue, no till with 60% crop residue, mulch-strip-ridge till (MSR) with 20%, 30% and 40% crop residue were used to control soil erosion (Wilcox et al., 1988).

The soybean cultivation was divided into two categories, one with more than 20 inches spacing and one with less than 20 inches spacing. In each

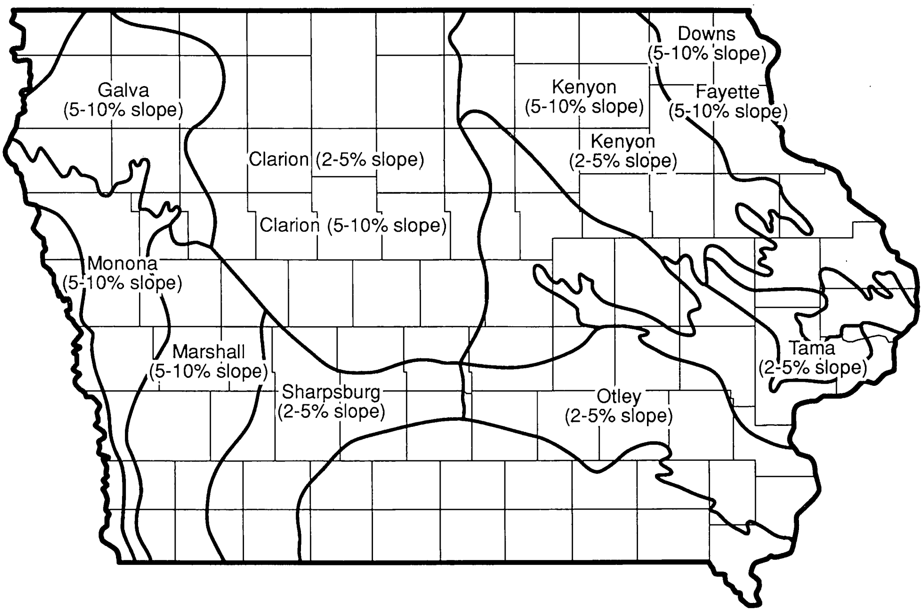

Fig. 2. Distribution of selected soil types (Iowa State, U.S.A.).

rotation the amount of soil erosion was estimated for the above mentioned four different soil erosion control measures. The twelve types of soils selected (Fig. 2) were: Marshall (5–10% slope), Monona (5–10% slope), Kenyon (2–5% slope), Kenyon (5–10% slope), Tama (2–5% slope), Clarion (2–5% slope), Clarion (5–10% slope), Downs (5–10% slope), Fayette (5–10% slope), Otley (2–5% slope), Galva (5–10% slope) and Sharpsburg (2–5% slope).

Estimation of cost of production and yield for different crops taking into account of the various cultivation practices

Cost of production in corn in CC and CB rotation, soybean, oats and alfalfa was estimated (Duffy, 1987) which is then used to estimate net profits for each rotation considered in the analysis. The cost of adopting different tillage practices was considered for each of the crops grown. For corn in CB rotation, the cost of production was estimated for three different yields: 90, 115 and 135 bushels per acre, since the yield and the cost of cultivation will depend on the soil type. Cost of production for soybean was estimated for yields of 30, 38 and 46 bu per acre. There was no yield variation in oats. Cost of hay production was estimated for 4, 6 and 8 $t\,a^{-1}\,y^{-1}$.

The yield for corn in CB rotation, soybean, oat, and alfalfa was estimated (Miller, 1987).

Soybean yield was estimated for less than 20 inch row spacing and more than 20 inch row spacing. A yield increase of 10% was used when the spacing was reduced from 30 inches to 15 inches based on Shroyer (1978). The cost of production of alfalfa includes the establishment cost, annual variable cost and the land cash rent equivalent.

