Soil Erosivity and Crop Yield: Implications of a Land Retirement Program for New York Cropland

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Policy issues surrounding Federal programs for land retirement as a means of curtailing soil erosion are discussed in this paper. The analysis is structured around productivity differentials observed for New York cropland rated as highly erosive, moderately erosive, or nonerosive.

Key words: soil erosion, soil productivity, land retirement

Traditionally, Federal erosion control policies and programs have stressed improved conservation management on cropland. This goal is promoted through technical or financial assistance to farmers who are interested in using soil-conserving practices on their land. Such strategies are not effective, however, for land so prone to erosion that acceptable soil loss goals cannot be achieved through conservation management in intensive crop production.

For these reasons, policymakers periodically consider measures which would encourage the conversion of erosive land to permanent vegetative cover. Such proposals date to the early 1930s (Salter), but the USDA recently instituted a special conservation program on acreage removed from production to comply with 1984 commodity programs (Ogg and Zellner; USDA, 1983). The objective of this pilot program is to convert highly erosive cropland to permanent vegetative cover; landowners receive increased cost sharing for removing land from production for 5-year or 10-year periods. A recent study by the American Farmland Trust concluded that the Congress should consider land retirement on a broad scale when drafting new farm legislation in 1985.

A concerted Federal effort to retire cropland as a means of achieving soil erosion goals raises at least two issues. First, it is important to know if such an approach is generally consistent with the Federal programs designed to meet supply management/income maintenance goals for producers of some food and fiber crops. The USDA has studies underway now to assess these relationships (Reichelderfer; Osteen). Second, relationships between crop yield and soil eorsion must be more clearly understood. A common assumption is that highly erosive land exhibits poor crop yield. If true, a comprehensive program with incentives (via cost sharing or some other mechanism) sufficient to induce widespread participation would involve little reduction in crop output. If relatively productive land is retired, on the other hand, the program would have a material effect on commodity markets and induce more intensive production on the less erosive land remaining in production.

This paper deals with the cropland credibility crop yield issue. The specific objectives are to estimate the acreage eligible for permanent conversion because of high vulnerability to soil erosion, describe its current use, and test the hypothesis that the productivity of highly erosive land is comparable to that of less erosive land. To take advantage of available data, the analysis is confined to New York cropland, but the results are probably applicable to other areas of the Northeast.

A discussion of the study results is prefaced by sections which discuss the literature on erosion-productivity relationships and describe the data and procedures followed in the study. A concluding section deals with the policy implications of the study.

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Soil Erosivity and Land Productivity

Although substantial data are available on crop yield (a standard measure of soil productivity), land quality, and land use, one cannot quickly fashion a working hypothesis about how a concerted Federal effort to retire "fragile" or "erosive" cropland might relate to the U.S. cropland base. This is due to both conceptual difficulties with definitions of fragile or erosive cropland and gaps in the available literature on how soil erosion relates to soil productivity. Consequently, this section is devoted to a discussion of the interplay between soil productivity, soil erosion, and erosive cropland.

At present, soil conservation policy for agricultural land is constructed around the notion of a soil loss tolerance (T-value). Soil erosion is a continuous physical process which can be retarded but not eliminated. Crop production increases the susceptibility of land to rainfall and wind erosion. Tolerable soil loss is defined as "the maximum amount of erosion that may occur and still permit a high level of crop productivity to be obtained economically and indefinitely" (Wischmeier and Smith). T-values, expressed in tons per acre per year (TAY), were established at a series of regional workshops in the early 1960s; T-values for individual soils range from 2-5 TAY (McCormick, Young, and Kimberlin).

Soil loss tolerances are a logical point of departure for soil conservation policy options dealing with land retirement. A 1984 USDA pilot program for establishing an Acreage Conservation Reserve, mentioned above, made erosion at rates exceeding 2T a criterion for landowner participation (USDA, 1983). However, a program designed around cropland eroding at some amount above tolerance appears to be unsatisfactory on conceptual grounds. Soil loss is predicated on physical factors (rainfall, topography, and credibility of parent material in soil), but also depends on management—reflected in crop selection, tillage practices, and use of conservation support practices—used by the farm operator. Making reference solely to erosion rate in relation to T-value misses the critical distinction to be made between a "fragile" or "erosive" soil and a soil which is not inherently erosive but erodes above tolerance because of soil-depleting management applied by the farm operator. One must clearly distinguish between soil erosion and the erosivity of a soil.

