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Assessing Erosion on U.S. Cropland

Land Management and Physical Features

Nelson L. Bills
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Abstract

The taxonomy of soil erosion presented here delineates land resources with high potential for erosion control. More than one-third of U.S. cropland is inherently nonerosive under all management regimes, about half requires conservation management to keep soil loss within tolerable limits, and the remaining 8 percent is so erosive that acceptable soil loss rates cannot be achieved under intensive cultivation. Nationally, no statistically important relationships were found between characteristics of farm owner-operators and erosiveness of cropland.

Keywords: Soil erosion, landowners, erosivity, erosion potential, conservation management, rainfall erosion.

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Preface

The persistence of soil erosion problems has prompted the Congress to call for new initiatives to deal with soil loss on cropland. The Secretary of Agriculture, with authorities granted under the 1977 Soil and Water Resources Conservation Act (Public Law 95-192), has called for more intense efforts to target federally sponsored erosion control programs on the Nation's most severe soil loss problems. This study is part of an effort by the Economic Research Service to examine the consistency between Federal commodity supply management/income maintenance programs and programs to control soil loss. Robert Boxley, George Casler, Charles Geisler, Thomas Hertel, Linda Lee, and Katherine Reichelderfer made helpful comments on an earlier draft of this report.

Contents

Summary

Erosion from rainfall causes nearly 100 million acres of U.S. cropland to erode by more than 5 tons per acre per year, which may jeopardize productivity. One-third of this land is so highly erosive that annual soil loss cannot be reduced to tolerance except under the most restrictive land management practices. Most often a change in land use to permanent vegetative cover will be required. Erosion on the remaining two-thirds can be reduced to tolerance with improved conservation management in crop production. This distinction suggests that Federal conservation efforts should be more accurately targeted to the inherent, physical characteristics of land used by farm operators. Such specific targeting of erosion programs will not disproportionately burden any particular class of farm operator. At the national level, characteristics of owner-operators do not appear to determine erosive management.

Those findings stem from applying a farmland erosion classification that considers both the land's physical characteristics and the operator's management of that land. The classification is designed to distinguish more clearly between land which can and cannot be managed to meet a maximum erosion rate of 5 tons per acre per year. (Soil scientists estimate that with an erosion rate of 5 tons per acre per year, the soil can be worked indefinitely with no decline in productivity.)

Land erosion classes devised for use in this report are as follows:

- *Nonerosive,* about 37 percent of U.S. cropland (156 million acres). Its rate of soil erosion will always be less than 5 tons per acre per year under any management. Yet, operators of 53 percent of such land, some of them encouraged by Federal programs, use one or more conservation practices to control their minimal erosion problems.

- ***Moderately erosive, but within the tolerable level,*** about 40 percent of U.S. cropland (171 million acres). This land has the potential to erode above the tolerable level of 5 tons per acre per year; but the operators, by using crop rotations, contour plowing, minimum tillage, and terraces keep their erosion below that level.

- ***Moderately erosive, but above the tolerable level,*** about 15 percent of U.S. cropland (63 million acres). With good farm management, this land could also be worked so that its rate of erosion is kept below the tolerable 5 tons per acre per year. But the type of management practiced causes the topsoil to wash away, in some places at rates exceeding 25 tons per acre per year. About half of the operators of such land apparently make no effort to stem their soil losses by applying conservation practices. This land and these owners should be targeted for Federal conservation programs.

- ***Highly erosive,*** about 8 percent of U.S. cropland (33 million acres). It will erode by more than 5 tons per acre per year with any kind of cultivation. The only way to prevent erosion on this land is to put it in permanent sod or convert it to another less intensive land use. More than two-thirds of this land is planted to row crops, like corn and soybeans, which cause serious erosion problems. Furthermore, operators of nearly half of this land have applied no conservation practices.

Other major findings:

- Information aggregated to the national level shows that the kind of owner-operator makes little difference in the land's rate of erosion. While some earlier studies suggested that age, education, type of owner, and so forth contributed to soil erosion, those studies usually focused on small geographic areas, failed to account for the inherent erodibility of the land itself, or both. For example, while young farmers may have more severe erosion problems than older farmers, that is usually because they own poorer land more susceptible to erosion.

- Erosive cropland is concentrated in the Corn Belt, Southeast, Delta States, Appalachian, and Northeast regions.

Assessing Erosion on U.S. Cropland:

Land Management and Physical Features

Nelson L. Bills
Ralph E. Heimlich

Introduction

Erosion from rainfall causes more than 2 billion tons of soil loss from U.S. cropland each year. Some cropland appears to be eroding at such high rates that the long-term productivity of the land may be jeopardized. Soil losses from cropland also impair water quality in some areas.

This report investigates relationships between landownership and erosion of cropland caused by rainfall. The physical parameters of soil loss, as reflected in the Universal Soil Loss Equation, are manipulated to place the role of resource management for erosion control in perspective. Such perspective is often absent because the now common measure of cropland erosion (soil loss in tons per acre per year) tends to mask the role of management. This study clarifies such relationships by introducing the notion of a tolerable soil loss applied to the inherent physical capacity of a soil to erode.

The cropland erosion taxonomy described here is based on the physical principles underlying accepted soil loss predictive models and avoids arbitrary and qualitative designations of erosiveness. By dividing erosion into its physical and management-related components, the erosion taxonomy described here allows analysts and decisionmakers to focus on erosion problems that can be controlled. The taxonomy can be a useful tool in designing programs or policies targeted to areas or producers with manageable erosion problems.

Owners with farmland holdings of 10 or more acres are described in detail to determine if cropland erosion can be discriminated on the basis of the features of ownership. This description helps set the stage for future studies that will compare owners of eroding cropland with owners who elect to participate in farm commodity/income maintenance programs.

A New Taxonomy of Cropland Erosion

The NRI estimated soil loss due to erosion using the Universal Soil Loss Equation (USLE). The USLE is an erosion model designed to predict average annual soil losses in runoff from specific field areas in specified cropping and management systems *(33)*.[1] Only erosion from sheet and rill processes occurring during rainstorms is predicted by the equation. Soil loss from gullying, road banks, stream banks, or wind is not accounted for in the equation. The USLE takes the form:

$$A = RK(LS)CP$$

where: A = computed average annual soil loss per unit area, usually expressed as tons per acre per year;

The authors are agricultural economists with the U.S. Department of Agriculture's Economic Research Service, stationed at Cornell University, Ithaca, N.Y.

[1]Italicized numbers in parentheses refer to sources cited in References at end of report.

