Soil Erosion: The Incentives for and Effectivness of Control Efforts on Cropland in the United States

Carol Halls
Department of Economics
McGill University
Montreal
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Carol Halls
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Department of Economics
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Abstract

Soil erosion from American cropland poses a problem to society in many ways. Ground and surface water is polluted by chemicals carried on the eroded soil, silt builds up in rivers and other water bodies, soil particles carried by wind pollute the air, and finally there is a decline in the productivity of the remaining cropland soil. The rate that soil is eroded from cropland is directly affected by the type of crops planted, tillage systems used and government agricultural programs. This thesis presents the economic costs of soil erosion from cropland and the private and social benefits that can be obtained by reducing erosion rates. Many conservation programs have been less than effective in controlling erosion levels and some commodity and income programs have actually increased erosion rates. A survey of government policies and their various effects on soil erosion rates is included in this thesis. Alternative government policy options are presented.

Précis

L'érosion du sol des terres américaines en culture pose un problème complexe pour la société. Les eaux souterraines et de surface sont polluées par les produits chimiques présents dans la terre érodée, la vase s'accumule dans les rivières et autres cours d'eau, les particules de sol transportées par le vent polluent l'air et, finalement, il y a une baisse significative de la productivité dans ce qu'il reste de terres cultivées. Le taux d'érosion est directement fonction du genre de culture, des méthodes de labour et des programmes gouvernementaux d'aide aux agriculteurs.

Cette thèse fait état des retombées économiques de l'érosion des terres en culture et des avantages aux individus et à la collectivité que pourrait entraîner une réduction du taux d'érosion. Plusieurs programmes de conservation se sont avérés inefficaces dans le contrôle des niveaux d'érosion tandis que certains programmes visant à produire des denrées particulières ou à assurer un revenu équitable en ont augmenté le taux. Un relevé des politiques gouvernementales et de leurs effets sur le taux d'érosion du sol est inclus dans ce document et des suggestions de politiques qui pourraient être adoptées par le gouvernement sont présentées.

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Soil Erosion: The Incentives for and Effectiveness of Control Efforts on Cropland in the United States

Chapter One

Introduction

Soil erosion is a natural geologic process that occurs on all kinds of land at different rates depending on the weather, topography, vegetation, and various other factors. Most soil has the capability of regenerating itself in different degrees. For soil other than that used for growing crops, erosion is a relatively minor problem except in cases where the eroded soil contaminates water with sediment or toxic chemicals or where the remaining soil is rendered incapable of supporting plant growth needed to prevent soil erosion.

Soil eroded from cropland is another story. Of the 5 billion tons of soil eroded in 1991 in the United States, more than 3 billion tons were eroded by wind and water from cropland (1990 Fact Book of Agriculture, 1991: 68). (The figures for Canadian cropland are not available.) Soil eroded from cropland poses a problem to society in several ways; ground and surface water are polluted by chemicals carried on the eroded soil, silt builds up in rivers and in other bodies of water, soil particles carried by wind pollute the air, and finally there is a decline in the productivity of the remaining cropland soil.

Three factors affect the amount of soil erosion on cropland:

(i) the natural characteristics of the land, such as soil depth and slope and climate;

(ii) the characteristics of the crops grown and tillage system used; and

(iii) conservation practices.

Farmers make soil conservation decisions based on the costs and benefits of implementing a practice. They compare the reduction in current profits with the benefits of maintaining future output based on the price of the commodity grown. Many government programs modify real crop prices and influence farmers' expectations and decisions with regards to soil conservation. There is general agreement in the literature that the private returns to erosion control by farmers are relatively low or even non-existent. As a result, some farmers are imposing an intertemporal externality on future generations by allowing soil to erode, thereby diminishing the future productivity of their cropland.

Farmers produce crops up to the point that the marginal benefit just equals the marginal cost, to them, of the undertaking. In general, they ignore the marginal costs of pollution that spillover to society. Unless these externalities are internalized the true costs of cultivating cropland will not be reflected in farm production decisions. The amount of soil eroded will be higher than is socially desirable.

There are many government programs that attempt to stabilize agricultural markets, commodity production, and farm income. These programs create financial incentives which influence farmers' planting and management decisions, and therefore indirectly affect the amount of soil erosion on a field. For example, those programs that promote crop exports and income policies, such as the Reserve program, may encourage farmers to farm their cropland more intensively, increasing the damage done to the soil and making the soil more susceptible to erosion. The rate of soil erosion on cropland is higher than that which would be expected if the support programs were discontinued.

Since farmers have little or no incentive to control soil erosion on their own, there is potential for "market failure". The source of the market failure is twofold;
(i) The discount rates used by farmers and society to weigh the costs and benefits of conservation decisions regarding the long-term productivity of cropland are different, and
(ii) The negative externalities created by erosive farm practices are not absorbed by the farmer.

The question naturally arises as to whether there is a need for government action to control erosion. Neoclassical economic theory claims that given a perfectly competitive market, access to information, and defined property rights, farmers and society will reach a Pareto-efficient level of crop production and pollution through negotiation without government intervention. In 1960, Coase suggested that perfectly competitive markets were not a necessary condition for reaching an efficient solution but instead said the solution could be reached if no mutually beneficial agreements are missed. This means that all the people involved must be able to get together and negotiate to obtain an efficient solution.

> In a laissez faire economy so long as bargaining over rights is allowed and is almost costless, then it will not matter which party has property rights initially. The person who values the right the most will ultimately bid the highest for it. (Coase, 1960: 13)

Can such an argument be applied to soil erosion from cropland? The answer is no, for several reasons. First, there is a lack of information not only about where the pollution is coming from, but, as well, about how much pollution there is and how it got there. The strong information requirements the achieve a Coase solution are set out in Farrell, 1987. Second, the Coase solution will not work because of the large number of people adversely affected by agricultural pollution. It would be impractical and expensive for all the plaintiffs to get together and bargain with a vaguely defined group of polluters. The coordination required to get these large groups of people together is prohibitive. The bargaining costs in this case would not be negligible. Third, the specific source of many of the pollutants is undefined so property rights cannot be assigned. Therefore the Coase solution cannot be used to negotiate a solution to the pollution problems stemming from agriculture. There is a need for government intervention if the level of pollution from soil erosion is to meet the standards that society wants to achieve. Of course, if the costs of reducing soil erosion at the margin are greater than the benefit of reducing erosion by another ton, then from an economic standpoint it is not optimal to proceed.

In this thesis the following questions are addressed:

- How much soil erosion accompanies current crop production?
- How much soil erosion can be eliminated while maintaining crop production and how much will it cost?
- How can society achieve the desired level of soil conservation? and
- What is the best way to encourage socially responsible behaviour by farmers in areas of excessive soil loss?

In Chapter 2, the effects of pollution from cropland erosion are described. The costs, in terms of environmental damage and loss of productivity are reviewed. Some reasons for the increased levels of erosion are presented.

Alternative cropping systems that are less erosive are described in Chapter 3. Several cost-benefit studies of various systems are reviewed. Some factors affecting the ability of farmers to practice soil conservation, such as the type of ownership and renting agreements, age, education, and financial resources are discussed.

Current government programs designed to encourage conservation are reviewed in Chapter 4. Government commodity and income programs that attempt to stabilize agricultural markets, commodity production, and farm income are examined with respect to their impact on erosion levels. The effect of programs designed to increase farm exports on soil erosion levels are also reviewed. Alternative policy options for future soil conservation efforts are discussed.

Please note that much of the statistical data used in this thesis is ten to fifteen years old, collected from the period when many writers were researching the effects of cropland soil erosion. In recent years, fewer studies have been done but even if they had, there is no reason to expect the findings would be significantly different than those done in the past, unless the methodology used in calculating the data was changed. This thesis is about soil erosion on American cropland mainly because the statistical data was readily available while it is not available in Canada. Consequently, the statistics presented in this thesis are in Imperial units and have not been converted to metric units.

Chapter Two

The Nature of Pollution from Cropland

In this chapter it will be shown that serious environmental hazards are created by current farming practices. There are two major problems stemming from cropland soil erosion. The first is the negative externalities generated from the sediment, pesticide, and nutrient runoff associated with soil erosion. The second is the depletion of the natural productivity of the soil as a natural resource. In this chapter the environmental pollution and costs to society from soil eroded from cropland are described. In Chapter 3, a discussion of the decline in the soil's productivity from soil erosion is presented. Before these problems are discussed, a description of soil properties and the way soil reacts to various inputs is presented.

Soil properties

Soil is made up of several components including mineral particles, which come directly from rock, and organic compounds, derived mainly from plant and animal residues. The amount and size of mineral particles found in the soil determine its texture. Clay is composed of very small particles, silt and sand consist of larger particles, and loam is a combination of the two. The quantity of organic matter in soil is a key factor in determining soil productivity. Organic compounds affect the soil structure by forming large pore spaces in which air and water are combined to support plant growth. These compounds are a primary source of plant nutrients, especially nitrogen. Frequently, the capacity of the soil to supply moisture is the single most important determinant of crop yields, since fertilizer can be added to provide nutrients that don't occur naturally.

Subsoil, the layer of soil lying immediately under the topsoil, is not as good as topsoil for growing crops because there are fewer nutrients, less organic matter, and more gravel, stones and clay, which reduce the water holding capacity of the soil. As well, subsoil is less responsive to applied chemicals. Since herbicides are most effective when they cling to organic matter in the soil, the low organic content of subsoil reduces their effectiveness and requires even larger amounts to control weeds. When topsoil is eroded to the point where plant roots reach the subsoil, crop yields decrease unless there is an increase in the amount of fertilizer and or other inputs. Other plant growth inhibiting factors that can be found in subsoil include dense, brittle layers of soil, called fragipans, permanently high water tables, or chemically toxic zones.

Productivity increases and the effect on soil properties

Productivity in the farm sector has increased at an astonishing rate during the last century. Corn, which is the most abundant crop produced in the United States, is a spectacular example. Farmers, in 1980, produced 33 times more corn per hour of work than did farmers 60 years earlier (Agricultural Statistics, 1980: 429).

Table 2.1 indicates that agricultural productivity increased by an average of 2.3% per year in the 1970's and nearly 3% from 1980 to 1985 (1990 Fact Book of Agriculture, 1991: 47). American farmers in 1981 produced over 76% more crop output on the same number of acres than the previous generation did, and since 1967 farm productivity per worker has increased 60% compared with 15% in the non-farm sector (Soil and Water Resources Conservation Act: 1980, Part 2, 1981: 7).

Table 2.1 Agricultural Productivity

Year	Index of total farm output (1977 = 100)	Index of output per work hour (1977 = 100)	Crops harvested (million acres)
1930	43	NA	369
1940	50	NA	341
1950	61	22	345
1955	69	30	340
1960	76	42	324
1965	82	56	298
1970	84	74	293
1975	95	90	336
1980	104	109	352
1985	118	139	342
1986	111	139	325
1987	110	142	302
1988	102	135 (1)	298
1989	114 (1)	148 (1)	318

(1) Estimated
(1990 Fact Book of Agriculture, 1991: 47)

Table 2.2 shows that the average yields per acre of some key crops grown in the U.S. are also increasing. In the last fifty years the amount of corn grown on a single acre has increased 347%.

Table 2.2 Average Yields of Key Crops in the U.S.

	Crop (bushels/acre)		
Year	Corn	Wheat	Soybeans
1930-39	24.2	13.3	16.1
1940-49	34.1	17.1	18.9
1970-79	89.6	31.4	28.1
1980	118.0	37.5	34.1
1990	118.5	39.5	34.0

(Batie, 1983: 40 and 1990 Fact Book of Agriculture, 1991: 130-132)

The increased productivity in agricultural output can be attributed primarily to technical changes.

> Technology has been the major factor in the transformation of American agriculture from a collection of mostly self-sufficient farms in the 19th century to a highly efficient, highly mechanized work force today. (Soil and Water Resources Conservation Act: 1980, Part 2, 1981: 1)

Technical changes include; specialized machinery, more drought-resistant hybrid crop varieties, improved tillage practices, more productive management of water through irrigation and drainage, the application of chemicals to control weeds, fungi, and insects, and the increased use of synthetic fertilizers. From 1967 to 1980 farm consumption of nitrogen, phosphorous, and potash, primary plant nutrients, rose more than 64% (Fact Book of U.S. Agriculture, 1981: 26). As can be seen from Table 2.3, farmers used almost as many agricultural chemicals in 1989 as in 1980 even though crop acreage was cut back, reflecting the increased dependence of farmers on purchased inputs.

Table 2.3 Index of Agricultural Chemicals used 1920 - 1989
(1977 =100)

Year	Agricultural Chemicals
1920	5
1930	6
1940	9
1950	19
1960	32
1970	75
1980	123
1989	122

(1990 Fact Book of Agriculture, 1991: 15-17)

With the invention of the tractor, combine, refrigeration, and an expanded railroad system after World War I, farming became a more specialized operation. In the early 1950's with the arrival of low cost nitrogen fertilizer, farmers began to specialize in grain crop production which they sold to farmers who raised cattle in feedlots, using purchased grain. Field sizes increased and long straight rows were planted to accommodate larger machinery. The amount of land a single farmer could work increased from 150 to 450 acres between 1918 and 1978 (Agricultural Statistics, 1980: 417-418) and in 1989 was 456 acres (1990 Fact Book of Agriculture, 1991: 39).

The increases in productivity have had some environmental costs. The use of heavier machinery compacts soil, reducing soil tilth, that is the ability of the soil to bind plant nutrients in a form that will resist leaching but will still be available to plants. Compacted soils also reduce the rate of water infiltration, increasing runoff and erosion, and reduces root penetration, reducing yields. As well, large machinery cannot handle some soil conserving practices, such as terracing and contours.

Hybrid seed varieties, that increase yields substantially and are more drought, disease, and pest resistant, have been developed. The increased yields per acre require more water, fertilizer, and pesticides than were previously used. Heavy applications of these chemicals also reduces soil tilth and kill natural organisms in the soil. Without these binding organisms soil is more susceptible to erosion from wind and water.

Irrigation has contributed to the growth in productivity on approximately 15% of cultivated cropland. The majority of this irrigated land (83%) is in the West, where 25% of the total value of U.S. crops are produced (Soil and Water Resources Conservation Act: 1980 Appraisal, Part 1, 1981: 207). Between 1950 and 1977, 30 - 35 million additional acres of cropland were irrigated. This increased output by

70% on this land without increasing the harvested acreage (Crosson, 1982: 121). In 1978, more than 50 million acres were irrigated but the amount of irrigated land had fallen to just above 46 million acres by 1987 (1990 Fact Book of Agriculture, 1991: 11).

Once land has been irrigated it's erosion level can increase. It can also have the opposite effect, by increasing the plant cover of the land, thus reducing its exposure to the erosive effects of wind and rain. Because irrigation increases the productivity of the land compared with dryland farming, it requires a greater per acre use of fertilizer and pesticides, thus increasing the likelihood of environmental damage from these materials.

Salinity is the most pervasive environmental problem stemming from irrigation in the United States. In areas of extensive irrigation, mineral salts can accumulate on the surface of the soil as a result of evaporation. Erosion can transport considerable amounts of these salts to water bodies. In large quantities mineral salts can be toxic to plants and fish, and contaminated water may need treatment before it can be used for human consumption. Salt levels are high and generally rising in all western river basins, except the Columbia. In much of the Lower Colorado, parts of the Rio Grande, and the western portion the San Joaquin river basin, salt concentrations in either the water or the soils are approaching levels that threaten the viability of traditional forms of irrigated agriculture. Salinity and the resulting damages are passed downstream and the annual damages to the Colorado River are estimated to be between $75 and $104 million (Crosson, et al, 1982: 130).

Technical advances, with their associated productivity increases, have created many conservation problems. On the other hand, "..productivity advances brought environmental benefits because crop production was avoided on millions of acres of erosion-prone soils." (Johnson, 1981: 114).

