Soil
Conservation

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Erosion Control: Costs and Income Distribution Under Regulation, Tax and Subsidy[1]

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Background

The Lake Erie Wastewater Management Study of the U.S. Army Corps of Engineers is to develop a recommended management program for agricultural sources of pollution. The procedure is to identify land management practices which reduce pollutant loadings in the Lake Erie Basin, to quantify the effects of these practices on pollutant loadings, and to determine the economic cost of implementing the practices. This study concentrates on estimating the economic cost of implementing management practices which reduce pollutant loadings. It uses the Honey Creek Watershed of North Central, Ohio as the unit of analysis. The purpose of the study is to identify the relationship between water quality and farm income in the Honey Creek.[3]

Economic Mechanisms to Control Nonpoint Pollution[4]

In the current debate over control of nonpoint source pollution, the emission standard usually surfaces as the control mechanism. A standard is set on a firm,

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[3] While the broader objective is to develop a management program for all of the Lake Erie Basin, this study concentrates on a small (189 square mile) watershed within the basin. The reason for this limited scope is twofold. First, northern Ohio is a major contributor to non point pollution loadings in Lake Erie. There is strong evidence that agricultural activity is the predominant source of sediment and phosphate loadings from the area. Second, the Honey Creek Watershed is considered generally representative of rural land in northern Ohio, and analysis of this watershed allows inferences to be made about much of northern Ohio.

[4] A host of alternative strategies exist to restrict soil and phosphorus loss. They include: (1) emission standards, (2) taxes on pollutants, (3) subsidies for reducing pollutants, (4) regulation of production processes or inputs, (5) subsidies for inputs which reduce pollutants, (6) taxes on inputs which encourage pollutants, and (7) market solutions to force producer internalization of all costs. The first three strategies are analyzed.

such as soil loss shall not exceed four tons per acre. The producer is allowed to use his choice of technologies, inputs, and output as long as the emission standard is met.

The impact of the emission standard on farm income is represented graphically in Figure 1a and 1b. Soil loss can be considered a joint product from the production process, thus total revenue (TR) is linear. That is, the more output produced, the greater the soil loss and the greater revenue received by the firm. Total cost (TC) is curvelinear as soil loss increases. That is, as more output is produced, diminishing returns cause total costs to increase more rapidly than total revenue. The farmer maximizes profits by producing az income (Figure 1a) with b units of soil loss.

As soil loss is restricted to a lower level, profits fall. For example, soil loss might be restricted to level e where a'z' profits are received. The profit received by the firm for all levels of soil loss are shown by curve ON in Figure 1a.

The marginal benefits to farmers (MBF) of an extra unit of soil loss is shown in Figure 1b as curve ahb. As more soil loss is allowed, profit increases at a decreasing rate until b units of soil loss are produced. At b units, profit is maximized, and profit decreases as more units of soil loss are added.

A restriction on soil loss to level e reduces farm income by ehb. Before the restriction, farm income is the area under the marginal benefits curve or oab. With the introduction of a restriction on soil loss, profits are reduced to oahe.

Downstream costs and costs to future generations must also be considered in a decision of the optimum restriction on soil loss. Each additional unit of soil loss adds costs such as higher water treatment costs, higher ditch drainage costs, reduced reservoir life, and damaged recreation and fishing opportunities. Furthermore, these damages increase at an increasing rate as depicted by the marginal costs to society (MCS) curve or ogc in Figure 1b. As a restriction is placed on soil loss at level e, society's costs are lessened by the amount