R = the rainfall and runoff factor accounting for the number of rainfall erosion index units in the average year;

K = The soil erodibility factor, measuring the soil loss rate per erosion index unit for the specific soil;

LS = the topographic factor, accounting for the effects of slope steepness and length, relative to a 9-percent, 72.6-foot reference slope;

C = the cover and management factor, accounting for the specific crop and management relative to tilled continuous fallow;

P = the support practice factor, accounting for the effects of contour plowing, strip-cropping, or terracing relative to straight-row farming up and down the slope.

Factor values for the USLE are the results of more than 10,000 plot years of basic runoff data at 49 loca-

Sources of Data

The study is based on land use and landownership data from the U.S. Department of Agriculture's Resource Economics Survey. The Resource Economics Survey is a 12-part package of interrelated information on the ownership and use of land resources in the 48 conterminous States and Hawaii.

The first part of the package, the Soil Conservation Service's (SCS) 1977 National Resource Inventory (NRI), provided data on the use and quality of the land. The second part, the 1978 Landownership Survey (LOS), provided information on landowners.

The 1978 LOS was linked to the 1977 NRI (*18*—see References). The NRI was based on a point sample of the U.S. land area, stratified on the basis of land units that were generally 160 acres in size. Soil Conservation Service field technicians collected data on each of three randomly selected points in each of the 70,000 sampled land units.

To accomplish the LOS, field technicians obtained the name and address of the owner of the first sample point in each land unit. About 12,000 of the 70,000 points fell on land owned by units of government or on land held in trust for Indian tribes. These owners were eliminated from the LOS so that the survey could be confined to privately owned land.

Private owners were contacted with a mail questionnaire. A first and second mailing, selected personal interviews, and a telephone follow-up on nonrespondents ultimately resulted in collecting usable data from about 37,000 private landowners. Thus, the survey covered 65 percent of all sample points known to be privately owned.

Land use and landownership data from the NRI and LOS were merged for this study. Focusing on sample points identified as cropland in the 1977 NRI resulted in a data set containing 12,884 records. Included were points where field technicians found row crops, close-grown field crops, summer fallow, rotation hay or pasture, improved hayland, wild or native hay, orchards, vineyard, bush fruit, and other cropland not harvested or pastured.

To generate regional and national cropland totals, we expanded the records in the merged data file by using the probability of each sample point's selection in the NRI as a base. An expansion factor was computed for each respondent given the probability of selection in the sample and total acres owned in the county where the sample point fell. Thus, each respondent in the merged set represented a number of owners equal to the expansion factor.

This technique for expanding point sample data ensures a correspondence between the physical features of a cropland point and the characteristics of its owner, but produces estimates with absolute values that differ from those reported elsewhere for the full 1977 NRI data file. The difference stems from the fact that the merged file contains only a fraction of the 1977 NRI cropland points (only a fraction of the original points were included in the 1978 LOS) and the consequent modification of the LOS expansion factor. The 1977 NRI estimate of total U.S. cropland was 413 million acres. Techniques used in this study produce a cropland estimate of 424 million acres, a difference of 11 million acres or 2.7 percent.

tions throughout the Nation *(33)*. For the purpose of the 1977 NRI, technicians in the field characterized the USLE parameters of each sample point using guidelines developed by each SCS State office.

This approach to measuring soil loss reflects both relatively stable physical constraints—rainfall patterns, basic soil properties, and land slope and shape—and such management factors as crop selection and cultural practices used on the land. Most of these management factors are directly under the farm operator's control and can be changed from year to year.[2]

Measuring Erosion Potential

The simultaneous consideration of physical factors and management factors in the USLE, while producing useful measurements of annual soil movement, tends to hamper deliberations over erosion control policy. Such deliberations focus almost entirely on the provision of incentives (or disincentives) for cropland management; physical features of cropland are less amenable to manipulation via public policy. Since soil loss is predicated upon physical considerations, the same level of conservation management that produces tolerable soil loss on one parcel of land will result in higher erosion if applied to a relatively more erosive parcel. Conversely, added precision can be had by analyzing management decisions after accounting for the physical features of the cropland resource.

A traditional approach to controlling for the physical features of cropland involves classifying soils according to erosion hazard. The widely used SCS land capability class and subclass system identifies erosion hazards with subclass *e* and the degree of limitation with classes ranging from I (few limitations) to VII (very severe limitations) *(27)*. However, this method presents serious problems of interpretation because subclass *e* identifies only those soil resources for which erosion is the dominant limitation. Soils falling in other subclasses (e.g., cold, wet, or stony soils) can also have substantial erosion problems. The 1977 NRI showed that 28 percent of cropland eroding above 5 tons per acre per year was on land other than subclass *e* (*29*, pp. 2-34).[3]

An alternate approach was devised for this study. The USLE is partitioned into physical and managerial components of soil loss. If a field were continuously in clean-tilled fallow, the average annual soil loss would equal the product $RKLS$ (*33*, p. 40). This product encompasses the physical properties of the land; $RKLS$ can be thought of as a reference soil loss which is management neutral. The product of the C and P factors reflects the kind of management applied to the land. The product CP has a theoretical range from 0 to 1; the amount of erosion increases as the value of CP increases. However, the maximum CP recorded in the 1977 NRI was 0.7, and less than 5 percent of inventoried cropland had a combined CP of more than 0.5.

Partitioning existing erosion rates into physical and managerial components is the basis of conservation planning and technical assistance on individual farms, and has been used in regional studies under the USDA's Cooperative River Basin Planning Program (see, for example, *21*). Ervin and Ervin *(8)* incorporated this approach into a study of soil conservation adoption; Ervin *(9)* used $RKLS$ as a measure of cropland erosivity in a study of erosion rates on owned and rented cropland.

This technique for measuring physical erosion potential can be combined with the idea of a tolerable soil loss. Soil erosion is a continuous physical process that can be retarded but not eliminated. Tolerable soil loss is defined as "the maximum rate of annual soil erosion that may occur and still permit a high level of crop productivity to be obtained economically and indefinitely" *(33)*. Soil loss tolerances (T-values) range from 2 to 5 tons per acre per year and were established for U.S. soils at six regional workshops in 1961 and 1962 *(19)*.

[2]In some cases, land management affects the physical constraints on soil loss. For example, the principal effect of terraces and diversions on soil loss is through changes in slope length. Once a field is terraced, however, the slope length is altered permanently or until an equally intensive effort is made to destroy the terrace.

[3]Limitations of the SCS land capability class-subclass system are increasingly obvious to policymakers. For example, California Congressman George E. Brown, Jr., notes that the "old land class-subclass system lacks internal consistency" and "...desperately needs to be replaced or upgraded" *(2)*.

