THE ECONOMIC IMPACTS OF SOIL EROSION AND ITS CONTROL

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CHAPTER I

INTRODUCTION AND HISTORY

Soil erosion control policy in this country has a long history. For more than 40 years the Soil Conservation Service (SCS), the Agricultural Stabilization and Conservation Service (ASCS), the Agricultural Conservation Program (ACP), and the soil and water conservation districts have been components of a program which relies on voluntary compliance and provides economic incentives for farmers to implement soil conservation practices. The ACP is administered by the Agricultural Stabilization and Conservation Service (ASCS) of the United States Depart ment of Agriculture. The network of ASCS state and county offices is the focal point for ACP administration, with authority to determine local conservation needs delegated to elected ASCS committees composed of farmers and ranchers. The ACP functions as the funding and local decision-making arms of the ASCS while the SCS provides technical assistance needed to implement erosion control practices.

The ACP was authorized by Congress in 1935 to begin solving the pressing land and water resource problems caused by severe drought and economic depression. Farmers and ranchers were offered financial assistance for shifting acreage from soil-depleting to soil-conserving crops and for carrying out soil-conserving and soil building practices on cropland and pasture. Such practices included increased acreages of legumes and grasses combined with contour plowing, terracing, stripcropping, and cropland rotation.

"The ACP is currently authorized in sections 7 to 15, 16a, and 17 of the Soil Conservation and Domestic Allotment Act (SCDA) and Title X of the Agriculture and Consumer Protection Act of 1973. Sections 1 to 6 of the SCDA, enacted on April 27, 1935, invested the Secretary of Agriculture with certain powers for the control and prevention of soil erosion and provided for the establishment of the SCS. Sections 7 to 17 were enacted on February 29, 1936, to replace, in part, certain provisions of the Agricultural Adjustment Act of 1933 which were invalidated by the Supreme Court on January 6, 1936.

(Under the ACP, farmers are assisted through payments and grants-in-aid to carry out approved soil and water conservation measures.) The Secretary's authority to implement such a program on a national basis was originally limited to a period of 2 years. During that time, it was expected that a majority of the States would enact legislation enabling them to develop and carry out approved plans for achieving the following objectives: preserving and improving soil fertility; promoting the economic use and conservation of land; diminishing the exploitation and wasteful use of national soil resources; protecting rivers and harbors against the results of soil erosion as an aid to navigation and flood control; and re-establishing, as determined to be practical and in the general public interest, the ratio between the purchasing power of the net income per person on farms and that of the income per person not on farms that prevailed during the 5-year period from August 1909 through July 1914.

The Act of 1936 specified that the powers it conferred on the Secretary should be used to assist voluntary action calculated to achieve its stated purposes. The Act also indicated that due regard should be given to maintaining a continuous and stable supply of agricultural commodities adequate to meet consumer demand at prices fair to both producers and consumers. The Act stated that the interests of small producers were to be protected, 'in every practicable manner.'

Upon approval by the Secretary of State plans to achieve its purposes, the SCDA provided that the Secretary would make grants to the States for carrying out those plans. State plans were to be approved if there was a reasonable prospect that the purposes of the Act could be substantially achieved through implementing State plans, both individually and collectively. As stated in the Act, the operation of the State plan was to 'result in a substantial furtherance' in accomplishing the objectives of the Act, 'as may reasonably be achieved through the action of such State.'

No State plan, however, was to be approved unless it provided that the agency to administer the plan be designated by the Secretary of Agriculture and authorized by the State, or authorized by the State and approved by the Secretary; provided for methods of administration, and participation in the administration of the plan by county and community committees or associations of agricultural producers organized for such purpose; and provided for the submission of reports on the administration of the plan, as required by the Secretary, and to make possible the verification of such reports.

On nine separate occasions, Congress extended the authority of the Secretary to make grants to states for the administration of the ACP. However, only one State submitted a plan as required by the Act, and it was not acceptable. Finally, on September 27, 1962, the State plan provisions of the original Act were repealed. Congress then granted the Secretary continuing authority to carry out the program on a national basis.

The Act authorized the Secretary to utilize county committees of agricultural producers in the administration of the program until a State plan was submitted. When the States failed to submit acceptable plans as required by the Act, Congress amended the SCDA to require the Secretary to use local and State committees in the administration of the program. Local committees were to be elected from among farmers in each of the program's administrative areas (generally counties). State committees were to be composed of farmers who were legal residents of their respective States and appointed by the Secretary.

Public Law 92-419, enacted on August 30, 1972, extended the objectives of the ACP to include the prevention and abatement of agricultural and related pollution.

In December 1972, funds appropriated for the program were impounded and program operations terminated. However, when the impoundment decision was overruled (by Congress), severe restrictions were imposed (by the Executive Branch) on the use of funds for the 1973 and 1974 programs. These restrictions stimulated a congressional reaction in which appropriation language required that county and State committees have authority to select the practices to be eligible for cost-sharing (in the 1975 program) from among the same list of nationally approved practices offered for the 1970 program. This language appeared in the appropriation Acts governing the 1976, 1977, and 1978 programs.

Specific policy direction for the ACP was provided in the Food and Agriculture Act of 1977. Section 1501 of that Act (Public Law 95-113) specified that eligibility for assistance under the ACP would be based on the existence of a conservation or environmental problem which reduces the productive capacity of land and water resources or causes degradation of the environment. In determining the level of assistance, the Secretary is to consider the extent of the conservation or environmental benefits accruing to society from improved conservation practices; the cost of corrective measures or practices; the degree to which appropriate practices would be applied in the absence of assistance; and, the extent to which producers benefit from other conservation and environmental protection programs.

Public Law 95-113 also directed the Secretary, in formulating the national program, to consider the need to control erosion and sedimentation from land and to conserve water resources on such land; control pollution from animal wastes; facilitate sound resource management systems through soil and water conservation; encourage voluntary compliance with requirements to solve point and nonpoint pollution problems; consider national priorities reflected in the National Environmental Policy Act and other congressional and administrative directives; and consider the degree to which assistance contributes to a continuous supply of food and fiber and the type of measures necessary to improve water quality in rural America.

Beginning with the 1979 program, changes in the appropriations language relaxed the constraints on the Secretary's authority to administer the program and mandated increases in its problem-solving orientation. Public Law 95-448 appropriated funds for the ACP to be used to purchase conservation materials and services to carry out essential and enduring conservation and environmental protective measures. To be eligible for assistance under the reformed program, practices must be selected by the county ASC committees and approved by the State ASC committees and the Secretary. No assistance is to be offered for carrying out measures or practices that are primarily production-oriented or that have little or no conservation or pollution abatement benefits."[1]

Table 1 reflects the level of financial assistance provided to landowners since the program's inception. Expenditures for the program reached nearly $300 million in 1944, including funds for the production adjustment features of the program

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[1] National Summary Evaluation of the Agricultural Conservation Program, Phase I (Washington, D.C.: United States Department of Agriculture, 1981), Agriculture Stabilization and Conservation Service, pp. 3-5.

as well as for conservation purposes. As evidenced by the table, the funding levels in 1972 dollars have ranged from $884,911,000 in 1944 to $64,049,000 in 1974. Table 1 includes any amounts earned through the Rural Environmental Assistance Program (REAP) and the Rural Environmental Conservation Program (RECP).

At first, ACP functioned partially as a mechanism to transfer federal funds to farmers struggling to survive when the economy in general, and the agricultural sector particularly, were severely depressed. In the late 1930's, the program reached 3.7 million farmers and covered nearly 65 percent of the total cropland area in the contiguous states. Emphasis was on acreage allotments for major crops and aid to farmers in carrying out soil building practices. Gradually, the program emphasis shifted with changes in the agricultural economy and with legislative adjustments. The acreage allotment function was separated from ACP, and practices were added to meet soil, water, woodland, and wildlife conservation needs. By the late 1940's and early 1950's, practices involving vegetative cover constituted about 73 percent of program assistance. Structural practices such as terraces, diversions, waterways, and strip-cropping accounted for about 15 percent of total program assistance.

TABLE 1

ACTUAL COST-SHARE PAYMENTS EARNED BY RECIPIENTS
AGRICULTURAL CONSERVATION PROGRAM/REAP/RECP 1936-79

Program Year	Total Amount Earned (Nominal Dollars)	Total Amount Earned (1972 Dollars)
	$1,000	$1,000
1936	60,266	265,773
1937	90,431	398,801
1938	92,922	409,786
1939	115,439	509,086
1940	114,830	506,400
1941	122,220	439,992
1942	166,840	505,525
1943	214,132	629,548
1944	293,017	884,911
1945	230,394	721,133
1946	267,086	884,055
1947	244,052	695,548
1948	124,257	315,613
1949	223,573	534,339
1950	251,592	631,496
1951	245,623	520,721
1952	214,918	440,582
1953	184,986	368,122
1954	138,857	274,937
1955	186,811	366,150
1956	213,878	399,952
1957	214,632	386,338
1958	215,316	370,344
1959	208,565	354,561
1960	212,565	359,235
1961	229,077	382,559
1962	218,477	353,933
1963	213,622	337,523
1964	214,475	330,291
1965	216,488	322,567
1966	210,603	301,162
1967	221,684	305,924
1968	199,787	261,721
1969	185,577	231,971
1970	180,893	209,836
1971	146,294	157,998
1972	196,382	196,382
1973	195,600	185,820
1974	74,475	64,049
1975	138,700	108,186
1976	134,731	99,701
1977	175,347	122,743
1978	166,525	108,241
1979	232,781	137,341
Total	8,198,720	16,390,896

Source: National Summary Evaluation of the Agricultural Conservation Program, Phase I (Washington D. C.: United States Department of Agriculture, 1981), Agricultural Stabilization and Conservation Service, p. 7.

In the early 1970's, specific practices were added to help correct environmental pollution problems associated with farming, including animal waste and pesticide control practices. Other changes in the program during the 1970's placed emphasis on longterm agreements with farmers and ranchers to install complete conservation systems on their land. Emphasis was also placed on "enduring" conservation practices as opposed to "temporary" practices. By the mid-1970's, more than 90% of the ACP funds were cost-shared for measures identified as "enduring" practices. The estimated percentage of ACP payments expended under the general practice category for selected years over the life of the program is shown in Table 2.

TABLE 2

PERCENTAGE OF ACP PAYMENTS BY PRACTICE CATEGORY, 1940-79.

Practice Type	Year				
	1940	1950	1960	1970	1980
Soil Loss	85.0	85.3	64.3	57.6	59.3
Water Conservation	8.7	9.8	18.1	21.7	20.4
Water Quality	.7	4.6	13.1	15.5	18.4
Forestry and Wildlife	1.5	.3	4.5	5.0	1.9

Figures do not necessarily add to 100 percent. Some of the practices were not applicable to the categories selected. Figures were supplied by ASCS.

Source: National Summary Evaluation of the Agricultural Conservation Program, Phase 1 (Washington D.C.: United States Department of Agriculture, 1981), Agricultural Stabilization and Conservation Service, p. 8.

Beginning with the 1979 ACP, program operations were based on a new legislative mandate which includes the following long-term program objectives: control of erosion and sedimentation from agricultural operations, conservation of water resources, improvement of water quality in rural America, control of pollution from animal waste, achievement of national priorities reflected in the National Environmental Policy Act of 1969 and subsequent environmental legislation, and contribution to the national objective of assuring a continuous, adequate supply of food and fiber.

Financial incentives are to be limited to practices that result in effective solutions to conservation and environmental problems. The expenditure of funds that does not contribute to program objectives is to be avoided by prohibiting cost-sharing for practices that return an immediate benefit or that have little or no soil or water conservation or pollution abatement benefits. Since 1979, provision for enduring solutions to conservation and environmental protection problems is accomplished by requiring participants to maintain practices for a specified number of years (lifespan) as a condition of cost-sharing. Failure to maintain a practice for the specified lifespan requires a refund of all or part of the cost-share.[2]

Within the direction established by State and national policies, the county committees have full authority to administer the ACP. This authority includes identifying conservation

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[2] <u>National Summary Evaluation</u>, pp. 6, 8.

problems, setting priorities, selecting appropriate cost-share practices, setting levels of cost-sharing, approving applications, entering into contractual obligations, and making payments for completed conservation work. Funds are allocated to states based somewhat on their respective conservation needs. Information obtained from inventories of farmland resources is used as the general basis for determining each state's funding need and its allocation from appropriated funds. State ASC committees then allocate State funds to county committees.

Today there are 34 programs relating to soil and water conservation in agencies in the U.S.D.A. alone. There is some type of state soil conservation in all 50 states, Puerto Rico, and the Virgin Islands. There are 2,950 local conservation districts established under various state laws, and there are more than 2 million farmers and ranchers cooperating in conservation programs by applying conservation practices to their land.

A. Farmland Inventory

Because land resource inventories are used to help distribute soil conservation funds it is useful to examine the results of a comprehensive inventory authorized by the 1978 Resources Conservation Ace (RCA), as well as the National Resources Inventories conducted in 1977 by the SCS. In the RCA Appraisal-Part I, several facts about our land stand out. Only about one-sixth of the total surface area of the United States - about 2.4 billion acres (totals include U.S., Puerto Rico, and the Virgin Islands) - is now available for growing crops. About 99 million acres of the total area are covered by large bodies of water. Of the acreage that remains, about one-third is federal land, most of it in the West, and two-thirds - about 1.5 billion acres - is owned by individuals, by business and industry, and by states, counties, cities, and other units of government.

According to the National Resource Inventories, which were conducted by the SCS in 1977, the 1.5 billion acres are divided as follows:

- 413 million acres of cropland (27.3%)
- 548 million acres of grazing land (36.2%)
- 377 million acres of forest land (24.9%)
- 175 million acres in other uses (including urban and built-up areas, highways, and airports, 11.6%).

Lists of statistics tend to "freeze" pictures of land use in America, but in reality cropland shifts in and out of production. Between 1967 and 1975, for instance, 53 million acres shifted from cropland to pasture and 32 million acres shifted from pasture to crops. From 1967 to 1975, about 8 million acres of prime farmland were taken from agriculture - 6.5 million acres converted to urban and built up areas and 1.5 million acres to water areas. The 1977 data confirmed previous estimates that homes, factories, roads, and other similar uses are absorbing rural land at a rate of about 3 million acres a year.[3]

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[3] Soil and Water Resources Conservation Act - Summary of Appraisal, Parts I and II, and Program Report (Athens: United States Department of Agriculture, 1980), p. 5.

Prime farmland is that land best suited for producing food, feed, fiber, forage, and oilseed crops. Designation of cropland as "prime" indicates that it has a combination of soil characteristics, water supply, and climate conducive to continuously high crop yields under proper management. An important characteristic of prime farmland is a capability for maximum crop yields with a minimum of other inputs. Loss of prime farmland forces farmers to grow crops on marginal lands, which usually are more erodible, droughty, difficult to cultivate, and less productive. Two increasingly scarce resources - water and energy can be saved if agricultural production is carried out on prime farmland.[4]

In 1977 about two-thirds of the nation's 348 million acres of prime farmland was in crops.[5] Of the remaining one-third, 42 million acres were in forest land, 40 million in pasture and native pasture, 23 million in rangeland, and 11 million in farmsteads, farm roads, and other uses.[6] Between 1967 and 1975 about 1 million of the 3 million total acres lost per year were from prime farmland.[7]

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[4]W. E. Larson, "Protecting the Soil Resource Base," Journal of Soil and Water Conservation, 36 (January-February, 1981), 13.

[5]National Agricultural Lands Study (Washington, D.C.: Counci on Environmental Quality, 1980), Interim Report No. 1.

[6]Soil and Water Resources Conservation Act - The 1977 Nationa Resource Inventories (Athens: United States Department of Agricul ture, 1980).

[7]Ibid.

CHAPTER II

THE PROBLEM

> The public is becoming increasingly concerned about the irreversible depletion of natural resources. Soil is one of those resources that is being consumed at an increasing rate. Historically, the cost-price squeeze in agriculture has accelerated the trend toward intensive farming. This pressure to produce 200 bushels of corn where 100 were produced before has manifested itself in many ways.
>
> Many soils with a shallow layer of topsoil have already been depleted to the point where they cannot be used for row crop production. Other soils with deeper topsoils or productive subsoils have been kept productive only by substituting increased amounts of fertilizer for the depleted natural soil productivity.[8]

It has been estimated that of approximately 414 million acres of arable cropland in the 48 states, a total of 50 million acres have been ruined by soil erosion insofar as crop production is concerned; 50 million acres have been severely damaged; 100 millio acres have lost more than one-half of original topsoil; and another 100 million acres have lost more than a quarter of the topsoil.[9] Another study indicates that 272 million acres of cropland in the 48 contiguous states is in need of some type of conservatic

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[8]Lacy I. Harmon, Russel L. Knutson and Paul E. Rosenberry, Soil Depletion Study - Reference Report: Southern Iowa Rivers Basin (Washington, D.C.: United States Department of Agriculture, 1979), p. 1.

[9]N. Hudson, Soil Conservation (Ithaca: Cornell University Press, 1971).

treatment, with erosion control being a primary problem on 200 million acres.[10] These damages could be referred to as "on-site" damages.