In this study, soils which are inherently erosive are considered to be candidates for a land retirement program. Inherently erosive soils are ones which have the physical requisites to erode above an acceptable soil loss tolerance in crop production regardless of the management used by farmers. In reference to rainfall erosion and a 5 TAY soil loss tolerance, about 8 percent of U.S. cropland (about 33 million acres) is rated highly erosive because it has the physical potential to erode above tolerance unless it is converted to permanent vegetative cover (Bills and Heimlich). Of this amount, 21.3 million acres (6 percent) eroded at rates above 14 TAY during the 1977 crop year.

Retirement of such land would have a material or immaterial effect on food and fiber production, depending upon its productivity as reflected in crop yield. If crop yield on such land is high, or at least comparable to less erosive land, material amounts of production would be lost upon its conversion to permanent vegetative cover. Although little evidence exists on soil productivity soil erosivity relationships, the conventional wisdom is that erosive soils tend to be unproductive soils. For example, a recent analysis of differential agricultural program benefits to achieve soil conservation was prefaced on the unsubstantiated assumption that erosive soils exhibit low crop yields (Ervin, Hefferman, and Green).

The intuitive appeal of an inverse relationship between crop yield and soil erosivity is somewhat understandable. Highly erosive soils, by definition, have relatively high annual rates of soil loss when used for crop production. Soil loss at high rates implies diminutions in topsoil depth, which may lead to diminutions in crop yield sooner or later. However, a recent study funded by Resources for the Future concluded that available empirical evidence does not support valid general statements on how much national agricultural productivity has been, or is being, lost to soil erosion (Crosson and Stout). A similar review by the Council for Agricultural Sciences and Technology (1981) concluded that topsoil loss usually affects the inherent productive capacity of a soil but the quantitative effect of erosion on crop yield is highly variable among individual soils.

As soil scientists learn more about the physical and chemical properties underlying crop productivity of soils, the effect of continued erosion on crop yield will become clearer. A

number of promising efforts to model erosion-productivity relationships more precisely are now underway (Williams, Renard, and Dyke; Pierce, Larson, Dowdy, and Graham; Eleveld, Johnson, and Dumsday). In the interim, yield differentials on land one might choose to define as erosive or nonerosive appears to be an open empirical question for at least two reasons. First, erosion-yield relationships are soil-specific. For some soils, reductions in soil depth do not exert much, if any, influence on crop yield (Crosson and Stout; Miranowski). Second, near-term influences of soil loss on crop yield can often be masked by soil amendments applied by farmers (Crosson and Stout). Management practices used by farmers can ameliorate the effects of soil loss on some soils and maintain crop yield.

With these considerations in mind, one can hypothesize that a land retirement program aimed at erosive soils would exert a proportionate effect on crop production. That is, under good management with the technology now available to farmers, yields on erosive land compare favorably to yields on nonerosive land. A test of the hypothesis would require data on expected crop yield, an operational definition of soil erosivity, and information on how erosive and nonerosive soils are represented in the cropland base.

Procedures and Sources of Data

Such information was assembled for New York cropland. The USDA's 1977 National Resource Inventory (NRI) was used in the study. This source is useful because both land use and factors governing the annual soil loss rate can be associated with individual soil mapping units; NRI data for sample points can be expanded to represent the occurrence of individual soil units in the State's cropland base.

Two comprehensive sources of soil productivity data are available for New York soils. The New York State Board of Equalization and Assessment (E&A) maintains a master file which contains estimated hay yield and corn silage yield for all New York soils. Data on hay and corn silage yield are also available from the U.S. Soil Conservation Service Soils-5 soil interpretation records. It was decided that expected yields for these crops would be used as an indicator of the productivity of New York cropland. According to the 1977 NRI, 76 percent of all New York cropland is used to produce corn and hay.[1]

Land use and land quality data from the NRI were merged with crop yield data from E&A and SCS Soils-5. Both sources of yield data were used because they are poorly correlated with each other. Simple correlation coefficients for the two sources were 0.57 and 0.65, respectively, for corn silage yield and hay yield at each NRI sample point. These differences apparently reflect differences in judgment about how soils perform under a given level of management. For SCS Soils-5, technicians are instructed to record "... the predicted yield of crops approximating those obtained by leading commercial farmers at the level of management which tends to produce the highest economic return per acre." (USDA, 1975).

Procedures followed to develop yield estimates at the State level are not documented but they probably resemble those used by the USDA. Specifically, estimates of crop yield reflect much judgment and assume a high level of management as reflected in application of nutrients, timely field operations, and control of weeds and pests. The estimates for individual soil units are probably not always supported by substantive field data on biological yield.