Soil loss tolerances are controversial. First, soil loss tolerances are defined in terms of onsite effects on productivity and do not consider offsite effects on sedimentation and water quality. These latter effects could conceivably reduce tolerable losses. Second, the rate of soil formation of topsoil (the A-horizon) is about 1 inch in 30 years, corresponding to a 5-ton tolerable loss; but the rate of soil formation from parent material is much slower, corresponding to a 0.5-ton tolerable annual loss *(11, 19)*. Loss of soil above 0.5 ton per year will eventually reduce available rooting depth, hence reducing productivity. Third, gross soil erosion refers only to soil movement on a field and is not equivalent to sediment yield. Thus, much of the soil lost is redeposited on the field from which it was generated, increasing soil depth at the point of deposition.

As soil scientists learn more of the physical and chemical properties underlying crop productivity of soils, the effects of continued erosion on productivity will become clearer *(24, 25, 20)*. Mathematical modeling of effects of erosion on productivity currently being developed will allow a more precise definition of tolerance levels *(32, 23, 7)*. Until then, existing tolerance levels are the only reference points in the current debate over soil loss on the Nation's cropland.

The fundamental distinction to be made between physical and managerial components of erosion, combined with the notion of a soil loss tolerance, suggests a taxonomy to classify cropland according to its contribution to the Nation's soil erosion problem. Such a taxonomy was devised for use in this study by selecting a soil loss tolerance of 5 tons per acre per year *(29)* and partitioning the USLE to control for the inherent erosivity of the cropland base.

Table 1—A taxonomy of cropland erosivity

Erosion class	Definition
Nonerosive	RKLS ≤ 7
Moderately erosive:	
Managed below tolerance	RKLS > 7; USLE ≤ 5
Managed above tolerance	7 < RKLS < 50; USLE > 5
Highly erosive	RKLS ≥ 50; USLE > 5

Under the taxonomy, cropland falls into one of four categories (table 1). The maximum observed *CP* combination and simple arithmetic indicate the first classification in the taxonomy. Since no *CP* combination greater than 0.7 was observed, an *RKLS* less than 7.14 (5 ÷ 0.7) cannot result in an erosion rate greater than 5 tons per acre per year regardless of the management applied. Land with *RKLS* of 7.0 or less is, therefore, classified *nonerosive*.

Analogous with the nonerosive category, a class of cropland can defined with sufficiently high *RKLS* so that almost no management except permanent sod cover yields a tolerable annual erosion rate. An *RKLS* value of 50 or more cannot achieve a soil loss tolerance of 5 tons per acre or less except under the most restricted rotations and support practices (a *CP* value under 0.1); this cropland is classified as *highly erosive*.[4]

Identifying the land that can and cannot be associated with tolerable soil losses because of its underlying erosivity or lack of it, regardless of management, leaves a residual classified as *moderately erosive*. Keeping this land within tolerable soil loss limits depends on the farm operators who manage it. The portion of the moderately erosive cropland farmed with *CP* combinations resulting in erosion rates at or below the 5-ton limit is categorized as cropland *managed below tolerance*: The portion that erodes above 5 tons per acre per year because of the relatively high *C* factors and lack of support practices employed is land *managed above tolerance*.

Cropland Erosion and Erosion Potential

About 3 percent of the Nation's cropland erodes at annual rates of 25 tons per acre or more (table 2). Another 3.6 percent of the cropland base erodes at rates between 14 and 24 tons per acre per year. Both the 25-ton rate and the 14-ton rate have been defined as critical erosion levels *(21, 28)*. However, neither definition is satisfactory because the contributions made by physical factors and management factors are not clear when an erosion rate alone is used as a point of reference.

[4]No-tillage technology, with adequate residues left on the field, could potentially reduce this minimum *CP* value to 0.05 for corn, grain, and close-grown crops. At present, only about 8.6 million acres, or 2 percent of U.S. cropland, is planted with no-till systems *(4)*. The need for occasional turn plowing to reduce weed and insect problems may still result in rotation *CP* values over 0.1.

At the other extreme, 77 percent of U.S. cropland erodes at tolerable rates of less than 5 tons per acre per year. Thirty-seven percent of all cropland erodes at tolerable rates because it is inherently nonerosive (table 2). For such land, no likely set of management practices will generate annual soil losses at rates above tolerance.

On the other hand, virtually all cropland eroding at an annual rate of 25 tons or more is so inherently erosive that few, if any, management strategies will achieve tolerable amounts of annual soil loss. For such land, erosion control is largely synonymous with conversion to permanent vegetative cover. Similarly, about 60 percent of all cropland now eroding at rates between 14 and 24 tons per acre per year is highly erosive; 17 percent of cropland eroding in the 5- to 13-ton range is highly erosive as well. This cropland is not amenable to erosion control measures to reduce soil loss to tolerance under any intensive cultivation. Altogether, 8 percent of the Nation's cropland base is so susceptible to erosion from rainfall that the production of high-valued row crops or close-grown crops will raise soil losses above tolerance under any type of management.

Between these extremes of inherent erosivity and nonerosivity, soil loss depends upon land management. This moderately erosive acreage amounts to 55 percent of the total cropland base (table 2). These resources, presumably, are the principal point of reference for current deliberations over publicly sponsored erosion control policies because of the importance of management in soil loss. Involved are the selection of crop enterprises, crop rotations, tillage practices, and the adoption of soil-conserving land treatments and improvements that allow continued intensive cropping. Based on the 1977 NRI, almost 75 percent of the moderately erosive land is managed below tolerance; well-managed but moderately erosive cropland constitutes 40 percent of total U.S. cropland. The remaining 15 percent of all U.S. cropland is moderately erosive and eroding above a 5-ton tolerance. Erosion on this land could be reduced with improved management practices.

Rainfall on cropland generates more than 1.9 billion tons of gross soil erosion each year (table 3). Nonerosive soils (37 percent of total cropland) account for 7 percent of gross soil erosion. On the other hand, highly erosive soils generate 44 percent of gross soil erosion; 30 percent of gross soil erosion is attributable to cropland that is eroding at rates of 25 tons or more per acre per year. Moderately erosive soils under conservation management account for 20 percent of total gross soil erosion.

As expected, variations in climate, topography, and cropping patterns lead to wide regional differences in cropland erosivity. These regional differences can be highlighted by summarizing NRI/LOS data for farm production regions (fig. 1). When compared with the distribution of all cropland, a relatively large proportion of nonerosive cropland is found in the arid or semiarid Mountain and Pacific regions which account for 30 percent of nonerosive U.S. cropland. The Northeast, Appalachian, Delta States, and Southeast regions account for a small share of the nonerosive category.