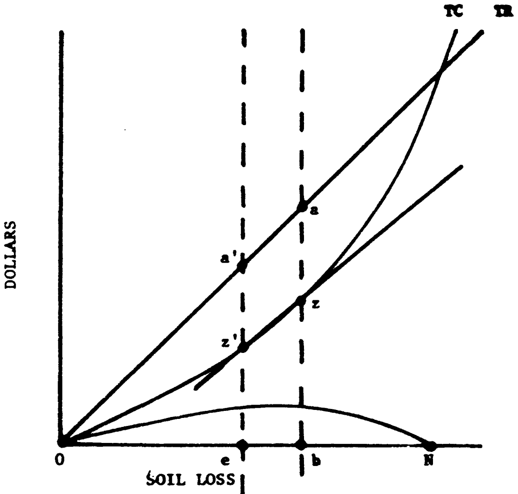


Figure 1a. The Effects of a Restriction for Reducing Soil Loss

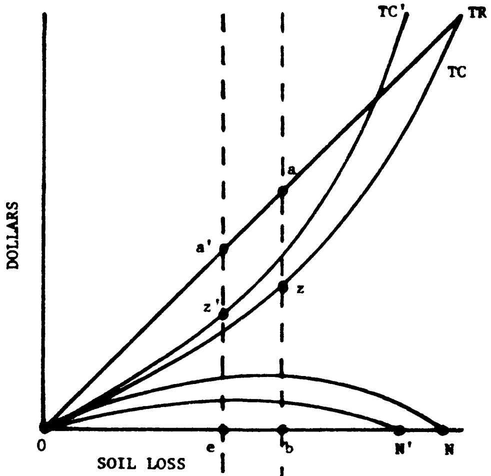


Figure 2a. The Effects of a Pollution Tax for Reducing Soil Loss

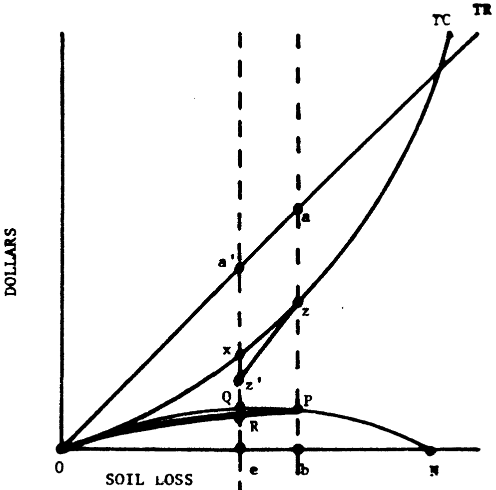


Figure 3a. The Effects of A Subsidy For Reducing Soil Loss

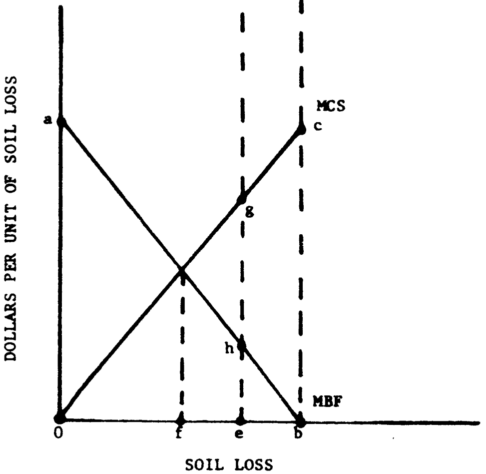


Figure 1b. The Effects of A Restriction On Soil Loss

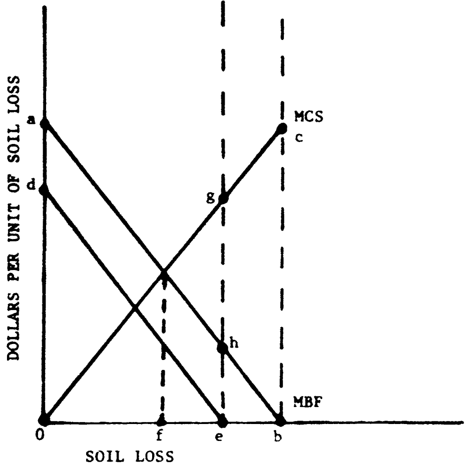


Figure 2b. The Effects of A Tax on Soil Loss

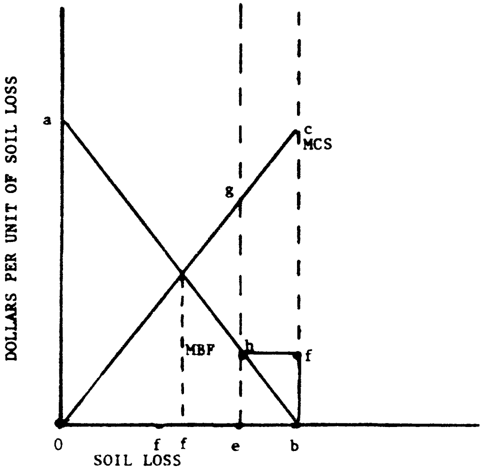


Figure 3b. The Effects of A Subsidy On Soil Loss

depicted by area egcb. Thus, the net gain (reduced downstream costs less reduced farmers profit's) as a result of the restriction is area hgcb.