Cropland erosivity was assessed by evaluating parameters of 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 (Wischmeier and Smith). Sheet and rill erosion from rainstorms is predicted by the USLE; it does not account for soil loss from gullying, road banks, or stream banks.[2]

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 (TAY);

[1] About half of the State's corn crop is harvested for grain rather than silage (New York State Crop Reporting Service). By neces sity, it was assumed that silage yield is proportional to grain yield. As a check, SCS Soils-5 corn silage yield was correlated with SCS Soils-5 com grain yield for each NRI cropland sample point. The simple correlation coefficient (r) is .979, signaling an almost per fect correlation between expected yield for grain and for silage.

[2] Wind erosion is also unaccounted for by the USLE, but ac cording to summary data from the 1982 NRI, New York cropland is not damaged by wind erosion (USDA, 1984).

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

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

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 specified 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.

Following procedures devised in an earlier study (Bills and Heimlich), the USLE was partitioned into physical and management components. The product RKLS, the average annual soil loss if a field is in continuous clean-tilled fallow, was used as a measure of physical erosion potential. Soils represented in the NRI cropland data were assigned to one of three erosion classes. Each class discriminates cropland based upon RKLS and a 5 TAY soil loss tolerance (Table 1). Cropland designated as highly erosive becomes the focus of this study; such land cannot erode at 5 TAY or below except under the most restrictive management. A CP combination under 0.1 is required. Such management is, for the purposes of this study, considered synonymous with land retirement, i.e., conversion to permanent vegetative cover.

Highly erosive land contrasts sharply with resources where conservation management can lead to soil loss outcomes within a 5 TAY tolerance—see Table 1. Land classified as nonerosive cannot erode above 5 TAY regardless of the management applied; moderately erosive land is a residual which erodes above or below 5 TAY depending upon the crop and conservation support practices used by the farm operator.

Table 1. Taxonomy of cropland erosivity

Erosion class	**Definition**
Nonerosive	RKLS $\leq$ 7
Moderately erosive	7 < **RKLS** < 50
Highly erosive	**RKLS $\geq$ 50; USLE > 5**

Source: Bills and Heimlich.

ers use just under 6 million acres for crop production (Table 2).[3] As expected, this land differs greatly in terms of soil loss rate. About 78 percent erodes at or below 5 TAY. At the other extreme, 7 percent (425,000 acres) erodes at annual rates of 15 TAY or more.

Annual soil loss traces to the physical features of a soil and the treatment accorded it by the farm operator. The bulk of New York's cropland is prone to erosion at rates which exceed a 5 TAY soil loss tolerance (Table 2). Because of physical features—climate, topographical features, and the composition of the soil—12 percent of all cropland can be categorized as highly erosive. Under the technology currently used by farmers, permanent vegetative cover is required on this land to keep annual soil loss at or below a 5 TAY soil loss tolerance.

At the other extreme, 14 percent is rated nonerosive because of physical characteristics which preclude erosion above 5 TAY regardless of the management applied by farm operators. Nearly three-quarters of the New York farmland base is moderately erosive in the sense that annual soil loss can range above or below a 5 TAY tolerance depending on the management applied. Based on the USLE, management considerations include the use of traditional conservation practices (terraces, strip-cropping, contour farming, and the like) but also extend to selection of crop rotation, tillage practices, use of cover crops, and management of post-harvest crop residues. During the 1977 crop year, New York farmers used 86 percent of this moderately erosive cropland in a fashion which generated soil loss under 5 TAY. But this result can vary from year to year if farmers alter their management practices.

In contrast, over 45 percent of highly erosive cropland was managed during the 1977 crop year in a fashion which produced soil erosion at rates exceeding 14 TAY. Thus,

[3] The NRI cropland estimates compare very favorably to the acreage reported in the Census of Agriculture. Census data for 1978 show 6,2 million acres of cropland for New York (U.S. Department of Commerce).

Table 2. Annual soil loss by soil erosion class, New York, 1977

Annual soil loss	Cropland erosivity: Total	Nonerosive	Moderately erosive	Highly erosive
		1 ,000 acres		
				0 382
	4,641	860 0		128
Tons/ acre/year	903 221	0 0	3,781	197
Under 5 5-14	204	860	521 93	707
15-25 Over 25	5,969	14.4	7 4,402	0.0
Total	77.8	0-0	63.4	6.4
Under 5 5-14	15.1 3.7	0.0	Percent 8.7 1.6	2.1
15-25 Over 25	3.4	0.0	0.1	3.3
Total	100.0	14.4	73.8	11.8

Source: 1977 National Resource Inventory.

highly erosive cropland is the predominant source of New York's gross soil erosion (Table 3). Indeed, this highly erosive cropland (12 percent of all cropland) accounts for 56 percent of gross soil erosion; over 40 percent of the gross soil erosion traces to erosive soils which erode at rates exceeding 14 TAY.