An approximately converse relationship exists between highly erosive and nonerosive cropland. Regions with relatively low amounts of nonerosive soils have relatively large amounts of highly erosive cropland acreage. Compared with the distribution of all cropland, highly erosive cropland is more

Table 2—Cropland by soil erosion class and rate of annual soil loss, United States, 1977

			Moderately erosive		
Annual soil loss	Total	Nonerosive	Managed below tolerance	Managed above tolerance	Highly erosive
Tons/acre/year			*1,000 acres*		
Less than 5	327,813	156,562	171, 251	—	—
5-13	69,205	—	—	57,409	11,796
14-24	15,099	—	—	5,895	9,204
25 or more	12,229	—	—	117	12,112
Total	424,346	156,562	171,251	63,421	33,112
			Percent		
Less than 5	77.3	36.9	40.4	—	—
5-13	16.2	—	—	13.5	2.7
14-24	3.6	—	—	1.4	2.2
25 or more	2.9	—	—	*	2.9
Total[1]	100.0	36.9	40.4	14.9	7.8

—Not applicable.
*Less than 0.1 percent.
[1]Excludes Alaska.

Table 3—Gross soil erosion by soil erosion class and rate of annual soil loss, United States, 1977

Annual soil loss	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
Tons/acre/year			*1,000 tons*		
Less than 5	544,016	142,250	401,766	—	—
5-13	549,229	—	—	443,264	105,965
14-24	272,700	—	—	101,977	170,723
25 or more	597,690	—	—	3,376	594,314
Total[1]	1,963,635	142,250	401,766	548,617	871,002
			Percent		
Less than 5	27.7	7.2	20.5	—	—
5-13	28.0	—	—	22.6	5.4
14-24	13.9	—	—	5.2	8.7
25 or more	30.4	—	—	.1	30.3
Total[1]	100.0	7.2	20.5	27.9	44.4

—Not applicable.
[1]Excludes Alaska.

Table 4—Distribution of cropland acreage by soil erosion class and land use, United States, 1977

Land use	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			Percent of U.S. acreage		
Most erosive:					
Corn	22.7	18.8	20.8	29.5	37.5
Soybeans	14.3	8.0	12.6	30.4	22.0
Other row crops	10.8	11.6	7.8	18.3	7.9
Subtotal	47.8	38.4	41.2	78.2	67.4
Less erosive:					
Wheat	17.4	20.3	18.9	10.7	8.4
Other close-grown crops	8.0	9.7	8.2	4.5	6.0
Subtotal	25.4	30.0	27.1	15.2	14.4
Other:					
Hay	16.5	17.3	22.1	1.0	13.4
Summer fallow	6.3	9.6	5.4	3.4	1.5
All other cropland	4.0	4.7	4.2	2.2	3.3
Subtotal	26.8	31.6	31.7	6.6	18.2
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.

prevalent in the Northeast, Appalachian, and Corn Belt regions. Also, relatively large amounts of moderately erosive cropland are managed above tolerance in the Appalachian, Corn Belt, Delta, and Southeast regions.

Cropping patterns, as reflected in 1977 NRI data, differ dramatically among erosion classes. More than two-thirds of the Nation's most erosive cropland was used for row crops during the 1977 crop year (table 4). Soil loss measurement is based on a crop rotation, but row crops, in general, produce higher soil losses than close-grown or hay crops. Concentration of crop production in relatively erosive crops is even more striking on moderately erosive cropland currently managed above tolerance; more than 80 percent of this acreage was devoted to corn, soybeans, andother row crops. Conversely, more than a fifth of all moderately erosive cropland managed at tolerance or below was in a sod crop in 1977.

Crop selection, however, is only one of several management factors that influence the rate of soil loss. Soil loss associated with the production of a crop can be reduced by the use of land treatment practices.

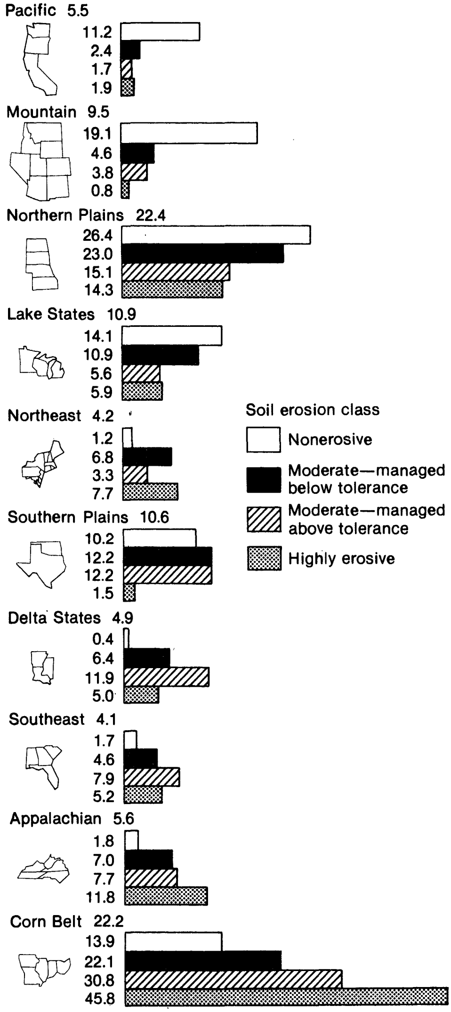
Several land treatment practices related to rainfall erosion on cropland were inventoried in the 1977 NRI (see box). Their incidence on cropland was compared for the erosion classes established in this study (table 5). The proportion of cropland without conservation practices is virtually identical among the classes. Operators of 55 percent of U.S. cropland employ practices designed to reduce soil loss from rainfall erosion. The most prevalent practice involves leaving crop residues on the soil. Multiple practices are also heavily used; 18 percent of all cropland is treated by more than one conservation practice.

Fifty-three percent of highly erosive cropland has the benefit of one or more conservation practices. Multiple practices are employed on 22 percent of this land; contour farming and contour stripcropping are used more often on highly erosive land than on nonerosive land.

The presence of conservation practices on cropland, regardless of its susceptibility to rainfall erosion, reflects in large measure the allocation of public funds for conservation assistance. A 1983 study by

Figure 1

Regional Distribution of Cropland Acreage Erosion by Soil Erosion Class, United States, 1977



Figures before each bar show regional share of the U.S. total in each erosion class.