In order to maximize benefits to society as a whole (downstream users and farmers), soil loss would be restricted to level f in Figure 1b. At that point, further restrictions on soil loss would reduce farmers profits more than it would reduce downstream costs. Soil loss less than f would be inefficient.

Implementation of a tax on soil loss is illustrated in Figure 2a and 2b. In Figure 2a the producer is facing a total revenue curve (TR) and total cost curve (TC). When the vertical distance between the two curves is subtracted, the total profit curve (ON) emerges. Maximum profits occur at b units of soil loss with az profit. This initial level of soil loss also is depicted in Figure 2b. Again, the marginal benefits to the farmer (MBF) is the area oab. However, downstream water users are bearing costs ocb. Society's benefits are maximized when only f units of soil loss are produced.

A tax on soil loss could move the producer in the proper direction. When a soil loss tax is levied against the farmer, a new cost curve (TC') and profit curve (ON') are created. Marginal benefits to the farmer decline to de, and the profit of the farm is area ode. Downstream costs are reduced by the area egcb. Farmers realize a loss of dabe, and the governmental body levying the tax receives dahe. Thus, the net gain to society is hgcb.

Notice that the tax and the regulation have the same net effect. In each case, the net gain is hgcb (Figures 1b and 2b). The question is, "whose ox gets gored?" In the case of the regulation, taxpayers pay the costs of administering the regulation. The farmer has only a slight loss in profits of ehb (Figure 1b). However, with the tax a redistribution of income occurs away from the farmer to the tax coffer. The farmer loses dabe in profits of which dahe ends up in the public treasury.

Another economic mechanism to reduce soil and phosphorus losses is to use subsidies. A subsidy might be awarded for reducing soil or phosphorus loss below some limit. A subsidy scheme is depicted graphically in Figures 3a and 3b. No subsidy is given if soil losses are at level b or greater. However, a per unit subsidy is awarded if soil loss falls below b. Originally, the farmer faces total revenue (TR) of oa and total cost (TC) of oxz in Figure 3a. With the advent of the subsidy, the cost curve changes. If e units of soil loss are produced, the total cost curve becomes oxz'z. Initially, the profit curve is ORPN, but with the subsidy the profit curve is ORQPN. In Figure 3b, the farmer is originally enjoying oab profits while downstream users suffer costs of ocb. When the subsidy is enacted, the farmer reduces soil loss to e, and increases profits to oahfb. The amount of the subsidy is ehfb, and the farmers receive it from the taxpayers. Downstream users enjoy reduced costs of egcb. The net gain to society is hgcb. Notice the net gain of hgcb is the same with the subsidy (Figure 3b) as it is with the regulation or tax (Figure 1b and 2b). Again, the question of who gains and who loses is the differentiating factor.

The Model

Linear Programming is used to represent the watershed and to analyze alternative erosion control strategies. The objective function used in the model is the maximization of net revenue in the watershed. The activities are agricultural enterprises found in the watershed which affect soil and phosphorous loss. These including growing corn, soybeans, wheat, oats, and hay on different soil types; using alternative levels of inputs and tillage practices on different sloping soils; and raising dairy cows, feeder steers, beef cow-calves, feeder pigs, and finishing hogs.

There are four major sets of activities, each comprised of numerous individual activities. These sets include crop production, livestock production, crop marketing, and livestock marketing.

Each crop activity is comprised of five components -- soil type, rotation, tillage practice, yield, and slope. Over 3,000 activities representing possible combinations of these five components comprise the crop production set. For each crop activity, the Universal Soil Loss Equation is used to estimate soil loss (Wischmeier and Smith). Phosphorus loss is assumed to be linearly dependent on soil loss.