The economic cost of decreased net incomes associated with increased inputs such as fertilizer and reduced productivity has not always been recognized by farmers and society. Often both the short- and long-run cost of erosion is masked by the short-run solution of increased inputs. Often the only economic analysis made is a "with and without erosion control" comparison of the annual cost-return relationship in crop production.[11]

In addition to the adverse impacts of erosion on the producer, sedimentation imposes off-site costs on downstream users of the water resource. Erosion also is an environmental problem; its magnitude is suggested by the fact that suspended solid loads delivered to streams and lakes as sediment from surface runoff is 700 times greater than the load from sewage by weight.[12] Sediment generates four types of adverse physical effects leading to economic costs.[13] First, sedimentation of streams reduces channel flow and water storage capacity. This leads to a greater

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[10]Basic Statistics on the National Inventory of Soil Conservation Needs (Washington, D.C.: United States Department of Agriculture, 1962), Statistical Bulletin 317.

[11]Harmon, Knutson and Rosenberry, p. 2.

[12]H. P. Johnson, and W.C. Moldenhauer, "Pollution by Sediment Sources and the Detachment and Transport Process," Agricultural Practices and Water Quality, Ames, Iowa State University Press, 1970.

[13]K. Guntermann, "Suggested Procedures for Evaluating Off-Sit Sediment Damage Caused by Alternative Soil Conservation Practices, Unpublished working paper, University of Illinois, November, 1972.

probability of flooding and greater flood damages when flooding does occur. In addition, sedimentation may preclude use of the waterway for shipping, or necessitate periodic dredging to maintain use value and/or avoid increased flood damages.

A second off-site effect of sediment is an increase in the turbidity level of waterways and reservoirs. Several different costs may result depending upon the uses made of the waterway, including additional treatment necessary to remove the excess sediment from industrial or municipal water supplies. Turbidity may also impair or eliminate the recreational activities or the commercial fishing values of a waterway.

A third physical effect is the accelerated loss of reservoir capacity. The type of damage or cost depends upon the purpose of the reservoir and its uses. For example, some reservoirs were built exclusively for flood control while others provide recreatio or are a source of industrial or municipal water supply.

A fourth physical effect of sediment is the restriction of drainage systems. Sediment deposition in grassed waterways, culverts, ditches, and other constructed drainage facilities may greatly reduce water capacity and contribute to greater flood damages. In addition, flood-borne sediment may damage growing crops and when deposited on fertile soils, may reduce their productivity.

In order to clarify the range of economic impact of sedimentation, damages might be regrouped by economic type of damage, rather than physical effect. The off-site costs of sedimentation would include: (1) dredging of rivers and reservoirs to maintain their use value, (2) greater flood damage, (3) increased water treatment costs, (4) reduced recreation benefits, (5) loss of commercial fishing value, (6) need to develop alternative sources of water supply, (7) increased maintenance cost of drainage systems, and (8) reduction in aesthetic values.

As discussed earlier, the economics of erosion for the producer relates largely to its effect on soil productivity. One of the most dangerous characteristics of the erosion-productivity problem is its difficulty of detection. Erosion reduces productivity so slowly that the reduction may not be recognized until land is no longer economically suitable for growing crops. Futhermore, improved technology often masks the reduction in productivity. Some eroded soils, for example, respond well to heavy fertilizer applications.

The difficulty of detecting erosion is compounded by the nonlinear nature of the erosion process. Erosion generally increases future runoff because of reduced infiltration, which reduces available soil, water and plant growth. Less plant growth means less residue. Less vegetation and residue provide less cover, which increases erosion. Because water erosion strongly relates to runoff, increased runoff leads to increased erosion. The process thus advances exponentially, causing subsoils to be exposed at an accelerated rate in many places.

Erosion reduces productivity first and foremost through loss of plant-available soil water capacity, which subjects crops to more frequent and severe water stress. Plant available soil water may be reduced by changing the water holding characteristics of the root zone or by reducing the depth of the root zone. The water holding characteristics of the root zone are almost always changed when topsoil is removed because topsoil usually has a higher plant-available water capacity than subsoil.

Erosion also reduces productivity by contributing to plant-nutrient losses. Eroded soil particles carry attached nutrients from fields into streams and lakes. Because subsoils generally contain fewer plant nutrients than topsoils, additional fertilizer is needed to maintain crop production. Although fertilizer can partially compensate for low crop yields on exposed subsoils, production costs are increased. The problem is further compounded if the subsoil contains more clay than the topsoil - a common occurrence. Clay tends to transform applied phosphorus quickly into forms not readily available to plants.

A third way erosion reduces productivity is by degrading soil structure, which increases soil erodibility, surface sealing, and crusting and leads to poorer seedbeds. Surface sealing and crusting reduce seedling emergence and infiltration. Reduced infiltration provides less opportunity for soil water storage.

Erosion also reduces productivity through nonuniform removal of soil within a field. Such differences in soil removal affect management practices, such as fertilizer and herbicide applications and timing of field operations, making optimal production impossible for all areas.

Nonuniform erosion also affects tillage effectiveness and causes inconsistent stands and variable emergence. Energy requirements are also greater for non-uniformly eroded fields. Tilling a subsoil usually requires more power than tilling a topsoil. Additional energy is also needed for filling and smoothing gullies. If gullies are neglected, row lengths are shortened, reducing farming efficiency.[14]

A. Study Objectives

As can be seen by the previous discussion, soil erosion from agricultural lands causes significant effects both in the productivity of our nation's farmland and in off-farm damages to watercourses and points in between. The passage of environmental quality oriented legislation in the early 1970's has made the water quality aspects of the soil erosion and sedimentation problem an important policy issue. These concerns about soil productivity, off-site damages, and water quality make it appropriate to analyze the economic impacts of alternative policies, particularly in view of the declining level of real dollars being spent on soil conservation over the years and the prospects for increased funding restraints in the future.

In studying the economic impacts of soil erosion and conservation, it is important to discuss both the costs and benefits

[14] "Soil Erosion Effects on Soil Productivity: A Research Perspective," Journal of Soil and Water Conservation, 36 (March-April, 1981), 83-84.

of various alternative policies and practices, as well as determine the least-cost solutions for reducing erosion in certain situations. This paper will review both issues as they relate to on-farm and off-site economics. While it appears that much work remains to be done in this area, particularly in the area of assessing damages and benefits, the available literature offers much valuable information for policy-makers.

CHAPTER III

THE ECONOMICS OF EROSION AND SOIL CONSERVATION

A definition of economics as the study of the allocation of scarce resources among competing wants or demands seems especially applicable to the field of soil conservation and soil conservation practices. Resources, such as water, soil, and money are limited. Competing wants, such as low taxes, low food prices, low water pollution, increased soil productivity, and better farm income, are many. In considering the economic impacts of soil conservation practices, much of the available literature on the subject evaluates the effects that alternative control programs (various subsidies, regulatory policies, and tax incentives and disincentives) have on such factors as soil productivity, farm income, social costs, and pollution abatement. In this section I will attempt to review the relevant economic concerns related to soil erosion control as they pertain to the producer and society.

A. Computer Modeling and Input-Output Relationships

Because the majority of the surveyed writings on the costs and benefits of soil conservation practices utilize computer models to obtain results, it is useful to review the components and types of output available from a basic model. Dr. Daryll D. Raitt of the Economics and Statistics Service of the U.S.D.A., in a report titled A Computerized System for Estimating and Displaying Shortrun Costs of Soil Conservation Practices provides an example. The report describes a computer system which can be used for rapidly estimating and displaying the shortrun annual on-site costs of soil conservation by soil types. Basic inputs consist of crop budget data, soil erosion data, and engineering data. Such data are entered for each type of soil and location. The computer then generates erosion rates, costs per acre, and costs per ton of erosion reduction. Combinations are ranked by cost per acre and cost per ton of reduced erosion. The model also computes the effect of incremental changes in underlying conservation input costs on per acre farming practice costs.

Raitt notes that the number of alternative conservation practices available for reducing erosion is relatively small, but when used in various combinations and degress of application, they provide several alternatives for any given soil or location. A large amount of information is required to consider all viable combinations of soils for an area.

Crop budgets are used to estimate the annual net income per acre associated with various annual conservation practices. Engineering data are used to compute the annual cost of capital expenditures and maintenance per acre for practices such as terraces. Soil erosion factors are used to estimate the annual erosion rates per acre for each combination of conservation practices. Gross annual sheet and rill erosion is defined as the tons of soil moved yearly by surface water and is estimated by using the Universal Soil Loss Equation (USLE):

A = RK (LS) CP where:

A = annual soil loss in tons per acre,
R = rainfall factor,
K = soil erodability factor,
LS = slope length and gradient factors,
C = cover factor, and
P = conservation practice factor.

The R, K, and P factors are usually available from SCS specialists, L and S factors are estimated by technicians for each soil type, and C factors can be obtained from agronomists for each type of tillage or crop residue management practice.

Once a basic crop budget for an area is produced, changes in inputs and yields to represent different soil types and management practices can be rapidly produced. In the budgets, conventional tillage generally consists of moldboard plowing, cultivation, and use of some herbicides. Minimum tillage consists of chisel plowing, less tillage, and enough additional herbicide application to allow at least 2,000 pounds of surface residue per acre to be maintained. Zero tillage in Raitt's model relies on chemicals for weed and disease control and assumes a 15 percent increase in applied nitrogen.[15] In practice, periodic tillage is recommended to prevent weed and disease buildup.

Conservation costs are computed by subtracting the net income associated with each practice or set of practices from the base net income. Continuous row cropping is used in this base because it usually represents the highest shortrun net income.

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[15]Research at the University of Missouri indicates that about 15 percent more nitrogen is required with zero tillage to obtain yields similar to those with conventional or minimum tillage. "Fertilizer and Pesticides in Runoff and Sediment from Claypan Soil." May, 1979.

Conservation costs in this model therefore include both changes in input costs and the value of output associated with each set of practices.

The costs of minimum tillage, zero tillage, winter cover crops, contouring, and terracing is reflected primarily by changes in input costs. Contour and stripcropping costs are based on the field efficiency losses in machine and labor time. (Ten percent of the machine and labor costs from the crop budgets was used to estimate contour costs and five percent was used to estimate stripcropping costs.) Annual terrace costs include the annual capital cost for construction; a maintenance cost; and if backslopes are permanently seeded to grass, a cost for the loss of income on the backslopes. Terrace costs can also differ based on terrace intervals (spacings).

Input relationships in a farming operation change both as erosion occurs and as erosion control practices are used. Fuel requirements, for example, vary for each kind and erosion phase of soil based on differences in soil texture, structure, organic matter, consistency, and bulk density. Other examples include the need to increase the quantity of seed after spring plowing due to more clods generally present at planting, increasing fertilizer requirements for no-till operations, increased herbicides with minimum tillage due to additional surface residue hampering the adhesion of the chemical to the soil, lower fuel and labor costs with minimum tillage, inefficiencies caused by terraces and contours (partially offset by field hazards that occur because of erosion), changes in harvest costs as yields change due to erosion, and changes in input and crop prices. Each has an impact on farm profitability.

Soil Loss Relationships. A 1974 SCS study on soil depletion in the Southern Iowa Rivers Basin serves to further clarify some pertinent relationships in the economics of soil loss and its control. The basic delineation of soils is the soil mapping unit (SMU), for which a typical code would be 9 B 031. The first number stands for soil type number, the middle letter stands for slope class, and the final digit represents the erosion phase. Erosion phase 1 represents soils where there is no mixing of surface soils and subsoils in the plow layer (slight erosion); erosion phase 2 soils (moderately eroded) have some subsoil mixing in the plow layer; and phase 3 soils (severely eroded) have a plow layer that is predominantly subsoil material. This study notes that because clay and other subsoil materials erode more slowly than topsoil, soil will erode from erosion phase 1 to phase 2 at a faster rate than from phase 2 to phase 3. This characteristic is accounted for in the USLE through factor K, which is the soil erodability factor. As each increment of erosion occurs, the amount of original topsoil lost decreases when tillage mixes the topsoil and subsoils. If deep tillage is not practiced occasionally, then only topsoil is lost.

B. The Economics of Erosion Control at the Farm Level.

As can be seen in the Raitt model, many factors contribute to the determination of the cost-effectiveness of soil conservation practices. Although other variables and inputs are sometimes used in the computer modeling in other research projects, the Raitt model contains the basic elements found in most of the other shortrun models.

> The erosion of farm land has two adverse impacts at the individual farm level, the physical loss of soil and the loss of plant nutrients and organic matter. Therefore, declining yields will necessitate increasing other inputs. In the short run, one year, economics would dictate that the farm operator will implement soil conservation practices only if there is a positive impact on his net returns in the year the practices are instituted. Since implementation of most practices involves some initial capital investment, either installation of facilities or purchase of equipment, soil conservation practices are often not economically implemented on the basis of this type of analysis. The economically rational farm operator will, however, invest in, or adopt, a conservation practice if the discounted expected net returns are higher than without the practice. The important variables in this decision are the expected impact on costs and returns, the discount rate used, and the length of the planning period.[16]

Costs and Returns. The major impact of soil deterioration can be quantified through changes in fertilizer, product yields, and power or fuel requirements. Soils vary in their response to fertilizer inputs as erosion occurs. As a soil is depleted

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[16] W. D. Seitz, M. B. Sands, and G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 11.

from erosion phase 1 to phase 2, additional inputs of nitrogen (N), phosphate (P_2O_5), and potassium (K_2O) are needed to keep productivity at levels recommended by soil tests. Even with these increased fertilizer inputs, yields generally fall as soil is eroded from one phase to another. The magnitude of the change can be observed by comparing the difference in crop yields between erosion phases, as shown in the following table:

TABLE 3
REDUCTION IN YIELD AS SOIL IS DEPLETED
SOUTHERN IOWA RIVERS BASIN REPORT

Change in Erosion Phase	Reduced Yield Per Acre			
	Corn	Soybeans	Oats	Hay
1 to 2	16 bu.	5 bu.	9 bu.	.6 ton
2 to 3	7 bu.	3 bu.	4 bu.	.5 ton

Source: Lacy I. Harmon, Russel L. Knutson, and Paul E. Rosenberry, Soil Depletion Study - Reference Report: Southern Iowa Rivers Basin (Washington, D.C.: United States Department of Agriculture, 1979), p. 10.

The monetary cost of lower yields and higher fertilizer and fuel requirements caused by erosion can be significant, as evidenced by the table on the following page.

As can be seen, the costs of erosion itself can be significant for the producer. In light of such costs or damages, it seems appropriate to consider the costs and benefits of various soil conserving practices.

TABLE 4
SPECIFIED ANNUAL COST OF SOIL DEPLETION*
SOUTHERN IOWA RIVERS BASIN REPORT

	Million Dollars/Year	
Item	2000	2020
Fertilizer	2.0	2.6
Yields	4.3	8.1
Fuel or Power	.4	.7
TOTAL	6.7	11.4

*Assuming 1974 conditions throughout time period to 2020.

Source: Lacy I. Harmon, Russel L. Knutson, and Paul E. Rosenberry, Soil Depletion Study - Reference Report: Southern Iowa Rivers Basin (Washington, D.C.: United States Department of Agriculture 1979), p. 10.

In considering the impacts of soil conservation practices on farm level costs and returns, it is important to understand the economic incentives private entrepeneurs have for reducing soil loss. Private economic incentives come about by reducing or eliminating one or more of the following effects of soil erosion:[17] (a) loss in production potential from topsoil loss; (b) loss of nutrients, such as nitrogen, phosphorous, and potassium; (c) lower

[17] Robert P. Beasley, Erosion and Sediment Pollution Control (Ames: Iowa State University Press, 1972).

infiltration rate and water-holding capacity; (d) deterioration of soil structure; (e) lower crop quality; (f) sediment deposition on fertile soil; (g) loss of cropland by gullies and streambank erosion; (h) increased power requirements for tillage operations; and (i) division of fields by gullies.

Two economic questions are important when considering costs and returns at the farm level. The first is the question asked by the producer who is determined to apply conservation practices only when returns exceed costs; i.e., "Under what situation, planning periods, and discount rates will returns exceed costs in applying such practices?" The second question is asked by the producer who is determined to maintain the natural fertility and productivity of his soil, i.e., "Which practices are least costly to maintain the long-term productivity of my soil?"

In the short run, one year, profit margins are low enough (sometimes nonexistent) for most farms that conservation practice benefits simply could not exceed costs. Benefits on a yearly basis are usually low while cost, particularly with some structures, is very high. Therefore, a farmer with a one year planning period must look to possible changes in tillage practices or cropping systems to find a soil erosion control strategy with costs low enough to provide a favorable opportunity cost. It should be noted, however, that the costs and returns produced by different tillage practices and cropping systems vary greatly, particularly for cropping systems.

Because conventional tillage (moldboard fall plowing, cultivation, and use of some herbicides) is most commonly used and because continuous row cropping usually results in the highest short run net income, these practices are used as the base against which to compare any changes in practices. Using highly erosive soil resource group 124 in Northwest Missouri, Raitt compared 50 practice combinations of tillage practices and cropping systems to the base of conventional tillage and continuous cropping of corn. A total of 46 of those combinations increased cost per acre The four combinations which reduced production costs per acre are shown in the following table with the achieved reductions in erosion.