Measuring soil erosion

Soil can be blown from land by wind or carried off by water. When fields are fallow, soil loses the binding effects of plant roots which can lead to increased soil erosion. If rainfall or irrigation is inadequate and the soil becomes light, dry, and powdery, when wind blows across the field's surface the detached particles become airborne. Heavier sand particles can even drop back to scour the earth of more soil. Wind erosion is a moderate to severe problem in many areas of the U.S. but the ten Great Plains states suffer the most from wind erosion.

Erosion from water is the most dominant problem on most cropland. Sheet erosion occurs when soil is splashed loose and is washed away in continuous layer by rain. Rill erosion occurs when moving water dislodges soil and splashes it away with a scouring action, carving out rills. These may form larger channels, which, if they are too large to smooth with ordinary cultivation, are called gullies.

Among the factors affecting the severity of erosion are the force and duration of storms, climate, and the amount of snowmelt. Soil characteristics such as soil depth, texture, percentage of organic matter, total pore space and size, the length and steepness of a field's slope also play a part in the rate of soil erosion. Finally, the amount of plant cover and the type of cropping system used are also important factors in the control of erosion and will be discussed in depth in Chapter 3.

Soil erosion losses from cropland in the U.S. are estimated using the Universal Soil Loss Equation (USLE) or the Wind Erosion Equation (WEE). Each equation estimates the average annual soil loss, in tons per acre, from each soil type, as a function of climate, topography, cropping system, and management practice (see Appendix 1). These equations have been developed from field experiments in various parts of the U.S. by the Agricultural Research Service.

The Soil Conservation Service has determined an annual soil loss tolerance (T) level at each sample point for each class of soil. This value is the maximum average annual soil loss, measured in tons per acre, that can be tolerated indefinitely without interfering with the land's productivity under continuous production. T values range from 1 to a maximum of 5 tons per acre annually, depending on the properties of the soil. Soil that is eroding at a rate greater than the specified T level has "excess" soil erosion.

Table 2.4 breaks down the 421.4 million acres of cropland into the number of acres with erosion levels in excess of their T value. The number of acres that are eroding at a rate below or at the level needed to maintain the soil's productivity are also included for comparison.

Table 2.4 Cropland acres with erosion in excess of T

T values	Wind Erosion	Sheet and Rill Erosion
	(million acres)	
T	353.6	315.1
T - T+2	18.2	36.0
T+3 - T+4.9	16.3	26.2
T+5 - T+13.9	19.6	26.1
>T+14	13.8	18.0

Source: (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 232-233).

The USLE and WEE equations have been criticized because they only measure the movement of the soil and not the distance of the move. That is, the equations only measure the amount of dislodged soil, not the net soil loss, and may therefore over-estimate the severity of erosion. Much eroded soil does not reach water bodies, instead it lands in gullies and other low lying areas. These equations may also over-estimate fertility losses if the eroded soil lands in another field, as it may increase the productivity in the second field, in which case there is no aggregate loss, just a transfer of resources. This implies that as a farm's acreage increases, as has been the trend, the external costs and benefits of erosion are increasingly internalized.

Overall as much as 75% of transported soil may eventually be deposited on the same field where it was dislodged, but the lighter, nutrient rich, organic particles are most likely to be carried the furthest and end up out of the field, leaving behind soil with less organic matter which decreases productivity. Sometimes when eroded soil is deposited on fertile soil it can reduce the productivity of the soil. In the case when eroded soil is deposited nearby in the same field, the fertility of the land becomes more variable. This means more fertilizer must be applied to the whole field and the effectiveness of herbicides can also be affected by the variability of the soil. Other authors have complained that the T values do not take into account any of the offsite damage caused by erosion and ignore the environmental costs of erosion.

The USLE ignores soil loss from irrigation and snowmelt which is significant in some areas, like the North West where 50 - 100 tons of soil per acre are estimated to be lost per year (Soil and Water Resources Conservation Act: 1980, Part 2, 1981: 37). Because of these limitations one must use these results with caution until more refined methods of measurement can be developed.

Some authors have criticized the T values chosen by the Soil Conservation Service (SCS) and say the rate of soil regeneration cannot be generalized as it varies so much from region to region. It has been suggested that the T value should reflect the soil's productivity, including technology, not just soil build up rates. The value should also reflect the depth of favorable topsoil where the loss in terms of productivity is negligible. The first reliable estimates of soil erosion of U.S. cropland were done in 1977 using these equations, however,

> It is generally agreed that the present values are, at best, crude estimates of the amount of erosion that is tolerable. (Cook, 1982: 89)

The USDA has developed an erosion index that measures the sensitivity of soil to erosion damage for identifying soils on which erosion control efforts should be targeted. It is a much more precise tool than the land capability classification system or estimates of current or potential erosion rates based on the erosion equations alone. The EI is derived by dividing the climatic factors from the USLE or WEE by the T value assigned to a soil area. Soils with a low EI are very slightly susceptible to damage while soils with a high EI are very highly susceptible to damage can generally be protected only by planting a permanent vegetative cover. Highly erodible land is defined as land with an EI greater than 8. This index is used when setting conservation policy criteria. The number of acres of cropland in each EI category are shown below in table 2.5.

Table 2.5 Cropland by EI Category

Erodibility Index

< 5	5 - 8	8 - 15	>15	Total
		(1000 acres)		
233,005.7	70,481.2	68,247.0	49,668.6	421,402.5

(Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 225)

The severity of erosion on cropland

In 1982, sheet, rill and wind erosion removed more than 3 billion tons of topsoil from cropland (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 25). The national average rate of soil loss per acre of cropland due to water was 4.7 tons per year in 1977 (Soil and Water Resources Conservation Act: 1980 Appraisal Part 1, 1981: 3). This figure includes the 33 million acres used for growing hay where erosion rates are negligible. The national average soil loss from wind erosion was 2.1 tons per acre per year and the combined average was 6.8 tons per acre per year, that is 1.8 tons per acre more than the maximum T value set by the SCS. Other estimates have found annual erosion losses averaging as high as 9 - 12 tons per acre nationally. The national average conceals the more severe local and regional problems. Losses of more than 60 tons per acre per year have been recorded in some areas (Carter, 1977: 409).

Of the 421 million acres of cropland in the United States, 173 million acres are eroding at rates greater than the T value. Approximately 23% of cropland in the U.S., or 96.5 million acres, have soil eroding at a rate greater than two or more times the soil loss tolerance (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 25). Other estimates suggest that up to a third of all cropland is eroding at more than the maximum tolerable limit (Carter, 1977: 409).

The best land for growing crops is nearly level with just enough slope for good drainage. Approximately 45% of cropland fits this description. The remaining cropland needs erosion control to prevent excessive topsoil loss and maintain soil productivity. Row crops, such as corn and cotton leave the soil particularly susceptible to erosion. In Iowa, the average erosion rate is 10 tons per acre per year. In eastern Washington, for every pound of wheat harvested, twenty pounds of topsoil are lost and for every pound of corn produced nationwide, 5 to 6 pounds of topsoil are lost (Empty Breadbasket?, 1981: 31).

Approximately 75% of erosion on cropland occurs from water but in certain areas, particularly in the Western states, wind erosion may be more severe.

> In one semi-arid portion of the Great Plains an average of nine inches (1350 tons per acre per year) of topsoil was removed from fields that were cultivated for about 20 years. (Pimental, et al, 1976: 150).

One study on experimental land in Ohio found topsoil losses due to wind erosion of 130 tons per acre per year. In Texas, wind erosion blows an average of 15 tons of topsoil off each acre per year (Empty Breadbasket?, 1981: 31).

Environmental impacts of soil erosion from cropland

Pollution from runoff of agricultural lands adversely affects 29% of the river basins in the United States. The incidence of pollution from agricultural runoff is greater than all the municipal and industrial point source pollution, which adversely affect about 10% of all streams (Soil and Water

Resources Conservation Act: The Second RCA Appraisal, 1991: 120). Soil eroded from cropland pollutes the environment in several ways. It can fill in waterways and reservoirs and kill fish. The soil particles carry pesticides and nutrients that have been applied to crops. When the soil is deposited in water systems the water becomes polluted. When the soil is eroded by wind, the coarser soil particles bounce along the soil surface, destroying plants and machinery.

Sediment

Sediment is the greatest single water pollutant by volume and is an end product of soil erosion. Sediment from crop and pasture land contributes approximately 37% of the total amount deposited in American rivers, lakes, and streambeds (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 106). Sediment causes damage while it is suspended in water and when it is deposited in water bodies or on flood plains.

Sediment from cropland carries absorbed pesticides and nutrients, dissolved minerals, such as salts, and animal wastes, with associated bacteria. When cropland sediment is deposited in the water system it affects the aquatic food chain and the quality of drinking water. Fine soil particles, which have a higher capacity to absorb phosphorous and organic matter, are carried away first by erosion and are carried further in runoff. Transported sediment often has a higher concentration of phosphorous and nitrogen than the original soil. Fine sediment can remain in suspension and attract pesticides and nutrients that have been dissolved in water.

Sediment deposited in the water system is the most severe pollutant to fish and aquatic life. It covers eggs and spawning areas, clogs gills, and decreases food supplies by diminishing light transmission and photosynthetic activity. Predation on young fish is much greater when sediment covers crevices, eliminating hiding places. Sediment also affects the usefulness of streams and lakes for recreation.

Sediment creates problems for hydroelectric plants and other industries that need a clean water supply. It may fill in irrigation ditches, impair drainage and cause flooding, which may increase deposits of infertile sediment on productive lands. Sediment deposits reduce the capacity of water bodies. It gets removed from highway ditches, lakes, harbours, navigation channels, reservoirs, and virtually all municipal and industrial filtering systems. The cost of dredging the sediment from rivers and harbours annually in the U.S. has been estimated to be between $250 million (Crosson, 1982: 150) and $500 million (Batie, 1983: 51) with half of the total sediment probably coming from cropland

(Jeske, 1981: 402). Between 1979 and 1983, the U.S. Army Corps of Engineers spent $311 million annually dredging channels, harbours, reservoirs, ditches, streams, and lakes (1980 $) (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 117). The Corps has considered relocating their post at Winyah Bay, South Carolina, because of the one million tons of sediment deposited in the Bay each year, most of which is from agricultural sources (Batie, 1983: 48).

Many reservoirs are silting up so rapidly that they will only last about half as long as originally intended. There are approximately 690 million acre-feet of reservoir capacity in the United States and approximately one million acre-feet of sediment is deposited in reservoirs annually (Soil and Water Resources Conservation Act: The Second Appraisal, 1989: 103.) The SCS water resources staff estimates that on average, the reservoirs will fill with sediment in 100 years and about half of this sediment is from cropland (McCormick and Larson, in Brady, 1965). This annual loss in capacity is estimated to cost between $50 million (Pimental, et al, 1976: 150) and $2.93 billion (McCormick and Larson, 1981: 402).

Other costs of sediment include the costs to extract it from municipal water treatment facilities and the extra costs to industry to maintain cooling equipment and turbines. The total cost of sediment damages was estimated to be $500 million per year in 1960 (Pimental, et al, 1976: 150) and $1 billion in 1980 (Crosson, 1982: 131).

Sediment in irrigation water can reduce productivity by forming a crust on the surface of the field. The crust reduces the amount of water that infiltrates the soil, reduces soil aeration, and makes it harder for plants to break through the soil surface.

A possible positive side effect of erosion is the 500 million tons of sediment from cropland that are carried out to sea annually, which may help maintain beaches and stabilize the coastline (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 102).

Airborne sediment

When carried by air it can increase the wear on cars and machinery. It has been known to affect the health of livestock and cause respiratory health problems in humans. When plants are covered with dust, photosynthesis is inhibited and their growth is stunted. Wind erosion also damages plants by sandblasting and defoliation.

> Often the abrasive force of these wind-driven particles is so great as to break off growing plants just above the surface of the land. (Bennet, 1939: 88)

Cropland's contribution to particulates in the air, caused by wind erosion, is estimated to be between 33 and 239 million tons annually, while emissions from point sources, such as smokestacks, contribute fewer than 20 million tons annually (Batie, 1983: 46).

Pollution from nutrients

Erosion is the source of 80% of the total phosphorus and 73% of the total nitrogen found in the nation's waterways. These nutrients come from several sources including, forestry, mining and resource extraction, construction runoff, waste disposal, salt water intrusion, hydrologic modification, and urban runoff. However "agricultural land is the most extensive source of nonpoint pollution." (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 106). As can be seen from table 2.6, suspended solids (sediment), phosphorous, and nitrogen found in American waterways come from many sources, however the biggest source is from soil eroded from cropland which contributes 37% of the sediment, 30% of the phosphorus, and 39% of the Kjeldahl nitrogen found in American waterways.

Table 2.6 Water Pollutant Discharge from Erosion

Source of pollutants	Erosion	Pollutant discharge: Total Suspended Solids	Total Phosphorus	Total Kjeldahl Nitrogen
	(million tons/year)		(thousand tons/year)	
Sheet and rill erosion from:				
Cropland	1,836	900	615	3,204
Pasture	190	95	91	292
Range	562	253	242	778
Forest	783	344	495	1,035
Other rural land	453	195	170	659
Streambanks	553	553	1	1
Gullies	295	197	1	1
Roads	167	112	1	1
Construction sites	80	54	1	1
All other (1)	-	16	394	2,186
Total	4,919	2,719	2,007	8,154

(1) Includes livestock runoff, dissolved nutrient runoff, acid mine drainage, urban runoff, and point sources. (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1989: 106).

Farmers used a record 23.7 tons of commercial fertilizers in 1981. After this consumption fell 24% in 1983 to 18.1 million tons, in proportion to the number of cropland acres idled. By 1989, crop acreage had increased again and farmers used 19.6 million tons (1990 Fact Book of Agriculture, 1991: 19). Up to one quarter of all the nutrients applied to cropland wash off into surface water (Allaby, 1972: 141). The actual amount depends on application rates, terrain, crop management practices, and the amount of rainfall (1990 Fact Book of Agriculture, 1991: 19).

One study in Santa Maria, California in 1976 found 39% of the nitrogen applied to the 57,000 acres of vegetable, field, and fruit crops had leached below the root line. Although nitrate concentrations in the water table didn't exceed 10 ppm, the standard set by the U.S. Public Health Service for drinking water, there are several areas in the U.S. where the 10 ppm limit is exceeded (Crosson, et al. 1982: 107).

> ...in order to increase yields, nitrogen fertilizers, synthesized from natural gas, are being applied to our soils in ever-increasing amounts. The side effects of this include the depletion of natural gas reserves, the contamination of food and water with nitrates, resulting in health and pollution problems, damage to the ozone layer by nitrous oxides and the accelerated decomposition of soil organic matter. The associated loss of soil structure has lead to increased erosion. (Lockeretz, 1977: 719)

Adding nitrogen fertilizers to the soil weakens natural bacteria which increases the possibility of soil erosion and the soil's need for more fertilizer to maintain productivity. Some growers have tended to apply nitrogen and phosphorous in excess of what is actually needed because existing technology cannot accurately predict the crop's fertilizer requirements. In Illinois, 40% of the corn and soybean fields have more than the suggested levels of phosphate fertilizer and more than 20% have too much potassium (Lockeretz, 1977: 700). A portion of unused fertilizer, especially nitrogen and potassium, are potential environmental hazards.

Low amounts of potassium and phosphorous relative to the nitrogen supply may result in considerable amounts of unutilized nitrates in the root zone. Plant nutrients seep into the water table which moves much more slowly than surface water, and takes longer to decontaminate than surface water. Since approximately 40% of the population gets its drinking water from ground water sources, the effects of this type of pollution are significant. Ground water contaminated with nitrates can be toxic to cattle and cause methemoglobinemia in infants (blue baby disease), and has caused some deaths (Allaby, 1972: 85 and Soil and Water Resources Conservation Act: 1980, Part 1: 199).