Net profits for each rotation per year

Net profits for each rotation per year is calculated by summing the profit for each crop in a particular rotation and dividing by number of crops in that rotation. The net profit is estimated for twelve types of soils, seven cultivation practices for the base and three soil erosion control measures as follows:

$$\mathrm{NPR}_{jkl} = \sum_{i=1}^{n} \pi_{ijkl}/n \tag{19}$$

where $\pi_i = \mathrm{TR}_i - \mathrm{CP}_i$ and TR_i is the total revenue from the ith crop; CP_i the cost of production for the ith crop; and j represents CB, CCB, CBO, CBOMM rotations; i corn in CB rotation, soybean with more than 20 inch spacing, soybean with less than 20 inch spacing, oats and alfalfa; k Marshall (5–10% slope), Monona (5–10% slope), Kenyon (2–5% slope), Kenyon (5–10% slope), Tama (2–5% slope), Clarion (2–5% slope), Clarion (5–10% slope), Downs (5–10% slope), Fayette (5–10% slope), Otley (2–5% slope), Galva (5–10% slope) and Sharpsburg (2–5% slope); l base, contouring alternate strip of row crop and grass and permanent grass strip; NPR_{jkl} net profits per year from the jth rotation, kth soil, when the lth tillage practice is adopted; π_{ijkl} net profits from the ith crop in the jth rotation, in the kth soil when the lth tillage practice is adopted; and n is the number of crops in the jth rotation.

Out of four rotations, the soil erosion was the least in CBOMM and highest in CB rotation. As expected the soil erosion was less in soybeans with narrower than 20 inches spacing when compared to a wider than 20 inches spacing. Out of four erosion control measures within each rotation, permanent grass strip covering 20% of the land has the least erosion. In total there were 224 ways of controlling soil erosion in each soil type. These data were used to analyze the effects of soil erosion on profit.

To analyze the effects of soil erosion on profits consider a simple Ordinary Least Squares (OLS) regression of the following from:

$$\begin{aligned}\mathrm{PROFIT} = {} & b_0 + b_1\,\mathrm{DSECMB} + b_2\,\mathrm{DSECMC} + b_3\,\mathrm{DSECMS} + b_4\,\mathrm{DSOYSG} \\ & + b_5\,\mathrm{DCBROT} + b_6\,\mathrm{DCCBROT} + b_7\,\mathrm{DCBOROT} + b_8\,\mathrm{SOIERO} + \pounds_1\end{aligned} \tag{20}$$

where DSECMB is a dummy variable for soil erosion control measure (SECM)-base, DSECMC is a dummy variable for SECM-contour, DSECMS is a dummy variable for SECM-contouring with alternate strips of row cropping and grass, DSOYSG is a dummy variable (1 if soybean spacing is more than 20 inches) for soybean spacing, DCBROT is a dummy variable for CB rotation, DCCBROT is a dummy variable for CCB rotation, DCBOROT is a dummy variable for CBO rotation, SOIERO is the level of soil erosion, and $£_1$ is the random error.

However, soil erosion is itself stochastic and it seems likely to be correlated with $£_1$. This causes simultaneous equation bias (Johnston, 1984). Define the following equation for arriving at an instrument for SOIERO:

$$\begin{aligned}\text{SOIERO} &= a_0 + a_1\,\text{DSECMB} + a_2\,\text{DSECMC} + a_3\,\text{DSECMS} + a_4\,\text{DSOYSG}\\ &\quad + a_5\,\text{DFALTIL} + a_6\,\text{DSPRTIL} + a_7\,\text{DNOTIL1} + a_8\,\text{DNOTIL2}\\ &\quad + a_9\,\text{DMSTIL1} + a_{10}\,\text{DMSTIL2} + a_{11}\,\text{DCBROT} + a_{12}\,\text{DCCBROT}\\ &\quad + a_{13}\,\text{DCBOROT} + \Omega_1 \qquad (21)\end{aligned}$$

where DFALTIL a dummy variable for fall plow, DSPRTIL a dummy variable for spring plow, DNOTIL1 a dummy variable for no till with 50% crop residue, DNOTIL2 a dummy variable for no till with 60% crop residue, DMSTIL1 a dummy variable for MSR till with 20% crop residue, DMSTIL2 a dummy variable for MSR till with 30% crop residue, Ω_1 is the random error.

