Economic and Physical Marginality of Highly Erodible Cropland

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ABSTRACT

The conventional notion that highly erodible soils are uniformly unproductive is not supported by empirical evidence. Highly erodible soils are capable of producing corn grain yields and net crop revenue statistically equivalent to that from nonerodible soils. Significant acreages with all but the highest productivity can be found at all levels of erodibility. Retiring highly erodible, physically marginal cropland is not synonymous with retiring less productive, economically marginal cropland.

Economic and Physical Marginality of Highly Erodible Cropland

A common assumption, stated explicitly in some analyses of soil conservation policies and implicit in many others, is that highly erodible land has low productivity. Conventional wisdom concerning the productivity of highly erodible cropland may lead to serious underestimates of the costs associated with controlling erosion on highly erodible cropland (Heimlich, 1986). The Conservation Reserve and Conservation Compliance provisions of the Food Security Act of 1985 (P.L. 99-198), seek to deny farm program subsidies to operators who crop highly erodible land. However, if some highly erodible land has high current productivity, meeting conservation reserve enrollment targets and compliance objectives may have higher monetary and opportunity costs than previously assumed.

Consider the following examples of the confusion between erodibility and productivity that creeps into discussions of resource condition and policy:

> "As more farmland is converted to other uses, marginal farmland will be brought into production. The pollution potential from this land is higher because marginal land is generally more erodible than other farmland (USDA, 1980, p. 5)."

> "If saving the most soil at the least cost were the paramount program goal, then available funds should be directed at those lands with the higher erosion rates. However, such a strategy ... could favor highly eroding but relatively less productive land at the expense of fragile land that may be more productive but less erosive (GAO, p. 39)."

> "...such [highly erodible] land generally provides lower and more variable yields, even if well-designed soil conservation and other management practices are applied (Board on Agriculture, p. 91)."

> "Not all land eroding excessively, however, is marginal or highly susceptible to erosion as indicated by the land capability subclass (USDA, 1986,p.4-14)."

Despite lengthy discussion of highly erodible land attendant on passage of the Conservation Title, high-ranking USDA officials and academics at a recent conference discussing implementation of these provisions equated highly erodible cropland with low productivity (Soil and Water Conservation Society).

The appeal of this assumption is understandable; if erodible soils are economically marginal, current production will be little affected but gains in the present value of future production and reduced off-site damages will occur. This notion is abetted by mental telescoping of erosion's effects over time to a conclusion about the current productivity of erodible land. However, results of long-term erosion impact studies do not preclude the possibility that conditions of topography, soil texture, and climate that lead to high soil erosion can be found across the entire range of current productivity levels (Crosson and Stout; AAEA; Pierce, et.al.; Williams, et.al.).

The conventional wisdom confuses physical and economic concepts of resource marginality. Soil scientists and agronomists focus on physical attributes of land which limit its usefulness for sustained crop production. Such physical properties as soil moisture, texture, acidity, depth, slope, porosity, organic matter content, temperature, and nutrient-holding capacity figure prominently in physical assessments of soil resources (USDA, 1980). Highly erodible land has been identified in recent policy as physically marginal land that should be retired from crop production.

In contrast to this concept of marginal land, economic theory suggests that factors of production, including land, will be used in a competitive environment as long as the marginal benefits from use exceed the marginal costs. Land which produces low crop yields can become economically marginal as crop prices decrease or production costs increase, even if there are few physical limitations that prevent its use for crop production. Conversely, even land with severe physical limitations for long-term crop production will be farmed at a given crop price if it has high enough yields to cover variable costs of production (marginal cost curve above average variable cost curve) in the short run. Different land resources are at the economic margin at different times because crop prices, production costs, and technology change over time.

Bills previously examined relationships between corn silage and hay yields and soil erodibility on New York cropland. Erodibility, as measured by the product RKLS of the Universal Soil Loss Equation, was not well correlated with either corn silage or hay yield estimates. Mean corn silage and hay yields for soil erodibility classes similar to those used in the present study were not significantly different, supporting the conclusion that highly erodible soils have the same productivity as nonerodible soils.