In some instances, fertilizer not absorbed by plants, because of the lack of organic material in the soil, is dissolved and runs off the land with water to ponds and lakes. This stimulates the growth of aquatic plants. When these plants are decomposed by bacteria, the bacteria consumes dissolved oxygen, leaving less oxygen in the water. This condition, known as eutrophication, causes fish to die, adding to the decaying material. When the level of oxygen in the water falls below the level that will sustain bacteria, the water becomes putrefied. Parts of Lake Erie are suffering from this, the main form of life in the water being algae. This degrades the value of surface waters for recreation with surface scum, foul odours, and dead fish.

Nitrogen fertilizer is turned into gaseous nitrogen by soil micro-organisms. It may add nitrogen oxide to the atmosphere and rain, contributing to the depletion of the ozone layer and acid rain.

> Nitrogen releases nitrogen oxides, one of which, nitrous oxide, may attack the earth's ozone shield. The resulting increase in solar radiation reaching the earth's surface would increase the risk of skin cancer. A study done by the National Academy of Sciences indicated a lag of about 100 years between the application of nitrogen fertilizer and effect upon the ozone shield. (Crosson, et al, 1982: 105)

This is a relatively minor form of pollution from agriculture and is not considered further here.

Pollution from pesticides

Pollution from pesticides is difficult to monitor. The more toxic pesticides are less persistent and any adverse effects on water quality generally will be close to the application site. Less persistent compounds will turn up farther away, in a diluted state that may be difficult to identify. Over time, through a process called biological magnification, these compounds can become quite dangerous. Currently ground water contamination from fertilizer is more strictly regulated than pesticide pollution because "the large number of pesticides and the lack of information on their persistence makes it difficult to set standards defining pesticide contamination." (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 112).

Almost all of the pesticide pollution comes from agricultural sources. Of the 2,179 tons per year discharged into the environment from nonpoint sources, 2,064 tons per year come from agriculture (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 104).

> Pesticides are considered to be the largest source of toxic pollutants in agriculture. More than 1800 biologically active compounds are sold in over 32,000 different pesticide products in the U.S.. In 1977 over 200 million acres of land were treated with herbicides, 75 million with insecticides, and 8 million with fungicides. Farmers used about 60% of the 1.5 billion pounds of herbicides and insecticides manufactured in the U.S. in 1977. (Soil and Water Resources Conservation Act: 1980, Part II, 1981: 83)

Pest insects, pathogens (bacteria, viruses, or fungi that cause diseases), and weeds destroy an estimated 33% of crop production in the U.S. annually (Pimental, et al, 1980: 130). The average application rate of pesticides is estimated to be between 2 and 2.6 pounds per cropland acre, excluding land used to grow hay (Soil and Water Resources Conservation Act: 1980, Part 1, 1981: 205). Corn, soybeans, and cotton accounted for 70% of all herbicides used on farms in 1979 and corn and cotton accounted for 64% of all insecticides used. Fungicides are used mainly on fruit and vegetable crops (Batie, 1983: 45). Except when heavy rains or high winds follow an application, the total runoff is low, about 5% of the total applied. But low levels are toxic to fish and persist in the environment for a long time (USDA, Soil and Water Resources Conservation Act: 1980, Part 1, 1981: 205).

When pesticides are applied under adverse weather conditions up to 20% of the application can be lost (Report and Recommendations on Organic Farming, 1980: 63).

Human exposure to pesticides occurs through food, water, inhaling contaminated air, and skin contact. The bulk of pesticides enter the water system in water runoff but some are carried in sediment and some seep into the ground to reach the water table. Pesticides may damage non-target species of plants, insects, soil and water micro-organisms, and wildlife. Some commonly used pesticides that present a threat to fish and other aquatic life, at low levels, persist in the environment for years. These compounds accumulate in the aquatic food chain reaching high concentration levels in predatory organisms at the top of the food chain. This process, called bio-magnification, kills fish.

> The dynamics of dilution and sediment exchange, and uptake, transfer, and metabolism by aquatic life of most of the pesticides presently in use are not known. Without this knowledge, the impact of a given pesticide input or the quality of water in a river or lake cannot be predicted. (Wauchope, 1978: 471)

Tests on fungicides revealed that they are only slightly toxic or even non-toxic to mammals. Tests on organochlorine insecticide compounds (DDT and other similarly persistent compounds) found that some were carcinogenic and or teratogenic, that is can cause fetal malformations. In 1972, the Environmental Protection Agency (EPA) banned or tightly restricted the use of organochlorine compounds and by 1976 only one, toxaphene, was still in general use. The use of organophosphorous and carbamate compounds has increased. These are not persistent and don't biologically accumulate. However, many are highly toxic to humans and other non-target organisms, with localized, short-term effects.

Insects genetically build up resistance to pesticides over time and more of an insecticide needs to be applied to prevent crop losses. The costs of farming rise, there is more damage to beneficial insects and other non-target organisms, and the resistance in the target insect is strengthened even more. This creates a constant demand for new varieties of pesticides.

Most herbicides are not toxic to humans, with the notable exception of Paraquat which is widely used with conservation tillage. A number of herbicides, including Paraquat, may be carcinogenic or cause genetic mutations. Atrazine accounts for almost 25% of all the herbicides applied, mostly to corn. It has a low toxicity but there is evidence that it may be transformed metabolically by plants to form a substance which is mutagenic. It has also been suggested that Atrazine can be transformed by the human stomach to a nitrogen derivative which is suspected to be carcinogenic (Plewa, 1976: 289). Propanil, another low toxicity herbicide used on rice, when dissolved in the soil is first metabolized by fungi and then micro-organisms to form a compound similar to dioxin, a known teratogen.

Continual heavy use of pesticides can destroy the living organisms that make up 1 - 5% of normal soil, reducing tilth, increasing water runoff,and erosion. They can kill invertebrates and micro-organisms that are essential for breaking down wastes and allowing the ecosystem to function.

In 1975, agricultural sources of pollution were responsible for 26% of source identified fish kills, second only to industrial causes. Agricultural chemicals have been found in estuarine systems and even in the drinking supply of some counties. Some chemicals have been thought to be responsible for creating harmful microbiological changes in soil and for causing reductions in the productivity of ecosystems, or for causing cancer (Batie, 1983: 46-47).

About half of all food tested in the U.S. contains detectable levels of pesticides and nearly 100% of the U.S. population has some pesticide residue in their fatty tissue, with the average being 6 ppm (Kutz, 1977: 530). Pesticides have been linked in humans to such problems as blood dyscrasia, allergy sensitivity, neurological alterations, hypertension, high blood cholesterol, cardiovascular disease, and liver disease

(Empty Breadbasket, 1981: 56-57).

The indirect cost of pesticide use in the U.S. has been estimated to be $839 million annually. This includes $184 million for the 45,000 annual fatal and non-fatal human poisonings, $12 million for livestock losses, $287 million for reduced natural enemies and pesticide resistance, including the inadvertent killing of natural predators and extra research costs involved in developing new compounds that pests are not resistant to, $135 million for honey bee poisonings and reduced pollination, $70 million for loss of crops and trees, $11 million for loss of fish and wildlife, and $140 million for government pesticide controls (Pimental, et al, 1980: 128).

The effects of erosion on soil productivity

Sediment eroded from cultivated land removes productive nutrients and degrades important soil structure characteristics, such as permeability and tilth. The removal of finer soil particles by wind and water leads to compaction of the soil and increased water runoff which reduces the amount of water available for crops and may cause flood damage to other crops.

Crop production costs increase as eroded soil becomes less productive and farmers are forced to use greater quantities of purchased inputs (fertilizers, pesticides, tractor and irrigation-pump fuel) to maintain yields. Estimates of the economic loss in plant nutrients, based on fertilizer prices, range from $6.8 to $7.75 billion a year (Pimental, et al, 1976:152).

The loss of productivity on cropland due to soil erosion is difficult to generalize because of differences in crop variety, soil structure, topsoil depth, drainage, temperature, moisture, and pests. Several studies have compared yields on both eroded and non-eroded fields with otherwise similar management systems and the results indicate that there is a relationship between soil erosion and reduced yields. On fields where the topsoil is deep, increasing the amount of fertilizer applied will replace the nutrients lost due to erosion. On soils where the moisture holding capability of the soil is reduced, increasing fertilizer applications will not offset the yield reducing effect of erosion. In areas where the subsoil with large amounts of clay is exposed, the clay can fix phosphorus, making it unavailable to plants and in many cases may also contain toxic elements, such as aluminum. As the soil erodes, plowing mixes more and more of the subsoil into the surface layer. This results in a surface soil that has unfavorable chemical characteristics and reduced infiltration capacity.

Yields in Illinois decline between 10 and 12% per acre for soils with favorable subsoils and 20 - 25% for soils with unfavorable subsoils when the land is eroded from slightly eroded to a severely eroded soil class (McCormick, et al, 1980: 394). The cost of repairing soil loss depends on the structure of the subsoil. One with fragipans, bedrock, or toxic material beneath the remaining topsoil will cost more to regenerate. The economic impact of soil erosion can be relatively minor for a single year, for example Pimental estimates that for each inch of topsoil lost, from a basis of 12 inches or less of topsoil, oat yields are reduced by an average of 2.4 bushels per acre, wheat yields are reduced by about 1.6 bushels per acre, corn yields are reduced by about 4 bushels per acre, and soybeans are reduced by about 2.6 bushels per acre (Pimental, et al, 1976: 152).

The damage to a field can be measured in terms of the costs of replacing nutrients and the decrease of productive potential once the erosion rate is greater than the T value. For example, on an average acre of corn, 96 bushels are produced at a cost of approximately $190.00. When 20 tons of topsoil are lost per acre annually in continuous corn production the annual per acre reduction in yield is about 1/2 bushel, worth about $1.50, so the loss in output is less than 1% per year. Over time, the cumulative effects of soil erosion on crop productivity can be significant, as the quality of the remaining soil declines. An estimated loss in crop production of $800 million per year results from erosion by wind or water or both (Pimental, et al. 1976: 152). Even where the loss of topsoil has begun to reduce the land's natural fertility and productivity the effects go unnoticed because of the positive response of crops to heavier applications of fertilizers and pesticides which keep crop yields up. On deep topsoil, where minor sheet erosion gradually lowers the plant root zone into a strata of phosphate and potash supplies, the relationship can even be complementary.

One study recently compiled by the USDA, using yield data from 1,100 county surveys and the Iowa State University Linear Programming Model estimated that,

> If the current level of erosion were allowed to continue for the next 50 years on the 290 million acres contained in the USDA - RCA statistical model, erosion would cause a reduction in productive capacity equivalent to the loss of 23 million acres of cropland, 8% of the total base considered. (Batie, 1983: 43)

This estimate must be used with caution according to Crosson, since the data used in the model are not what the researchers ideally would have liked to use (Batie, 1983: 43). If erosion rates continue at 1977 levels, corn and soybean yields will decrease between 15 and 30% over the next 50 years (USDA, Soil and Water Resources Conservation Act: 1980, Part 2, 1981: 3). Other studies suggest that this may be conservative. This does not mean output will decline, but just that land will be less responsive to other inputs and will need more inputs to sustain a given level of output. Moreover, many researchers expect technological breakthroughs in the biological sciences, and plant and animal genetic research to increase productivity. The future productivity of cropland is a function of erosion rates, cost and availability of soil substitutes (ie. fertilizer and technology), cost of soil re-building and availability of such methods, the management of soils and physical attributes of plants and soils themselves (Batie, 1983: 37).

Aggregate costs of soil erosion

The costs to society of erosion from cropland are difficult to calculate. Some costs are hidden or as yet unknown. The Conservation Foundation has estimated the offsite costs of all erosion caused by water were between $3.2 and $13 billion in 1980, with the best single value estimate being approximately $6 billion per year. Of the total, about one third, or $2.2 billion, can be attributed to erosion from cropland (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 117). Included in this calculation were the effects of sediment, nutrients, and pesticides carried from cropland to streams and lakes. The estimates do not include the effects on the biological community because no recognized methodology exists for setting a value on the damage caused to aquatic ecosystems. Included in the estimates were damages to lakes for recreational purposes, the cost of reduced storage capacity of lakes and reservoirs, dredging costs of channels, harbours, and ditches, maintenance costs to water treatment facilities and other water using equipment (ie. hydro-electric power plants), flood damages, and damage to commercial fisheries. The loss of productivity on cropland when sediment lands on fertile land is not included in the calculation but damage caused by sediment landing on growing crops is. The loss of production ranges from $150 to $500 million annually (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 117).

The total cost of erosion from wind was estimated to be $466 million annually in New Mexico (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 120), based on a survey of households and businesses which asked respondents to estimate how much damage, if any they were experiencing.

Soil eroded from cropland causes damage to the environment in many ways. Several authors have tried to estimate the economic costs associated with erosion and their findings are summarized in the following table.

Table 2.7 Estimated Costs of Damage Caused by Soil Erosion

Source of Damage	Nature of Problem	Estimated costs
Sediment	Kills fish, fills irrigation ditches, reduces capacity of reservoirs. Increases costs to filter water for hydroelectric plants, municipal water treatment plants, industrial uses.	Dredging costs between \$250 million (1) and \$500 million (2) per year. Loss of reservoir capacity costs between \$50 million (3) and \$2.93 billion annually (4). Total costs including extraction from treatment plants, between \$500 million (3) and \$1 billion (1) annually.
Mineral Salts	In large quantities can be toxic to fish. Water needs to be treated before it can be used for human consumption or irrigation.	Total costs between \$75 and \$104 million (1) per year.
Nutrients	Contaminates ground and surface water and causes eutrophication in lakes.	Costs not available.
Pesticides	Pollutes ground and surface water for human use and irrigation.	Total costs \$839 million (5) annually.
Productivity	Degrades soil structure and removes nutrients and pesticides.	Costs in terms of lost crop production are \$800 million a year. In terms of lost nutrients, \$6.8 and 7.75 billion (3) yearly.

(1) Crosson, (1982)
(2) Batie, (1983)
(3) Pimental, et al (1976)
(4) McCormick, et al (1981)
(5) Pimental, et al (1980)

Summary

With the increased productivity of cropland, due to better seeds, larger machinery, irrigation, and chemical inputs there has been an increase in environmental damage from soil erosion. Heavy applications of fertilizer and pesticide reduce soil tilth and kill natural organisms in the soil, increasing erosion rates and requiring even more of the chemicals be applied to maintain output.

Soil erosion negatively affects the productivity of the soil in most cases, but synthetic supplements allow a farmer to maintain output even though the quality of the soil is actually declining. The onsite damage of modern production techniques is minimal or not yet visible, however the offsite damages are becoming increasingly more visible.

Pollution from pesticide and nutrient runoff and damage from sediment to water systems is a serious problem. These pollutants impose costs on society in terms of removing or correcting the damage caused by the pollutants, the increased health risks, and aesthetic costs of a degraded natural environment. Currently these costs are borne by society and are shared by farmers only to the extent that they too pay for the clean up with their taxes and face the same health risks as other members of society. Sediment, pesticide, and nutrient runoff relate directly or indirectly to tillage practices and soil erosion as well as to each other. The nature and extent of these interactions are neither well understood nor easily quantifiable. There is a need for the government to support research of these interactions so that the best techniques for controlling pollution can be developed.

Chapter Three

Alternative Cropping Systems

In this chapter some of the soil conservation techniques that are available to farmers are described. The purpose of soil conservation on cropland is to preserve the fertility, usefulness, and value of the soil resource and to prevent offsite damage caused by soil erosion. There are many different ways that farmers can control erosion such as, building control structures or using conservation tillage. Each of these options will be described in detail.