To obtain unbiased estimates, an instrumental variable regression procedure is applied. In the process, the predicted value of SOIERO (i.e., SOIERO *) from (21) was substituted for SOIERO in equation (20):

$$\begin{aligned}\text{PROFIT} &= b_0 + b_1\,\text{DSECMB} + b_2\,\text{DSECMC} + b_3\,\text{DSECMS} + b_4\,\text{DSOYSG}\\ &\quad + b_5\,\text{DCBROT} + b_2\,\text{DCCBROT} + b_7\,\text{DCBOROT} + b_8\,\text{SOIERO}^* + £_2\end{aligned}$$

The transition cost involved in changing the tillage practices is negligible, but a change in rotation or a change in SECM will involve more costs. The instrumental variable estimate of the coefficients of the net profit equation are reported in Table 1.

As can be seen from Table 1, the change in net profit due to one unit change in soil erosion is given by b_8. The estimates of b_8 show differences across soil types. As stated in theory, if the marginal change in net profit due to the control of a unit of soil erosion (in other words marginal cost of controlling soil erosion) is not the same across all soil types, a coupon system will be more efficient. Using equation (17), if 1 $\text{t}\,\text{a}^{-1}\,\text{y}^{-1}$ of soil erosion is to be controlled, let the ith acre be soil type Clarion (2–5%

TABLE 1

Instrumental variable regression results on soil erosion and net profits

Variables	Soil type with slope (%)											
	Sharpsburg 2–5	Galva 5–10	Otley 2–5	Fayette 5–10	Downs 5–10	Clarion 5–10	Clarion 2–5	Tama 2–5	Kenyon 5–10	Kenyon 2–5	Monona 5–10	Marshall 5–10
CONST.	144.00 ***	100.71 ***	155.80 ***	116.72 ***	134.36 ***	105.01 ***	126.25 ***	178.43 ***	123.93 ***	138.55 ***	107.72 ***	120.44 *** [a]
	(81.93)	(52.91)	(84.81)	(67.86)	(61.19)	(57.75)	(78.00)	(78.00)	(60.57)	(87.09)	(46.62)	(72.12) [b]
DSECMB	37.41 ***	40.57 ***	40.16 ***	39.91 ***	33.19 ***	37.16 ***	37.89 ***	45.45 ***	49.98 ***	34.99 ***	51.94 ***	37.93 ***
	(16.14)	(16.16)	(16.57)	(17.59)	(11.46)	(15.49)	(17.76)	(16.76)	(18.52)	(16.67)	(17.04)	(17.22)
DSECMS	17.08 ***	14.46 ***	18.45 ***	15.28 ***	15.29 ***	13.99 ***	15.30 ***	21.10 ***	17.19 ***	15.87 ***	17.09 ***	15.09 ***
	(9.65)	(7.54)	(9.97)	(8.82)	(6.92)	(7.39)	(9.39)	(8.34)	(9.90)	(7.35)	(8.97)	
DSECMS	17.08 ***	14.46 ***	18.45 ***	15.28 ***	15.29 ***	13.99 ***	15.30 ***	21.10 ***	17.19 ***	15.87 ***	17.09 ***	15.09 ***
	(9.65)	(7.54)	(9.97)	(8.82)	(6.92)	(7.64)	(9.39)	(9.39)	(8.34)	(9.90)	(7.35)	(8.97)
DSOYSG	−54.77 ***	−44.43 ***	−57.32 ***	−46.84 ***	−51.01 ***	−43.48 ***	−47.32 ***	−61.15 ***	−43.61 ***	−49.66 ***	−44.62 ***	−47.67 ***
	(−44.06)	(−33.01)	(−44.11)	(−38.50)	(−32.85)	(−33.80)	(−41.34)	(−41.34)	(−30.13)	(−44.13)	(−27.30)	(−40.36)
DCBROT	42.46 ***	54.78 ***	44.58 ***	43.42 ***	31.36 ***	41.91 ***	30.40 ***	46.92 ***	42.15 ***	29.07 ***	65.14 ***	36.23 ***
	(19.36)	(23.07)	(19.45)	(20.23)	(11.45)	(18.47)	(15.05)	(15.05)	(16.51)	(14.64)	(22.60)	(17.39)
DCCBROT	−1.43	19.57 ***	−1.17	10.41 ***	−3.39	10.43 ***	0.77	−0.38	10.35 ***	−8.28 ***	27.60 ***	6.08 ***
	(−0.67)	(8.52)	(−0.53)	(5.01)	(−1.28)	(4.75)	(0.39)	(0.39)	(4.19)	(−4.31)	(9.90)	(3.02)
DCBOROT	25.91 ***	27.83 ***	25.38 ***	24.54 ***	15.50 ***	25.40 ***	19.17 ***	24.18 ***	26.65 ***	18.86 ***	41.57 ***	23.11 ***
	(13.61)	(13.51)	(12.76)	(13.18)	(6.52)	(12.90)	(10.94)	(10.94)	(12.03)	(10.95)	(16.61)	(12.78)
SOIERO*	−2.03 ***	−4.66 ***	−1.74 ***	−1.85 ***	−0.60 ***	−2.80 ***	−6.06 ***	−2.03 ***	−4.75 ***	−2.32 ***	−4.73 ***	−4.73 ***
	(−3.22)	(−10.63)	(−3.08)	(−9.44)	(−2.06)	(−8.77)	(−7.82)	(−2.89)	(−13.24)	(−3.55)	(−13.34)	(−8.06)