TABLE 5
TILLAGE PRACTICES AND CROPPING SYSTEMS WHICH RESULTED IN REDUCED COST PER ACRE FOR CORN

Obser-vation	Cost/Acre	Erosion Reduction Tons/Acre	Tillage Practice	Cropping System	Cost/Ton Reduction
1 (base)	$ 0.00	0.0	Convent.	Contin.	$ 0.00000
2	-3.50	24.9	Minimum	Contin.	-0.14045
3	-1.05	33.5	Minimum	Rotation*	-0.03133
4	-0.67	28.4	Zero	Contin.	-0.02362
5	-0.10	32.7	Minimum**	Contin.	-0.00306

*Rotation is corn-corn-corn-wheat-alfalfa-alfalfa-alfalfa.

**Contouring used in combination with tillage practice.

Source: Daryll D. Raitt, A Computerized System for Estimating and Displaying Shortrun Costs of Soil Conservation Practices (Washington, D.C.: U.S.D.A. Economics and Statistics Service, 1981), p. 17.

A similar table for soybeans is shown in Table 6.

TABLE 6
TILLAGE PRACTICES AND CROPPING SYSTEMS WHICH
RESULTED IN REDUCED COSTS PER ACRE FOR SOYBEANS

Observation	Cost/Acre	Erosion Reduction Tons/Acre	Tillage Practice	Cropping System	Cost/Ton Reduction
13	$ 0.00	0.0	Convent.	Contin.	$ 0.00000
14	-13.70	27.5	Minimum	Contin.	-0.29891
15	-11.10	37.4	Minimum*	Contin.	-0.29714
16	- 4.72	32.4	Minimum**	Contin.	-0.14545
17	- 2.11	39.9	Minimum***	Contin.	-0.05294

*Tillage practice includes contouring.
**Tillage practice includes winter cover.
***Tillage practice includes contouring and winter cover.

Source: Daryll D. Raitt, A Computerized System for Estimating and Displaying Shortrun Costs of Soil Conservation Practices (Washington, D.C.: U.S.D.A. Economics and Statistics Service, 1981), p. 19.

These results are based on the summary of practice costs and net returns for the same soil resource group shown in the table on page 32.

It can be concluded that certain tillage practices and cropping system can favorably affect both per acre costs and net returns In fact, on this highly erosive soil group, minimum tillage had significant impacts on net returns and costs. Continuous cropping was evident in all but one of the eight most profitable combina tions. The evidenced cost saving and increased profit associated with minimum tillage is confirmed by Narayanan and Associates in a 1974 economic analysis of erosion in the Mendota West Fork Watershed in Illinois.[18]

[18]A.S. Narayanan, and others, Economic Analysis of Erosion and Sedimentation - Mendota West Fork Watershed (Urbana-Champaign: University of Illinois, 1974), Department of Agricultural Economics p. 4.

TABLE 7
SUMMARY OF PRACTICE COSTS AND NET RETURNS
MONROE COUNTY, MISSOURI

Item	Corn			Soybeans	
	Conventional Tillage	Minimum Tillage	Zero Tillage	Conventional Tillage	Minimum Tillage
		$/acre			
Net returns: 1/					
Without rotation	27.73	31.23	28.40	62.33	76.05
With rotation 2/	27.46	28.78	27.72	40.44	45.58
Tiller practice costs:					
Tillage alone	0.	-3.50	- .67	0.	-13.72
Rotation alone	.27	2.45	.68	21.89	30.47
Tillage and rotation	.27	-1.05	.01	21.89	16.75
Machine and labor costs: 1/					
Without rotation	38.86	34.03	33.36	34.24	26.12
With rotation 3/	17.42	15.61	15.36	15.69	12.65
Contour costs: 4/					
Without rotation	3.87	3.40	3.34	3.42	2.61
With rotation	1.73	1.57	1.54	1.57	1.26
Strip cropping costs: 5/	1.84	1.75	1.74	1.76	1.60
Winter cover costs	9.00	9.00	9.00	9.00	9.00
Terrace costs	43.00	42.00	37.00	43.00	42.00

Source: Daryll D. Raitt, A Computerized System for Estimating and Displaying Shortrun Costs of Soil Conservation Practices (Washington, D.C.: U.S.D.A. Economics and Statistics Service, 1981), p. 13.

1/ From budget generator. Machinery and labor costs include these items: tractor fuel and lube, tractor repair, equipment fuel and lube, equipment repair, machine labor.

2/ Net income for rotation RRRGMMMM computed as follows: row crop (R) net income X 0.375 + wheat (G) net income (-17.24) X 0.125 + alfalfa (M) net income (38.44) X 0.5.

3/ Machine and labor cost for rotation RRRGMMMM computed as follows cost for row crop X 0.375 + wheat cost (22.85) X 0.125.

4/ Contour costs are 10 percent of machine and labor costs.

5/ Strip cropping costs are 5 percent of machine and labor costs.

Their results showed an increase in net income of approximately 75 cents per acre based on 1972 price levels for a plow-plant system of minimum tillage under continuous cropping and several rotation systems. The plow-plant and continuous cropping of corn was again the most profitable. It should be noted that this watershed was much less erosive than the area analyzed by Raitt, with continuous cropping of corn under conventional tillage producing 12.26 tons/acre of soil loss.

In another economic analysis of erosion controls in the corn belt, Taylor, Frohberg, and Seitz[19] estimate that when chisel plowing as a form of minimum tillage is used in all situations where it is profitable, over 77 million acres are chisel plowed, compared to the estimated 33 million acres on which chisel plowing is currently used. This study estimated lower producer costs with corn belt chisel plowing of $551,150,000 while production in bushels varied by an insignificant amount. Soil losses decreased from 5.17 to 2.96 tons/acre.

It is important to note that the Raitt model results produced a favorable net income for use of a rotation only when used in combination with minimum tillage and that zero or no-till was profitable only when used with continuous corn, with the profit margin much smaller than minimum tillage. It is also important to note that in the study by Taylor and Associates,

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[19]R. C. Taylor, K. K. Frohberg, and W. D. Seitz, "Potential Erosion and Fertilizer Controls in the Corn Belt: An Economic Analysis," Journal of Soil and Water Conservation, 33 (July-August, 1978), 1974.

the 77 million acres where chisel plowing was more profitable represented only 70 percent of the total acreage included in the study. Chisel plowing was not recommended on the remainder of the corn-belt acreage because tight soils would result in much lower yields. Consequently a need exists to utilize tools such as the Raitt computer model to assist farmers in knowing the most profitable short-run tillage practices and cropping systems.

Impact of Discount Rates and Planning Periods on Cost-Effectiveness. Because conservation structures do produce long-run benefits, it is necessary to use discount rates to determine the cost-effectiveness of such practices. Mitchell, Brach, and Swanson, using 1978 data, undertook a study to determine if terrace systems are economically justified from the farmers standpoint.[20] Terraces of both the gradient and tile-outlet-storage type were investigated. Various Illinois soil types, as well as two subsoil types and two management levels, were also considered. Soil losses for various conditions were estimated using the USLE. Corn and soybean prices for 1978 were used in the study.

[20] J. K. Mitchell, J. C. Brach, and E. R. Swanson, "Costs and Benefits of Terraces for Erosion Control," Journal of Soil and Water Conservation, 35 (September-October, 1980), 233.

The study assumed the tillage system without terraces to be up and down fall plowing. To calculate the percentage yield reductions due to erosion, total inches of soil eroded per year was calculated. Such soil losses were converted to volume using a bulk density of 84 pounds per cubic foot, an average value for the plow layer of several silt loam soils.[21] It was assumed that terrace spacing and contouring were such that the soil losses on terraced land did not exceed SCS tolerance levels. It was assumed that moderate erosion (presence of subsoil over much of the area after fresh plowing) had occurred on the soils before the study. Yields were reduced by the amounts in Table 8.

Terracing costs were compiled using SCS estimated costs of engineering practices in Illinois in 1978. Costs were calculated for field slopes from 1-15 percent, with grass-backslope terraces used for slopes over 6 percent. A 50 percent government subsidy was assumed in the total construction costs. Annual maintenance and reduced efficiency costs were estimated to be $4.50 per acre per year.[22]

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[21] N. C. Brady, The Nature and Properties of Soil (New York: MacMillan, 1961).

[22] M. T. Lee, and others, Economic Analysis of Erosion and Sedimentation, Hambaugh-Martin Watershed (Urbana-Champaign: University of Illinois, 1974), Department of Agricultural Economics, p. 4.

TABLE 8
PERCENTAGE ADJUSTMENTS IN YIELDS FOR VARIOUS LEVELS OF MANAGEMENT, SLOPES AND EROSION CONDITIONS*

Slope(%)	High Management, Favorable Subsoil			High Management, Unfavorable Subsoil		
	Uneroded	Moderate Erosion	Severe Erosion	Uneroded	Moderate Erosion	Severe Erosion
0-2	100	97	90	100	95	80
2-5	99	96	89	99	94	79
5-10	97	94	87	96	91	76
10-15	93	90	83	91	86	71
	Basic Management, Favorable Subsoil			Basic Management, Unfavorable Subsoil		
0-2	100	95	85	100	90	75
2-5	98	93	83	98	88	73
5-10	95	90	80	94	84	69
10-15	90	85	75	88	78	63

*Illinois Cooperative Extension Service, 1978.

Crop management characteristics and soil properties and productivities were also defined by the Illinois Extension Service.

Source: J. Kent Mitchell, John C. Brach, and Earl R. Swanson, "Costs and Benefits of Terraces for Erosion Control," Journal of Soil and Water Conservation, 35 (September-October, 1980), 234.

All cost and yield considerations described above were then computed for each year of the 20-year period. For each year, the study calculated:

1. total depth of soil lost by erosion to date;
2. percentage reduction in yield;
3. cost of the yield reduction; and
4. cost of the yield reduction discounted to present value.

The results of the study can be summarized as follows:

1. Cost of terrace construction does not increase at a constant rate with increasing slope. Grass-backslope terraces are more cost-effective for slopes six percent and over because they reduce the effective field slope, allowing terraces to be spaced further apart.
2. For any initial level of productivity, terrace systems are more costly for soils on favorable subsoils than on unfavorable subsoils due to the larger productivity drop which occurs when unfavorable subsoils are exposed by erosion. Therefore, returns on investment are higher on those fields with unfavorable subsoils.
3. The highest net benefits (<u>although negative</u>) occur on slopes from 1-3 percent because of low initial construction costs. On steep slopes (11-15 percent), initial construction costs exceeded yield benefits, despite serious erosion.
4. Higher levels of management result in higher net benefits from terracing because the higher yields achieved at that level would suffer greater reductions from erosion. This difference in net benefits averaged $37 per acre for unfavorable subsoils and $21 for favorable subsoils.
5. The only study situation in which terracing increases farm income is when a gradient system is used on highly erodible soils with unfavorable subsoils at a high level of management. Most Illinois soils did not meet this criteria. Net benefits were lowest on topsoils of low productivity where the farmer could least afford terracing.

It should be noted that the conclusions listed above do not consider the indirect private costs of erosion such as reduced land values and the cost of removing sediment from waterways. Other non-farm costs are also significant, such as reduced reservoir life, costs of pollution, etc. These costs will be considered later in this paper.

Ervin and Washburn[23] in a study of Missouri soils in Monroe County, used a new procedure to estimate productivity losses and evaluate the effect of such losses on the long run profitability of conservation practices using different discount rates, planning periods, and cost-sharing levels. They calculated net present values and annualized net incomes for existing cropping activities and included increasingly effective soil conservation practices to evaluate the effect of incremental reductions in erosion rates on crop yields and net returns over time. Twelve crop rotations, three tillage systems and four conservation practices, including contour farming with terraces, were studied. Budgets were developed for each crop rotation and tillage system on each soil, with crop yields based on 10 year area averages. Yields for minimum, conventional, and zero tillage systems were assumed to be equal. Crop prices were 1976 normalized prices: corn, $2.61 per bushel; soybeans, $5.22 per bushel; wheat, $4.94 per bushel; milo, $2.44 per bushel; and hay, $50 per ton.

Ervin and Washburn then subtracted the annual soil conservation costs from the net returns for each crop rotation and tillage

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[23]David E. Ervin and Robert A. Washburn, "Profitability of Soil Conservation Practices in Missouri," Journal of Soil and Water Conservation, 36 (March-April, 1981), 108.

method combination. Per acre annual costs of various soil conservation practices are shown in the following table.

TABLE 9
ANNUAL COSTS PER ACRE FOR SOIL CONSERVATION PRACTICES
MONROE COUNTY, MISSOURI, 1976-1978*

Practice	Annual Costs
Terraces	
Putnam soils (0-2% slope)	$10.90
Mexico soils (2-5% slope)	20.59
Leonard-Armstrong soils (5-9% slope)	26.47
Armstrong soils (9-15% slope)	28.83
Contour farming	3.00
Contour-stripcrop farming	4.00

*Source: Soil Conservation Service, U.S. Department of Agriculture. Reference: David E. Ervin and Robert A. Washburn, "Profitability of Soil Conservation Practices in Missouri," Journal of Soil and Water Conservation, 36 (March-April, 1981), 108.

Terracing costs included an amortized initial construction cost for 10 years at a 10 percent interest rate, plus an annual operation and maintenance charge of five percent of the initial construction cost. The contouring and stripcrop costs reflect increased labor, fuel, and machinery depreciation due to increased time requirements over up- and down-hill cultivation. Both the initial costs of terrace construction and the annual costs of contouring and contour-stripcropping were assumed to be eligible for cost-sharing (ACP currently allows only one-time cost-sharing for contouring and contour-stripcropping). In figuring productivity losses due to soil erosion, it was assumed that fertilizer levels remained constant as the soil erodes.

The tabular results presented by Ervin and Washburn can be summarized as follows:

1. Using discount rates of 4, 8, and 12 percent, the costs of contouring with terraces and contour-stripcropping significantly outweighed the benefits in most cases. Terracing was shown to require heavy subsidies to compare favorably with up- and down-hill cultivation or contouring. Average per acre soil loss for the most profitable cropping activities was 12 tons under the 12 percent discount rate and 7.4 tons under the lower discount rates, reflecting the increased profitability of contouring and the consequent reduction of erosion as the discount rate drops.
2. Assuming no cost-sharing and a discount rate of eight percent, increases in the planning period from 5 to 25 to 50 years resulted in contouring being more profitable than up- and down-hill cultivation on the Leonard-Armstrong and Armstrong soils (5-15 percent slopes). This pattern held for the continuous corn and the corn-soybeans rotation with one exception. Contouring with terraces and contour-stripcropping were not as profitable as contouring despite lower erosion and higher productivity.
3. Using a 10 year planning period and a discount rate of eight percent, cost-sharing of $1.50 (50%) annually resulted in contouring becoming more profitable for the Leonard-Armstrong and Armstrong soils under both continuous corn and the corn-soybean rotation. However, even 75 percent cost-sharing did not result in net incomes for contouring exceeding up- and down-hill cultivation on either Mexico or Putnam soils. Terrace and contour stripcropping expenses eligible for cost-sharing, based on current guidelines, did not constitute enough of the

total costs of each practice for production increases to exceed the remaining costs. Increasing the cost-share rate from zero to 50 or 75 percent reduced erosion from 12 tons to 7.4 tons per acre on the most profitable cropping activities. Using these parameters for planning period and discount rate, cost-sharing rates or eligible expense for terraces or stripcropping must increase dramatically to lower the erosion rate further.

Given all the various assumptions, Ervin and Washburn make a number of conclusions: (1) that non-monetary concerns (e.g., maintaining productivity for future generations) may be a more important factor in farmer decisions than the relatively small profit differences between contouring and up- and down-hill cultivation; (2) that because the most favorable study scenarios did not produce an erosion rate of three tons (T value) or less on any of the soils, consideration should be given by the SCS to annual cost-sharing for contouring and subsidization of terrace system operation and maintenance expenses; (3) because less sloping soils do not generate large potential gains in productivity, priority should be given to steeper sloping soils to increase the cost-effectiveness of programs.

Before continuing, it is important to note that a great deal of variation exists in the results of studies on the relationship of soil erosion to productivity. For example, Pimental and Associates estimated the annual reduction in per acre returns from corn that is due to soil erosion is less than one percent of the cost of producing corn.[24] Their study, however, quotes another

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[24] David Pimental, and others, "Land Degradation: Effects on Food and Energy Resources," Science, 1976, 149-55

researcher as saying that losses due to soil erosion cost most farmers about $50 per acre annually.

These statements reveal two generalizations about the effect of soil losses on crop yields. First, the yield-decreasing effect is subject to considerable variation, depending on soil type, crop, and other site specific factors. Second, and most important for economic research on productivity losses, there is little definitive agronomic evidence about the relationship between soil erosion and crop yields.[25]

For example, Swanson and MacCallum[26] studied the water erosion effects on farm income for three types of Illinois soils for 10, 20, and 50 year planning horizons. Their results generally concluded that contouring produced a higher return than up- and down-hill cultivation, due to the significant reduction in erosion and productivity losses from contouring and the relatively small cost ($0.65/acre). Changes in the crop rotation, however, to reduce productivity losses generally were not profitable, except on thin topsoils over the 50-year planning period.

In general, Illinois watershed studies show that efforts to offset crop yield declines by adopting soil conservation practices yield slight increases in annual returns on more erosive watersheds, assuming a 20-year planning period and a 7.5 percent discount rate.[27] However, Seitz and Associates, in an analysis

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[25]Ervin and Washburn, 107.