Data

This study integrates information from the 1982 National Resources Inventory (NRI) conducted by the Soil Conservation Service, the Soil Interpretation Record (Soils Form 5), and the Firm Enterprise Data System (FEDS) crop budgets with an erodibility classification developed previously.

1982 National Resource Inventory (NRI)--Data on 291,466 cropland observations from the NRI data set provided land capability class, prime land, soils information, and erosion equation parameters used to calculate the erodibility index. Predicted yields of crops approximating those obtained by leading commercial farmers at the level of management which tends to produce the highest economic returns per acre are recorded on the Soil Survey

Interpretations Record (SOILS 5) computer data base by the Soil Conservation Service (SCS) for all established soil series (SCS). Estimated crop yields for major field crops contained on the SOILS 5 record were matched to the NRI record pertaining to each sample point (SCS-ISL).

Firm Enterprise Data System (FEDS) Crop Budgets--Periodic surveys of farm operators are conducted to obtain data on farm production expenditures and technical relationships for major agricultural commodities. FEDS budgets in each State were prepared at Oklahoma State University for research purposes that were also partially based on this data (Krenz). FEDS budgets and season-average commodity prices for 1982 were used in this study.

Because fixed costs of production, such as charges for land, buildings, and the machinery complement, depend heavily on the size of the operation and the mix of enterprises on which they are used, input costs used in this analysis are restricted to variable costs. FEDS production costs only imperfectly reflect variation in costs due to resource differences because they were prepared for wide geographic areas. Nevertheless, the FEDS budgets using 1982 survey data are the only localized production cost data that can be used for a national assessment of erodibility and productivity relationships.

Physical and Economic Productivity Measures--One possibility for a productivity measure is the physical yield of a ubiquitous indicator crop, such as corn grain. However, corn yields are not reported by SCS on soils where corn is not commonly grown, despite the fact that physical conditions may be appropriate for corn production. Corn yields were estimated for only about 60 percent of cropland soils in the 1982 NRI. Also, as Gersmehl and Brown have shown, yields for important crops are often not correlated with each other on the same soil.

Weighting the yields of various crops that could be grown on the soil circumvents this problem by incorporating all the yield information available into a single economic measure. This is a more complete measure than corn grain yield since yields for at least one of the major field crops are reported on more than 98 percent of cropland. Because soil productivity, as distinguished from crop yield, is measured by the relationship between outputs and inputs necessary to obtain those outputs, simple average net crop revenues at each NRI sample point were calculated using the following formula:

$$NR = (\sum_{i=1}^{n} Qi*Pi - Ci)/n$$

where NR = net revenues from crop production of the eight major field crops at the sample point;
Qi = crop yield of the ith crop;
Pi = price per unit of the ith crop;
Ci = variable production cost of the ith crop;
n = the number of with nonzero yield.

Assessing Cropland Erodibility--Heimlich and Bills used the universal soil loss equation (USLE) to partition cropland into classes based on its physical characteristics and the cropping system applied to it. Land with climate and topography such that erosion above tolerable levels occurs under any practical cropping system short of permanent grass was defined as highly erodible. Land that can meet tolerable soil loss limits under all cropping systems was termed nonerodible. The remainder is land which may or may not erode excessively depending on how it is managed, termed moderately erodible.

This measure of inherent soil erodibility was calculated from USLE parameters contained on each NRI record. Wind erodible land was segregated in a separate class because parameters of the wind erosion predictive equation were not available. Numerical limits to the classes are as follows:

Nonerodible-- $[RK(LS)]/T \leq 2$;
Moderately Erodible
- Managed to erode below T-- $2 < [RK(LS)]/T < 15$ and $A \leq T$;
- Managed to erode above T-- $2 < [RK(LS)]/T < 15$ and $A > T$;

Highly Erodible-- $[RK(LS)]/T \geq 15$;
Wind Erodible-- $W > T$.

where the rainfall erosion index (R), soil erodibility index (K), topographic factor (LS), and the soil loss tolerance value (T) are all parameters of the USLE, A is the estimated rate of sheet and rill erosion and W is the estimated rate of wind erosion using the wind erosion equation.