Figures above bars show each region's share of the U.S. cropland acreage.

the U.S. General Accounting Office, for example, concluded that Federal funds have historically been distributed in a way that is only indirectly linked to the Nation's soil loss problem *(31)*. Procedures for administering such programs contrast sharply with more recent USDA initiatives to target Federal funds and technical assistance to more severe erosion problems.

A Profile of Owner-Operators of Erosive Soils

Merged data from the 1977 NRI and the 1978 LOS provide unprecedented information on the relation between soil erosion and landownership. The NRI is the first effort to make quantitative estimates of rainfall erosion for the entire Nation. Previous national inventories, conducted in 1958 and 1967 by the USDA, were restricted to a qualitative assessment of conservation treatment needs. USDA conducted the first national study of farmland ownership in 1946 *(13)*; but unlike the 1978 LOS, the 1946 survey procedures did not permit ownership to be associated with soil loss on cropland.

Data from the 1978 LOS were used to describe who manages U.S. cropland. This description is possible because ownership data from the LOS were associated with each cropland point. Two major problems are encountered, however. First, much cropland is rented. Management decisions on rented land presumably involve both the landowner and the renter. Second, some cropland points probably are associated with ownerships that are too small to coincide with the conventional (Census Bureau) definition of a farm.[5] This stems from the fact that LOS respondents were not asked to value the production on land they categorized as "land in farms and ranches." LOS describes owners rather than farm operators.

The ownership-farm operation problem cannot be overcome. LOS describes owners of land rather than renters of land. Consequently, the description of landowners must be confined to those owners who could be identified as the operator of the cropland point sampled in the 1977 NRI. Fortunately, such owner-operators use about 50 percent of U.S. cropland (table 6). About one-third of all cropland is owned by owners who have no farming operations but rent cropland to others (landlords). A smaller fraction of land is held by owners who rent land to others and also operate land as a farm (operator-landlords). The owners of 7 percent of all cropland did not report on tenure status. When owned by a landlord, the features of the operator of the cropland included in the NRI sample cannot be determined.

[5]The Census definition of a farm is a place with farm production valued at $1,000 or more during the census year *(30)*.

Table 5—Distribution of cropland acreage by soil erosion class and conservation practice, United States, 1977

Conservation practice	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			Percent of acreage		
No practice	45.2	47.1	43.0	46.0	46.7
Grassed waterway	2.3	.9	2.3	4.3	5.0
Contour	2.3	.5	3.2	2.2	6.8
Contour strip	.7	.3	1.3	.2	.8
Terraces	.6	.2	.6	1.1	.9
Diversions	.2	.2	.2	.2	.5
Residue use	28.2	34.4	25.1	27.9	15.7
Minimum tillage	2.2	2.9	1.7	1.9	1.8
Combinations of practices:					
Minimum tillage and residue	7.1	8.5	6.9	5.1	4.7
All other combinations	11.2	5.0	15.7	11.1	17.1
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.

Conservation Practices*

Grassed Waterway—A natural or constructed waterway or outlet, shaped or graded, and established in suitable vegetation for the safe disposal of runoff. (412)

Contour Stripcropping—Growing crops in a systematic arrangement of strips or bands on the contour to reduce water erosion. The crops are arranged so that a strip of grass or close-growing crops is alternated with a strip of clean-tilled crop or fallow or a strip of grass is alternated with a close-growing crop. (585-A)

Crop Residue Use—Using plant residues to protect cultivated fields during critical erosion periods. (344-A)

Contour Farming—Farming sloping land so that plowing, preparing land, planting, and cultivating are done on the contour. (This includes following established grades of terraces or diversions.) (330-A)

Terrace—An earth embankment, channel, or a combination ridge and channel constructed across the slope. (600)

Diversion—A channel with a supporting ridge on the lower side constructed across the slope. (362)

Minimum Tillage—Limiting the number of cultural operations to those that are properly timed and essential to produce a crop and prevent soil damage. (478)

*As defined in *National Handbook of Conservation Practices.* Numbers in parentheses are the conservation practice codes defining standards for the practice.

Similarly, the operator of cropland owned by an operator-landlord cannot be described because the NRI sample point may have fallen on cropland operated by the owner described in the LOS or on cropland that the owner rented to another farm operator.

There is no satisfactory way to adjust LOS data to overcome the problem of farm definition. For this study, we discarded cropland points associated with landholdings of less than 10 acres under the assumption that few owner-operators with such small acreages meet the commonly used definition of a farm. This procedure further confined the scope of the study. Owner-operators with holdings of 10 or more acres became the focus of the ownership description; these owners account for 210.9 million acres of U.S. cropland.

Owner attributes described are type of ownership, size of farmland holding, net farm income, age, occupation, and education. Information on type of ownership and size of holding is available for all ownership units; information on personal owner characteristics is not available for ownership units organized as large corporations, unsettled estates, or other institutions.

These owner characteristics were selected because of their assumed relevance to current discussions about the consistency of Federal program with regard to soil erosion. To increase precision, we tested for the statistical significance of differences in landowner characteristics among erosion classes (see appendix). The tests show that none of the differences observed is statistically significant at this national level of aggregation.

Where possible, previous studies of the relationships between operator characteristics and soil erosion are discussed in light of our findings. Direct comparisons are limited because, in general, the available litera-

Table 6—Cropland holdings by land tenure, United States, 1978

Land tenure	Cropland	
	1,000 acres	*Percent*
Operator	211,749	49.9
Landlord	140,459	33.1
Operator-landlord	39,888	9.4
No response	32,250	7.6
Total[1]	424,346	100.0

[1]Excludes Alaska.

ture deals with perceptions of erosion problems or adoption of conservation practices. Few studies relate operator characteristics directly to objective measures of erosion. Use of subjective erosion measures, combined with a focus on small areas, has made much previous research inconclusive, if not inconsistent, in regard to the role of ownership characteristics in erosion control *(16)*.

Age

The structure of farmland ownership—its acquisition, use, and disposal—is conditioned by the life cycle of farmland owners. Older individuals have constituted the major class of owners for many years *(10)*. Farmland is an asset, and aging is generally associated with the accumulation of capital assets. Inheritance is an important route to farmland ownership, but more than three-quarters of all owners acquired their farmland via purchases in the land market *(5)*. Many farmers continue to participate in farm operation and ownership well beyond normal retirement age. Finally, as the cost of starting a farm business (including the purchase of farmland) has increased, younger people have more often entered nonfarm occupations or began farming as renters.

Most owner-operators are 50 years old or older (table 7). A relatively high proportion of owners between 35 and 49 years old operate nonerosive cropland; few owners of nonerosive cropland are over 65 years old. By contrast, the age distribution of owners with highly erosive cropland is comparable to the age distribution of owners of all cropland. There is no appreciable difference in the age distribution of owners with moderately erosive cropland, however, regardless of the level of conservation management.