The second set of activities considered in the model are the five different livestock producing enterprises. These are dairy cow, feeder steer, cow-calf, feeder pig or swine breeding, and fed hog production. Inclusion of these activities provides an alternative means to market the grain being produced. Also, the phosphorous obtained from manure can be used in raising crops as an alternative to purchasing phosphorous outright.

Resource restrictions include constraints on total acreage in the watershed, limitations on corn, wheat, soybeans, oats, and hay acreages, and upper and lower bounds on beef, swine and dairy raised. Additional restrictions are imposed which force the various land characteristics to be equal to those actually found in the watershed.

Results of the model are obtained under five alternative scenarios. The first scenario, "base" represents current agricultural practices in the watershed. It requires that 90 percent of all tillage be done by conventional tillage methods. The results from this scenario provide estimates of net farm income, soil loss, and phosphorous loss under current practices (Becker).

The "unrestricted" scenario represents the watershed under the most profitable agricultural practices. It is known that, in the long run, minimum and no tillage practices are more profitable than conventional tillage on many soils. The unrestricted scenario removes the base model's restriction on conventional tillage and allows the most profitable tillage system to be used. If farmers tend to behave as profit maximizers, the results of this scenario estimate farmers long run behavior.

Policy set B restricts soil loss on each acre of soil by some multiple of the T value, soil loss tolerance factor (Weischmeier and Smith). The next model, policy set C, taxes soil loss. In the objective function of the unrestricted model, the cost of a ton of soil is $0.00. When a negative value is substituted in its place, the optimal solution will represent the watershed when a tax is levied on soil loss. Policy set D is a subsidy for reducing soil loss. If the farmer reduces soil loss below that of the unrestricted model, a subsidy is awarded.

Results

Base Model

The acres of crops and number of livestock represented in the base model closely approximates that which actually exists (Becker). Base model results indicate that net returns to farmers in the watershed are $16.1 million. Net returns are defined as returns above all costs except land costs. Soil loss is occuring at an average annual rate of 6.19 tons per acre per year. Phosphorous loss is occuring at an average annual rate of 13 pounds per acre per year.

Unrestricted Long Run Model

The unrestricted long run model, which maximizes net revenue, absent of any soil loss restriction, yields some very surprising results. Acreages devoted to each crop are the same as the long run base model. However, annual net revenue in the watershed is almost one million dollars greater in the unrestricted model than in the base model, and yearly soil loss is reduced by more than three tons per acre to 3.19 tons per acre. Annual phosphorous loss is reduced to 6.98 pounds per acre.

The results indicate that an incentive to reduce soil loss is present and total net revenue can easily rise if soil loss reducing practices are adopted. These practices include adopting reduced tillage technologies on well drained and moderately well drained soils. Also, poorly drained soils are tilled and ditched, and reduced tillage technologies are used on these soils.

Policy Set B

Figure 4 summarizes the results of restricting soil loss on each acre to some multiple of the T value. As the soil loss constraint becomes more restrictive, net returns decrease at an increasing rate. Points A and B identify results under the "base" run and "unrestricted" run. Points C, D, E, F, G, H and I illustrate results under soil loss constraints of 2T, 1.75T, 1.5T, 1.25T, T, 0.75T, and 0.5T.

Net returns decline gradually as the restriction approaches the T value for each soil. More severe restrictions than the T value cause net returns to decline dramatically. When soil loss restricitons are T or greater, farmers' net returns are affected only slightly. With these restrictions, the predominant crops continue to be corn and soybeans; however, the acreages devoted these crops decline on sloping land. Hay and pasture acreage increase, and livestock numbers increase to consume the forages.

When soil loss is restricted below the T value, drastic changes take place. First, corn and soybean acreage decreases to less than two-thirds of those in the "unrestricted" run. Second, hay and pasture acreage increase more than threefold and now comprise over one-fifth of the cropland. Dairy and beef cow calf enterprises both grow to historically high levels.