Essentially there are two negative externalities from soil erosion, environmental pollution associated with runoff and reduced soil productivity. The effects of the first externality were described in the previous chapter and the second will be examined in this chapter. The problem of soil depletion as it relates to future soil productivity arises because different discount rates are being applied by farmers and society to land use. For the private sector the discount rate reflects the collective judgement of private agents operating through the capital markets while the social rate of discount is a measure of how society measures the welfare of future generations. The costs and benefits of implementing conservation measures, as perceived by farmers, with respect to sustaining the long term productivity of the soil and environmental quality will be discussed later in this chapter.

Conservation cropping systems

Rotating crops with various grass covers, the use of crop residue, stubble mulching, and fertility treatments allow crop vegetation to do some or all of the job of controlling erosion. Alternating years of row crops with legumes and sod forming grasses improves soil structure and decreases soil erosion. A comparison of erosion rates with different cropping systems is shown in Table 3.1.

Table 3.1 Cropping systems and soil erosion

Crop	Average annual loss of soil (tons/acre)
Bare cultivated, no crop	41.0
Continuous corn	19.7
Continuous wheat	10.1
Rotation of corn, wheat and clover	2.1
Continuous bluegrass	.3

Source: Batie, 1983: 57

Leaving some crop residue (ie. harvested crop roots) helps water infiltrate the soil. One study found if one ton per acre of crop residue is left in the soil, soil erosion from water decreases 65% (Batie, 1983: 59). Cover crops of leguminous plants such as, soybeans, peas, vetch, alfalfa, and clover, can be planted during the eight or nine months regular crops are not on the field. Grasses, such as annual rye and legumes take nitrogen and combine it with oxygen and other substances to produce nitrates, which when plowed back in to the soil fertilize the field, reducing the amount of synthetic fertilizer that needs to be applied. These "green manure" plants protect the soil within a couple of weeks of planting and also add organic matter to the soil, improving soil tilth. Interseeding a legume, such as winter vetch with corn in late summer, protects the soil from erosion as well as adding 133 pounds of nitrogen per acre to the soil when the vetch is plowed under. (The value of the nitrogen was about $13.00 (Pimental, et al, 1976: 152)). Rotating crops that require little or no nitrogen fertilizer, such as soybeans and alfalfa, with crops requiring high nitrogen levels, such as corn and wheat, will reduce the long term average amount of nitrogen available for leaching. Nitrogen and phosphate losses from runoff were 3 - 6 times less in a corn-wheat-clover rotation compared with continuous corn cultivation. Corn planted with a rye grass cover crop had a 50% reduction in runoff and a 400% reduction in the loss of sediment (Report and Recommendations on Organic Farming, 1980: 62). In Georgia, cotton planted continuously had an average topsoil loss of 20.7 tons per acre which fell to 6 tons per acre when crop rotation was practiced. Another study in Missouri found corn grown continuously averaged topsoil losses of 19.7 tons per acre but when rotated with wheat and clover the average fell to only 2.7 tons per acre.

In Illinois, cotton grown in rotation decreased the erosion rate from 23 tons per acre to 14 tons per acre (Pimental, et al, 1976: 151).

Wind erosion can be controlled by reducing the width of fields by installing barriers. Windbreaks of trees and shrubs have been found to decrease particulates in the air by approximately 5% (Batie, 1983: 59). Growing row crops at right angles to the prevailing winds will also help prevent erosion from wind. Planting the soil with cover crops can reduce erosion by 100% (Soil and Water Resources Conservation Act: The Second RCA Appraisal, 1991: 30).

Applications of livestock manure can substantially reduce soil erosion by increasing the level of organic matter in the soil and improving soil texture. Extensive expansion in the use of manure would require the decentralization of feedlot operations so that manure is generated closer to the point of application. Substituting organic wastes for chemical fertilizers would reduce the total amount of energy used in the farm sector. Most of the energy saved would be in the form of natural gas, used to produce synthetic fertilizers. But the consumption of gasoline or diesel fuel would increase as most of the energy used to apply the manure comes from these fuels. If all the organic wastes currently available were applied to farmland they would only be able to replace about 20% of the chemical fertilizers now being applied (Report and Recommendations on Organic Farming, 1980: 50).

In Iowa, when 16 tons of manure per acre was applied to corn crops, erosion rates were 4.7 tons per acre, whereas without the use of manure, erosion levels averaged 22.1 tons per acre. Other organic matter would have a similar effect in reducing soil erosion (Pimental, et al, 1976: 151). The main advantage of using synthetic fertilizers is that they are less bulky, their nutrient value is more consistent, and they are more water soluble than organic fertilizers (Allaby, 1972: 85).

Structural measures

Locating crops on the best soils, rotating crops, stripcropping, retaining crop residue, and using techniques for decreasing wind erosion can be relatively low cost methods of achieving soil conservation goals. Construction measures, such as building terraces, diversion, grading of rows, levelling, and tile drainage are more expensive, and though some require considerable expertise to manage, they can be very effective in reducing rill and gully erosion. Terracing breaks the length of the slope into shorter segments, which reduces water velocity, slowing water runoff. These must be carefully designed to accommodate machinery. Grassed waterways and underground drainage paths are very effective methods for diverting water away from problem areas and for controlling deep rills and gullies.

Grassed waterways are less popular when crop prices are high since they take up land space that could be used to grow crops and farmers must lift tillage and planting equipment when crossing them, slowing down their operation. Sediment basins and barriers across waterways can be installed to slow water velocity and cause silt to be deposited in the basin. While this controls the effects of erosion off-site it does not help maintain the productivity of the soil in the eroding field. The increased use of grass-killing herbicides has made the maintenance of waterways more difficult and the installation of underground drains more popular, even though the drains cost more to install.

Conservation tillage

Conservation tillage practices are cultivation techniques that reduce the exposure of soil to the potentially erosive effects of wind and water. They greatly reduce the number of times a farmer needs to work the land, and reduce or eliminate the practice of plowing, harrowing, disking, and cultivating to control weeds. Both weeds and insects can be controlled with herbicides and insecticides. When conservation tillage is practiced, fall plowing is eliminated and the new crop is planted in the residue of the old crop.

This keeps moisture in the soil and keeps the soil from eroding. Conventional tillage has traditionally meant early plowing (even as early as the preceding fall) leaving a field exposed to storms and wind during the winter as most plant residue was removed from the field at harvest. Generally, a field is plowed again before planting and rows are planted up and down the field, ignoring slopes, resulting in a high erosion potential. Fields can be plowed on the contour (that is where rows go around a hill instead of up and down it). This can increase water infiltration in the furrows and catch soil runoff and can reduce erosion by as much as 50% over the up and down hill conventional plowing method (Batie, 1983: 64).

Contour planting is the most common method of soil conservation and one of the most effective. In some situations, contour planting increases crop yields by conserving soil, moisture, and nutrients. One study in Illinois found yields increased from contouring for corn, soybeans, and wheat. Another study in Texas found cotton yields increased with the use of contour farming. Cotton grown in up and down hill rows resulted in an annual soil loss of 89.1 tons per acre while cotton planted on the contour had a soil erosion rate of 39 tons per acre. Land planted on the contour in 24 foot wide strips of cotton and grass in rotation had a soil erosion rate of only 3.4 tons per acre. The combination of contour planting and rotation appears to give better results that either one alone. Potatoes grown in New York in up and down hill rows had a soil erosion rate of 14 tons per acre and when the rows were arranged on the contour the loss was only .1 ton per acre. Contour planting does require a 5 to 7% increase in both labour time and fuel consumption (Pimental, D. et al., 1976: 151). Farming on the contour takes more time that straight row farming and is used less often on large farms with bigger equipment.

No-till and minimum till techniques are extremely effective for controlling erosion. Usually a plant residue cover is preserved and cut through only to plant seeds and a blanket of plants or plant residue remain on the surface to protect the soil from wind and water erosion. Methods of leaving residue cover vary from chisel plowing, where all the soil is completely disturbed to no tillage at all, except for the small slot where the seed is planted. A large disk may be used to till the ground with considerable disturbance while leaving lots of residue on the surface. The USDA estimated in 1982 that one quarter of U.S. cropland (just over 100 million acres) was plowed using minimum tillage, in which the soil is churned lightly with disks and harrow and no-till, which involves virtually no disturbance of the soil before seeding. Soybeans grown in rotation with corn reduces the effectiveness of no-till in controlling erosion. Little residue remains following soybeans and this breaks down rapidly in comparison with corn or wheat residue.

Minimum tillage requires more attention and careful management to produce the same crop yields. Seeding, herbicide, and pesticide applications must be much more carefully timed. No-till cuts costs by 5 to 10%, primarily in labour and fuel and uses smaller machinery, which is more adaptable to working on the contour and terraces. The no-till method can't be used everywhere. For example, in the north, the ground must be plowed to loosen, warm, and dry the soil before seeding or the seeds won't germinate. In some places the weeds can't be controlled without plowing (Batie, 1983: 68).

Other conservation tillage methods that have been developed will be briefly described next. Soil can be plowed to develop ridges leaving the residue in the furrows. The seeds are then planted in the ridge and the residue in the furrows collects runoff and any eroded sediment is deposited next to its source. This plowing technique is known as ridge planting.

Plow-planting eliminates secondary tillage and seeds can be planted in a plowed field with no seedbed preparation. This reduces the amount of time the soil is exposed to wind and water before plants begin developing and protecting the soil.

Till-planting involves opening a seed furrow, sowing, and covering in one process and has been particularly effective when rows are laid out in contours. An area 7 to 10 inches wide is tilled, and usually there is a little residue left of the surface.

Chisel-plowing loosens the soil for air and water flow without inverting it. A specially designed plow cuts through the soil with pointed shanks which are then pulled through, leaving some residue on the surface. This minimizes the exposure of subsurface soils yet allows for enhanced root growth and can be especially useful where soils have become compacted from the use of large machinery.

Sweep-tillage lifts and breaks the soil to kill weeds but leaves any residue in place to enhance water infiltration and help to protect the soil. A study comparing chisel-plow, no-till and till-plant systems with conventional tilling in Indiana and Illinois found chisel-plowing decreased soil loss by 94%, till-plant by 60%, and no-till by 85%, after a high intensity storm (Batie, 1983: 67).

One study found no-till with residue reduced erosion 63% over conventional tillage, while conventional tillage with residue reduced erosion by 14% (Larsen, 1979:75). Another study found "No-till farming can reduce sheet and rill erosion by as much as 90% on many soils" (Soil and Water Resources Conservation Act: 1980 Appraisal, Part 1, 1981: 103). There is more than just the advantage of less soil loss to farmers from practicing conservation. Less tillage, less soil exposure, and more residue usually cause soil to retain more moisture, which means there is less demand for irrigation water. Less tillage gives farmers more flexibility in land use since row crops can be planted on steeper slopes with less danger of soil loss. When conservation tillage is practiced, fuel requirements decline and less fertilizer is needed because plant nutrients are left in place. In the long run soil quality improves because of the increased organic matter in the soil and the soil is less compacted.

The major disadvantage of using conservation tillage is the need to apply more herbicides and pesticides to control weeds and insects. It has been estimated that herbicide use increases by 250% when conservation tillage is practiced (Bennet, 1977: 10). Herbicide residuals may build up and damage future crops, for example, herbicides used with corn can kill soybeans so this can constrain corn-soybean rotations. Increasing herbicide applications may not always be successful in controlling weeds and the lack of an effective weed control is the main factor limiting the adoption of conservation tillage. It is not clear whether or not using the no-till conservation practice causes less chemical runoff because plant residues and cover crops hold the soil in place, however more chemicals are applied. It is possible that this technique, while controlling erosion, may increase the contamination of water systems.

Factors affecting a farmer's ability to practice soil conservation

One of the goals of soil conservation is to maintain the productivity of the soil over time. The benefit to society if conservation projects are successful will be the maintenance of agricultural output in the future. Because some time may have to elapse before society realizes these benefits, the results may be considered relatively indirect. The value of the future food supplied may not be significant when compared to the costs of implementing soil conservation programs.

As has been shown so far, the more intensive farming techniques used by modern farmers has led to an increase in soil erosion levels. This will eventually affect the level of productivity of the soil which may or may not pose a problem to society. Farmers may decide to "mine" their soil, that is farm their land in such a way that the soil is eroded at a rate faster than it is regenerated, and still may be acting in their own best interests. There is general agreement in the literature that the discount rate needed to encourage farmers to practice soil conservation in order to preserve the productivity of their soil for future generations is much lower than the discount rate that farmers can realistically be expected to use.

> Because of age, income, or other factors, individual farmers acting to maximize their current incomes will likely discount the need for future soil productivity more than society will. (Easter, et al, 1982: 283-4)

According to standard economic theory, individuals are assumed to behave so as to equate their private marginal costs and benefits of an activity, in this case the farming of American cropland, to achieve an efficient allocation of resources. By so doing they ignore the marginal external costs or benefits of their behaviour on the rest of society.

> If soil management practices are currently imposing offsite costs and benefits on other interests, then there is some evidence that agricultural products derived from such land use practices are artificially priced. Their value at the margin does not reflect the full social cost of their production. (Bromley, 1982: 231)

The costs of implementing soil conservation projects are both direct and indirect. Direct costs to society include program payments and administrative costs incurred in promoting conservation programs or regulating erosion control. Farmers may incur direct costs if they are taxed or fined for allowing soil to erode from their land. The indirect costs to society involve the reduction in current farm output which may increase output prices to consumers, when conservation practices are enacted. For instance, grassed waterways take land out of production and some no-till methods may show reduced germination, due to weeds, plant disease, or insects. Farm costs may rise with the installation and maintenance of terraces and contour plowing. This may lead to an increase in the price of farm output which will give some farmers extra profit and just cover the increased production costs on farms that practice soil conservation.

As was described earlier in this chapter, many conservation tillage techniques, such as minimum or no-till require more fertilizer and pesticides to keep up production. This is another indirect cost to society in the form of increasing contamination of the water system.

The benefits of soil conservation are also direct and indirect. The direct benefits include the reduction in off-site damages from sediment, nutrient and pesticide runoff, and the maintenance of soil productivity for future generations. Studies have shown that it may take a farmer between 62 and 196 years to implement a soil conserving system based on economic cost benefit theory (Walker, 1982: 695). The government, representing society, may want to encourage soil conservation before soil productivity levels fall to the point where farmers would decide to implement erosion control measures for many reasons, the most obvious being to protect the environment. Another reason may be that the cost of restoring land that has been severely eroded may be much more expensive later on than if restoration was started on less severely eroded soil. If the government believes that it is in the interest of society to maintain the productivity of cropland for future generations, then it will have to provide incentives for farmers to conserve the soil, since the marketplace is failing to do so.

The effects of soil erosion are evident in reduced crop yields before all the topsoil is stripped from a field. "As erosion exposes subsoil to cultivation, a rough seedbed results in decreased germination yields" (Walker, 1982: 690). Yields decrease partly because there are fewer essential nutrients and less organic matter as you approach the subsoil. Less organic content means subsoil is less capable of storing moisture, therefore runoff is greater and crop output declines.

The obvious question is why don't farmers operating these lands control the erosion levels to maintain soil productivity. Several authors have suggested different answers to this, such as "Farmers are simply too busy with too many other problems" (Renard, et al, 1978: 1278). Other more plausible suggestions include; farmers may not be aware of a decline in soil productivity, or may be unconcerned with declining productivity because they can substitute other inputs for topsoil depth, such as fertilizer, in the short run.

> The lack of information or imperfect knowledge concerning the impacts of alternative farming practices on soil productivity can cause farmers to use practices that are not in their best interests...some of the basic information concerning practices, soil losses, and productivity over time is just not available. (Easter, et al, 1982: 284)

In the following review of cost benefit studies of soil conservation adoption by farmers, the most common answer to this question is that even though in the long run practicing soil conservation may pay, the long run is beyond the time horizon of most farmers.