The perspective provided by contrasting soil loss and soil erosivity clarifies issues surrounding eligibility for a comprehensive land retirement program. NRI information can also be used to determine current land use and gain some insight into the production affected. During the 1977 crop year, relatively erosive row and close-grown crops are overrepresented on highly erosive cropland (Table 4). Most notably, nearly 50 percent of this land was used to produce corn; nearly one-fifth of the State's corn acreage—almost 350,000 acres—is grown on land that could well fall within the scope of a comprehensive land retirement program. This is not at odds with production patterns found on erosive land at the national level; for the U.S., 67 percent of all highly erosive cropland is used for production of row crops (Bills and Heimlich).

To examine differences in productivity on erosive and nonerosive New York cropland, corn silage and hay yields were correlated with RKLS, the measure of soil erosivity se-

Table 3. Gross soil erosion by soil erosion class, New York, 1977

Annual soil loss	Cropland erosivity: Total	Nonerosive	Moderately erosive	Highly erosive
	5,280		1,000 tons	
	7,753			
	4,203	466 0	4,814	0 3,629
Tons/ acre/year	11,200	0 0	4,124	2,513
Under 5 5-14	28,436	466	1,690	9,772
15-25 Over 25	18.6	1.6	1,428	15,914
Total	27.2	0.0	12,056	0.0
Under 5 5-14	14.8	0.0	Percent 17.0	12.8 8.8
15-25 Over 25	39.4	0.0	14.4 6.0	34.4
Total	100.0	1.6	5.0 42.4	56.0

Source: 1977 National Resource Inventory

Table 4. Cropland use by soil erosion class, New York,1977

Land use	Cropland erosivity			
	Total	Nonerosive	Moderately erosive	Highly erosive
		310	1,000 acres	346
		64 8		144
	1,835	68	1,179	81
Other row crops	175 91	311	97 79	209
Close-grown crops	420	29 70	271	34 19
Hayland Trees and	3,054	860	2,534	707
vines Other	216 178	5.2	153 89	5.8
cropland Total	5,969	1.1	4,402	0.2
Corn Vegetables	30.7	0.1	19.7	0.1
Other row crops	2.9 1.5	1.1	1.6 1.3	1.4
Close-grown crops	7.0	5.2	Percent 4.5	3.5
Hayland Trees and	51.2	0.5	42.5	0.5
vines Other	3.7 3.0	1.2	2.7 1.5	0.3
cropland Total	100.0	14.4	73.8	11.8

Source: 1977 National Resource Inventory.

lected for use in this study. As expected, soil erosivity (RKLS) and yield are negatively correlated—see Table 5. However, the relationship is too weak to be important from a statistical point of view. For all New York cropland (5,969,000 acres), the simple correlation coefficient between crop yield and RKLS ranges from -0.09 to -.34. (A coefficient of — 1.0 would signal a perfect, inverse correlation between RKLS and expected crop yield.) Correlation coefficients for E&A yield estimates are uniformly higher than for SCS Soils-5 data, but in no case does RKLS account for much over 10 percent (r^2) of the variability in estimated crop yield.

This result can be refined by focusing on soil erosion classes and upon land actually used to produce hay and corn crops. About a quarter of New York cropland is used for tree, vine, vegetable, or small grain crops. Much of this land may be inferior in terms of expected hay and corn yield. Acre-weighted average corn yields for cropland used for corn in 1977 are presented in Table 6. Because they are not well correlated, Federal and State yield estimates give a slightly different impression about yield-erosivity relationships. For Federal data, average yield is virtually identical in

Table 5. Simple correlations between soil erosivity (RKLS) and crop yield for 5,969,000 cropland acres, New York, 1977

Yield per acre	RKLS
	Correlation coefficient (r)
&A: Corn silage	
Hay	-.339 -
CS Soils-5:	.311
Corn silage	-.093 -
Hay	.106

Table 6. Acre-weighted average corn silage yield by soil erosion class for 1,835,000 acres used for corn, New York, 1977

Soil erosion class[1]	E&A	SCS
	Tons per acre	
Nonerosive	18.5 (26)[2]	20.3(17)
Moderately erosive	19.0 (28)	19.7(19)
Highly erosive	16.8 (45)	20.6 (20)
Total	18.5(31)	20.0(19)

[1] Nonerosive cropland will not erode at a rate greater than 5 TAY regardless of management applied; moderately erosive cropland will erode above or below 5 TAY depending on management applied; highly erosive cropland will not erode at or below 5 TAY except under the most restricted rotations and support practices (Bills and Heimlich).