Policy Sets C and D

Policy set C is a tax on soil loss. Levied on a per ton basis, the implicit assignment of property rights is to the downstream user. On the other hand, Policy set D is a soil loss subsidy. Total soil loss in the watershed is reduced by subsidizing the polluter to produce crops which minimize soil loss. Thus, the implicit assignment of property rights is to the polluter.

The net economic impacts are depicted in Figure 5. With Policy Set C, the soil loss tax, the net economic impacts are the net farm returns plus the public sector tax receipts. With Policy Set D, the soil loss subsidy, net economic impacts are net farm returns minus the public sector subsidy expenses. As with

Figure 4. The Impact of Policy Set B on the Entire Watershed

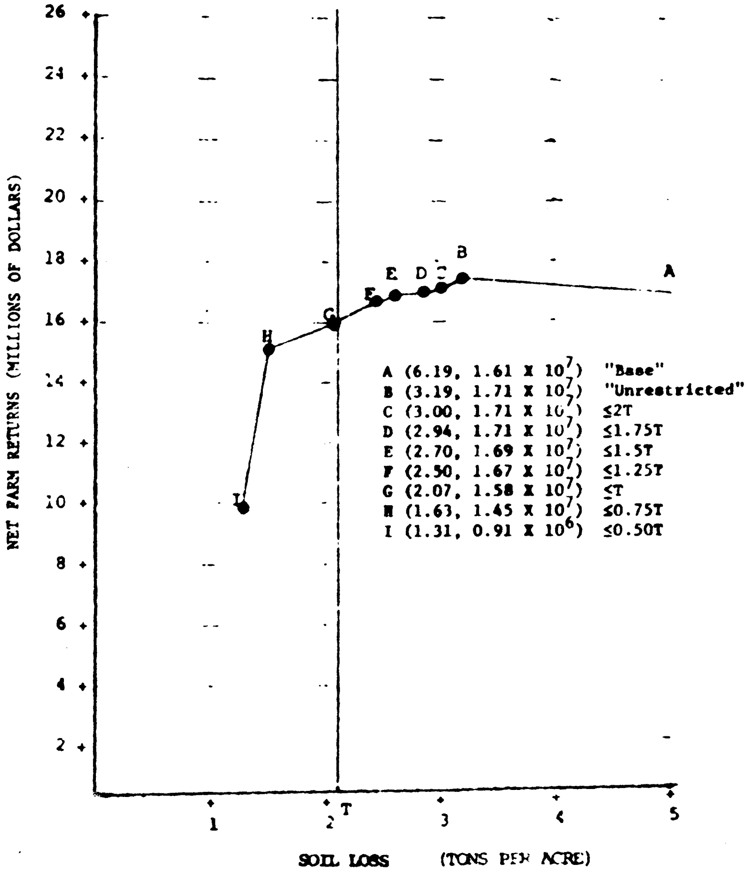


Figure 5. The Impact of Policy Sets C and D when the Public Sector Returns and Net Farm Returns Are Combined