This result runs counter to some hypotheses concerning age and soil erosion. One can argue that age is negatively associated with erosion because the older farmers will possess better land resources, will have experienced the effects of erosion, or will have greater financial resources to deal with erosion problems on their land. Hoover and Wiitala *(12)* found that a significantly higher proportion of younger farmers in a Nebraska watershed perceived an erosion problem than did older farmers, although fewer

Table 7—Owner-operators by age and soil erosion class, United States, 1978

Age	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
Under 35 years	112.9	32.0	51.2	17.8	11.9
35-49 years	301.1	104.0	125.5	38.9	32.7
50-64 years	390.6	123.4	174.9	54.9	37.4
Over 65 years	148.8	31.3	73.1	29.6	14.8
Total reporting age	953.4	290.7	424.7	141.2	96.8
Age not reported	41.8	15.3	16.7	7.0	2.8
Corporations, unsettled estates, and other institutions	22.5	6.6	9.3	3.7	2.9
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent[2]		
Under 35 years	11.8	11.0	12.1	12.6	12.3
35-49 years	31.6	35.8	29.5	27.5	33.8
50-64 years	41.0	42.4	41.2	38.9	38.6
Over 65 years	15.6	10.8	17.2	21.0	15.3
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.
[2]Percentage of owners for which age of owner was reported.

young farmers participated in SCS programs. Ervin and Ervin, however, did not find age significant in explaining perception of erosion problems in Missouri *(8)*.

The mean age of operators adopting conservation or minimum tillage in two Iowa studies was significantly lower than that of later adopters or nonadopters *(3, 14)*. More generally, Ervin and Ervin found that younger, less experienced operators adopted higher numbers of conservation practices and exerted more conservation effort than did older, more experienced farmers *(8)*. Younger operators judged more conservation practices to be profitable than did older farmers. Baron found a strong negative correlation between age and investment in conservation expenditures for operators in the Southern Plains, Delta, Corn Belt, and Northern Plains, based on 1978 LOS data *(1)*. However, neither Earle *et al.* nor Hoover and Wiitala found age significant in explaining adoption of soil conservation practices *(6, 12)*.

Size of Holding

Farmland has always traded freely in the land market and passed from one generation to another via inheritance. These avenues for land transfer, coupled with new technology in livestock and crop production and population growth, have presented owners with opportunities to consolidate or subdivide their farmland holdings.

The size distribution of holdings for owner-operators is shown in table 8. Owner-operators of highly erosive cropland have proportionally more small holdings (under 100 acres). A higher proportion of owners in the nonerosive class have larger holdings (over 260 acres) than for other erosion classes. Owners of moderately erosive cropland managed above tolerance have the highest proportion of holdings in the middle range (100-259 acres).

As with age, our findings related to farm size do not necessarily contradict the divergent soil conservation literature. Ervin found that farm size was not significant in explaining observed erosion rates on rented cropland in Missouri *(9)*. Several other studies found that farm size is positively associated with adoption of reduced tillage technology *(17, 14, 3)*. Earle *et al.* found that farm size was the most effective variable in discriminating between adopters and nonadopters of conservation measures in Australia *(6)*. Farm size was positively and significantly related to conservation investment in four midwestern farm regions *(1)*. Conversely, Hoover and Wiitala concluded that farm size was not significant in explaining perception of erosion problems or adoption of erosion control practices *(12)*. Relationships between farm size and adoption of reduced tillage, on the other hand, may have more to do with efforts to control production costs than to control erosion *(16)*.

On balance, adoption of conservation practices may be related to farm size simply because a larger farm has more varied erosion problems, which promote the use of a wide range of control techniques. The connection between farm size and conservation effort is not convincingly shown in the literature. After controlling for erosion potential of the land, our study suggests that farm size is not a significant factor in soil loss from erosion caused by rainfall.

Net Farm Income

Farmland owners who participated in the 1978 LOS were asked to report their 1977 net farm income (table 9). However, such information is difficult to interpret *(5)*. First, many landowners consider income from farming to be privileged information. A relatively large fraction of all owners did not respond to the income question. Second, the income question was asked for a specific year (1977). Since net farm income can vary greatly from year to year, the average or typical net income might diverge substantially from that reported for the survey year. Finally, net income can be computed in a number of ways, but LOS respondents did not receive specific instructions on how the calculation should be made. This problem is particularly acute for a farm operation because the operator and family often supply capital, labor, and management services to the business. Implicit, and often arbitrary, charges for any capital, labor, and management services supplied by the farm family can be included in a calculation of net farm income for some purposes but excluded for others. It seems unlikely that all respondents, without specific directions, handled such calculations in a consistent fashion.

Table 8—Owner-operators by size of holding and soil erosion class, United States, 1978

Size of holding	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
10-99 acres	468.9	130.3	214.6	71.5	52.5
100-259 acres	345.5	102.6	152.7	54.8	35.4
Over 260 acres	203.3	79.7	83.4	25.6	14.6
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent		
10-99 acres	46.1	41.7	47.6	47.1	51.2
100-259 acres	33.9	32.8	33.9	36.1	34.6
Over 260 acres	20.0	25.5	18.5	16.8	14.2
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.

Table 9—Owner-operators by net farm income and soil erosion class, United States, 1977

Net farm income	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
None	69.8	20.3	30.8	11.7	7.0
Loss	171.1	51.3	74.0	28.6	17.2
$0-$6,999	300.9	87.8	138.7	42.4	32.0
$7,000-$19,999	189.7	60.4	81.5	26.3	21.5
$20,000 or more	95.2	32.9	44.3	11.9	6.1
Total reporting income	826.7	252.7	369.3	120.9	83.8
Income not reported	168.5	53.3	72.1	27.3	15.8
Corporations, unsettled estates, and other institutions	22.5	6.6	9.3	3.7	2.9
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent[2]		
None	8.4	8.0	8.3	9.7	8.3
Loss	20.7	20.3	20.0	23.7	20.5
$0-$6,999	36.4	34.8	37.6	35.1	38.3
$7,000-$19,999	23.0	23.9	22.1	21.7	25.6
$20,000 or more	11.5	13.0	12.0	9.8	7.3
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.
[2]Percentage of owners for which net farm income was reported.

With these rather serious reservations in mind, one can associate farm income with soil erosion class. Results show a remarkably similar income distribution among the classes (table 9). Just under 30 percent of all owners reporting an income, regardless of soil erosivity, indicated that they realized no net farm income or incurred a loss during calendar 1977. The proportion of owners with relatively high net incomes—$20,000 or more—tends to be lower for cropland eroding at rates above tolerance than for all cropland. These differences, however, do not appear to be very large.