A study done in Nebraska by the Soil Conservation Service (SCS) classified 82% of the farms examined as having major soil erosion problems although only 2% of the operators and none of the landlords classified their farms similarly. This implies that most farmers don't feel they have to worry about soil erosion while the SCS perceives a large problem. Moreover, 54% of the operators and 55% of the landlords indicated they had either no or few erosion problems; yet the SCS classified only 4% in this category (Hoover, et al, 1980: iii).

Ownership boundaries and the farm layout can interfere with contouring or terracing. Practicing conservation can mean increased production costs for a farmer. He may have to make a capital investment in building up terraces and contours, and new machinery may be necessary to farm this way. Crop rotation and stripcropping costs the farmer the foregone income from the area now used for cover corps. Using manure for fertilizer and organic methods of pest control may decrease the output per acre. Although no-till requires less labour and conserves soil moisture, it increases pest problems and consequently requires the use of more chemicals. Eliminating fall plowing means a farmer must spend more time in the spring, when time is at a premium, preparing for planting. Conservation tillage programs can increase costs because often new management skills, improved plant varieties, new machinery, and different chemicals are needed. Some conservation methods may require adding livestock, which is expensive, more time consuming, and requires different management skills.

Farmers can choose to forego the future productive capacity of their soil by failing to adopt conservation practices. The choice of whether to incur costs now or in the future will depend on the returns to the conservation investment and the relative price of soil substitutes, such as fertilizer. The production costs of a depletive system will probably rise over time and can eventually exceed the cost of a conservation system, as the loss in revenues from lower yields and higher fertilizer costs becomes greater than the increased cost of a conserving practice.

There is general agreement in the literature that economic returns to soil erosion control are relatively low or non-existent and if there is a positive return, it will not show up for many years. Many studies have found crop yields were down slightly over a 20 year period and income was higher when conventional tillage techniques were used on farms (batie, 1983: 78). Farmers found the extra income from growing corn continuously more than offset any gains from saving topsoil using rotations. One study found most farmers would lose personal income by investing in terraces even when the government paid 50% of the construction costs (Mitchell, 1980: 235). Another study in southern Iowa found the cost of meeting erosion limits, to be three times higher than benefits (Rosenberry, 1980: 134). None of the above studies considered no-till, which needs new machinery but in some cases does show positive returns. One study in Ohio found yields increased 10% on well drained soil farmed using no-till; however, on poorly drained soil, there were yield decreases. Two other researchers found that at best, no-till would equal conventional tillage yields in the climates of New England and New York (Batie, 1983: 79). There does appear to be a financial incentive for some farmers to try no-till though the return will obviously differ by soil type and annual rainfall. The USDA has found the average total cost of reducing erosion to 10 tons per acre per year from 14 is less than $1 per ton, while going from 10 to 0 costs between $2.16 and $45.40 per ton. Therefore, in highly eroding areas, considerable soil savings can be obtained at little cost, up to a point, after which the costs increase substantially (Batie, 1983: 80).

The majority of studies conclude most soil conservation practices are not economical investments for farmers with the exception of conservation tillage, contour plowing, and leaving crop residue. These were found to be effective in decreasing erosion and in some cases increasing profits.

The returns to conservation investments are not reflected in the value of cropland when it comes time to sell it. ASCS and SCS officials in Texas, Tennessee, Iowa, and New Mexico found almost no premium is paid for land on which permanent conservation practices have been introduced, such as terraces, possibly because farmers lack knowledge about the effects of erosion on future yields.

> The land market seems to take little account of the soil conservation status of the farm; a farm with adequate conservation measure may sell for a little more than one lacking such measures, but the difference is likely to be far less than the cost of installing the measures. (Held, et al, 1965: 110)

The majority of cost-benefit studies reviewed found that when the discounted value of the output of farms using conservation techniques is compared with those that do not, that conservation would show a positive return only if the discount rate used was below the range of 2.5 and 5%, in real terms. Using a higher rate resulted in returns to conservation that were negative. This implies that it is not efficient for a farmer to implement a conservation practice and that there is a need for government intervention if conservation is to be implemented.

> In the early years net income under conservation would be reduced below incomes obtained under low conservation. (Held, et al, 1965: 226)

In a simulation analysis of a typical western Iowa farm, the maximum net farm revenue obtainable was $4,278 when the average annual soil loss was held to 6 tons per acre, but increased to $4,573 when soil loss per acre was 22 tons. Other studies found that lowering erosion rates to 3 - 5 tons per acre per year would increase the costs of producing cotton and soybeans but would have little effect on the production costs of corn and hay (Pimental, et al, 1976: 152).

Land ownership

If a farmer cannot capture future gains of conservation decisions he has no incentive to conserve. The direct financial involvement of the landowner in the farm operation appears to be important in conservation decisions. Tenants with short term leases have short term planning horizons and are motivated to maximize their immediate income.

> Tenure problems are one of the major "stumbling blocks" to the adoption of conservation practices in the Corn Belt... On many farms the tenant is only interested in short run profits. He may have only a one year lease with no assurance of renewal, or the leasing agreement may require him to shoulder a larger share of the conservation costs than he receives in benefits. (Eckholm, 1976: 173)

In 1987, tenant farmers made up 11.5% of all farm operators and they farmed 126.9 million acres (approximately 30%) of cropland (1990 Fact Book of U.S. Agriculture, 1991: 43). Most tenants have relatively poor living conditions and generally rent smaller farms and can't afford to cut back on crop acreage in order to practice conservation. One study in New York state found that farmers with short term leases will grow corn continuously for four to six years but if they owned the land they would only grow it for one or two years. Tenants were found not to establish fields in strips or add manure to the land. Tenants also were found not to invest heavily in fertilizer, lime, tile drainage, ditches, or long term alfalfa rotations. Once the land was purchased by former tenants, large investments in fertilizer, lime, and drainage were made. Rotations were changed and corn rotations were implemented on flatter fields.

Farm income

In times when farm income is low there is more pressure on farmers to cultivate their land more intensively, increasing the risk of soil erosion. The pressure of making interest and property tax payments forces farmers to generate enough income annually to cover these payments, if they are to maintain ownership. They will attempt to do so regardless of the long term consequences to the quality of the soil. During the mid 1980's farmers faced a financial crisis. In the late 1970's farmers expected to export record amounts of grain at very good prices and the inflation rate was high. Many young people entered crop farming during this period and many existing farmers expanded their capital investment in land and machinery. Land prices were bid up and both groups contracted large debts based on inflated asset prices and on the expectation of future prosperity. Farm debt was valued at almost $174.5 billion in 1981, over three times the 1970 level (1990 Fact Book of U.S. Agriculture, 1991: 18). Inflated land values gave farmers the collateral necessary to support these loans.

During the early 1980's real interest rates rose, commodity prices fell and export sales declined. The price of farmland declined leaving farmers with a staggering debt load. Many conservation plans were put aside as the capital was unavailable to invest in any structural changes and the field space was needed to maximize crop output.

By 1986 the income picture was starting to look better for farmers and by 1989 gross farm income was $177.5 billion. A major share of farm income comes from government programs. The government paid farmers $14.5 billion in 1988 and $10.9 billion in 1989 (1990 Fact Book of U.S. Agriculture, 1991: 129). The amount of money the government spends in the agricultural sector is directly related to the amount of soil conservation farmers practice.

Input costs

Part of the decline in net farm income in the late 1970's to mid 1980's can be attributed to the higher price of oil during this period. 93% of the energy used in agriculture comes from petroleum and farming uses more petroleum than any other single industry (USDA, Fact Book, 1981). From 1975 to 1979 the prices paid by farmers for gasoline increased by 61%, diesel fuel by 75%, natural gas by 42% and electricity by 38% (Handbook of Agricultural Charts, 1980: 17). Fertilizers and pesticides are energy intensive to extract, synthesize, and transport, so their relative prices increase whenever the price of oil increases.

The most common way to fix nitrogen for fertilizer is to combine it with hydrogen to make ammonia. The most widely used source of hydrogen is natural gas which accounts for 45% of the price of anhydrous ammonia (1979-80). More energy is used to produce synthetic fertilizers than is used in tilling, planting, cultivating, and harvesting all the crops in the U.S. Making potash fertilizer is very electricity-intensive using 1,500 k.w.h. to make 1 ton. The increase in non-agricultural use of water has increased pumping costs for irrigation due to the decline of the water table. The cost of running irrigation pumps also increases significantly when the price of oil increases (Empty Breadbasket, 1981: 50).

Summary

To sum up, there appears to be little or no economic incentive for farmers to practice conservation if the declining productivity of soil is the only cost to them of erosion. The long term benefits of erosion control are too small to warrant the expense now, in most cases. Moreover, if farmers don't own the land they are working, they have virtually no incentive to practice soil conservation. Even when farmers do own the land, they can't afford to practice conservation in years when farm income is low.

Chapter Four

The Role of Government in Erosion Control

As documented in Chapters 2 and 3, there are environmental and productivity problems stemming from erosion on U.S. cropland. Many alternative cropping systems are available that can be used to control erosion. Unfortunately, as has also been demonstrated, farmers, acting as rational economic agents are not inclined to practice these soil conserving techniques on their own for many reasons. In this chapter the influence of government policies on farmer's decision making, with regards to conservation, will be discussed. In the first part of the chapter the direct influence of the conservation programs and their effectiveness in controlling soil erosion is analyzed, while in the second part of the chapter the effect of existing economic policies on the demand for crops and the rate of erosion is examined. In the last part of the chapter alternative government policy options are presented.

Government conservation programs

In the early part of this century it was assumed by politicians that landowners would conserve soil without any public assistance, once they were made aware of the consequences of soil erosion, because it was in their long term interest to maintain soil productivity. As has been demonstrated, the private long term view is significantly shorter than that of society.

The depression and drought of the 1930's ultimately drove legislators to enact soil conservation legislation. In 1936, the Soil Conservation Service (SCS) was created to assist farmers in controlling soil erosion and flooding. Now essentially all privately held farmland is part of one of the 2,950 conservation districts administered by the United States Department of Agriculture (USDA).

In 1937, a new level of local government was created to work with the millions of landowners more effectively. Soil Conservation Districts (SCD's) were created and are administered by the SCS. In some states, the SCD has the power of taxation and enforcement, which permits them to do some planning and build control structures. The SCD can order particular methods of cultivation, such as contouring or even the withdrawal of some land from cultivation in areas with extremely high erosion rates. In areas where the erosion rates are less than the T values (that is the maximum average annual soil loss, measured in tons per acre, that can be tolerated indefinitely without interfering with the land's productivity under continuous production, defined by the SCS), the SCD does not have the authority to specify cultivation practices. Soil Conservation District personnel are elected by land owners and therefore, one assumes, they use discretion when applying land use regulation.

One example of a SCD regulating land use occurred in Vernon county, Wisconsin, in 1976. The SCD declared that all agricultural land of more than one acre, with a slope greater than 6% must be farmed on contour strips or managed according to an SCD supplied conservatio.. plan. This is mandatory except when technical assistance or government cost-sharing funds are unavailable. Enforcement is restricted to areas where a complaint has been received, generally the worst areas. Usually a neighbour makes a complaint when his land is affected by sediment from another farm. Many areas have more volunteers and complaints than government funds can support, so there are long waiting lists for assistance. The SCD's have never filed a complaint on their own, presumably because they want to remain popular, and they have enough complaints to keep them busy.

The following is an example of the legal enforcement of erosion control. After receiving a complaint from a farmer, the SCD in Woodbury, Iowa, investigated and found that the amount of erosion from two farms, was more than 5 tons per acre per year (the T value) and was damaging neighboring farms (Batie, 1983: 105-6). The two farmers, Ortner and Schrank, were ordered to either seed the land to permanent pasture or terrace it. Terracing would have cost Ortner $12,000 and Schrank $1,500, with the state providing grants for the balance of the total cost. When they refused to comply, the Woodbury County Soil Conservation District filed suit against them in 1979. The court upheld the SCD recommendations. Ortner and Schrank challenged the court decision on the grounds that it was unconstitutional for the government to take private property without just compensation. The state argued that the law could not be considered unconstitutional simply because the defendants had to make a substantial payment. The statute was ruled to be reasonably related to the legislative purpose of soil erosion control and the defendants had to comply.

If a complaint is filed and a farmer will not voluntarily participate in a 50% cost share program, as was the case above, the SCD can force the farmer to implement a prescribed conservation practice but the SCD will pay 75% of the cost. The structure of the program creates an incentive for neighbors to complain about each other in order to force the government to pay a larger share of the cost. There is no evidence however, that such complaints are widespread, perhaps because SCD enforcement of erosion control is rare. Even though the SCD has the authority to force farmers to adopt their plans, most operate on a voluntary basis, with farmers asking for assistance and sharing the cost of installing a conservation practice with the federal government.

The Conservation Operations Program (COP), authorized by the 1935 Soil Conservation Act, supplies the funding the SCS needs to provide technical assistance and information to farmers and ranchers for soil conservation measures. This program is run on a strictly voluntary basis: that is, farmers must ask for assistance.

The Great Plains Conservation Program (GPCP), created in 1956, is similar to the COP but offers cost-sharing along with the technical assistance to farmers in the Great Plains. It is mainly aimed at long term (3 - 10 year) agreements and provides funding for permanent cover. The type of conservation practice to be followed is specified and the amount of funding is limited to $25,000 per contract and in any one case cannot be more than 80% of the value of the project. Any farmer who does not comply with the terms of the contract can be forced to repay the money received. As of 1980, over 50,000 farmers had participated in this program and over 5,000 were waiting for funds to become available (Batie, 1983: 93).

The Agricultural Conservation Program (ACP), authorized as part of the Soil Conservation and Domestic Allotment Act of

1936, is administered by the Agricultural Stabilization and Conservation Service (ASCS). It provides long and short term agreements for financing practices that "help maintain the productive capacity of American agriculture" (Moore, et al, 1979: 61). Eligibility for assistance is based on the existence of a conservation or environmental problem that decreases the productive capacity of the land and water resources or causes environmental degradation. The federal government will pay between 50 and 75% of the cost of installing an approved conservation practice up to a maximum of $3,500 per farmer per year (Batie, 1983: 93). A locally elected committee recommends measures that are to be subject to cost-sharing and the SCS provides the technical assistance for implementing and establishing the approved practices.

The goals of conservation programs coincided with the goals of agricultural commodity programs, designed to maintain farm income until World War II, at which point there was an increase in demand for agricultural output. Federal funds were allocated to programs directed by the ASCS to increase crop production. "Despite the return to surplus production conditions following World War II, cost-sharing for production-oriented practices continued until 1980" (Batie, 1983,: 93). As was shown earlier, increased output per acre puts more pressure on the land and increases soil erosion rates. In times of surplus agricultural output government cost-sharing programs that increase production seem somewhat redundant and inconsistent with the goals of soil conservation, especially as the programs are administered under conservation programs.

In 1976, U.S. Senators demanded evidence that the USDA conservation programs were working and created the Soil and Water Resources Conservation Act of 1977 (RCA). In 1979, the General Accounting Office (GAO) submitted their report which criticized all of the conservation programs being administered by the USDA. They found that on the 283 farms visited, 84% had soil losses greater than the allowable rate for sustained productivity. They also found "no significant difference in the erosion rates of the vast majority of land receiving federal assistance and similar land not receiving federal assistance." (Bouvard, 1989: 213).

The COP was criticized for spending too much on individual farm plans and not directing more assistance to areas with critical erosion problems. The voluntary nature of the program made targeting the plans to the most severe areas difficult as it was not necessarily those farmers who applied for aid. Many of the plans that were drawn up were too elaborate and many were never used by farmers.

The GPCP was criticized for spending three quarters of their funds on things like fencing, livestock water facilities, and irrigation systems instead of paying for farmers to install ground covers as was originally intended. Two factors contributed to the poor level of soil erosion control, the lack of incentive to withhold land from production, due to high crop prices and insufficient targeting of the worst areas. When the price of grain increased in the 1970's, farmers had little incentive to renew contracts that withheld land from production and as contracts expired they returned thousands of acres to cultivation, leaving no long-term conservation cure.