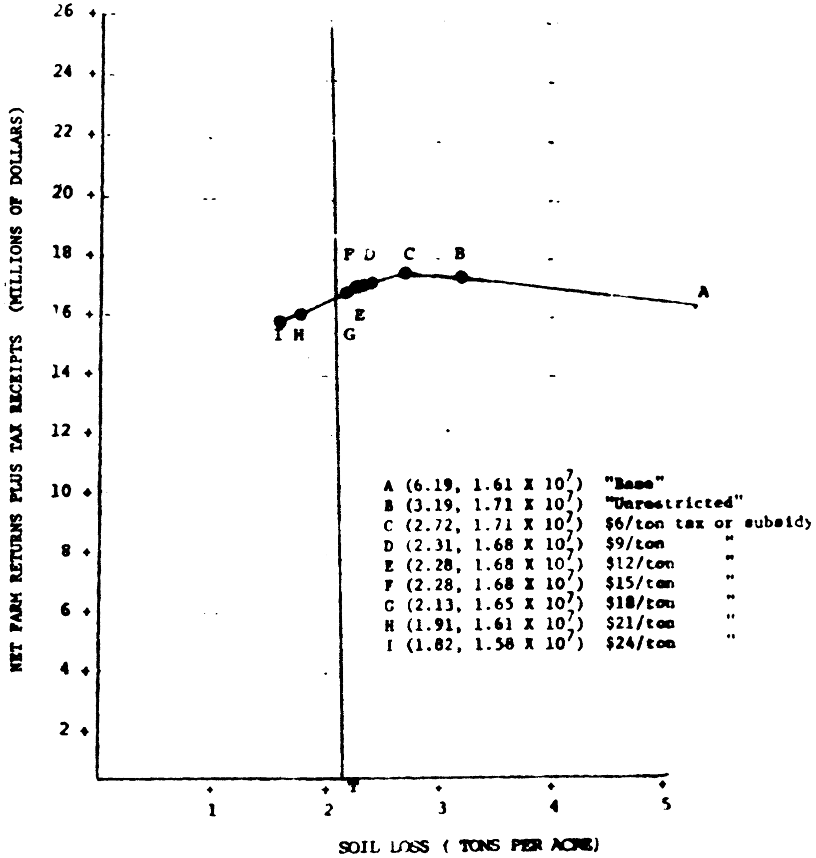


Figure 6. The Impact of Policy Set C on Farmers' Net Return

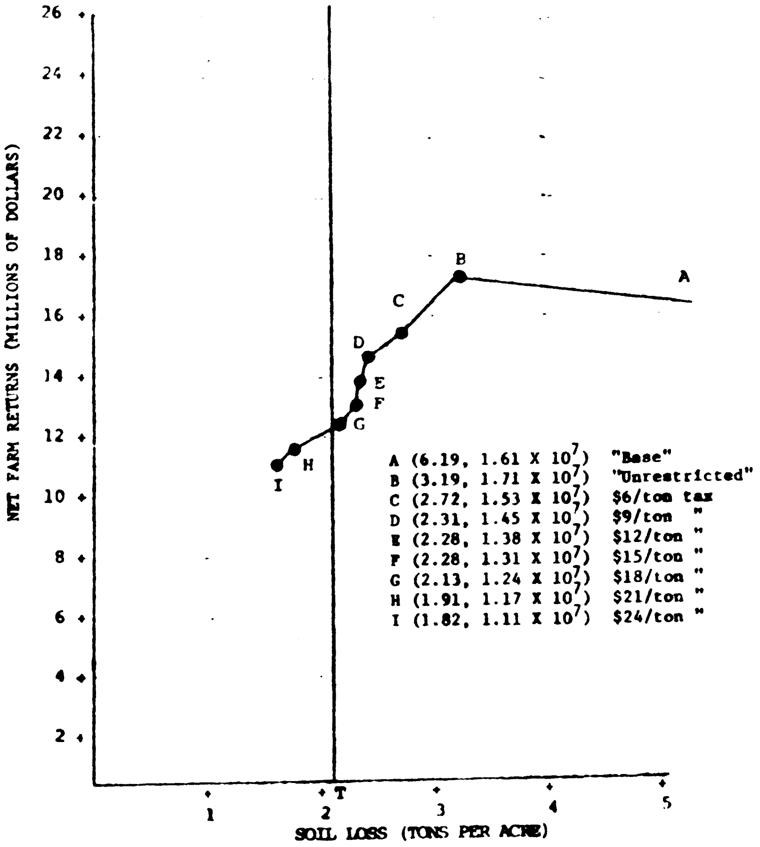
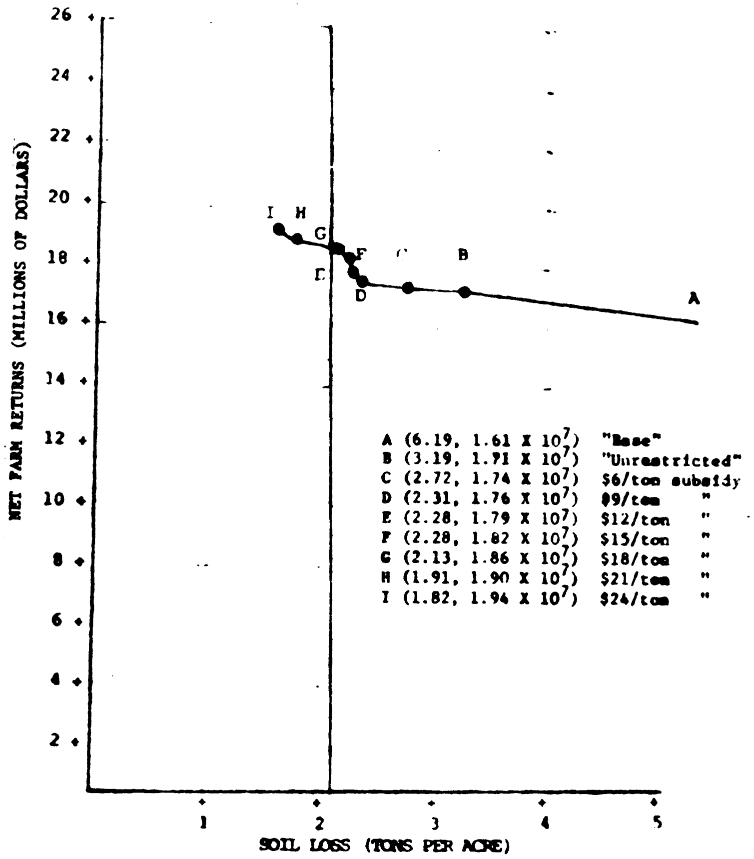