Prior evidence on the relationship between farm income and soil erosion is not always consistent with our findings. Lee found that mean erosion rates did not differ among income classes at the national or regional levels until tenure was taken into account *(15)*. National mean erosion rates were significantly lower for owner-operators with net farm income between $3,000 and $50,000 than for those in lower or higher income classes. These differences were also significant in the Corn Belt and Southern Plains. Baron found a positive, but weak, relationship between net farm income and conservation investment *(1)*. He argued that income did not pose an important constraint on investments in conservation structures.

On the other hand, studies related to the adoption of conservation practices and reduced tillage have often stressed the importance of income as an explanatory variable. For example, Bultena-Hoiberg and Korsching *et al.* found significantly higher mean gross farm income levels for conservation tillage adopters than for nonadopters *(3, 14)*. Earle *et al.* also found that with declining farm income, adoption of conservation practices likewise declined *(6)*.

Education

Owners of highly erosive and moderately erosive cropland managed above tolerance are slightly less educated than owners of cropland in other erosion classes (table 10). A slightly higher percentage of owners of nonerosive cropland are college graduates than are owners of cropland in other erosion classes. A higher proportion of owners of highly erosive cropland have elementary educations than owners of land in other erosion classes.

Education is often thought to be negatively related to erosion and positively related to perception of erosion problems and adoption of soil conservation practices. The literature consistently supports this hypothesis, although the strength of the reported relationships varies. As before, few studies investigated the direct relationship between educational attainment of landowners and erosion rate. Ervin and Ervin reported that education was positively and significantly associated with all three of their dependent variables: perception of erosion problems, number of erosion control practices installed, and soil conservation effort *(8)*. Baron found that education was positively and significantly related to conservation investment in the Delta, Corn Belt, and Northern Plains regions but was insignificant in the Southern Plains *(1)*.

Research on conservation practice adoption generally provides only modest support for the education hypothesis. Earle *et al.* included educational level as the last independent variable in a discriminant analysis between adopters and nonadopters because of its modest effect as a discriminator *(6)*. Korsching *et al.* found the mean years of education for minimum tillage adopters to be only 0.7 year higher than for nonadopters, a difference not statistically significant *(14)*. Bultena and Hoiberg found that the percentage of operators with post high school education was higher for early and late adopters of conservation tillage than for nonadopters *(3)*. The difference was significant only between late adopters and nonadopters, however.

Occupation

Most owner-operators listed their principal occupation as farming (table 11). The highest proportion of farmers and lowest proportion of retired owners have land in the nonerosive class. Few important differences in the proportion of blue-collar workers and white-collar workers are observed among the erosion classes.

Type of Ownership

Most owner-operated farms, regardless of soil erosion class, are held by individuals or families (table 12). Differences in ownership type among erosion classes are small.

Table 10—Owner-operators by education level and soil erosion class, United States, 1978

Education level	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
Elementary	204.8	49.9	101.2	28.2	25.5
High school	497.2	156.9	203.9	82.3	54.1
Some college	121.8	39.5	58.3	14.9	9.1
College graduate	106.0	39.0	48.0	12.8	6.2
Total reporting education	929.8	285.3	411.4	138.2	94.9
No response to education	65.4	20.7	30.0	10.0	4.7
Corporations, unsettled estates, and other institutions	22.5	6.6	9.3	3.7	2.9
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent[2]		
Elementary	22.0	17.5	24.6	20.4	26.9
High school	53.5	55.0	49.6	59.5	57.0
Some college	13.1	13.8	14.2	10.8	9.6
College graduate	11.4	13.7	11.6	9.3	6.5
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska. [2]Percentage of owners for which education level was reported.

Table 11—Owner-operators by principal occupation and soil erosion class, United States, 1978

Principal occupation	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
White collar	95.5	27.2	50.6	11.1	6.6
Blue collar	131.2	39.3	54.2	23.5	14.2
Farmer	650.4	212.1	279.6	93.4	65.3
Retired	62.3	8.1	32.7	14.0	7.5
Other	15.9	6.4	6.0	1.8	1.7
Total reporting occupation	955.3	293.1	423.1	143.8	95.3
No response to occupation	39.9	12.9	18.3	4.4	4.3
Corporations, unsettled estates, and other institutions	22.5	6.6	9.3	3.7	2.9
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent[2]		
White collar	10.0	9.3	12.0	7.7	6.9
Blue collar	13.7	13.4	12.8	16.3	14.9
Farmer	68.1	72.3	66.1	65.0	68.5
Retired	6.5	2.8	7.7	9.7	7.9
Other	1.7	2.2	1.4	1.3	1.8
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska. [2]Percentage of owners for which occupation was reported.

Few studies examined ownership as a variable associated with erosion problems. An exception was Lee who found no significant differences between erosion rates for ownership types at the national level, but did find differences in four regions *(15)*. In the Northeast, Southeast, and Mountain regions, family-owned land had erosion rates between 1.6 and 8.6 tons per acre per year higher than the mean erosion rate of land owned by nonfamily corporations. Nonfamily partnerships in the Lake States had erosion rates 6.5 tons higher than nonfamily corporations.

Lee concluded in a separate analysis that differences in erosion rates by type of owner could be attributed to higher percentages of erosion-prone land in the family ownerships. In the Southeast, family owners had more erosive land than nonfamily owners and used fewer erosion control practices. Since the erosion taxonomy used in this report controls for both inherent erosivity and management, however, the apparent relationships found by Lee do not manifest themselves in data aggregated to the national level.

Korsching *et al.* found a significant difference in an index of business complexity (e.g., sole proprietor = 1.0 and corporation = 5.0) between adopters and nonadopters of minimum tillage *(14)*. They conclude that more innovative operators are more likely to adopt both minimum tillage technology and more complex business organizations. Hoover and Wiitala, on the other hand, found type of ownership to be insignificant either in discriminating between operators with differing erosion perceptions or in explaining differences in adoption of conservation practices *(12)*.