The ACP was also criticized for not spending their funds in the most critical areas. Only 48% of all assistance provided was spent on land with erosion rates of more than 5 tons per acre per year. More than half of the cost-sharing funds were used for increasing productivity with investments in drainage systems, land leveling, liming, and irrigation. The GAO suggested that the returns to these investments were large enough that farmers would have implemented them on their own anyway (Batie, 1983: 95).

Some production-improving practices do help control erosion. Fences keep cattle out of over-grazed, erosion-prone land and draining wet fields allowed farmers to remove row crops from steep hills and reduce surface runoff. As with the GPCP, the most efficient conservation methods were not necessarily implemented. Conservation tillage, one of the most cost-effective practices for soil erosion control, was the least often assisted by the ACP in 1980 (Moore, et al, 1979: 61).

Other factors also limit the effectiveness of the various conservation programs.

> "The effectiveness of the ACP has been limited by a high degree of uncertainty over funding levels and practice eligibility. ACP has undergone four substantial revisions in the past eight years, resulting in confusion about cost-share rates and funded practices. Farmers find it difficult to plan ahead for conservation under these circumstances." (Moore, et al, 1979: 61)

In 1977, the Rural Clean Water Program (RCWP) was introduced to provide long term (3 - 10 year) cost-sharing contracts for the installation of management practices to improve water quality, primarily by controlling agricultural runoff. Up to 75% of the cost of improvements, or $50,000 per farmer, could be paid for by the program. Farmers who take advantage of the contracts are obligated to maintain the practices at their own expense when the contract expires. The RCWP is administered by the USDA and the EPA and is the only program that requires its funds be spent in high priority areas. Funds are available to farmers who use a plan approved by their SCD and local committees determine priority among farmers for funding. In 1980, the program was still in the experimental stage, had annual funding of $70 million and had only approved 20 projects. Many farmers are already involved in long-term projects with the ACP and apparently are hesitant to enter into another cost-sharing program until other work is finished (Batie, 1983: 98).

A farmer's share of more expensive improvements, such as those requiring animal waste facilities or major design changes in irrigation systems, can be financed by the Farmers Home Administration (FHA), which provides low cost loans for conservation projects. To qualify for a FHA loan a farmer must be unable to finance a conservation project with his own resources and cannot get a loan at other sources (ie. commercial banks or the Small Business Administration). Loans are directed towards low income operations. A farmer may receive a 50% cost-share for a project, borrow the other 50% and deduct the expenses on his federal income tax return. To obtain a loan from the Small Business Administration a farmer must have a citation from the EPA stating that the proposed alterations are necessary to control water pollution.

> "Farmers are easily discouraged by the large amount of paperwork and endless delays that plague many loan programs." (Moore, et al, 1979: 63)

Many of the farmers who are eligible for cost-sharing programs are tenants with little incentive to become involved with improvements for which they will receive little benefit. Often the amount of money available through cost-sharing is insufficient to induce farmers to make the very expensive changes that will most improve the quality of the water. To help get the RCWP going, the Model Implementation Program (MIP) was introduced as a cooperative effort supporting the installation of conservation practices in critical areas until the RCWP can be fully implemented. Up to 90% of the costs of a project are paid for by this program (Batie, 1983: 99).

In 1985, the Reagan administration passed the Food Security Act (Farm Bill) to deal with income transfers to farmers as well as address the problems of environmental quality. The income support policy was changed by lowering the loan rate, that is, the price per unit at which the government makes loans to farmers in exchange for the commodity grown. Lowered rates make accumulated stocks easier to export and decreases the possibility that stocks will pile up like they did when the rates were higher. In 1990, the Farm bill froze target prices at the 1985 level and let them fall from 1988 to 1990. The government pays farmers who grow program commodities the difference between the target price and the free market price or the loan rate, whichever is higher. Export subsidies are included in the act.

The Farm Bill authorizes extensive new conservation efforts. Soil conservation is encouraged using a combination of a conservation reserve (CR) program, cross-compliance (CC), and land easements. As well, farm base acreage is based on the triple-base plan.

The first part of the law to be implemented was the CR program. The objective was to retire 45 million acres of "highly erodible" cropland from production by 1990. Highly erodible land is defined as eroding at a rate greater than 3 times the soil loss tolerance level (T), or having an erodibility index (EI) greater than 8 (Ribaudo, 1989: 321). The CR program sets up contracts with farmers to retire land from crop production and have the land planted with trees, grass, legumes, permanent wildlife habitat, erosion control structures, grass waterways, and managed using an approved conservation plan. Farmers receive cash or "payment-in-kind" rental payments (limited to $50,000 cash per farmer per year for wheat and feed grain farmers) plus a one-time payment to cover 50% of the cost of establishing the land treatment practice (Osteen, 1987: 299). If the farmer takes payment in kind (PIK) certificates the $50,000 limit doesn't apply (Bouvard, 1989: 92). Cotton and rice farmers are covered under the "marketing bill" and have essentially the same deal but there is no limit to how much the government cash subsidy can be (Rapp, 1988: 46). Farmers submit bids to the local ASCS office for the amount of rental payment that they would accept annually per acre to convert their land. Landowners bidding below the USDA maximum acceptable rental rate are given contacts (Osteen, 1987: 299). By July 1989 over 30 million acres were under 10 year contracts and the cost of the CR program had reached 1.4 billion dollars per year and average erosion rates were reduced from about 22 tons per acre per year to less than 2 tons per acre per year (Steiner, 1990: 175). By 1990, 34 million acres had been retired (1991 Yearbook of Agriculture, 1991: 1).

Some critics of the CR programs complain that since the program is run on a voluntary basis the most highly erodible land is not necessarily being retired. Many farmers are not convinced of the long term commitment of the government and will probably convert the retired land back into crops when the contract expires, as occurred while the Soil Bank program was in effect in the 1950's. "In addition to wasting a productive resource, these programs make land artificially scarce, pushing land prices above what they would be otherwise, thus raising production costs." (Lipton, 1989: 8). Farmers also apply inputs more intensively on land remaining in production, adding to existing pollution problems.

When the program was initiated in 1985, farmers were not allowed to use the retired land for anything except growing trees or grass during the contract period. These limitations made the program less appealing for many farmers. In June

1989, the program was changed to allow farmers to use the land for haying and grazing if the conservation agent agreed.

It has been suggested that the CR program encourages speculation in farmland. In 10 years the CR rental payments will exceed the total value of the land for more than half of all the land enrolled in the program. Some real-estate firms specialize in marketing farms put in the CR program. The CR program has been described as the perfect vehicle for investors who have wanted to buy farm land, "they can put 30% down and let the government pay for the rest" (Bouvard, 1989: 221).

One side effect of converting fields to grassland has been from wheat aphids which have attacked the grassland, costing wheat farmers about $100 million (Steiner, 1990: 187). The CR program is very expensive to run. The total cost to retire 45 million acres of land for 10 years is expected to be about $14.4 billion in rental payments (Steiner, 1990: 176).

Implementation of the Conservation Compliance section of the Farm Bill has been delayed until 1995. Initially, CC regulations required that by 1995 operators who wish to participate in USDA programs must implement a conservation plan on all "highly erodible" cropland that was used for crop production between 1981 and 1985. The SCS expected to prepare 800,000 plans between 1988 and 1989 (Steiner, 1990: 177).

Farmers who plant crops on "highly erodible" land can lose their eligibility for nonrecourse loans, program payments (price supports, ACP cost sharing, CR annual payments), Commodity Credit Corporation (CCC) storage payments, Federal crop insurance, disaster payments, storage facility loans, and FHA loans for all crops in the year of violation (Osteen, 1987: 299). One problem with tying benefits to these programs is that not all farmers participate in these programs equally and therefore will not have the same incentive to conserve soil. This could lead to efficiency and equity problems. For example, in the states of Texas and Washington, a lot of farm acreage is planted in corn, cotton, and wheat, all of which are supported strongly by commodity price support programs. In contrast, in western Tennessee mainly soybeans are grown, and there are very few commodity programs. Under the sodbuster and swampbuster provisions, farmers or landowners who plant annually tilled crops on "highly erodible" fields that were not planted between 1981-1985 will lose federal agricultural benefits for each year they plant the land with crops.

Critics of the CC program have pointed out that even though 75% of farmers participate in some federally funded agricultural program, and would therefore have an incentive to control erosion rather than have funding cut off, they only farm 39% of the cropland in the United States (Steiner, 1990: 177). If funding for agricultural programs continues to decline, the motivation for farmers to control erosion will shrink in proportion to the amount of funding they will be giving up.

Originally, CC regulations required that erosion rates had to be reduced to T levels. That has since been changed so that erosion rates have to meet SCS local field office technical guides "addressing considerations of economic and technical feasibility", leaving the possibility that farms could still have excess erosion and collect government benefits (Steiner, 1990: 146).

The introduction of the triple-base plan for determining base acreage is a very positive step towards decreasing erosion rates on cropland planted with program crops. Keeping their base acreage high is of great importance to farmers who qualify for commodity program payments and has in the past kept farmers from rotating crops or idling land. The crop acreage base is the average acreage planted with program crops, plus land not planted because of acreage reduction or diversion programs. The permitted acreage is the maximum amount of the crop acreage base which may be planted for harvest. Under the triple-base plan a third payment base is established as a percentage of the permitted acreage. The difference between the permitted acreage and the payment acreage base can be planted with any other program crop, allowing farmers the flexibility to respond to market signals without losing base acreage credit. As well farmers will not be penalized for rotating crops, as they were in the past.

Farmers who are not able to repay loans due to the FHA have the option of retiring "highly erodible" cropland permanently in exchange for writing off part of their loan. Called conservation land easements, this program is limited to very few farmers but is a permanent solution to erosion on a limited number of acres.

In 1987, the USDA received funding to start the Low-Input Sustainable Agriculture Program (LISA). The program is designed to support research and educational efforts to help farmers make a profitable transition from heavy dependence on chemical pesticides and fertilizers. Methods being studied include alternative cultivating practices including mechanical cultivations to control weeds and crop rotations, integrated pest management, that is the introduction of natural enemies to control insects instead of using pesticides and the use of manure, municipal sludge, and compost to replace fertilizer.

Under the Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA), farmers who convert wetlands to crop production can lose their eligibility for farm program benefits. As well, this law set up the Water Quality Incentive program (WQIP). The WQIP is a voluntary program with the goal of enrolling 10 million acres of farmland in agricultural water protection plans by 1995. Incentive payments are provided to farmers to promote the efficient use of pesticides and fertilizers, and safe storage and disposal of farm chemicals. The Integrated Farm Management Program (IFMP) is another new voluntary program introduced in 1991. Farmers who contract to use soil-conserving crops and rotations on part of their crop base will not lose their base acreage when applying for other government programs.

The effect of taxes on soil conservation decisions

Federal tax policies can affect the way a farmer perceives the costs of installing conservation practices. Allowing the interest on a loan used to purchase farmland as a business expense may encourage speculation in farmland and bring marginal, erosion-prone land into production, as has occurred in the Great Plains states. Investment tax credits, the methods of calculating accelerated depreciation and the treatment of capital gains are all things that encourage investment in non-prime farmland.

Certain tax policies are designed to encourage conservation but have been criticized for favoring farmers in a higher tax bracket because of the progressive nature of the tax structure. Some landowners are allowed to deduct the cost of soil or water conservation projects as an operating expense up to a value of 25% of their gross income in one year, with the rest carried over to future years. In some states the cost of a conservation project can be capitalized into the price of the land, providing a tax advantage only when the land is sold by reducing the capital gain. The ramifications of choosing one deduction over the other are detailed and complex and are affected by such things as the income tax bracket a farmer is in, the length of time a piece of property is going to be held, the expected rate of return, the change in the marginal tax rate caused by the deduction and other factors.

> "...the complex nature of the law and regulations could make it difficult for a landowner to evaluate the potential tax consequences of a conservation project. It seems likely that some people might avoid participating in a conservation project because of uncertainty about, or misunderstanding of the tax laws." (Collins, R. 1982: 322)

Tax credits that are subtracted directly from the tax bill have been suggested as an alternative. These benefit taxpayers in the lower tax brackets more than tax deductions do, as the value of the extra dollars is higher to them.

The value of cost-share conservation programs implemented on a farm are not taxed by the federal government provided they don't increase farm income, but any property value increase due to the project is taxable. As was pointed out in Chapter 3, so far the price of property with soil conservation improvements is not significantly higher than land without them.

The Tax Reform Act of 1986 eliminated preferential tax rates for capital gains accrued when cropland was sold after it had been developed from pasture, range, or forest. Deductions for land improvements including clearing, irrigation development, and drainage were also eliminated. The tax treatment of passive investments were tightened, decreasing the opportunity to shelter non farm-income by investing in cropland development (1991 Yearbook of Agriculture, 1991: 4).

Government commodity and farm income programs

There are a number of commodity programs that attempt to stabilize agricultural markets, commodity production, and farm income. As mentioned earlier, these programs create economic incentives which influence the planting and management decisions of farmers. These programs can either complement or conflict with programs designed to encourage soil conservation.

As the demand for agricultural products increases so do the demands a farmer makes on his land. Government commodity programs designed to maintain crop prices through price supports, target prices, and other means, essentially control the demand for crops.

Commodity production programs introduced by the government have had a large impact on the demand for U.S. grain. Prior to 1973, there were large grain surpluses, mainly due to government price support programs which valued crops above their market value. The high prices of the early 1970's increased the expansion of wheat cultivation, mainly in the Great Plains, into former pasture lands and low cattle prices caused some rangeland to be shifted into crops. Both of these types of land are more likely to erode. Between 1967 and 1977, over two million acres of newly cultivated cropland came from lands with poor soil. In many areas strip cropping and windbreaks were eliminated to increase crop acreage and allow farmers to benefit from government crop subsidies (Batie, 1983: 5).

Throughout the 1970's, the demand for U.S. corn, soybeans, wheat, rice, and cotton grew rapidly. One of the most significant factors was the increased demand from foreign sources, which was due partly to the increased average income per capita in developed and developing countries and a favorable exchange rate. Approximately 40% of U.S. cropland is used to grow crops for export (1990 Fact Book of Agriculture, 1991: 2)

Farm policies that encourage production for export may indirectly affect the quantity and quality of U.S. soil. Row crops such as soybeans, wheat, and corn are the crops most often exported.

> "The shift to soybeans in the last decade may have contributed more to increased erosion than any other single factor." (Heady, 1982: 274)

The soybean plant has two characteristics that contribute to high soil loss. First, its root system tends to loosen the soil, making it susceptible to erosion. Second, the plant provides little residue after harvest to protect the soil from erosion. In 1980 more than half of the rice, wheat, soybeans, cotton, and sunflower seeds produced were exported (Fact Book of U.S. Agriculture, 1981: 45). In 1990, 64.7 million acres of corn were harvested of which 31% was exported. 61.% of the 69.4 million acres of wheat and 32% of the 56.5 million acres of soybeans were exported (1990 Fact Book of Agriculture, 1991: 48-9).

Agricultural exports are encouraged by government policies that stimulate production through price support payments. In 1990, the U.S. agricultural exports stood at $40.2 billion, down from the record high set in 1981 of $43.8 billion (1990 Fact Book of Agriculture, 1991: 48). The collapse of the export market in 1981 was due to the global recession, a stronger U.S. dollar, an increase in trade barriers, and the restructuring of third world debt. The Agriculture and Food Act of 1981 raised price supports and loan rates for major commodities in anticipation of a continued high level of foreign demand and some inflationary pressure on production costs. At the same time, competition increased as foreign governments increased subsidies and offered price supports to farmers. Crop productivity was also improving in countries that used to be major purchasers of American crops, like Eastern Europe, China and the far east. The demand for American agricultural goods declined. This resulted in a decrease in farm income and land values, an increase in program payments, and the accumulation of huge inventories under government loan. By 1986, the value of farm exports had fallen to $26.2 billion (Lipton, 1989: 5).