[26]E. R. Swanson and D. E. MacCallum, "Income Effects of Rainfall Erosion Control," Journal of Soil and Water Conservation, 24 (March-April, 1969), 56-59.

[27]Earl R. Swanson, Economic Evaluation of Soil Erosion: Productivity Losses and Off-Site Damages (Lincoln: Great Plains Agricultural Council, 1978), pp. 53-74.

of a highly erosive watershed in Northeastern Illinois over a 100-year planning period, predicted that the discounted (five percent) cumulative net watershed income under constrained soil conservation conditions was only slightly different than income under unconstrained conditions.[28] The divergence between the results of this study and the other Illinois watershed studies appears to be due in part to the use of small grains and meadows in the Seitz conservation solution, which reduces the profitable effect of soil conservation in row crop rotations.

Frohberg and Swanson concluded that in the Big Blue Watershed, reduction of soil productivity was a minor factor in determining optimal soil losses.[29] This result apparently is attributable to the substitution of nitrogen for topsoil losses over time. If the crop price-nitrogen cost ratio declines over time, the reduction in productivity due to soil erosion will become more important in determining optimal soil loss.

Harmon and Associates[30] attempted to determine the effect that current levels of soil erosion would have on individual soils by the year 2020. They then computed energy, fertilizer, and yield costs of soil depletion and compared such costs with the costs of alternative soil conservation practices necessary to reduce soil losses to tolerable levels (T), as defined by the SCS.

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[28] W. D. Seitz, et al., Alternative Policies for the Control of Nonpoint Sources of Water Pollution from Agriculture (Athens: United States Environmental Protection Agency, 1978), EPA 60015-78-005.

[29] Klaus K. Frohberg and Earl R. Swanson, A Method for Determining the Optimum Rate of Soil Erosion (Urbana-Champaign: University of Illinois, 1979), Department of Agricultural Economics.

[30] Harmon, Knutson, and Rosenberry, p. 14.

They concluded that farmers cannot normally justify soil conservation practices from a profitability standpoint without cost-sharing or other form of government assistance. While the results of these studies vary, they all conclude that soil erosion control is not generally economical from the farmers standpoint.

Cost Effectiveness of Erosion Control Practices. If, with the exception of minimum tillage, soil erosion control is generally not economical for the farmer, what are the most cost-effective methods of erosion control for the farmers who choose to reduce erosion for non-economic reasons? In the National Summary Evaluation of the ACP, the ASCS produced perhaps the most comprehensive assessment to date of the efficiency of soil conservation practices at the farm and national level. The ASCS compared costs and erosion reductions for 61,000 cost-shared practices for which financial assistance was provided during program years 1975, 1976, 1977, and the first half of 1978. The sample practices were located in 171 counties in the 46 states. In evaluating the impact on sheet and rill erosion, 23,911 practices were evaluated. For those practices as a group, the average pre-assistance erosion rate of 10.7 tons per acre annually was reduced by 6.5 tons to 4.2 tons per acre annually. This amount is within the average soil loss tolerance for most cropland soils, but may be above tolerances on some range soils. The impacts of those practices on erosion is illustrated by the following ASCS table.

TABLE 10
IMPACT ON SHEET AND RILL EROSION - 23,911 CONSERVATION PRACTICES BY TYPE OF PRACTICE, 171 SAMPLE COUNTIES, AGRICULTURAL CONSERVATION PROGRAM, 1975-1978

Erosion Control Practice	Number of Cases	Average Erosion Rate Before Assistance (T/ac/yr)	Average Erosion Reduction (T/ac/yr)	Average Erosion Rate AFter Assistance (T/ac/yr)
Critical area treatment	217	31.3	30.3	1.0
Diversion	429	21.8	10.6	11.2
Terraces	1,754	14.2	9.3	4.9
Establishing permanent vegetative cover	10,315	11.9	8.3	3.6
Minimum tillage	119	9.7	5.9	3.8
Improving permanent vegetative cover	6,978	7.9	4.5	3.4
Interim cover	2,916	13.7	3.1	10.6
Stripcropping	172	8.0	3.1	4.9
Competitive shrub control	1,011	3.0	1.0	2.0
TOTAL	23,911	10.7	6.5	4.2

Source: National Summary Evaluation of the Agricultural Conservatio Program, Phase I (Washington, D.C.: United States Department of Agriculture, 1981), Agricultural Stabilization and Conservation Service, p. 26.

The average cost per ton of such impacts is shown by a related table

TABLE 11
AVERAGE COST PER TON OF TOTAL EROSION REDUCTION: NINE CONSERVATION PRACTICES, 171 SAMPLE COUNTIES, AGRICULTURAL CONSERVATION PROGRAM, 1975-1978

Practice	Number of Cases	Average cost per ton of erosion reduction (Dollars)
Critical area treatment	217	0.37
Diversions	429	0.69
Conservation tillage	119	0.98
Terraces	1,754	1.17
Stripcropping	172	1.52
Competitive shrub control	1,011	1.88
Establishing permanent cover	10,315	1.91
Improving permanent cover	6,978	2.90
Interim cover	2,916	8.07
AVERAGE TOTAL	23,911	2.22

Source: National Summary Evaluation of the Agricultural Conservatio Program, Phase I (Washington D.C.: United States Department of Agriculture, 1981), Agricultural Stabilization and Conservation Service, p. 28.

The average unit cost of erosion reduction for the nine practices shown above varied with two factors. One is the relative efficiency of each practice regardless of the situations in which it is used. The second factor reflects the influence of the specific situations in which the practices tend to be used. Where the unit cost of erosion reduction is concerned, the pre-application erosion rate is important in determining the efficiency of the practice in erosion reduction.

Averages, however, have only limited meaning to the individual producer, primarily because runoff on a particular farm is related to a number of variables which produce different levels of soil loss. If we assume that total soil loss in tons per acre is the most valuable aggregate measure of the farm's condition prior to assistance, Table 12 will adapt itself more readily to assessing the relative merits of various practices normally applied to tillable farmland.

The cost figures reflect total costs and not farmer or government share only. As can be seen by the table, interim cover was the least efficient of all practices in reducing erosion regardless of the rate of erosion prior to cost-shared treatment. It should be noted, however, that the cost per ton saved for any of the practices did not include erosion from wind. The cost per ton and relative effectiveness of interim cover might change if its effect on wind erosion is included. Because interim cover is particularly compatible with production of soybeans and other crops which allow double cropping, and because many farmers would pasture cattle on the winter cover, in many situations the 3.1 ton erosion reduction per acre per year would simply be a windfall, being overshadowed by the economic benefits of the other factors. In other words, interim cover may be particularly valuable for many farmers, simply because returns normally exceed costs of applying the practice.

TABLE 12
AVERAGE COST PER TON OF EROSION REDUCTION BY PRE-PRACTICE EROSION RATE, 171 SAMPLE COUNTIES
AGRICULTURAL CONSERVATION PROGRAM, 1975-78

Average Annual Soil Loss Before Treatment (tons per acre)	Type of Practice: Stripcropping	Terrace	Interim Cover	Conservation Tillage	Average For All Practices
	----Average Cost Per Ton of Erosion Reduction in Dollars----				
0 - 1	7.57	9.48	65.52	63.45	45.40
1 - 1.99	7.10	6.91	61.39	4.98	14.23
2 - 2.99	6.28	3.43	31.53	2.35	5.85
3 - 3.99	2.15	3.14	29.13	1.76	4.19
4 - 4.99	.92	4.13	18.43	1.50	4.70
5 - 5.99	1.61	3.60	15.30	.90	3.10
6 - 6.99	1.14	2.68	15.19	.98	3.46
7 - 7.99	.52	2.57	9.49	.53	2.33
8 - 8.99	.88	2.66	7.69	.53	2.40
9 - 9.99	1.07	2.08	7.21	.61	2.16
10 -10.99	1.43	1.68	6.77	.39	2.16
11 -11.99	--	1.95	5.77	.39	1.57
12 -12.99	.30	1.43	5.95	.83	1.54
13 -13.99	1.07	1.12	3.99	.61	.94
14 -14.99	--	1.21	3.90	.21	1.12
15 -19.99	.69	.99	3.94	.32	.84
20 -24.99	.06	.87	3.07	.29	.54
25 -29.99	--	.77	2.38	--	.48
30 -49.99	.02	.44	1.81	.08	.39
50 -74.99	--	.15	2.21	.13	.24
75 -99.99	--	.03	2.19	.04	.22
Over 100	.01	--	1.36	--	.21

Source: National Summary Evaluation of the Agricultural Conservation Program, Phase 1 (Washington, D.C.: United States Department of Agriculture, 1981), Agricultural Stabilization and Conservation Service, p. 30.

The table also shows that for almost every level of soil loss before treatment, conservation tillage (contouring, minimum and no-till) was more cost effective than stripcropping. This advantage becomes even more pronounced when considering the income reducing effects of the rotations required in stripcropping. Stripcropping, however, was the most effective of all the practices in controlling erosion for erosion intervals checked in excess of 30 tons per acre annually.

Except at very low or very high rates of sheet and rill erosion, terraces were among the most expensive practices in reducing erosion when measured in terms of installation cost per ton. Terraces were cost effective at erosion rates of over 50 tons per acr

Walker and Timmons, in an evaluation of policies to reduce soil erosion,[31] compared the effectiveness of contouring and minimum tillage. Because contouring did not produce significant reductions in erosion, minimum tillage was much more cost-effective despite costs three to eight times greater than contouring (depending upon the rates of costs and farm prices). Contouring, however, was shown to pay its own way on slopes from three to seven percent due to increased crop yields resulting from control of soil and nutrient losses and greater infiltration of water.[32] Minimum tilling is required with the use of contouring on steeper slopes because contouring alone is not effective due to water breaking across the tillage ridges.

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[31] John Walker and John Timmons, "Costs of Alternative Policie for Controlling Agricultural Soil Loss and Associated Stream Sedimentation," Journal of Soil and Water Conservation, 35 (July-Augus 1980), 181.

[32] E. L. Sauer and H. C. M. Case, Soil Conservation Pays Off (Urbana: Illinois Agricultural Experiment Station, 1954), Bulletin 575.

The Southern Iowa Rivers Basin Study also compared net income lost with various methods of erosion control, in this case all used in conjunction with the same rotation program. Most cost-effective in this study was a combination of contouring and residue (minimum tillage). Least cost-effective was terracing in the absence of other conservation practices. Terracing and residue in combination proved to be more cost-effective than minimum tillage alone or contouring alone.

One important point made by Seitz, Sands, and Spitze[33] after consultation with University of Illinois Extension Agronomist W. R. Oschwald, was that chisel plowing, despite being very cost-effective in terms of soil saved per dollar, may cause yield reductions by as much as five percent on some well drained soils and 15 percent on some poorly drained soils.

C. Economics of Erosion Control at the Watershed Level

Under the current institutional framework, the impact of the eroded sediment on the watershed does not enter the calculations of the farm operator. The increase in the rate of sedimentation over the natural rate is an illustration of an external diseconomy or a spillover effect. The spillover effect of the agricultural production process, sediment, generally results in a deterioration of environmental quality or a direct economic loss to third parties.

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[33] Seitz, Sands, and Spitze, p. 35.

The nature of this problem and the optimum theoretical solution is indicated in Figure 1. The demand for crops is symbolized by Curve D. MPC is the marginal private cost of producing crops, ignoring off-site damages. MSC is the marginal social cost (private plus additional societal costs borne with no conservation practices) of production under the same conditions. Without policy restrictions, production will occur at 0 and MSC will be at Point A. The price of the product will be P. Under the assumption of an implementation of soil conservation practices the MPC curve increases to MPC' and MSC is reduced to MSC'.* There are 0' units of crops being produced at a price of P'. Output is therefore reduced and price is increased in order to reduce social costs to the level desired by society through a conservation program.[34]

Kneese indicates that pollution problems generally occur within areas not directly coinciding with existing government jurisdictional units, such as a watershed or some other problemshed.[35] It is within such problemsheds that spillover effects and the opportunities for their reduction are most likely to occur, as more than half of the flood damage and most of the drainage needs

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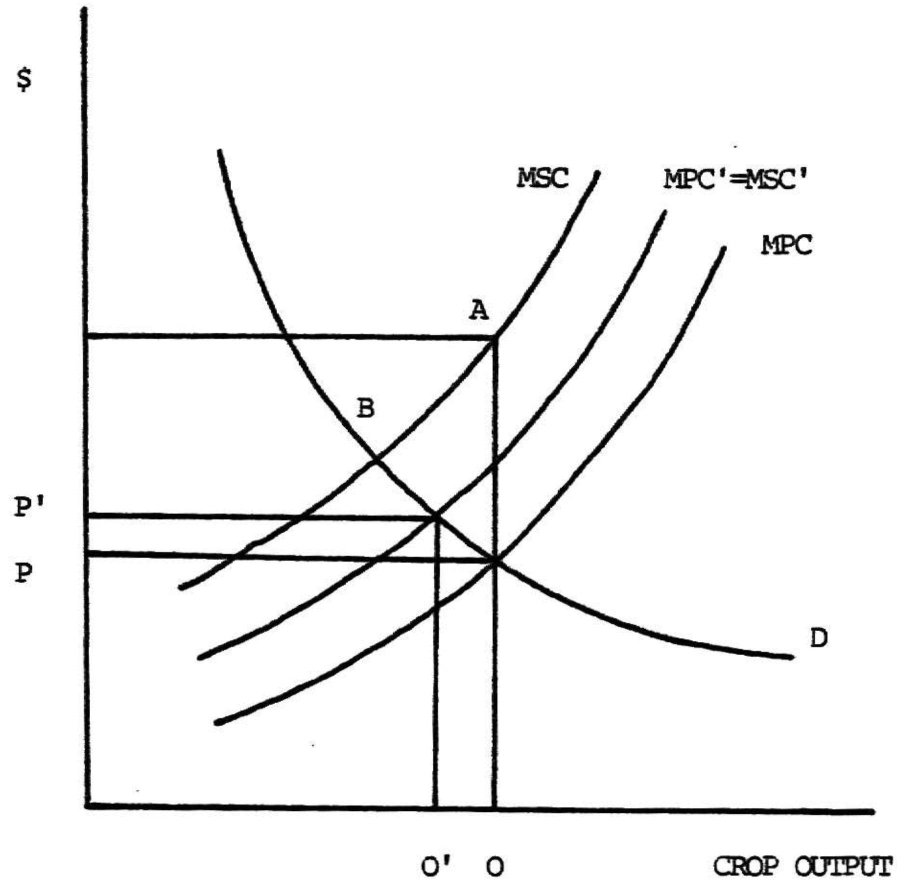
[34] Seitz, Sands, and Spitze, pp. 11-13.

[35] A.V. Kneese, "Environmental Pollution: Economics and Policy," American Economic Review, LXI (May, 1971), 161.

* MPC' and MSC' are not necessarily identical throughout. They will be the same only if all offsite damages are completely eliminated.

FIGURE 1
MARGINAL PRIVATE AND SOCIAL COSTS OF CROP PRODUCTION
WITH AND WITHOUT SOIL CONSERVATION ACTIVITIES



Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitz Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 13.

in the U.S. occur in small watersheds.[36] A watershed is therefore an appropriate macro-unit for study since it allows an accounting of soil losses, resulting damages, and an aggregation of the physical and financial impacts of proposed public policies.

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[36]A.V.S. Narayanan, "Economic Evaluation of the Impact of Selected Crop Practices on Water Quality and Productivity - An Application of Linear Programming" (PhD Thesis, University of Illinois, 1972).

However, soil erosion occurring on agricultural cropland and resultant sediment damages are generated at the farm level. Therefore, policy actions intended to reduce erosion and sedimentation must influence the independently determined land use and crop production decisions made on the individual farms. Regulations, subsidies, and effluent charges (taxes) have been suggested as alternatives for controlling spillover effects. These incentive schemes are more easily applied to point sources of pollution, but subject to some limitations, may be useful in solving problems with non-point sources such as sediment.[37] This section of my report will review economic effects of these three policy approaches, as well as their relative efficiency, at the watershed level.

Watershed Level Damages. In an economic analysis of erosion in the Mendota West Fork Watershed in Illinois, Narayanan, et al.,[38] used a procedure for estimating off-site sediment damage that is based on estimates of the drainage area, the quantity of sediment, and the cost per ton of the sediment damage. The sediment damage in the watershed is thus defined as:

$$D_s = (A_n)(D_r)(E)(P_r)$$

where D_s is sediment damage (dollars per year),

A_n is the net drainage area in acres,

D_r is the sediment delivery ratio,

E is the soil loss (tons per acre), and

P_r is the cost of sediment damage per ton of sediment.

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[37] Seitz, Sands, and Spitze, p. 17.

[38] Narayanan, and others, p. 12.

The net drainage area can be measured from a map of the watershed. The sediment delivery ratio in this study was estimated as .55 in the SCS work plan for the Mendota Watershed. Soil loss is estimated using the U.S.L.E. The major problem in the use of this formula is to determine the cost of sediment damage per ton of sediment (P_r). Such costs include several types of damage: (1) an increase in annual reservoir costs due to the decreased life expectancy of the reservoir caused by sediment filling the reservoir's sediment pool and interfering with the remaining flood pervention and water supply functions; (2) an increase in flood damage following the useful life of the reservoir, assuming that flood damage in the watershed returns to its level prior to the construction of the reservoir; (3) an increase in upstream drainage maintenance costs in the form of cleaning or dredging costs to maintain the viability of the drainage network; (4) sediment damage as a part of downstream flood damage in the form of silt deposits over flooded areas; (5) an increase in municipal and industrial water supply costs after the end of the reservoir's economic life and after the end of the sediment pool capacity; and (6) an increase in water treatment cost to remove suspended sediment from the municipal and industrial water supply.