Figure 7. The Impact of Policy Set D on Farmers' Net Return



the soil loss restrictions, the soil loss tax and soil loss subsidy have a relatively small effect on net economic impacts over a wide range of soil losses. Farmers are able to make adjustments in tillage practices and crop rotations which lower soil loss sharply but only slightly lower net economic impacts.

The interesting results of Policy Set C and Policy Set D are their effects on income distribution. In Policy Set C, the right to less polluted water is assigned to the downstream user. Taxation of soil reduces farmer's net returns dramatically as seen in Figure 6. For example, a $6 per ton tax (Point C) reduces farmers' net returns to $15.3 million, and an $18 per ton tax (Point G) reduces farmers's net returns to $12.4 million. However, the net economic impacts are relatively slight as can be seen by comparing Point C and Point G in Figure 5.

In Policy Set D, the right to produce soil loss is assigned to the farmer. Subsidizing reduction of soil loss provides higher net returns for farmers as soil loss is reduced (Figure 7). For example, a subsidy of $18 for every ton of soil loss less than 3.19 tons per acre (Point G) improves farmers' net returns to $2.13 million.

Summary and Conclusions

Several strategies to reduce nonpoint pollution are available. These include restrictions on pollutants, taxes on pollutants, subsidies to reduce pollutants, restrictions on inputs or processes causing pollutants, taxes on pollutant producing inputs, subsidies on pollutant abating inputs, or direct bargaining between perpetrators and sufferers. Three of these strategies are examined in detail in the analysis: restrictions on soil loss, taxes on soil loss and subsidies to reduce soil loss.

Results indicate that initial reductions in soil and phosphorous losses are inexpensive to the farmer and society. Soil and phosphorous losses can be reduced by nearly one-half with little or no reduction in net farm income. Reductions in pollutants are due to shifts toward reduced tillage systems which either maintain or enhance net farm income. If the assumption is made that adequate drainage is available or installed in the watershed, minimum tillage and no tillage rotations could be employed on over three-fourths of the crop acreage compared to the current practice of using these systems on only 10 percent of the acreage.

The soil loss tolerance factor, T-value, is the approximate level of soil loss where substantial costs increases are incurred for added reductions in pollutant loadings. Reducing soil loss below the T-value forces dramatic shifts in crop and livestock production within the watershed.

The net economic impacts of restrictions on soil loss, a tax on soil loss, or a subsidy for reducing soil loss are approximately the same. However, the strategies differ in their impact on the farmer and the taxpayer. Generally, the farmers' order of preference would be a subsidy, then regulation, and finally a tax. Conversely, taxpayers' order of preference would be a tax, then regulation, and finally a subsidy. This ordering assumes administrative costs are similar for the three strategies.

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