The Food Security Act of 1985 lowered support prices of many crops and created the Export Enhancement Program (EEP). In this program exporters are awarded bonus certificates, which are redeemable for CCC owned commodities, allowing the farmer to sell certain commodities to specified countries at prices below those in the U.S. market. Along with the lower value of the U.S. dollar this program helped raise total export sales to $37.1 billion in 1988 (Lipton, 1989: 5).

The following description of farm income policies draws extensively from Craig Osteen's article (1987). In 1973, the government started giving farmers direct payments to subsidize their income. To determine the amount of the payment, the government established a target price for major commodities (wheat, feed grains (corn, oats, barley and sorghum), rice, and cotton) and paid farmers the difference between the target and average free market price after harvest. The target price varied with the farmer's production costs. Eligible farmers received their payment automatically when they sold or stored their commodities. Total deficiency and diversion payments are limited to $50,000 per farmer, per year. This policy, while increasing farm income, also led to an increase in the value of farmland. This program encouraged farmers to expand production of crops whose target price was the highest above the market price, further distorting real market supply and demand forces.

The acreage reduction or limitation (ARP), set-aside, and paid land diversion (PLD) programs are designed to reduce crop production and program payments when inventories are high and prices are low. The ARP and PLD apply to wheat, feed grains, cotton, and rice, the set-aside only to wheat and feed grains. There are no production control provisions for soybeans.

Under the ARP and set-aside programs a percentage of cropland is retired and put into an approved conservation use. Under a PLD, the farmer is paid to allocate land in production to conservation use. The per acre payment for these three programs can be in cash or PIK certificates.

The Reserve program, administered by the Commodity Credit Corporation (CCC) offers loans to farmers based on their crop output. The idea is that the government takes control of surplus grain when a farmer, in exchange for a price-support loan, agrees to keep a crop off the market for a limited time. This is to prevent all crops being dumped on the market at harvest time. Farmers have the option of repaying the loan after nine months, with interest, or turning over their crop in payment of the loan, without interest. This means that in years when crop prices are high farmers will sell the crop on the open market and in years when the selling price is low they turn it over to the government. In some years farmers must reduce the acreage of specified crops to qualify for a loan and the farmer can get cash diversion payments on part of this reduced acreage. Despite the reduction in acreage planted, output has continued to increase due to more intensive farming techniques with their associated erosion risks.

The CCC offers farmers who grow wheat, feed grains, cotton, soybeans, and rice nonrecourse loans for 9 or more months. If crop prices at loan maturity fall below the loan rate, the commodity pledged as collateral can be used to fully repay the loan, including interest. The CCC can only sell the crops it receives at a price higher than the loan rate, which varies depending on the crop.

Farmers may also be able to put the wheat or feed grains in the Farmer-Owned Reserve (FOR) and extend their nonrecourse loan for three or more years. Incentives, in the form of higher loan rates, storage payments, or interest waivers are sometimes offered when the government stocks are lower than the estimated domestic and export needs for the year. The commodity remains in storage until a target price is reached or the loan matures. When the target price is reached, interest rates on the loan increase or storage payments decrease to encourage farmers to redeem the loan. The government can call the loan in order to force farmers to market their grain. The CCC cannot sell these crops for less than 110% of the trigger price. Both of these policies influence program crop prices by modifying the amount of goods available to the market.

The PIK program, first introduced in 1982, offered payments in commodities for ARP and PLD participants to reduce the land planted in crops and to help cut down the huge grain surpluses that had accumulated because of the loan and reserve programs. The PIK program paid farmers for reducing their planted acreage in proportion to the average per acre yield. Farmers responded by idling almost 77 million acres, significantly more than the 23 million anticipated, to the point that the government was buying crops from producing farmers to make up the payments after they had exhausted the grain reserves in stock. In 1983, good weather and intensive cultivation on the remaining land produced more output than anticipated, depressing crop prices and increasing the cost of farm support payments. Some farmers were receiving as much as one million dollars per year not to farm their land. By 1986 the total program cost was over $1 billion (Bouvard, 1989: 88).

In 1986 the government introduced PIK certificates to pay farmers the difference between the market crop price and the government set target price. The certificates are generic, that is they can be redeemed for any commodity stored in government grain bins. The PIK certificates took on the characteristics of a new kind of money, backed by wheat, barley, or other grains, instead of gold or silver. By 1987, over $13 billion worth of certificates were circulating and another $5 billion were expected to be issued in 1988. By 1988, nearly one third of all farm subsidies were being paid in PIK certificates instead of dollars (Rapp, 1988: 55). Brokerage firms handle certificate transactions and trade the certificates on a "forward contract" basis, creating a separate futures market for PIK certificates. Farmers, grain merchants, and market speculators are paying a 15 to 25% premium for PIK certificates due, in part, to a shortage of storage space for crops and pressure for a place to put the next crop (Rapp, 1988: 56).

Farmers can put program crops in storage in return for federal price support loans, default on the loan and get paid in PIK certificates when the crop is not sold at the target price. Then, the government allows farmers to buy back the same crops using the PIK certificates, at a lower price than they paid the farmers for the crops. That is, the government buys high and sells low. Ultimately the government dumps the grain on the world and domestic markets at the lower price, causing the next round of crops to be sold to the government again. Farmers can of course keep the crops and sell them at the market price, if it is higher than the loan rate. However, the loan rate has been higher than the market price of all program crops since 1981 (Rapp, 1988: 58).

As a condition of receiving price and income supports wheat and grain farmers have had to decrease their acreage planted. Wheat farmers had to reduce their planted acreage by 20 to 30% and feed grain growers had to cut back their planted acreage by 12.5 to 20%. The government has also offered to pay farmers up to 92% of their income-support benefits if they cut their acreage by 50%. In 1987, they offered to pay 92% of the benefits if these farmers cut their acreage 100% (Rapp, 1989: 67).

Aside from being very expensive, the PIK program contributed to erosion by encouraging farmers to farm the land remaining under cultivation more intensively. In some cases, land was cleared and plowed for the two year period required to qualify for this program that would normally never have been cultivated, then left fallow while the land owners collected their payments. Most of the land submitted to this treatment was found in the arid rangeland in the west which is particularly susceptible to erosion.

In 1987, the Federal government funded the Low-Input Sustainable Agriculture (LISA) program, administered by the USDA. The program is designed to support research and education in farming techniques that use fewer pesticides and fertilizers. Methods being researched include using manure, municipal sludge, and compost for fertilizer, integrated pest management to control insects and crop rotations and mechanical cultivations to control weeds.

Potential effects of commodity and income programs on erosion

If the government is to design conservation policies that are effective, it is important that the effects of commodity and income policies do not conflict with conservation goals.

As was demonstrated earlier in this chapter, commodity programs modify crop prices and influence farmer's management decisions. As well, some authors believe that commodity programs create financial incentives to increase the acreage planted in program crops. Crops eligible for program benefits are generally associated with higher rates of erosion than ineligible crops such as hay, pasture, grassland, or forest, as shown below in table 4.1.

Table 4.1
Crops, Relative Erosiveness, and Program Eligibility

Crop	Relative erosiveness	Program Eligibility: Deficiency and diversion payments, production controls/a	Nonrecourse loans	Federal crop ins. and disaster payments/b
Cotton	Most	Yes	Yes	Yes
Soybeans	Most	No	Yes	Yes
Corn	Moderate	Yes	Yes	Yes
Grain sorghum	Moderate	Yes	Yes	Yes
Wheat	Less	Yes	Yes	Yes
Barley	Less	Yes	Yes	Yes
Oats	Less	Yes	Yes	Yes
Rice	Less	Yes	Yes	Yes
Grassland	Least	No	No	No
Hayland	Least	No	No	No/c
Range and pasture	Least	No	No	No
Forest & tree crops	Least	No	No	No/c

Yes = eligible, no = not eligible
/a Participation in acreage reduction, set aside, or diversion programs may be required to receive benefits.
/b Disaster payments in conjunction with commodity programs are not generally made where Federal crop insurance is available.
/c Federal crop insurance is available for forage, forage seeding, or tree fruit crops in only a few U.S. counties.
(Osteen, 1987: 302)

Nonrecourse loans and deficiency payments set crop prices for participants at target prices, and in effect "transfer price risk from the private sector to the government" (Osteen, 1987: 303). As a consequence, risk averse farmers will be encouraged to increase their acreage planted in program crops. Export policies that reduce domestic supplies and maintain higher crop prices will also encourage farmers to increase program crop acreage.

> "The increasing trend in carryover and CCC stocks since 1976, which decreased temporarily after production controls were implemented, provides evidence to support this claim." (Osteen, 1987)

The effects of government commodity and income programs on erosion levels are not clearly defined. They can contribute to severe erosion where corn, wheat, or cotton are grown on more erodible soil in the Great Plains, the Corn Belt, Appalachia, and the Southeast. The various program incentives could encourage farmers to rotate different program crops and decrease erosion rates in some areas. The overall effects on erosion rates are unknown at this point.

The 1985 Farm Bill should substantially decrease incentives for erosion compared to policies in the past. Commodity program target prices have been lowered along with the loan rates, so the incentives to plant program crops have been decreased, hopefully along with the level of soil erosion. If the lower crop prices increase the demand for crops, production could increase leading to possibly even more erosion. Indirectly, changes in the commodity programs will continue influence erosion levels.

In summary, there are many different commodity and income programs, with multiple objectives that affect the farmer's management decisions. In many cases it is not clear whether a program is contributing to soil erosion on cropland or controlling erosion. Table 4.2 summarizes the government programs objectives and their effectiveness in controlling erosion.

Table 4.2 Government Programs, Their Objectives and Effects on Soil Erosion

Conservation Programs and Objectives	Effects on Soil Erosion
Conservation Operations Program (COP) 1935	
Provides technical assistance and information for soil conservation measures.	The plans drawn up by the SCS were too elaborate and never used. The voluntary nature of the program meant that the most erosive areas were not those necessarily receiving assistance. (1)
Great Plains Conservation Program (GPCP) 1956	
Provides technical assistance and cost-sharing for installing soil conservation measures. Funds long term land retirement (3 - 10 years).	When crop prices are high this program is ineffective, since farmers will make more farming the land than the lease is worth. The program was supposed to fund the installation of ground cover plants but instead paid for things that improved productivity (ie. fencing, irrigation). The most highly erosive areas were not targeted to receive program funds. (1)
Agriculture Conservation Program (ACP) 1936	
Provides long- and short-term funding to finance farm practices that maintain cropland productivity or control damage to the environment.	Most of the program funds went to increase farm productivity, not control erosion and the funds were not targeted to the worst areas. (1)

Table 4.2 continued Conservation Programs and Objectives	Effects on Soil Erosion
Rural Clean Water Program (RCWP) 1977	
Funds long-term cost-sharing contracts to control runoff and improve water quality. The experimental program is run on a voluntary basis but is designed specifically to deal with water quality problems stemming from runoff.	Funding is targeted to the worst areas and may be the best program operating at the moment. (1)
Food Security Act 1985 Conservation Reserve Program (CR)	
Funds long-term (10 year) land retirement contracts. Pays for up to half of the costs of planting ground cover on this land.	The voluntary nature of the program means funds are not targeted to the worst areas. As happened in the past, when the contracts come due many acres will be returned to cultivation, so this program only provides a short term solution. As well, it may increase speculation in farmland as an investment. This program is also very expensive to run. (2 & 6)
Conservation Compliance Program (CC)	
Forces farmers who want to participate in USDA programs to implement a conservation plan on all highly erodible land.	Not that many farmers with major erosion problems participate in USDA programs so the most erosive areas may not qualify. Recently, funding for USDA programs has been declining so the incentive to participate in the CC program will decline in proportion. (2)

Table 4.2 continued Conservation Programs and Objectives	Effects on Soil Erosion
Conservation land easements	
Pays farmers to permanently retire highly erodible land.	For now, land easements are tied to a few farmers that default on FHA loans. This program would work better if it was targeted to the worst areas. (2)
Low-Input Sustainable Agriculture Program (LISA) 1987	
Funds research and education to help farmers use fewer chemicals raising crops.	Funding is limited so there hasn't been much work done in this area yet. (3)
Target price protection (deficiency payments)	
Maintain farm income.	Increases production of crops with the highest target price, generally those with the highest rates of erosion. (4)
Paid land diversion and acreage reduction programs	
Reduce surplus crop production and maintain crop prices.	Increases the value of remaining farmland, raising production costs, putting pressure on farmers to farm the remaining land more intensively, increasing erosion rates. (3)
Reserve program	
Lends farmers money using the crop as collateral, to stabilize farm income. Tied to acreage reduction.	The land remaining in production is farmed more intensively, increasing the risk of erosion and pollution. Increases the acreage planted in program crops, usually those with the highest rates of erosion. (4 & 5)

Table 4.2 continued

Production and Income Policies and Objectives	Effects on Soil Erosion
Non-recourse loans and the farmer owned reserve (FOR)	
Lends farmers money using their crops as collateral, to stabilize farm income. Extends non-recourse loans for up to 3 years or until a target price is reached.	Increases production of crops with the highest target price, generally those with the highest rates of erosion. (4)
Export policies	
Increase exports to improve the balance payments and get rid of surplus crops.	Increases the production of export crops. Land is farmed more intensively, increasing the risk erosion and pollution. (3 & 6)

(1) Batie, (1983)
(2) Steiner, (1990)
(3) Lipton, (1989)
(4) Osteen, (1985)
(5) Rapp, (1988)
(6) Bouvard, (1989)

Alternative policy options

A crucial question in designing public policy to control erosion is how much soil conservation should society purchase? One way to determine the amount is to discover whether the purchase of soil conservation is economical for society even if it is not for the individual farmer, using the present value approach. Having estimated the costs and benefits of soil conservation in the present and future, society could then decide to conserve in those areas where the additional benefits of increased crop production and improved water and air quality are greater than or equal to the costs associated with erosion.

When farmers make decisions about which conservation measures, if any, are going to be used, the costs and benefits of the various alternative cropping systems are weighed and the choice is made. The discount rate used by the farmer reflects the productivity of capital and time preference. If the benefits of installing a conservation measure will not be evident for a long time, a farmer may postpone the installation because he prefers to enjoy a larger crop now, and the return on the capital investment may be too small to warrant the installation now. This is why farmers do not practice conservation even when they know the productivity of their soil is declining. Their time horizon is too short to worry about the long-term effects of erosive farming. Society on the other hand, has a much longer time horizon and uses a much lower discount rate when making conservation decisions.

In practice, it is difficult to derive accurate estimates of present or future benefits or costs. Another difficulty in using the present value approach is choosing an appropriate discount rate. Any discount rate used, greater than zero, contains a bias against future generations. Policy makers must decide which way to maximize society's investment opportunities, either in soil conservation or alternative investments, such as education or improving job skills while protecting the environment for future generations.

There are many uncertainties involved using the present value approach. Consequently some writers feel that the long term productivity of cropland should be maintained even when the costs outweigh the benefits of using conservation techniques, conservation being just a form of insurance against technical changes, which may or may not occur. Some authors have questioned whether the present generation has the right to discount the benefits of a future generation.

"There is wide agreement that the state should protect the interests of the future in some degree against the effects of our irrational discounting, and of our preference for ourselves over our descendants. The whole movement for "conservation" in the United states is based upon this conviction. It is the clear duty of the government, which is the trustee for unborn generations as well as for its present citizens, to watch over, and if need be, by legislative enactment, to defend the exhaustible natural resources of the country from rash and reckless spoilation." (Batie, 1983: 111)

Other authors feel that the productivity issue is redundant since even when acres of land are retired the total crop output is still maintained by farming the land remaining under cultivation more intensively.