One damage cost not mentioned above is that of recreation damage. Narayanan, et al., estimated recreation damage based on reduced activity space in the reservoir. Loss of surface water area having a depth of 10 feet or more was considered to be the recreation damage. In a watershed with a navigable stream, additional recreation damage could also occur.

If a watershed does not have a reservoir, there is obviously no damage from reservoir capacity or reservoir recreation loss. In addition, a watershed without a reservoir has a larger net drainage area as well as an increased level of flood sediment damage because there is no reservoir sediment trap.

Such off-site sediment damages represent the potential benefits of pollution control. As will be discussed later, however, such damage or benefit estimates vary greatly. Difficulties in accurately assessing such damages include problems of quantifying the functional relationships between pollution and water users, placing a value on aesthetic and recreational benefits, estimating reservoir lifespans, understanding the relationships between sediment and other water pollutants, and estimating damages to human and animal health. It is also important to understand that while traditional soil conservation practices affect water quality by reducing sediment and chemicals, water quality is only one of four factors insuring healthy stream ecosystems. Public protection of the other three factors (maintenance of stream flow, adequate habitat for fish and other aquatic life, and energy relationships capable of maintaining community structure and function) would likely have impacts on agriculture and vice versa. Because the relationship of these factors to agricultural erosion is not clear, however, it is necessary to concentrat primarily on sediment damage.

In order to determine the likely range of off-site sediment damage, the Mendota Watershed Study utilized two previous studies. The first estimate used for the rate of reservoir sediment damage is the $.50 per ton cost of dredging reported by Roberts.[39] The second estimate is a more detailed, itemized estimate reported by the Dow Chemical Company for the Potomac River Basin. This estimate included damage to the metropolitan water supply, dredging costs, commercial fishing losses, recreation losses, aesthetics, and flood damages. Because of several differences between the Mendota and Potomac Basins, the damage rate was adjusted from $6.80 per ton of sediment in the Potomac to $4.00 per ton in the Mendota

Estimating sediment damage on the basis of dredging costs is most appropriate when loss of reservoir capacity is the sole type of damage. It appears, however, that the dredging cost ($.50 per ton) may underestimate total damages, because some damage may occur even with timely dredging. Because of the large difference in the damage estimates, damage costs were recomputed by estimating sediment damage associated with flooding, loss of reservoir capacity, and recreation damage. These estimates will be discussed later in this report in a review of net social costs.

Narayanan, et al., also estimated sediment damage without a reservoir in this watershed. While these estimates are not as inclusive as the six categories of damage mentioned earlier, they do allow a comparison of damages with and without a reservoir. They also serve as an estimate of the amount society could economically spend to abate such damages. Such a comparison is illustrated in the following table:

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[39] W. J. Roberts, "Dredging to Extend Reservoir Life," Public Works, 100 (November, 1969), 98-99.

TABLE 13
ANNUAL SEDIMENT DAMAGE WITH AND WITHOUT RESERVOIR

	Total Damage[a]	Damage Per Ton of Sediment
With reservoir		
Sediment damage associated with flooding	$ 1,790	$0.36
Reservoir capacity loss	3,560	0.71
Recreation damage	844	0.17
TOTAL	-----	$1.24
Without reservoir		
Sediment damage associated with flooding	$13,200	$2.64

[a]Based on 5,000 tons per year of sediment delivered.
Source: A. S. Narayanan and others, Economic Analysis of Erosion and Sedimentation Mendota West Fork Watershed (Urbana-Champaign: University of Illinois, 1974), Department of Agricultural Economic p. 15.

Sediment damage associated with flooding is estimated to be 10 percent of total flood damage based upon estimates in the Upper Mississippi River Comprehensive Basin Study. The loss of reservoir capacity is based upon annual reservoir capacity loss (.52 percent) as estimated in the Illinois State Water Survey. The basis for recreation damage assessments was mentioned earlier.

In another analysis of an area associated with a relatively large multi-purpose reservoir in the Big Blue Watershed in Pike County, Illinois, Seitz, Sands, and Spitze estimated off-site damages for the six categories defined earlier based on data from the same published sources noted in the Mendota West Fork analysis Because this watershed was selected as representative of the corn-soy belt, the analysis results give a broader look at watershed economics, and can therefore be applied with some degree of accuracy to erosion control beyond individual watershed or state boundaries. In this economic analysis, regulatory policies to restrict soil losses are compared with subsidy payments and soil loss taxes based upon their respective effect on such factors as sediment damage per acre, net crop return per acre, cost-per-ton of sediment reduction, and net social income per acre.

Hypothetical farm units approximately the size and location of actual major farm units were developed to include the entire watershed. Due to limited time and resources available, the researchers selected a sample of nine farms for the detailed analysis to represent the physical and topographical characteristics of the Big Blue Watershed. In calculating linear programming model coefficients for the study, the activities in the model were restricted to crop production with a set of rotations and a range of intensity of land use to reflect different capacities of land types to support crop production activities with varying levels of soil losses. Two model restrictions imposed were that permanent pasture and woodland activities were not alternatives on land with slopes less than four percent and that those activities were the only alternatives offered on land with slopes over 18 percent. Three tillage practices (conventional, plow-plant, and chisel plowing) were considered along with contouring and terracing as conservation practices. Conservation practices were limited to those areas and slopes recommended by the SCS. The net returns above land costs for each crop production activity comprised the objective function of the linear programming model.

Three basic solutions to the linear programming model were generated to compare alternative sediment control policies. Solutions were generated under the assumption that net crop returns are maximized: (1) without crop, soil loss, or conservation and tillage practice constraints; (2) subject to conservation and tillage constraints; and (3) subject to constratins specifying amounts of crops produced.

In the first basic solution, Base Solution #1 (BS1), conventional tillage and chisel plowing are the only tillage practices and up- and down-hill cultivation is the only conservation practice employed. In BS2, the model is constrained to permit only conventional tillage and up- and down-hill cultivation to generally reflect existing tillage practices in the Big Blue Watershed. The effect of the constraints in BS2 is to eliminate soybean-wheat double cropping from the optimal solution by removing the zero-tillage option for such double cropping. BS3 is constrained to add the historical crop distribution for major crops to BS2 conditions. Maximum net return totals and total soil losses for each of the basic solutions are compared in the following table:

TABLE 14
CROP ACTIVITIES

Basic Solution	Row Crops (acres)	Small Grains (acres)	Pasture & Woodland (acres)	Up & Down Tillage (acres)	Net Returns (dollars)	Soil Loss Per Acre (tons)
BS1	1,781.2[a]	------	354.3	1781.2	121,514	22.0
BS2	1,781.2	------	354.3	1781.2	121,089	24.5
BS3	790.0	790.0	581.5	1554.0	90,706	6.0

[a]460.6 of these acres were double cropped, using zero tillage.
Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitz <u>Evaluation of Agricultural Policy Alternatives to Control Sedimentation</u> (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, pp. 58-61.

The remainder of the Big Blue Watershed analysis compares these nine-farm totals to those produced under soil loss regulatio subsidies, and sediment taxes. In addition to the Big Blue Analysis, I will review the results of an analysis of various policy (regulation, tax, and subsidy) costs for controlling agricultural soil loss and associated stream sedimentation in the Nishnabotna River Basin in Southwestern Iowa. This study not only examines some additional policy options, but also encompasses 1.8 million acres as compared to 26,690 acres in the study portion of Big Blue Watershed. Erosion rates are comparable in the two watersheds.

Soil Loss Regulations. Seitz, Sands, and Spitze evaluated three types of regulations in the Big Blue Watershed Analysis: (a) limits on soil losses at the watershed level; (b) regulations on soil losses at both the watershed and individual farm level, based upon SCS T-values; and (c) a regulation on sediment delivere to the reservoir, established at the watershed and individual farm level, and based upon the design life of the reservoir.

In addition to controlling erosion by restricting allowable soil losses, regulatory policies may curtail the use of specific farm practices associated with high soil losses, such as straight row or fall plowing.

In the Big Blue analysis, watershed level soil loss limits were reduced by 15 percent increments from the initial soil loss level of 52,336 tons in BS2. The income and cost results of these solutions is presented in Table 15.

TABLE 15
WATERSHED LEVEL RESULTS AS ALLOWABLE SOIL LOSS IS INCREMENTALLY REDUCED FROM THE MAXIMUM NET RETURN LEVEL OF BS2

	Crop Activities			Tillage Practices[a]		Conservation Practices[a]				Average
Soil Loss (tons)	Continuous Corn (acres)	Double Crop (acres)	Pasture (acres)	Plow Plant (acres)	Chisel Plow[b] (acres)	Contouring (acres)	Terracing (acres)	Net Returns (dollars)	Marginal Cost Per Ton Reduced (dollars)	Soil Loss Per Acre (tons)
52336 (BS2)	1781.2		354.3					121089	0.00	24.5
46946 (BS1)	1321.4	460.6	354.3		460.6			121519	0.00	22.0
44486	1189.0	592.2	354.3		592.2			120712	.05	20.8
36636	1177.6	603.6	354.3	287.0	603.6			120461	.03	17.2
28786	1177.6	603.6	354.3	739.0	603.6			119895	.07	13.5
20936	1044.4	736.8	354.3	422.8	961.3	165.8		119112	.10	9.8
13086	1028.3	752.9	354.3	352.1	879.2	827.6	358.6	118019	.14	6.1
5236	835.2	946.0	354.3	497.1	1284.1	866.4	914.8	113862	.53	2.5

[a]Total tilled acres = 1,781.2. Unless otherwise noted, acreage is under conventional tillage up and down the slope.

[b]Includes both chisel plow and zero tillage methods.

Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 62.

As can be seen by the table, additional reductions in soil loss limits result first in additional shifts toward conservation tillage methods; second, in conservation practices; and last, in substantial shifts in crop activities. The net crop returns for the watershed decline as sediment limits are decreased because of lower net returns associated with improved conservation and tillage practices, and changes in crops produced.

Seitz, Sands, and Spitze note that reducing allowable soil loss limits affects all farms in the same general manner, with only a few differences apparent. For example, shifts in crop activities and tillage practices, as well as in conservation practices, are implemented relatively sooner on hilly and less productive land than on more productive flatter land. This is due both to the relatively higher initial soil losses on the hilly land and the lower productivity of such land, which makes it less expensive in terms of reduced net watershed returns to reduce soil losses.

Walker and Timmons,[40] in their Nishnabotna Basin study, simulated results on soil loss, sediment load, and net farm income for a base run, a ban on fall plowing, a ban on straight-row plowing, and a combination ban on fall and straight-row plowing. These results were produced under low, average, and high price-cost ratios. Results under average price-cost rates for the period 1966-1975 are shown in Table 16.

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[40]Walker and Timmons, 178-79.

TABLE 16
COMPARISON OF TILLAGE CONSTRAINTS COST-EFFECTIVENESS IN REDUCING SOIL EROSION
POLICY SIMULATION RESULTS: AVERAGE PRICE-COST RATIO

Policy	Ave. Soil Loss (t/a)	Income Penalty (%)	Net Farm Income ($)	Marginal Cost Per Ton Reduced ($)
1. Base run*	20.3	-----	$27,860	$0.00
2. Fall plow ban	10.0	2.2	27,240	0.19
3. Straight-row plow ban	4.1	5.3	26,380	0.45
4. Ban on fall and straight row plowing	2.1	7.1	25,880	0.78

*320 acre farm

Source: John Walker and John Timmons, "Costs of Alternative Policies for Controlling Agricultural Soil Loss and Associated Stream Sedimentation," Journal of Soil and Water Conservation, 35 (July-August, 1980), 178.

The base run for this simulation used continuous row crop production, in addition to using the historic production of hay and nursecrop oats on the steeper cropland. A corn-corn-soybean rotation was used with conventional tillage and fall plowing. Contour ing was used on gentle slopes and combined with minimum tillage on moderately sloped land. Because BS1 in the Big Blue Watershed Ana ysis was unconstrained, it is most similar to the Base Run for the Nishnabotna Basin analysis, which also assumed no policy constrain Calculations of the marginal costs per ton of soil reduction (shadow prices) will enable us to compare the two policy approache

TABLE 17
AVERAGE SOIL LOSS PER ACRE AND MARGINAL COST/TON OF SOIL LOSS REDUCTION FOR VARIOUS EROSION CONTROL REGULATIONS

Practice	Ave. Soil Loss Per Acre (t)	Marginal Cost Per Ton (Dollars)
BS1	22.0	$0.00
Base-Nishnabotna	20.3	0.00
45% loss reduction	13.5	0.07
60% loss reduction	9.8	0.10
75% loss reduction	6.1	0.14
Fall plow ban	10.0	0.19
Straight-row plow ban	4.1	0.45
90% loss reduction	2.5	0.55
Combo. plow ban	2.1	0.78

Although any comparison between basins cannot be precise, the similarities in these two basins and the base runs enable approximate comparisons. As can be seen by the shadow prices, tillage constraints can compare favorably to soil loss restrictions of from 75 to 90 percent. Restrictions of lesser amounts are significantly more efficient than mandated tillage constraints. It is evident that the ban on fall plowing compares favorably with a 75 percent reduction in soil losses and that the other two tillage limitations compare reasonably well to a 90 percent soil loss reduction.

As can be seen by these comparisons, the most efficient or cost-effective regulatory policy at the watershed level would be t establish soil loss limits on a watershed basis for the first 60-7 percent of desired erosion reduction. This allows conservation practices, tillage practices, and crop rotations to be optimally allocated without regard to individual farm impacts. Some farm operators, however, particularly those farming hilly and less productive land, would receive significant income reductions under the soil loss constraints. Furthermore, monitoring watershed level constraints would be difficult in that the amount of soil leaving the farm cannot be economically measured. Both factors would make a watershed level soil loss limit policy difficult to implement.

Prescribed tillage limitations, while not as efficient at higher levels of soil loss allowed, not only compete favorably at erosion rates less than 10 tons per acre, but enable relatively easy monitoring. Monitoring is particularly easy for the plowing bans discussed through the use of aerial photos of farms, watersheds, or even states. Because minimum tillage competes favorably with conventional spring tillage, a baon on fall moldboard plowing may encourage minimum tillage practices. One important result of the combined ban of fall and straight row plowing is that the highest annual soil loss from any activity in the solution was about 5 tons per acre. On most soils the highest level may well fall below prescribed SCS T-values, thereby allowing an easily monitored tillage constraint to substitute for a difficult to administer soil loss per acre standard or for a watershed standard based on SCS tolerances. Use of SCS tolerances will be discussed in the following section.

The use of SCS soil loss tolerances to limit soil losses was another regulatory approach considered in the Big Blue Analysis. The SCS has developed tolerances for various soils indicating the maximum soil loss in tons per acre per year under which curren production levels can be maintained at current levels in the futur with existing technology. Usually called T-values, such erosion tolerances can be established as limits for the farm or the watershed. When imposed as an aggregate in the Big Blue Watershed, a soil loss of 4.0 tons per acre at a shadow price of $0.48 resulted As indicated in the previous table, a straight row plowing ban was more cost-effective in reducing soil losses. As before, lower producing, hillier farms were required to make much earlier and larger shifts to conservation and tillage activities and use of rotations.

Application of a total soil loss constraint applied to each farm in the Big Blue Watershed results in identical total soil losses, but at a lower level of net returns. T-values tend to be higher on more productive farms and lower on less productive units. As with watershed constraints, declining T-values result in conventional tillage and up-and-down cultivation declining while plow-plant, chisel plowing, contouring, and terracing increase. One interesting result of reducing soil loss constraints at the farm level is that some acreage moves out of double crop into a continuous corn rotation with improved conservation and tillage practices at only a small decrease in profits. Again, the problem of monitoring soil losses would force the administrative agency to either prescribe a set of practices or evaluate a farmer's plan for meeting such standards, both of which reduce the freedom of the farm operator to make decisions. Net income differences were insignificant between watershed level and farm level T-value constraints, thereby favoring the more easily administered farm level constraints.

Seitz, Sands, and Spitze also developed soil loss constraints based upon quantities of sediment delivered to the reservoir. This analysis required converting the gross soil loss coefficients to quantities of sediment delivered to the reservoir. The soil loss coefficients for each activity were then multiplied by the appropriate individual farm sediment delivery ratio adjusted for distance. The converted coefficients are approximations of the quantity of sediment delivered to the reservoir per acre.

Generally, requiring watershed level soil loss limits on a sediment delivery basis confers a locational advantage to farms relatively more distant from the reservoir due to the fact that more distant farms generally have a lower sediment delivery ratio. This allows these farms to reduce soil losses less and thereby attain a higher level of net farm returns. The watershed level constraint on sediment delivery results in lower gross soil loss than a non-regulated situation, but higher soil losses and net returns than under the watershed level SCS constraint.