Policy Discussion

Application of the soil erosion taxonomy described here to the problem of erosion caused by rainfall on cropland adds precision to discussions of Federal soil conservation programs and policies. If confining annal soil loss to a tolerance level is the policy goal, public programs must be more accurately targeted to the physical properties of the resources used by farm operators. Much cropland is simply not vulnerable to substantial soil loss from rainfall. On the other hand, 8 percent of U.S. cropland is so vulnerable to rainfall erosion that conventional soil conservation techniques—selection of rotations, tillage practices, conservation treatments, and the like—will not achieve a tolerable annual soil loss. Appropriate management of these highly erosive resources im-

Table 12—Owner-operators by type of ownership and soil erosion class, United States, 1978

Type of ownership	Total	Nonerosive	Moderately erosive: Managed below tolerance	Moderately erosive: Managed above tolerance	Highly erosive
			1,000 owners		
Sole proprietor	364.7	107.6	163.8	59.4	33.9
Family ownership	544.6	171.3	237.2	78.1	58.0
Partnership	70.4	23.0	29.4	10.7	7.3
Corporation	28.1	7.9	15.7	1.6	2.9
Other	9.9	2.8	4.6	2.1	.4
Total[1]	1,017.7	312.6	450.7	151.9	102.5
			Percent		
Sole proprietor	35.8	34.0	36.3	39.1	33.1
Family ownership	53.5	54.8	52.7	51.4	56.6
Partnership	6.9	7.4	6.5	7.0	7.1
Corporation	2.8	2.5	3.5	1.1	2.8
Other	1.0	.9	1.0	1.4	.4
Total[1]	100.0	100.0	100.0	100.0	100.0

[1]Excludes Alaska.

plies changing land use from cropland to permanent vegetative cover.

The residual, labeled "moderately erosive" cropland in this study, makes up 55 percent of the total cropland base. This land has the physical potential to erode at excessive rates, but actual soil loss depends on the management applied by the operator each year. These resources and the individuals who own or operate them for farming purposes presumably are a principal focus for government erosion control policies because such policies focus on, or indirectly affect, cropland management. Questions related to the effects of Federal commodity/income maintenance programs on soil loss are particularly relevant to this land because of the paramount role management plays in acceptable (or unacceptable) soil loss rates.

Our taxonomy of erosive cropland provides a firmer conceptual basis for targeting soil conservation efforts. Public programs to control soil erosion should focus on land with the following criteria:

- Productive soil.
- Manageable erosion problems.
- Impairment of productive capacity if erosion is not remedied.

If any of these criteria are missing from a particular field, that land should be accorded a lower priority for erosion treatment.

To clarify the relationships between land management considerations and landownership, we compared the characteristics of owner-operators of cropland with their land's erosion class. We selected size of holding, type of ownership (individual, partnership, or corporate), net farm income, age, occupation, and education as characteristics for study because of the emphasis placed upon them in recent soil erosion literature. Our study, built on comprehensive data for the entire Nation, provides an opportunity to amplify on the importance of these attributes in soil erosion because much existing evidence is anecdotal or limited to case studies of local situations.

We found no statistically significant associations between those features of owners and soil loss on cropland. We did find that size of holding tends to vary inversely with the degree of soil erosivity. Relatively larger numbers of owners with highly erosive cropland hold farmland in smaller parcels, while relatively large numbers of owners of nonerosive cropland hold farmland in larger parcels.

No important differences were observed between owners organized as corporations, partnerships, joint owners with their spouses, or sole proprietors. Similarly, few contrasts could be drawn between owners with different occupations or between owners who realized varying amounts of net farm income during the 1977 crop year. Only small differences were observed in the age and educational levels of owner-operators of cropland in each erosion class.

On balance, therefore, our study provides little support for the idea that Federal programs need to be tailored to specific types of farmland owners. There are few demonstrable relationships at this highly aggregated level of analysis between the characteristics of owner-operators and soil loss. Conversely, our findings suggest that policies targeting on land of moderate to high erosion potential need not single out certain classes of farm operators for special consideration. Thus, the burden of more intense efforts to take remedial public action probably will not fall disproportionately on any one class of farm operators.

This finding is contrary to much (but not all) of the accumulated literature on the role of ownership in the generation of soil loss on cropland. However, an important amount of this literature is either without empirical support or is based on case studies of small watersheds. The latter studies demonstrate the effects of ownership on soil loss in local situations but are too fragmentary to support broader public policy decisions.

Regardless of geographical scope, our study does demonstrate the importance of taking the erosion potential of cropland into account before inquiring into whether the characteristics of farm operators, their attitudes, and behavior affect soil loss. The procedures devised for this study appear to merit further application in future studies of the U.S. erosion control problem.

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Appendix: Measures of Statistical Significance

Since the data presented in the text are based on a sampling procedure, measures were taken to examine the statistical significance of differences in landowner characteristics observed among erosion classes. Appendix table 1 presents two kinds of chi square tests for goodness of fit. First, we tested the hypothesis that the distribution of owner-operator characteristics among erosion classes is the same as for the whole sample. The null hypothesis is that owner-operators of land in the specific erosion class have the same characteristics as all owner-operators. Second, we tested the differences between the two groups of owners of moderately erosive cropland. The null hypothesis (HO in appendix table 1) in this case is that owner-operators managing their land both above and below tolerance level are drawn from the same population.

The general formula used to calculate the chi square statistic is:

$$X^2 = \sum_{i=1}^{n} \frac{(f-F)^2}{F}$$

where: f = the observed frequency in an erosion class;
F = either the frequency in the whole population of owner-operators (test 1) or in the population of owner-operators of moderately erosive land (test 2);
n = the number of classes of the characteristic (e.g., age groups).

This application of the chi square statistic to test goodness of fit to a known distribution is described in section 1.14 and 9.3 of Snedecor *(26)*.

Appendix table 1 indicates that none of the differences between owner-operators of land in different erosion classes are significant at commonly accepted levels. There are no significant differences between owner-operators of land in different erosion classes.

Appendix table 1—Statistical significance of the results

Table and characteristic	HO: Same population, all erosion classes				HO: Same population, moderately erosive
	Nonerosive	Managed below T	Managed above T	Highly erosive	
			Chi square (degrees of freedom)		
Table 7: Age	2.14 (3)	0.32 (3)	2.56 (3)	0.32 (3)	1.12 (3)
Table 8: Size of holding	1.97 (2)	1.11 (2)	0.68 (2)	2.26 (2)	0.30 (2)
Table 9: Net farm income	0.33 (4)	0.12 (4)	1.01 (4)	1.73 (4)	1.50 (4)
Table 10: Education level	1.46 (3)	0.69 (3)	1.58 (3)	4.36* (3)	3.96 (3)
Table 11: Principal occupation	2.58 (4)	0.79 (4)	2.83 (4)	1.38 (4)	3.04 (4)
Table 12: Type of ownership	0.16 (4)	0.22 (4)	1.58 (4)	0.75 (4)	2.09 (4)

*Significant at 75-percent level.

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