Currently most conservation projects that are government subsidized are run on a voluntary basis, which means the general taxpayer pays most of the costs while farmers and people affected by farm runoff are the prime beneficiaries. Programs where the costs are spread out over many taxpayers and the benefits accrue to a relatively small group have been successfully implemented politically.

Fundamental to any conservation decision is a thorough understanding of all aspects of the problem. To achieve this, the government should invest in education, research, and technical assistance programs. These programs may have limited success because not all farmers will see the same need to control erosion even if they were all made aware of the problems and techniques available to solve them.

> "Education and technical assistance can include such strategies as informing farmers of methods to reduce chemical use without reducing productivity or income. Integrated pest management strategies, for example, can assist farmers in adopting limited chemical use for pest control. Some organic farming methods can reduce chemical needs without necessarily reducing net income. Both these strategies may improve water quality in some cases as well. " (Batie, 1983: 114-115)

As discussed in Chapter 3, one could expect these programs to have the most positive impact when introduced along with a conservation tillage program, such as minimum-till or no-till.

Government policy concerning tax deductions for conservation investments by farmers may have had a less encouraging effect than anticipated. Farmers in low income brackets benefit very little from tax breaks but often farm land with high erosion rates, as observed in Chapter 3. Direct subsidies for conservation efforts might be a better incentive to install conservation measures.

Earlier in this chapter the availability of low-cost government sponsored loans was addressed in detail. To recap briefly, the Farmers Home Administration will make low-cost loans for pollution abatement, erosion control structures, and for the establishment of permanent pastures. The Small Business Administration is authorized to finance projects for farmers whose receipts are less than $1 million and who cannot get a commercial loan. Additional conservation loan programs could be offered by the government but they also would be a less than effective incentive unless the conservation project installed could show a profit.

Traditionally, cost-sharing arrangements for the implementation of conservation measures have played a major role. This type of arrangement has the advantage of being easily designated for a particular area and type of control measure. As described in Chapter 3, most conservation measures are not economical for farmers and cost-sharing is the only way they can be induced to implement conservation practices, particularly in cases where the investment will reduce offsite damage but do little to maintain soil productivity.

> "In western Tennessee, for example, some farms have as many as 80 feet of topsoil. Lands with topsoil of this depth could be eroded at a rate of 40 tons per acre for approximately 3,600 years before normal plowing would mix subsoil with topsoil." (Batie, 1983: 77)

A variation on the cost-sharing strategy that could be offered to farmers in cases where income falls because of the implementation of a measure, is a direct payment or 100% cost-sharing payment plus compensation for the loss of income.

Several authors have suggested that targeting cost-sharing funds to the areas most seriously affected by erosion would be the most cost-effective way to reduce erosion, since most sheet and rill erosion occurs on a relatively small percentage of the total cropland. Despite the concentration of erosion problems, only 19% of the cost-sharing soil conservation practices installed have been on the most erosive lands and "over half of the cost-shared practices have been placed on lands with erosion rates of less than 5 tons per acre per year." (Batie, 1983: 116)

This does not imply that all areas with serious erosion should be reclaimed. Some areas are so severely eroded that the cost to control it would be prohibitive. The relative benefits and costs of each target area would have to be weighed to design the most cost-efficient program. An obvious problem with targeting is choosing the criteria that should be used to determine a target area. These would have to be decided by factors such as whether preserving long term soil productivity or water quality were primary objectives.

A problem of equity also arises. If farmers who have particularly high rates of erosion are to receive the most benefits of targeting, is this fair to a farmer who has spent more time and money on a successful conservation effort. This type of program could possibly have incentive effects that could be counter-productive in the long run.

The way that targeted funds would be distributed might also pose equity problems. Many soil conservation districts contain cropland that is not eroding severely. If the funds were targeted nationally, the regional impacts of the funding would be quite different than if each state were given a share of the money and directed it to their own worst areas. Similarly, the impact would be quite different again if each Soil Conservation District was given federal funds and allowed to target these funds in their own district. In those districts not experiencing high rates of erosion, SCD personnel are concerned about a State or National targeting policy. They argue that they should not be penalized for having less erosive lands or better conservation results within their boundaries.

Another policy alternative could be taxing a farmer for each ton per acre of soil eroded from his land over the limit prescribed by the USDA using the Universal Soil Loss Equation (USLE). Conversely, a farmer could be paid for each ton of soil under the erosion limit. While this may be an efficient solution, the administrative costs would likely prove to be great. The difficulties in using the USLE would also pose a problem (see Chapter 2).

Regulation is another approach to controlling soil erosion that appeals to some writers. Controlling water and air quality and preserving the productivity of farmland are the two primary objectives of government conservation programs, but using regulation to attain these goals conflicts with the notion of private property rights. Earlier in this chapter, the first constitutional test of the regulatory option was presented. In the Ortner and Schrank case, the court ruled that the defendants had to pay for soil conserving measures to be installed. The acceptability of regulation governing how a farmer must conserve his land would probably increase if the government guaranteed financial assistance to cover most of the cost of implementing a recommended conservation plan, as was done in the above case. Batie (1983), has suggested that regulation be directed only to farms with the worst erosion records, to produce the largest impact at the lowest marginal cost, since there is a declining return to any conservation investment. This implies that the rate of erosion that should be aimed for in the program must be carefully determined to maximize the government investment return. Obviously not all areas would receive the same support which again leads to problems of equity.

Researching ways to control weeds for minimum or no-till farmers, reduce crop spoilage on the way to market and developing more productive strains of plants, would decrease the amount of land that would need to be tilled to produce the same crop output. Although this might decrease the total amount of erosion, more fertilizer and pesticides might need to be applied to a smaller number of acres, possibly increasing pollution levels.

Several more controversial methods for reducing erosion have been suggested, including reducing exports and improving the ability of foreign countries to grow their own crops through government aid programs. Reducing the demand for grain fed animals in the American diet has also been put forward as a possible solution. As these appear to be dubious candidates for approval they are not considered further here.

In some cases where erosion is extremely severe, it simply cannot be eliminated. In cases of this nature the land should be taken out of crop production and used for pasture or forest. This would again raise the problem of private property rights and the public's demand to clean air and water. Unless the farmer could be compensated for his loss of income and enjoyment in farming that section of land, this solution would not approach a Pareto optimum. There are several ways in which the land could be removed from production: the government could buy it, as it does when it buys land easements from FHA loan defaulters, arrange a long term rental, as is done in the CR program, re-zone the property, thereby making it illegal to farm that land or by regulation. Each of these possibilities has drawbacks, the most important being high enforcement costs.

Any policy decision should be flexible enough to meet the specific needs of any one area. As there are 2,950 soil conservation districts, it would appear that the most efficient method for developing and implementing policy reforms would be through these agencies.

In 1982, the Secretary of Agriculture recommended that 25% of the funds spent by the SCS and the ASCS for technical and financial assistance be targeted and that the USDA match state and local funding those SCD's experiencing the most severe erosion problems. The report also suggested farmers applying to the FHA for loans be asked to submit conservation plans. The report also recommended that the USDA resolve inconsistencies in the various agency programs.
In 1987, proponents of low-input agriculture recommended reviewing the price and income policies that promote chemically dependent farming practices, such as growing corn continuously. The inclusion of the triple-base plan in the 1990 Farm Bill may help alleviate this problem.

There appear to be many political and financial constraints to the adoption of these measures including vested interests in old programs, limited budgets and personnel, traditional views on property rights and conflicts between policy objectives. There is a broad public awareness of environmental problems currently and a willingness to support conservation efforts. The challenge now will be to implement laws that will motivate farmers to continue to produce crops while taking responsibility for the off-site effects of their production. In other words, the government should design public policies that alter economic incentives in the market in such a way that improvements in efficiency can be realized.

Chapter Five

Conclusion

Government policies in the past have been less than effective and in some cases counter-productive in terms of controlling erosion. A clear guideline of what the government is trying to achieve might make it easier to formulate a straightforward policy that would be simpler to implement. The conflict between soil conservation and income support policies needs to be resolved.

There is clearly a need for soil conservation to protect the future productivity of cropland and to control environmental pollution agricultural runoff. Throughout the Reagan years the problems of nonpoint pollution were largely ignored. President Reagan eliminated nonpoint source pollution programs from the federal budget. In 1987, Congress restored funding for these programs with the Water Quality Act, over President Reagan's veto. Research funds for the Resource Conservation Act were cut so the amount of damage from soil erosion has not been recorded. These cutbacks have probably led to a great deal of environmental damage not yet discovered. Funding for the RCA needs to be restored and the damage assessed.

Implementing the CC and land easement policies would be a positive step towards controlling erosion. The federal programs that CC is linked to should be enlarged to include irrigation projects and tax write offs.

Funding for the LISA program should be increased. If farmers are able to produce crops using fewer chemical inputs, the amount of pollution from erosion would be reduced, along with the amount of soil eroded.

Paying farmers to permanently retire highly erodible land from production is the most efficient method of controlling soil erosion. Most eroded soil comes from a relatively small area of land. In 1985, a report published by the GAO found that "43% of all cropland sheet and rill erosion in the United States originates from only 6% of the cropland." (Bouvard, 1989: 213). Conservation easements could provide a permanent solution to soil erosion in the worst areas and avoid the inevitable negative reaction to land-use regulation. Land that is retired permanently and is no longer generating revenue, should be property tax exempt. Land that is retired, but used for pasture or other profitable crops, should be taxed at a lower rate than the rest of the farm.

There is a lack of empirical evidence making it difficult to assess the real damage being done by erosion. More research needs to be done on the real effects of erosion. We need to know more about the link between soil erosion and nonpoint pollution so that conservation efforts can be targeted to the most severe problem areas.

Local SCS agents should work with county governments to pinpoint the most erosive areas. With cost-sharing programs to install conservation measures and conservation compliance, government funds could be targeted to the most severe areas. The argument that targeting is not equitable is frivolous. Funding is limited, and targeting funds to the most erosive areas is the most efficient way to achieve the greatest amount of soil erosion control. A 1986 USDA study found that "The benefits of erosion control measures exceed the costs involved only on land eroding at about 15 tons per acre per year and above.". If conservation funding was targeted to the 25 million acres of land that eroded at 15 tons per acre per year instead of spread over the 100 million acres that erode at 5 or more tons per acre per year, a lot more conservation could be achieved with each dollar spent (Bouvard, 1989: 216-7).

There is a need for information about the on- and off-site effects of soil erosion. Several studies have found that many farmers who believe that soil erosion is a problem do not see themselves contributing to it. They need to be shown how their management techniques contribute to the problem. They also need more information on the costs and benefits of conservation practices.

In summary, there is no optimal policy choice to be made concerning the control of soil erosion from American cropland. All the solutions so far developed have some flaws. There is general agreement in the literature, however, that given the current situation the most efficient and effective strategies now available would appear to be targeting conservation efforts, removing the most erosive land from production, encouraging farmers to adopt at least the low-cost conservation practices, such as reduced tillage, residue retention, and contour plowing and implementing some cross-compliance strategies.

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Appendix One

Measuring Soil Erosion Losses

The first attempt to quantify water-caused erosion was in 1914 by M.F. Mill, a researcher at the University of Missouri. Other institutions and researchers soon joined the effort. After years of experimentation, a cooperating team of scientists from the U.S. Department of Agriculture (USDA) and Purdue University, led by W.H. Wischmeier, developed the Universal Soil Loss Equation (USLE). The USLE is specifically designed to measure water-induced rill and sheet erosion. The equation was designed to estimate soil loss from fields in the northeastern, southern, and middle regions of the United States. It incorporated 6 factors, all of which can be measured from available data with on-site tests. The equation is

$$RKLSCP = A$$

where A is the average rate of soil erosion, a product of the following 6 factors:

1. R is the rainfall/runoff factor. A value for R is based on the amount of rainfall and the rate of runoff due to the intensity and duration of rainstorms. R is calculated as the average annual value of the rainfall erosion index (EI). The EI is the product of 2 rainfall characteristics -the total kinetic energy times the maximum 30-minute intensity of the storm.

2. K is the soil erodibility factor. Different soil types have varying susceptibilities to erosion. Values of K include the percentage of silt and very fine sand, the percentage of organic matter, and assigned valued for both soil structure (coarseness) and permeability. Because the interest is in the soil's resistance to being moved by erosive forces, K is expressed as the rate of erosion per unit of the EI, for a plot 72.6 feet in length with a 9 percent slope, tilled up and down in continuous fallow.

3. L is the slope length factor. This factor is a ratio of the field's soil loss along the slope length to that of a 72.6-foot slope under the same conditions. It accounts for the phenomenon that soil loss per unit generally increases as slope length increases. As more water accumulates on the long slope, it has the power to erode and transport more sediment.

4. S is the slope steepness factor. This is a ratio of the field's soil loss to that of a 9 percent slope under the same conditions. Increases in slope mean significant increases in soil loss unless crop cover such as pasture offsets the slope effect.

5. C is the crop cover and management factor. This factor is a ratio of the soil loss from a field of a certain cropping management practices compared with an identical area

clean-tilled in continuous fallow. The value of this factor accounts for cropping sequence, time between canopies, presence of crop residue, and surface roughness, and this factor differs regionally according to the timing of rains with seasonal harvest.

6. P is the farming practice factor. It is the ratio of soil loss on a field with certain tillage practices to soil loss under straight row plowing up-and-down the slope. Cropland practices to control erosion include contour tilling, strip cropping on the contour, and terracing. On-the-farm water channels to catch excess rainfall can also be part of farming practices.

Past precipitation records and other research data are assembled to determine values for these 6 factors for various areas around the country.

The soil loss prediction equation is meant to serve as a guide for the selection of farming practices. That is, by selecting the allowable level of average soil loss A, and the appropriate farm values for K, L, S, then the cropping and tillage practices (C and P) which equate the relationship can be selected.

There is a modification of the USLE (MUSLE) developed by C.A. Onstad and G.R. Foster that attempts to improve the USLE.

Whereas the USLE measures soil dislodged, the MUSLE measures the movement of the soil based on both the amount of energy generated by falling water and the amount of soil that can be dislodged by water striking soil. The MUSLE formula is quite complicated:

$$Y = 0.646\ EI + 0.45\ (Q)\ (qp)\ (K)\ (CE)\ (PE)\ (LS)$$

where: Y is the sediment yield measured in tons per hectare;

EI is the rainfall energy factor in metric units;

Q is the water runoff in milliliters;

qp is the peak runoff rate in milliliters per hectare;

K is the soil erodibility factor;

CE is the crop management factor;

PE is the farming practice factor; and

LS is the slope length and steepness factor.

An attempt to quantify soil loss from wind erosion has resulted in a similar equation to the USLE: E = IKCLV, where E is the potential average soil loss due to wind erosion in tons per acre per year.

1. I is the erodibility factor. It is the inherent erodibility of a particular soil and is based on the percentage of soil particles greater than 0.84 mm in diameter. Larger particles are more stable against breakdown and transport by wind erosion.

2. K is the ridge roughness factor. A comparison of this

standard to an actual field-measured ratio can be abstracted to a value for K. Unridged surfaces are more susceptible to wind erosion, provided that ridged rows are oriented at right angles to the prevailing wind.

3. C is the climatic factor. It includes average wind velocity and surface soil moisture and temperature measurements.

4. L is the field width factor. It is the measure of the unsheltered distance across a field in the direction of the prevailing wind.

5. V is the vegetative cover factor. Its value depends on the kind, quantity, and orientation of crop cover.

The wind erosion equation is a method of estimating wind-induced soil loss so that the various factors can be ccnsidered when determining treatment for wind erosion problems. Wind erosion has been studied much less extensively than water erosion, in part because it's economic significance has not been recognized and it is more difficult to measure.

Source: Batie, 1983 and USDA, The Second RCA Appraisal, 1989