Reductions in quantity of sediment delivered caused a general change from continuous corn to double cropping and a complete shift from conventional tillage and up-and-down cultivation at sediment reductions of 87 percent. Percentage reductions in total soil loss per acre (86%) were nearly identical to percentage reductions in sediment delivered per acre (87%). The shadow price in terms of soil loss per acre was $0.30 per ton at an 87 percent level of sediment reduction, making such a policy much more cost-effective than the 90 percent soil loss limit tolerances discussed earlier. This appears to be explained by the fact that a sediment based watershed standard can focus conservation efforts on fewer, more erosive areas because it is not as concerned with soil losses which become trapped in the watershed before reaching the reservoir. Under an individual farm constraint of 1.5 tons of delivered sediment, the locational advantage is greater because farms near the reservoir generally have higher soil losses resulting from steeper, hillier land.

Soil Loss Taxes or Effluent Charges. Another watershed level policy approach for soil loss abatement and pollution control is through a levy of effluent charges or soil loss taxes whereby the producer is assessed a fee per ton of sediment eroded. The assessment is to cause the farmer to utilize the most efficient means possible to reduce erosion to a prescribed level. It is, theoretically, an economically efficient procedure, but would be impractical to implement due to the need to physically measure the amount of soil loss on each farm. Because of this problem, Walker and Timmons note that a more readily observable basis for such a tax must be found for policy implementation. They state that a tax levy would have to be specified for a particular area in terms of each crop activity on each slope and type of soil, considering soil conservation practices used. The amount of the tax for each particular cropping situation could be calculated using the USLE soil loss estimate. For purposes of administration, the tax would be specified in terms of particular crop activities, but the actual basis for the tax would still be estimated soil loss resulting from each activity.

Walker and Timmons considered tax levels of ten cents through fifty cents in ten cent intervals and from \$.50 to \$4.00 in fifty cent intervals for the Nishnabotna River Basin. Under average price-cost ratios, the soil loss tax was effective in reducing soil loss in two steps. A tax of ten cents per ton induced practice changes that decreased average annual soil loss from more than 20 tons per acre in the base run to approximately 11 tons per acre due to revised tillage practices on steeper slopes, where minimum tillage replaced conventional tillage for the corn-corn-soybean rotations. There were no significant effects from increasing the tax until the $1.00 level was used, at which point average soil loss was reduced to 2.1 tons per acre (net farm income declined 9.0 percent below the base level). This soil loss reduction was achieved through the adoption of terracing on the steeper land and minimum tillage on the moderately sloped land. Further increases in the tax brought no significant change in soil loss or cropping patterns. Therefore, a tax greater than $1.00 per ton appeared unwarranted.

Two interesting results emerged from these taxing policies. First, in none of the scenarios did the tax produce a shift from fall plowing to spring plowing, where soil losses are less. Because yearly costs are higher and yields are lower with spring plowing, a more profitable solution than spring plowing always entered the solution as taxes increased, either minimum tillage in the spring or contouring with fall plowing.

Second, a soil loss tax approach could still result in excessive soil loss on some land classes because farmers could choose to produce high-profit row crops on moderately sloped lands, resulting in excessive soil loss on those slopes. To minimize taxes, then, they could curtail row crop production on highly erosive lands. Because of this possibility, a goal of tolerable soil losses on all land classes might best be achieved through curtailment of highly erosive tillage practices or a soil loss limit per acre. By comparing marginal costs per ton of soil loss reduction, the ten cent tax equals the ban on fall plowing, which is more effective in reducing soil losses and in ease of administration. The tax of $1.00 per ton had a marginal cost per ton of $1.61, and therefore compared poorly against all policy options except the 90 percent soil loss limits in the Big Blue Watershed, for which the shadow price of the reduction between 89 and 90 percent was $1.57.

Because of the difficulty in administering soil loss taxes or effluent charges, it is important to note the similarity betwee such charges and soil loss constraints. Solutions generated with constraints at the farm or watershed level are symmetrical to solu tions generated with shadow prices imposed as charges per ton of soil loss.[41] The shadow price related to a constraint indicates the change in values of the objective function associated with a one unit change in the constraint. Imposition of these shadow prices as an effluent charge per ton of soil loss would result in the same model solution as the regulatory constraint that generate the price initially. At the non-constrained maximum net return level, the shadow price is equal to zero. As the soil loss constraint is reduced, total net returns decline at an increasing rate while shadow prices increase at an increasing rate. Therefore, it requires increasingly higher soil loss charges to achieve additional reductions in soil losses, which in turn result in lowe levels of net return.[42]

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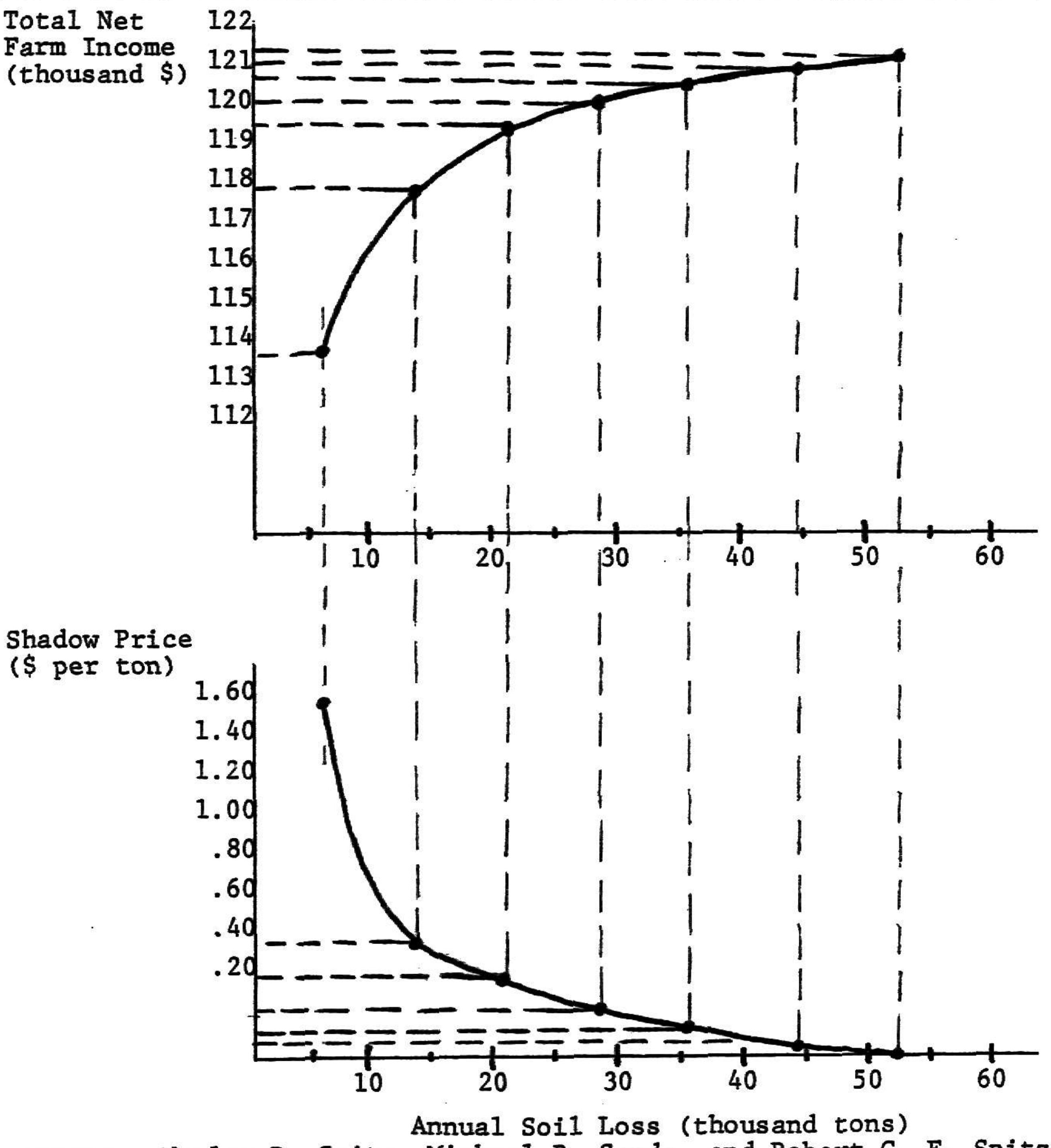
[41]Lee and others, p. 34. A graphical and mathematical explan tion of this and other types of damage extimates are presented.

[42]Seitz, Sands, and Spitze, pp. 66-67.

The following graph shows the relationship between soil loss constraints, shadow prices, and net farm income:

FIGURE 2
RELATIONSHIP BETWEEN SOIL LOSS CONSTRAINTS, SHADOW PRICES, AND TOTAL NET FARM INCOME AS SOIL LOSS RESTRICTIONS ARE REDUCED OR SHADOW PRICES ARE INCREASED



Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 68.

Soil Conservation Subsidies. A number of erosion control subsidy systems can also be devised. The classical system is to offer a payment to the producer if he will reduce the quantity of residuals discharged. The producer will consider the payment a source of income and adjust his operations to maximize total income. He will therefore implement conservation practices or modify the crops produced if the payment for doing so is larger than the income foregone. In this case society pays for the increased environmental quality through general revenue sources rather than forcing the customers of the polluting industry to bear the costs. This approach is difficult to implement and monitor due to the non-point nature of the erosion problem. Further, as in any subsidy program, the possibility exists that operators could exaggerate their requests for payments.

As in the case of regulations, a number of other subsidy schemes can be devised. Subsidies to farm operators to reduce the row crop acreage have been used to control erosion. Such a subsidy would, however, be inefficient if the only policy objective is reducing sedimentation. Another alternative, which has been implemented in varying degrees in the past, is the subsidization of the construction of soil conservation facilities. This, as noted at the beginning of this report, has taken the form of federal cost sharing and has resulted in considerable improvement. It is more workable than the previously discussed policy schemes since these are investment type activities rather than recurring annual works. It has the disadvantage of not adjusting to the possible impacts of other modifications such as crop rotations and tillage practices, and is an expense to the federal treasury rather than being passed to the consumer of the products produced.[43]

The subsidy payments in the Big Blue analysis were based upon the cost adjustment for improved soil conserving practices relative to the cost of conventional tillage and up-and-down production. The effect of the subsidy is to increase the net return of all crop activities, by the amount of the subsidy, relative to the net return generated from crop activities produced with conventional tillage and up-and-down cultivation. Subsidy payments equal to 25, 50, 75, 100, and 102.5 percent of the additional cost of conservation and tillage practices were evaluated. Because producers might apply practices at the 102.5 percent rate as a means of increasing net returns rather than on the basis of need, practices offered as alternatives under each crop production activity were restricted to SCS recommendations for various slopes and land types.

As can be seen from Table 18, subsidy rates of 75 percent or below had relatively little impact on either soil losses or net returns. The largest reduction in soil loss is achieved only above the 100 percent level. At the 102.5 percent subsidy level, total soil loss decreases by 73 percent at a cost of $.16 per ton in subsidy payments, and substantial shifts occur in tillage and

[43]Seitz, Sands, and Spitze, pp. 15-16.

TABLE 18

TOTAL NINE FARM RESULTS OF SUBSIDIZING CONSERVATION AND TILLAGE PRACTICES AT VARIOUS LEVELS COMPARED TO RESULTS UNDER BS1 AND WATERSHED LEVEL SCS TOLERANCE AND DELIVERED SEDIMENT CONSTRAINT

	Crop Activities[a]		Tillage Practices			Conservation Practices					
Control Policy	Continuous Corn (acres)	Double Crop (acres	Conventional (acres)	Plow Plant (acres)	Chisel Plow[b] (acres)	Up & Down (acres)	Contouring (acres)	Terracing (acres)	Subsidy (dollars)	Total Net Return (dollars)	Average Soil Loss Per Acre (tons)
BS1	1321.4	460.6	1321.4		460.6	1781.2				121519	22.0
BS3	527.0	26.5	1554.0			1554.0				90706	6.0
SCS Tolerance	1153.2	628.9	493.9	659.3	628.0	178.2	827.6	775.4		116427	4.0
Delivered Sed.	1108.2	673.0	529.0	314.2	938.0	1544.8	180.1	56.3		119526	9.9
Subsidy Rates											
25%	1183.2	598.0	1183.2		598.0	1781.2			148	121608	20.8
50%	1183.2	598.0	1183.2		598.0	1781.2			296	121756	20.8
75%	1177.6	603.6	1177.6		603.6	1781.2			477	121907	20.7
100%	1177.6	603.6	704.5	473.1	603.6	1618.0	163.2		1222	122182	16.0
102.5%	1177.6	603.6	307.4	870.2	603.6	353.8	703.2	724.2	5437	122224	5.6
(Percent Change as Subsidy Rates are Increased from 25 to 102.5 Percent)											
	- .5	+ .9	- 74		+ .9	- 80				+ .5	-73

[a]Crop activities produced 354.3 acres of pasture in all policies except BS3, with 278 acres of pasture.

[b]Includes zero tillage associated with double crop rotation.

Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 88.

conservation practices, with a 74 percent increase in plow plant tillage and an 80 percent increase in ground either contoured or terraced. Net returns for all subsidy rates are increased above BS1. Seitz, Sands, and Spitze make the following comparisons between the 102.5 percent rate and other alternatives:

a) the 102.5 percent rate does not reduce soil losses to the level used in the watershed SCS soil loss tolerance regulation. Therefore, non-subsidy net returns are higher. Also, soil conservation practices are used less with the subsidy due to yield changes.

b) the 102.5 percent rate does reduce soil losses below the level observed under the delivered sediment restriction, through the increased use of soil conservation practices, and increases net returns.

The Nishnabotna Basin study analyzed various subsidy rates on a per acre basis for contouring and minimum tillage practices. Because contouring is not effective on slopes over seven percent due to runoff over-topping the rows and because contouring had already been adopted in much of the base solution, contouring subsidies alone reduced soil loss only one-tenth of a ton per acre at a cost of $402,200 for 670,390 contoured acres. In the absence of the subsidy, 640,280 acres would have been contoured anyway. Consequently, the marginal cost per ton of soil loss reduction was $133.58 per ton. In summary, such a subsidy was very costly for the negligible effect it had on soil loss.

Under the average price-cost scenario, minimum tillage subsidies began to change the farmer's practices at a level of

$2.70 per acre, encouraging a switch to minimum tillage with contouring on the gentler slopes in place of conventional tillage. This change only produced a reduction in soil loss from 20.3 to 19.2 tons per acre. Increasing the subsidy slightly to $2.90, however, reduced soil losses by 50 percent to 10.1 tons per acre. This reduction was due to the application of minimum tillage to corn-corn-soybean rotations on the steeper land. In the base run, minimum tillage was adopted only on moderately sloped land. A further increase in the subsidy to $3.00 per acre reduced soil losses to only 10.0 tons per acre, a relatively expensive and non-productive exercise. The results of these subsidy policy simulations indicate that while a subsidy on minimum tillage is effective in reducing average soil loss by around 50 percent, lower soil losses could not be expected because minimum tillage by itself cannot control soil loss within acceptable levels on slopes over five percent.

Net Social Income. Net social income at the watershed level is defined as net income above nonland costs minus the cost of off-site sediment damage. Both the Mendota and Big Blue Watershed studies discuss and make estimates of net social income. In the Big Blue analysis, off-site damages were estimated for each of the six categories discussed earlier using incremental reductions of 15 percent in the level of soil lost at the watershed level. Those damage estimates are tabulated in Table 19.

TABLE 19
OFFSITE DAMAGES FOR BIG BLUE WATERSHED AT VARIOUS LEVELS OF WATERSHED LEVEL SOIL LOSS RESTRICTIONS

Estimated Watershed Level Soil Losses	Average Soil Loss Per Acre	Dollar Damage Estimates by Category of Damage $(Ds)_1$	$(Ds)_2$	$(Ds)_3$	$(Ds)_4$	$(Ds)_5$	$(Ds)_6$	Average Sediment Damage Per Acre	Average Net Return Per Acre
178478	24.5	240	333	36817	799	698	3261	5.79	56.70
157367	22.0	199	301	32830	799	578	2802	5.18	56.90
151706	20.8	163	120	31289	799	446	2772	4.89	56.88
124936	17.2	77	84	25768	799	310	2284	4.03	56.74
98166	13.5	8	40	20247	799	147	1795	3.16	56.53
71395	9.8	1	13	14725	799	48	1307	2.32	56.07
44455	6.1	[a]	2	9169	799	5	818	1.48	55.27
17855	2.5	[a]	1	3683	799	3	329	.66	53.33
15724	2.0	[a]	1	3130	799	2	299	.58	52.55

[a]Estimated damages were less than $1.

$(D_s)1$ = Damage for increase in annual reservoir cost.

$(D_s)2$ = Increase in flood damage following the useful life of the reservoir.

$(D_s)3$ = Drainage system maintenance cost.

$(D_s)4$ = Sediment damage as part of down-stream flood damage.

$(D_s)5$ = Increase in water supply costs after the end of the reservoir's economic life.

$(D_s)6$ = Water treatment cost.

Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illi-

As can be seen from the table, damages for increase in annual reservoir cost $(Ds)_1$, increase in flood damage following the useful life of the reservoir $(Ds)_2$, and increase in water supply costs after the end of the reservoir's economic life $(Ds)_5$ are all relatively minor because they occur at relatively distant times in the future. These costs are particularly small at low soil loss levels. Drainage system maintenance cost increases represent the major damage item, contributing 74.0 to 87.4 percent of total damage estimates, with the higher percentages contributed at higher soil loss levels. Water treatment cost $(Ds)_6$ increases are also shown to be a significant part of sediment damage, with such damages decreasing in direct proportion to the reduction in gross soil loss. Because of the high trap efficiency of the reservoir, sediment damage as a part of down-stream flood damage $(Ds)_4$ is relatively small, remaining constant over the range of soil loss parameters.