[a] Triple asterix indicates significance at 0.01 level, two-tailed test.

[b] t-ratios are in parentheses.

slope) and the jth acre be Downs (5–10% slope), then by assigning the unit erosion control to Downs instead of Clarion, the society would gain:

$$\Delta TC = -0.60 - (-6.06) = \$5.46$$

While comparing across different types of soils the loss in net profit due to 1 t increase in soil erosion varies from \$0.60 to \$6.06. This implies that the marginal cost of controlling soil erosion is not the same across different soil types and these are the conditions in which a coupon system will be more efficient. The target soil erosion control can still be achieved under a coupon system but at a lower cost. Furthermore if the MC of soil erosion control goes down, the producers who were not under conservation program due to high cost of control, may comply with the program, after the introduction of tradable coupon system. This will bring in more land under conservation. Therefore a tradable coupon is not only cost-efficient, but it will also bring in more land under soil conservation. In contrast to the information requirements of the command-and-control system, a tradable coupon system does not require any information on the cost of control. The coupon system also has the advantage of being able to easily adopt to changes in costs due to new technology development for soil erosion control (Tietenberg, 1985). Because it is tougher to hit a moving target, the control authority is more likely to have up-to-date knowledge on the amount of soil erosion than on erosion control costs.

CONCLUSION

The marginal opportunity cost of controlling soil erosion is not the same across different soil types. The coupon system would achieve target soil erosion control at a lower cost than a t-value requirement. The study suggested that a saving of about \$5.00 occurs assigning one ton of soil erosion control per acre annually to Iowa soil type Downs (5–10% slope) instead of Clarion (2–5% slope). The tradable coupon system is not only cost-efficient but will also bring more land under soil conservation.

ACKNOWLEDGEMENT

The authors acknowledge the assistance of Joseph A. Herriges, John A. Miranowski and the anonymous reviewers for their helpful comments.

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