[2] Numbers in parentheses are coefficients of variation, expressing standard deviation from the mean as a percent of the sample mean.

each soil erosion class. State yield data bear a closer correspondence to each soil erosion class but variability around each mean, as reflected in coefficients of variation, tends to be greater than for the Federal yield data. Overall, this information provides little support for important corn yield differentials on highly erosive cropland.

A similar inference can be drawn from data on hay yield (Table 7). Land used for hay exhibits remarkably small differences in yield among the soil erosion classes.

Taken together, the crop yield comparisons suggest that, in the New York situation, highly erosive cropland performs much like less erosive cropland when used with a high level of management. This result clearly suggests that efforts to retire erosive cropland to meet soil erosion goals will sacrifice crop production in approximately the same proportion to crop acreage. In the New York case, this could involve up to 20 percent of the State's total production of row and close-grown crops and 7 percent of total hay production.

Policy Discussion

The findings of this study have several implications for public programs designed to control soil loss on fragile or erosive cropland via land retirement. Comparisons of soil loss rates and soil erodibility, as reflected in the Universal Soil Loss Equation, underscore the need for precise definitions of fragile cropland. All land with a high annual erosion rate cannot be categorized as erosive cropland. The erosion rate is determined by physical factors and management factors. Land with the inherent, physical capacity to erode above an acceptable soil loss tolerance should be the focus of a land retirement program. About 12 percent of New York cropland falls in this category. Conversely, land with excessive soil loss due to the management applied by farm operators should be targeted for existing programs which stress improved conservation treatment in crop production.

Evidence assembled for New York suggests that a comprehensive effort to retire highly erosive land from the cropland base would have a dramatic effect on the amount of gross soil erosion experienced each year. Highly erosive New York cropland (12 percent of the cropland base) accounted for 56 percent of gross soil erosion during the 1977 crop year. Retirement of such land would reduce sediment and nutrient loads in surface water and generate off-site benefits in some cases. The nature of these benefits and their importance for the State, however, is beyond the scope of this study.

The evidence presented suggests that hay and corn yields on erosive New York cropland are similar to yields on nonerosive cropland. This finding is at odds with the commonly expressed view that erosive land is unproductive land. However, such a result is not necessarily in conflict with the available evidence on soil erosion-productivity relationships. That literature stresses that diminutions in productivity due to diminutions in topsoil depth are soil-specific. For some soils, productivity losses due to erosion develop over a long period of time and can often be offset in the near term by factors other than erosion which also govern yield response under good management.

Comparable crop yield on erosive land also implies that retirement would sacrifice production about in proportion to the acreage removed from production. This result does not necessarily mean that land retirement is a bad idea. However, this approach will generate side-effects which warrant the attention of policymakers concerned with the design of soil conservation programs. In the New York situation, much land is used to produce livestock feed for use on the farm where it is produced. Retirement of erosive land could conceivably lead to more intensive (soil-losing) production on less erosive land as livestock producers seek to sustain on-farm production of livestock feed. This analysis shows

Table 7. Acre-weighted average hay yield by soil erosion class for 3,054,000 acres used for hay, New York, 1977

Soil erosion class[1]	E&A	SCS
	Tons i ?er acre	
Nonerosive	3.85 (42)[2]	3.94 (30)
Moderately erosive	3.69 (33)	3.75 (26)
Highly erosive Total	2.96 (56)	3.45 (28)
	3.66 (36)	3.75 (26)

[1] Nonerosive cropland will not erode at a rate greater than 5 TAY regardless of management applied; moderately erosive cropland will erode above or below 5 TAY depending on management applied; highly erosive cropland will not erode at or below 5 TAY except under the most restricted rotations and support practices (Bills and Heimlich).

[2] Numbers in parentheses are coefficients of variation, expressing standard deviation from the mean as a percent of the sample mean.

that the majority of New York cropland can be rated as moderately erosive because it has the inherent, physical capacity to erode well above an acceptable soil loss tolerance under certain management. An aggressive Federal land retirement program may, in effect, induce farmers to alter their management in a way which shifts an important amount of the soil erosion problem from highly erosive to less erosive land.

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