Average net returns per acre increase at a decreasing rate as average soil loss increases, reaching the highest levels at a non-constrained optimum net return level, which corresponds closely to the highest average soil loss per acre. The off-site damages generated were then subtracted from the net crop returns per acre to generate the net social income estimates. As average soil loss per acre increases, net social income first increases at a decreasing rate, reaching a maximum between six and ten tons per acre of soil loss in the Big Blue Watershed, and then declines. Therefore, as soil loss per acre increases, the increase in net crop returns is eventually offset by increases in off-site damages which decrease net social income.

Off-site sediment damages, net crop returns, and net social income under each soil loss policy scenario in the Big Blue Watershed are compared in the tables on pages 79 and 80.

In the Big Blue Watershed, net social income increases as soil losses are reduced through different policies to a range of 5-10 tons of soil loss per acre, after which it declines rapidly. General watershed soil loss restrictions, SCS soil loss tolerances, delivered sediment constraints, and conservation practice subsidies of 102.5 percent all achieved optimum net social income levels within soil loss levels of from 5-10 tons per acre per year. Within this range, net social incomes of the various policies differed less than one dollar per acre per year. Only general watershed soil loss restrictions and SCS tolerance levels were capable of reducing soil losses below five tons per acre.

While a subsidy rate of 102.5 percent was a slightly less efficient practice than the other constraints, the cost difference of less than one dollar per acre per year might not be sufficient to offset the administrative costs of the other policies, or the political costs of limiting farmer's freedom of choice

The Mendota study confirmed these results in an indirect way by finding that over planning periods of 20 or more years, soil conserving practices and tillage systems resulted in higher net social income than conventional tillage with up and down cultivation. The results of these studies are very significant. They confirm that soil erosion control results in higher net social income than conditions where such erosion is unconstrained.

TABLE 20
OFFSITE SEDIMENT DAMAGES, NET CROP RETURN, AND NET SOCIAL INCOME UNDER EACH SOIL LOSS POLICY

	Total Soil Loss	Estimated Offsite Sediment Damages Total	Estimated Offsite Sediment Damages Per Acre	Net Crop Return Total	Net Crop Return Per Acre	Net Social Income Per Acre	Average Soil Loss Per Acre	Cost Reduction From Maximum Net Return Level Total	Cost Reduction From Maximum Net Return Level Per Acre	Cost Reduction From Maximum Net Return Level Per Ton
BASIC SOLUTIONS										
(BS1)	46946	37500	5.18	121519	56.90	51.72	22.0			
(BS2)	52336	42142	5.79	121089	56.70	50.91	24.5			
(BS3)	12812	10600	1.46	90706	42.88	41.02	6.0	30813	14.43	0.90
WATERSHED SOIL LOSS CONSTRAINTS										
	44486	35589	4.89	120712	56.88	51.99	20.8	807	0.38	0.32
	36636	29375	4.03	120461	56.74	52.71	17.2	1058	0.50	0.10
	28786	23036	3.16	119895	56.53	53.37	13.9	1624	0.76	0.09
	20936	16893	2.32	119112	56.07	53.75	9.8	2407	1.13	0.09
	13086	10793	1.48	118019	55.27	53.79	6.1	3500	1.64	0.10
	5236	4815	.66	113862	53.33	52.67	2.5	7657	3.59	0.18
	4451	4231	.58	112205	52.55	51.97	2.0	9314	4.36	0.22
WATERSHED SCS TOLERANCE										
	8631	7300	1.00	116427	54.52	53.52	4.0	5092	2.38	0.13
EQUAL AVERAGE SCS TOLERANCE										
	8631	7300	1.00	116405	54.51	53.50	4.0	5114	2.39	0.13
INDIVIDUAL FARM SCS TOLERANCE										
	13811	11450	1.57	118161	55.33	53.76	6.5	3358	1.57	0.10
	12516	10450	1.43	117787	55.16	53.72	5.9	3732	1.75	0.11
	11221	9450	1.30	117377	54.96	53.66	5.3	4142	1.94	0.12
	9926	8250	1.13	116932	54.75	53.60	4.6	4587	2.15	0.12
	8631	7300	1.00	116389	54.50	53.50	4.0	5130	2.40	0.13
	7336	6300	.86	115512	54.09	53.23	3.4	6007	2.81	0.15
	6041	5500	.76	113896	53.33	52.57	2.8	7623	3.57	0.20
	4766	4300	.59	108739	50.92	50.32	2.2	12780	5.98	0.30

	Total Soil Loss	Estimated Offsite Sediment Damages Total	Estimated Offsite Sediment Damages Per Acre	Net Crop Return Total	Net Crop Return Per Acre	Net Social Income Per Acre	Average Soil Loss Per Acre	Cost Reduction From Maximum Net Return Level Total	Cost Reduction From Maximum Net Return Level Per Acre	Cost Reduction From Maximum Net Return Level Per Ton
				WATERSHED DELIVERED SEDIMENT CONSTRAINT						
	34148	27400	3.76	121023	56.67	52.91	16.0	496	0.23	0.04
	28680	23000	3.16	120611	56.48	53.31	13.4	908	0.43	0.05
	23595	18750	2.57	119962	56.18	53.60	11.0	1557	0.73	0.07
	21045	16950	2.32	119526	55.97	53.65	9.9	1993	0.93	0.08
	17949	14600	2.00	119000	55.72	53.72	8.4	2519	1.18	0.09
	11891	9800	1.35	117362	54.96	53.60	5.6	4157	1.95	0.12
	4611	4230	.58	112163	52.52	51.94	2.0	9356	4.38	0.22
				INDIVIDUAL FARM DELIVERED SEDIMENT CONSTRAINT						
	21679	16700	2.29	119221	55.82	53.53	10.1	2298	1.08	0.09
				CONSERVATION AND TILLAGE PRACTICE SUBSIDIES						
25%	44416	35589	4.89	121460	56.88	51.99	20.8	59	0.03	0.02
50%	44416	35589	4.89	121460	56.88	51.99	20.8	59	0.03	0.02
75%	44226	35500	4.87	121430	56.86	51.99	20.7	89	0.04	0.03
100%	34086	27400	3.76	120960	56.64	52.88	16.0	559	0.26	0.04
102.5%	12099	9800	1.35	116787	54.68	53.33	5.6	4732	2.22	0.14

Source: Wesley D. Seitz, Michael B. Sands, and Robert G. F. Spitze, Evaluation of Agricultural Policy Alternatives to Control Sedimentation (Urbana-Champaign: University of Illinois, 1975), Department of Agricultural Economics, p. 98.

In other words, from society's viewpoint, benefits exceed costs for such practices over longer planning periods up to a point. This is confirmed to an even greater degree when one considers that efforts to control sediment also control fertilizer and chemical pollution which benefits were not included in the watershed calculations. It is also important to know that at the watershed level, control of erosion to levels below 5-10 tons per acre quickly becomes very counterproductive.

Perhaps most important, however, is the comparison between watershed cropping practices as they have historically existed (BS3) and the constrained solutions. Net social income under simulated present conditions in the Big Blue Watershed (BS3) is over $10 per acre less than any of the soil loss control policies discussed at the watershed level. In other words, the model shows that producers could achieve significantly higher net returns and reduce soil losses by producing relatively more continuous corn and wheat-soybeans double crop using improved soil conservation practices. One limitation of these results is that net farm income under BS3 may be higher than the model suggests due to livestock production's exclusion from the study, a factor which may require production of relatively more forage crops.

Summary of Watershed Impacts. Seitz, Sands, and Spitze make a number of conclusions as a result of their analysis of the Big Blue Watershed. These include:

1. That soil loss and income performances can be substantially improved by shifting to a more intensive cropping pattern with substantially increased use of soil conservation

practices and an implied shift from a livestock oriented to a cash crop operation. Even existing cropping patterns, however, can generate improved net incomes and reduce soil losses by implementing soil conserving practices.

2. Off-site damages are a major factor in determing optimal cropping and conservation practices in the watershed. If net social income is maximized, soil losses must be reduced from approximately 20 tons per year to six. If only net farm returns are maximized, only income increasing practices are adopted and erosion remains high.
3. Use of SCS T-values suggested would require significant reductions in soil losses as well as alternate policies to maintain the productivity of the soil and protect the water resources.
4. Despite the need for a subsidy rate of over 100 percent to achieve significant erosion reductions, a subsidy program is considered to be desirable because net social income would increase. This desirability may be enhanced significantly if subsidies are combined with an educational program indicating the long run effects of erosion on soil productivity and net income or if subsidies are an alternative to mandatory soil loss restrictions or required crop rotations and conservation practices.
5. There is very little difference in farm income, conservation practices, or crops produced among the alternative policies of regulating the level of soil loss at the watershed or at the farm level. Each reduces erosion to the socially optimal

rate of six tons per acre at costs of less than $2 per acre or $.12 per ton. Because of this, the theoretically more efficient policy of soil loss taxes can be dismissed without a serious loss of economic performance due to difficulties in implementation and administration.

6. While watershed level constraints are slightly more economically efficient than farm level constraints, the differences are small enough that farm level constraints may be preferable, due to easier administration and implementation.

In the Nishnabotna analysis, Walker and Timmons were able to group policies generally according to a two-tiered effect in reducing soil loss and sediment pollution in the Basin, although some intermediate results were produced. One group of erosion control policies appeared to be effective in reducing soil loss by approximately 50 percent. Another group reduced soil loss by 90 percent, an average of about two tons per acre. For reductions in average soil loss of 50 percent, the income penalty ranged from 2.2 to 3.0 percent. The smallest income penalty in this group of policies was associated with a ban on fall plowing. The policy group that succeeded in cutting average soil loss by 90 percent is of interest because it approximated the degree of control specified by the SCS, five tons per acre or less. The smallest income penalty in this group was realized with a dual ban on straight row and fall plowing. Table 21 illustrates the two-tiered effect.

TABLE 21
POLICY EFFECTIVENESS GROUPS

Policy	Average Soil Loss (t/a)	Income Penalty* (%)
50% reduction in soil loss and sedimentation		
Ban on fall plowing	10.0	2.2-2.3
Soil loss tax 10 cents (average P/C)	11.2	2.2
Minimum tillage subsidy $2.90 (average P/C)	10.1	---
90% reduction in soil loss and sedimentation		
Ban on fall plowing and straight row plowing	2.1	5.5-9.5
Soil loss limit of 5 tons/acre	2.5	6.8-13.5
Soil loss tax $1.00 (average P/C)	2.1	9.0

*Percent reduction in net farm income under the indicated policy compared to income in the base run.

Source: John Walker and John Timmons, "Costs of Alternative Policies for Controlling Agricultural Soil Loss and Associated Stream Sedimentation," Journal of Soil and Water Conservation, 35 (July-August, 1980), 182.

This effect was due mostly to a change in crop management practices on the steeper land, which accounts for 31 percent of the river basin at slopes between 9 and 14 percent. If the policy analysis were applied to a study area with a more uniform distribution of acreage across land classes, Walker and Timmons conclude that there probably would be a more gradual pattern of policy response.

D. Regional and Substate Impacts

Under section 208 of Federal Public Law 92-500, states and areas within states are independently preparing and implementing water quality plans. Although section 103 of the act states, "The administrator of the EPA shall encourage, so far as practicable uniform state laws relating to the prevention, reduction, and elimination of pollution...," it is quite likely that erosion control policies will not be imposed uniformly nationwide. States or areas may differ both in whether to impose erosion control policies and in how stringent such control policies will be. It is valuable, therefore, to discuss those additional economic impacts that extend beyond a single watershed. In order to make such an analysis, Illinois was studied as a sub-area of the corn belt[44] using a modified comparative linear programming model. In the modified model, a three ton per acre soil loss restriction was applied in Illinois only, uniformly in all areas of the corn belt except Illinois, and uniformly in the entire corn belt. The benchmark solution imposed no soil loss restrictions.

When soil loss constraints were applied in the corn belt, and in all of the corn belt except Illinois, corn prices decreased and soybean prices increased. This impact was due to corn being substituted for soybeans because it is less erosive. The regional analysis also revealed that none of the three policies had much impact on Illinois's comparative economic advantage, as producers net returns varied by less than one percent over all of the constraints considered. The largest decrease in producer's

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[44]W. D. Seitz and others, "Economic Impacts of Soil Erosion Control," Journal of Land Economics, 55 (February, 1979), 34.

surplus (gross revenue less non-land production costs and less the costs of terracing) for Illinois occurred when the constraints were applied in Illinois only. This occurs because erosion control costs affected only Illinois producers while price changes occurred uniformly in both regions.

The impact of erosion control costs on profitability is moderated by shifts of crops among regions. For example, under the policy of constraints for all areas except Illinois, corn price decreases and soybean price increases, causing Illinois farmers to switch to the more erosive soybean crop. This shift also occurs to a lesser degree under the corn belt restrictions, because such restrictions confer an advantage to the flatter, less erosive Illinois land. In other words, when soil loss restrictions are not applied uniformly to all areas within a region, farmers in the non-constrained areas switch to more erosive crops to take advantage of higher prices resulting from a decrease in the production of those crops in the constrained areas. Decreases in soil loss, however, more than offset the increases, producing a total reduction in soil loss. In this analysis, soil losses decrease 33 million tons from the benchmark when restrictions are applied only in Illinois, but such losses increase only 66,000 tons in other areas of the corn belt outside Illinois.

Price changes also impact farm income of substate areas. For example, restrictions only in Illinois result in increased returns on non-erosive land because of increases in both corn and soybean prices. Under restrictions in the corn belt and all of the corn belt except Illinois, returns per acre on all Illinois land decrease \$4 to \$5 per acre because decreases in the price of corn, small grains, and hay offset increases in soybean prices. In the case of restrictions imposed in all areas except Illinois, however, the income reductions are greater in the less erosive sections of the state than in the more erosive sections. This occurs because the change in relative prices is not sufficient to cause significant changes in cropping patterns in the less erosive areas of the state, while the difference in relative yields in the more erosive areas makes it more profitable to switch to soybeans. This shift is not possible if soil loss constraints are applied uniformly.

Despite such adjustments to farm income, some erosion control policies assess direct economic penalties more heavily on consumers than producers. This occurs when an economic model includes demand and supply functions for the major crops, and does not assess the indirect economic costs of off-site damages. The impacts of controls are then translated into higher prices, which affect the consumer in a negative manner and the producer in a positive manner. This effect is confirmed in an economic analysis of corn-belt controls by Taylor, Frohberg, and Seitz.[45] Their results indicate greater penalties for nitrogen restrictions in particular. The system which caused the greatest relative advantage for the consumer was a soil loss tax of \$4.00 per ton of erosion.

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[45] R.C. Taylor, K.K. Frohberg, and W.D. Seitz, "Potential Erosion and Fertilizer Controls in the Corn Belt: An Economic Analysis," Journal of Soil and Water Conservation, 33 (July-August, 1978), 174-75.

E. National Impacts

In the previous sections, T-values, or the tolerable level of erosion for land to maintain its long-run productivity, have been discussed. The ASCS National Summary Evaluation of the Agricultural Conservation Program - Phase 1 states that the average soil loss tolerance for cropland soils in the United States is approximately five tons per acre annually. The range of tolerance is from three to five tons per acre annually on cropland. The National Resource Inventories of the SCS show us that only 21.1 percent of our nation's soil acreage is eroding at rates of over three tons per acre per year while only 13.3 percent of that same acreage is eroding at rates of over five tons per year. That same source estimates that 82.1 percent of excess erosion above T-values occurs on only 4.0 percent of the national acreage, and occurs at rates of over 15 tons per acre. The same source revealed that over half (52.4 percent) of the government subsidized erosion control practices occurred on lands that were eroding at rates of five tons per acre or less prior to the application of the practice. Approximately 27 percent of all practices occurred on lands eroding at rates between 5 and 14 tons per acre annually. Lands eroding in excess of 14 tons per acre caused an estimated 86 percent of total excess sheet and rill erosion but received only 21 percent of the government assisted practices. The ASCS Summary Evaluation notes that such data suggests that the incidence of ACP assistance on lands subject to excess erosion tends to be concentrated on lands experiencing relatively low rates of excess erosion at the expense of more serious problems. Overall, it appears that ACP practices are spread fairly evenly among all farmland, regardless of the level of erosion.

The ASCS evaluation continues by noting several likely reasons for distribution of practices in this manner. These include: (1) the possibility that assistance may be offered at essentially equal rates regardless of erosion severity because of a lack of available data to enable program managers to set priorities; (2) farmers who operate on relatively non-erosive land tend to be in a better income position to utilize cost share programs; (3) farmers often can maximize income by placing cost-share practices on lands with less erosion because yield responses are often greater than on sloping acreage where runoff is more difficult to control; and (4) many farmers regard highly erosive land on their farms as temporary, either to be farmed only when prices are high enough or fit for permanent retirement when it is no longer productive.

Considering the relatively new legislative mandate that ACP cost-sharing be used only for soil conserving or water quality improving practices, the criticisms discussed above should prove valuable in helping to achieve more sediment control for the dollar. Clearly, gross soil erosion and sediment damage could be better controlled with available program funds by concentrating cost-share funds on more highly erosive areas.

F. Other Impacts

Other economic impacts worth noting for their importance in policy considerations are those associated with long-term planning, additional water quality concerns, and various institutional costs.

Long-Term Impacts. By expanding the planning period for the Big Blue Watershed analysis discussed earlier in this report, Seitz, Taylor, Spitze, Osteen, and Nelson estimated the long-term impacts of each control policy. By revising yield and net revenue coefficients each 10 years to account for the change in depth of topsoil remaining, new inputs were derived for the next 10-year solution of the optimum combination of activities. This procedure was repeated in 10-year intervals for a 100-year period. In each case the model was solved with a five percent discount rate and on an undiscounted basis.

The physical impact of soil loss constraints is considerable. If current tillage and cropping practices are continued, 57 percent of the acres in the model lose all topsoil within the 100-year period. If soil losses are constrained only 9.3 percent of the acreage loses all of its topsoil in 100 years.

The long-term economic impacts are also important. During the first 25 years average watershed income is higher in the unconstrained condition. After that time, income is rapidly reduced because of soil productivity losses, with constrained annual income becoming higher after 40 years and much higher over the next 60 years. If price effects are included in the analysis, the short run reduction in income from erosion constraints would be offset by increased prices because of lower production. Likewise, the substantial reductions in long-run income for the unconstrained case would be offset by increases in prices.

If cumulative income is discounted at a rate of five percent, income differences between constrained and unconstrained scenarios becomes nearly insignificant. In addition, discounted cumulative income in the constrained case takes 60 years instead of 40 to become more profitable. This result indicates that despite significant erosion, farmers could not profitably adopt soil conservation practices unless their planning period was over 40 years or 60 years if they discounted earnings.[46]

Water Quality Impacts. In the earlier discussion of watershed level sediment damages, the sixth category of damage was an increase in water treatment costs due to the sedimentation of the reservoir and the resulting increase in the sediment levels of municipal and industrial water supplies. In addition to these damages, nitrogen, phosphorus, and pesticides are carried by sediment to contaminate public water supplies. Fluctuating water levels, wildlife habitat, and energy and nutrient sources are all factors necessary for healthy streams, and all factors which are affected by agricultural runoff. While these factors are numerous and their interrelationships uncertain, water quality control appears to be largely confined to three alternatives - control at the source (soil conservation practices), intermediate control (reservoir sediment trap), or treatment by the user (municipal or industrial water treatment).

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[46] Seitz and others, 38-39.

From a public policy perspective, then, it would be useful to know and understand the relative efficiencies or cost-effectiveness of these three alternatives. Because all three systems provide significant benefits in addition to water quality, however, such an analysis would be important but of limited value. For example, in a study of agricultural land use practices to control water quality, Jacobs and Timmons[47] conclude that the reduced municipal treatment costs associated with incremental reductions in suspended sediment represent only a small fraction of the increased costs of sediment control at the farm or watershed level. As noted earlier, however, municipal and industrial water quality costs are only a small portion of total watershed damage costs, not including the cost of lower soil productivity at the farm level.

Another significant consideration is that as farmers adopt increasingly improved soil conservation systems and practices, runoff will be reduced. As runoff is reduced, water flow downstream is also reduced, sometimes to critical levels. In other words, water quality and quantity can be inversely related.

Institutional Costs and Arrangements. The principal components of an erosion control policy are performance indicators, control instruments, control techniques, compliance measures, and temporary penalties.[48] Performance indicators are needed to

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[47] James J. Jacobs and John F. Timmons, "An Economic Analysis of Agricultural Land Use Practices to Control Water Quality," American Journal of Agricultural Economics, 56 (November, 1974), 797.

[48] Seitz and others, 39-41.

indicate whether a problem exists and, subsequently, the need for and the effectiveness of a policy. Control instruments are the methods used to induce changes in decisions to achieve a desired goal. Education, economic incentives, and regulation are common examples. Control techniques are the means of achieving the objectives of the policy. Such techniques may be specified in the policy or left to the discretion of the individual producer. Compliance measures are used to determine whether individuals are conforming to the requirements of the policy. Temporary penalties are used in those policies which mandate performance to insure compliance.

Using estimates generated from information provided by SCS personnel, equipment price lists, and several other sources, Seitz, et. al., developed estimates of the unit costs of carrying out the required functions of erosion control policies. Those estimates are condensed and illustrated in Table 22.

Estimates of the costs of implementing each component of a policy can be obtained by adding the costs of the necessary functions. Total policy costs can then be secured by adding the component costs. It is important to note that the costs in the table assume that new agencies would have to be created to implement the policies. Relying on the experience of existing institutions would likely speed the rate of accomplishing goals and reduce the costs of such accomplishments. Seitz, et al., note that in spite of the obvious modifications needed in any cost estimate, the costs of administering a policy which affects a large number of individuals will be significant. For the more stringent policies which require higher levels of contact, the cost of policy implementation is significantly greater. While these costs are obviously different three years later, the table does enable relative cost comparisons.

TABLE 22
UNIT COST OF INSTITUTIONAL FUNCTIONS REQUIRED TO IMPLEMENT EROSION CONTROL POLICIES

Description	Unit Cost
Monitoring	$12.63/farm + training cost
Reporting Impact	$4.75/report
Notification of Assessment of Penalty	$9.75/notification
Board of Review	$525.00/year + $9.81/case
Court Action	$40.00/case
Subsidy	$14.50/$100 of subsidy paid
Office Maintenance	
I. For One Administrator	$11,703.25/year
II. For One Technician	$10,501.00/year
III. For One Secretary	$5,998.32/year
IV. State Central Office Equipment	$997.95/year
V. County Office	$550.71/year + $100/person
Individual Analysis of Farm Needs	$153.82/farm + training cost
Contracting with Individual Farmer	$16.00/contract
Education	$205.50/session + training cost
Training of Technicians	($68.37/day + $7.50/sessions + $30.00/week)/trainee
Reporting Need	$306.00/report
Formation of a Program	$320.00/year
Publication and Notification of Legislation	$30.00/county
Central Coordination	$135,080.00/year

Source: Seitz et al. (1978), condensed from pages 260-86.

Reference: Wesley D. Seitz, and others, "Economic Impacts of Soil Erosion Control," Journal of Land Economics, 55 (February, 1979), 40.

CHAPTER IV

SUMMARY

In this report on the economics of soil erosion and its control, I have attempted to confine myself to questions such as cost-effectiveness and whether benefits exceed costs. In doing so, I have also attempted to avoid the value judgements required of social welfare economics and determinations of equity, both of which are appropriate questions for policy makers to determine. For example, it is one thing to say that a sediment delivery constraint confers a locational advantage to those farms furthest from the watershed; it is quite another thing to say whether such an advantage is good or bad. In this final section of my report, I will summarize from the literature reviewed those policy options which appear to be most economically efficient as well as the important equity considerations of various policy choices.

At the individual farm level, the reviewed literature indicates that producers cannot normally justify the use of most soil conservation practices from the standpoint of economic efficiency, unless planning periods of over 40-60 years are used. Two notable exceptions to this appear to be the use of additional chisel plowing in the short run on most land; and for cash crop farms, the abandonment of rotations in favor of continuous cropping or soybean-wheat double cropping with much greater use of conservation practices.

In other words, farms which are predominantly continuous corn or soybeans under conventional tillage systems may profit in the short run through the use of increased chisel plowing, primarily because of reduced input costs. Seitz, Sands, and Spitze note that cash crop farms which have traditionally included small grains and pasture in their rotations might greatly increase profits and also reduce soil erosion by switching from rotations to continuous corn or soybean-wheat double cropping with a much greater reliance on soil conservation practices. Because wide differences in soil slopes and structures may occur from farm to farm, economic efficiency would seem to favor the use of short run computer analysis by farmers, county extension agents, and farm management specialists in conjunction with an educational program to inform producers of soil erosion - net return tradeoffs on their farms. Furthermore, because several practices in this report enable farmers to greatly reduce erosion as well as <u>increase</u> net returns, it appears that the proposed use of computer analysis might increase both net farm income and net social income in many instances. Although this paper does not address the economic tradeoffs evident in the utilization of small grains and pasture used in conjunction with livestock operations, it would seem that such tradeoffs could be incorporated into the computer model. Such a model would ideally also incorporate the effectiveness of various soil erosion control practices on wind erosion.

Even for the farmer or governing body that is not interested in whether costs exceed benefits, but rather is singlemindedly determined to preserve the soil productivity, the cost-effectiveness of various practices becomes most important. In every erosion class reviewed, conservation tillage is either the least cost solution or competes very favorably with the least expensive practice. Chisel plowing, plow-plant operations, and other minimum tillage practices appear to be much more cost-effective than contouring. One exception to this may be on farms which regularly rotate their crops. Here contouring may have a slight edge, as indicated in the Southern Iowa Rivers Basin study. Stripcropping according to the National Summary Evaluation of the ACP, is shown to be equally cost-effective with conservation tillage on lands experiencing erosion rates of 3-5 tons per acre prior to conservation measures and is only slightly less efficient at pre-practice rates of 5-10 tons per acre. Only at rates of erosion between 15 and 50 tons per acre does stripcropping become more cost-effective than minimum tillage. At rates over 50 tons per acre, terracing becomes the most cost-effective option.

Cost-effectiveness was shown in this report to be a valuable standard for either the farmer or the policy maker. It does not, however, show whether a particular practice is reducing erosion enough to meet prescribed SCS soil loss tolerances. For example, although conservation tillage practices were most cost-effective when the entire range of pre-practice erosion rates was considered, when practiced alone they cannot reduce soil losses to tolerable levels on slopes of over five percent. Consequently, combinations of activities were shown to be more important on the higher slopes. To illustrate, it was noted earlier in this report that for farms under erosion control rotations in the Southern Iowa

Rivers Basin, terracing and minimum tillage together was more cost-effective than either contouring or minimum tillage. Walker and Timmons noted that this is particularly true on steeper slopes, where either stripcropping or terracing must enter the solution to reduce erosion to T-values, and that contouring alone is actually counterproductive on slopes over seven percent. For terraces, Mitchell, Brach, and Swanson note that grass-back-slope terraces are more cost-effective than gradient terraces on slopes over six percent, despite the lost acreage, because they reduce the effective field slope and thereby allow fewer terraces to be spaced further apart. Returns for terraces of any type were highest when applied to areas with highly erodible topsoil and/or poor subsoils. As a general principle, it appears that producers would receive the greatest long-term benefits by applying conservation practices to their steeper land first, assuming such land is farmed annually.

The literature reviewed for this report shows that because conservation practices which are adequate to reduce soil loss to T-values often require construction of terraces or other structures, farmers cannot normally justify such practices from an economic standpoint, except over very long planning periods and low discount rates. Because sediment produces off-site costs and damages, however, it is necessary to analyze both costs and benefits of control on a watershed basis or larger area to adequately determine net social costs.

In the Seitz, Sands, and Spitze study, benefits exceed costs for sediment control for society (net social income increases), at least until erosion rates of 6-10 tons per acre in a highly erosive area are achieved. After that point, which does not meet T-value standards on most soils, net social income declines rapidly.

In order to reduce soil losses to levels that maximize the net social income, soil loss constraints, subsidies, and soil loss taxes were compared. As noted earlier, it was shown that there is very little difference in farm income, conservation practices, or crops produced among the alternative policies of regulating the level of soil loss at either the watershed or the farm level. Because of this, the theoretically more efficient policy of soil loss taxes was dismissed by Seitz, Sands and Spitze without a serious loss of economic performance due to difficulties in implementation, monitoring, and administration.

Because soil loss taxes would be very difficult to implement, policy makers would likely be faced with choices between various subsidy and soil loss constraints if they determine that erosion control is necessary. In considering these options, a number of equity relationships may be considered. For example, in comparing the effect of a statewide soil loss constraint in Indiana for various counties and farm sizes, Miller and Gill[49] produced results which show that for each county and farm size, the net revenue differs in magnitude, the level of soil loss constraints at which net revenue begins to decline is different, and the incremental

[49]William L. Miller and Joseph H. Gill, "Equity Considerations in Controlling Nonpoint Pollution From Agricultural Sources," Water Resources Bulletin, 12 (April, 1976).

change in net revenue as soil losses are progressively reduced varies. These differences are due to a number of factors, including (1) hillier topography requiring adoption of conservation practices much earlier and more frequently, (2) cost per acre differences between large and small farms associated with the size of machinery appropriate for the different sized farms, and (3) small farms tending to be located on poorer quality soil types, requiring more income restraining management measures to achieve the required levels of soil loss.

From a policy point of view the results suggest that applying a standard soil loss restriction would result in significant differences in economic impact among farmers, ranging from net income reductions of 0.3 percent to 14 percent. As noted earlier, these differences are also caused by increases in returns on non-erosive land due to increases in both corn and soybean prices. If the regional income foregone as a consequence of reduction in income in the agricultural sector is included, the differences in economic impacts might be even greater. These economic differences are greater at low levels of soil loss than at high levels.

One advantage of a subsidy program is that it can be used to achieve reductions in soil loss with a more equal change in net revenue among different sized farms and topographic areas than would occur under the application of a statewide standard for soil loss. Also, the costs of monitoring program compliance may be quite high for soil loss restrictions. Assessing the economic impact of these alternatives can be an expensive and time consuming analytical problem. The costs of program implementation, monitoring, and required analysis would have to be considered social costs, in addition to other impacts to determine total program costs.

At the watershed level, Seitz, Sands, and Spitze show that economic efficiency without consideration for administrative and monitoring costs and difficulties would favor watershed level soil loss constraints. If administrative and monitoring costs are considered, however, subsidization of soil conservation practices may well be the most efficient of the various control policies.

If the goal of policy makers is to reduce soil loss to T-values in each watershed, each farm, or each area within each farm, policy options become restricted further. Those options shown in this report to be viable alternatives to the use of soil loss restrictions greater than 75 percent include bans on fall or straight-row plowing and soil conservation subsidy levels of 102.5 percent. As these policies were all comparable in effectiveness, policy makers would decide whether society should finance soil conservation efforts from general revenue sources or whether specific tillage constraints should be imposed which would be financed by producers and, to various degrees, consumers of the farm products.

If soil loss constraints are chosen by policy makers to reduce erosion to "acceptable" levels, it appears that the very slight economic advantages shown earlier are not likely sufficient to justify watershed level constraints over farm level constraints, which are much easier to monitor and administer. Under a choice to control soil loss by regulation, policy makers would then need to decide what level of soil loss (per acre, per farm, or per watershed) is desirable. Once the permissable level of soil loss is decided, finding the least-cost solution is simpler. As shown earlier, at levels of soil loss below T-values, tillage constraints should perform comparably with soil loss limits, and are much easier to monitor. As with any restriction, however, the producer's freedom of choice would be limited.

If a subsidy system is chosen, as it has been in the past, it appears that economic advantages could be attained by requiring such payments to be restricted to improved practices on steeper cropland, with additional payments for less erosive land to be made only if the more erosive land was adequately treated. This is true both at the watershed level and nationally. It also appears that net social income under a subsidy program could be maximized by giving certain practices (e.g., minimum tillage) priority over generally less efficient practices (e.g., terracing), and by restricting more costly practices requiring construction to soil slopes and classes where it is clearly a part of the most cost-effective solution. These policy approaches would require greater restrictions on certain practices than exist under current programs. More efficient utilization of terracing, for example, might be achieved both by placing much greater restrictions on their use for various slopes and soil structures and by the government providing a minimum of 100 percent of financing for construction and perhaps maintenance of terraces, thereby eliminating the current problem of landowners on poorer, highly erodible soils being unable to afford to contribute to cost-sharing for such structures. Another policy option would be to restrict construction subsidies for terracing to those farmers who were utilizing chisel plowing wherever profitable. For those producers which would be required to make an equipment purchase, subsidy or property tax incentives could be provided. One obvious disadvantage of a subsidy program from a policy maker's standpoint is that general tax sources are used to finance such programs, rather than the producers of the sediment or the consumers of the product.

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THE ECONOMIC IMPACTS OF SOIL EROSION AND ITS CONTROL

by

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ABSTRACT

The economic impacts of soil erosion and various erosion control policies on crop producing land are reviewed at the farm level, the watershed level, regionally, and for the corn belt. Particular attention is given to the cost-effectiveness of erosion control and whether benefits exceed costs for the producer or society. Based upon review of a number of analyses of the economic impacts of erosion control policies in the corn belt, it is shown that most erosion control practices under existing cropping patterns are not profitable for the individual producer unless planning periods exceed 40 years if the farmer does not use a discount rate and 60 years if a discount rate of five percent is used. Societal benefits, however, do exceed the costs of erosion control to a point (approximately six tons of soil per acre per year on the average), after which costs exceed benefits. It is also shown that on many cash crop farms, net farm income can be significantly increased and soil erosion reduced if farmers would abandon traditional rotations and cropping patterns in favor of continuous corn or soybean-wheat double cropping with a much greater use of conservation practices. From a policy standpoint, the literature reviewed suggests that soil conservation subsidies of 100 percent or more compare favorably in cost-effectiveness with theoretically more efficient regulatory and tax policies when administrative and monitoring concerns are considered.