Results

Continuous measures of soil productivity based on recorded corn grain yields and estimated net returns from nonirrigated production of major field crops are not correlated with a continuous measure of soil erodibility based on measured factors of the Universal Soil Loss Equation (USLE) (table 1). Correlation between productivity measures, land capability class, and the prime farmland definition is weak. The corn grain yield measure of soil productivity is positively correlated with the net revenue measure, but only weakly.

On average, highly erodible land can generate higher current net revenue than nonerodible land, although the difference is small (table 2). Moderately erodible land managed to erode below T can produce lower net revenue at the same level of crop management than erosively managed land.

Differences in mean net revenue by erodibility classes are statistically significant in all cases.

The distribution of net revenue for highly erodible land is similar to the distribution for nonerodible land, except that highly erodible land has smaller negative returns. In absolute terms, almost forty percent of the cropland with negative estimated returns is nonerodible. Only wind erodible cropland has a higher proportion of nonirrigated cropland with negative net revenue, primarily due to the need for irrigation in areas where wind erosion is a problem. Two-thirds of wind erodible cropland that was irrigated in 1982 has positive estimated net revenue as irrigated cropland. While the largest portion of the cropland with more than $75 per acre in estimated net revenue is nonerodible (36 percent), almost nine percent of such land is highly erodible. Highly erodible, erosively managed, and wind erodible cropland make up more than one-third of all high-return cropland.

Factors Affecting Productivity

Relationships between attributes of the land and productivity cannot be adequately shown using simple correlations and cross-tabulations. Multiple linear regression can help decompose the relative contributions of these attributes toward the soil's productivity. The regression model discussed here takes the form:

$$Y = B1D1 + B2D2 + B3D3 + B4D4 + u$$

where Y = Either corn grain yield or crop revenue measures of soil productivity;

D1 = Vector of dummy variables for soil erodibility classes, 5 levels;

D2 = Vector of dummy variables for land capability classes, levels I through VIII;

D3 = Vector of dummy variables for land capability subclasses, levels c through w;

D4 = Dummy variable for USDA prime farmland, 2 levels;

B1-B4 = Vector of coefficients for each level of each of the dummy independent variables.

u = An error term measuring variation in productivity unaccounted for by the independent variables.

The independent variables are all discrete categorical variables that show into what class of the particular attribute (erodibility, capability, hazard, "primeness") the observation on the dependent variable falls. The estimated coefficient for each level of each attribute adds or subtracts from the mean productivity. For example, average net crop revenue on nonerodible prime land in class II with an erosion hazard is estimated to be $-18.05 + 30.00 -25.30 + 14.61 = $1.26.

The explanatory power of the yield regression model is good, with almost 94 percent of the variation in corn grain yield accounted for by the model (R^2 = .938). The same independent variables account for only about one-quarter of total variance in net revenue. These soil attributes are only easily determined proxies for the underlying physical factors that determine productivity, but the model does help us see the relationship of each of these classification systems to soil productivity, controlling for the presence of the other classification systems.

In both models, erodibility actually adds more to average productivity than nonerodibility. That is, the average productivity on highly erodible land is higher than that for nonerodible land, other factors held constant. Erosively managed moderately erodible land has the second highest productivity, while wind erodible soils have the lowest productivity.

In both models, capability classes and subclasses into which land is grouped based on the kind of hazard or limitation to cropping are associated with reductions in productivity, other factors equal. Class I land is more productive than is apparent since, by definition, class I land has no subclass to further reduce average productivity, while all other classes must have a subclass rating. The apparent contradiction between the large productivity reduction associated with the erosion hazard subclass and the large addition to productivity associated with highly erodible land may be explained in part by recalling that subclass e is first in the hierarchy of limitations. If land is not rated class I and no other limitation is judged dominant, subclass e is assigned. Thus, 51.7 percent of cropland inventoried in 1982 was in subclass e, although only 7.1 percent of all cropland was highly erodible (Heimlich and Bills).

Conclusions and Implications

The conventional wisdom regarding the current productivity of highly erodible soils is incorrect. Highly erodible soils are not significantly less productive than nonerodible soils, in terms of either corn grain yield or net crop revenue from common field crops. Although continued erosion may decrease yields in the long-run, establishing evidence for that relationship is beyond the scope of this study.

Policy and program decisions designed to affect use of erodible land cannot presume that this land has low opportunity costs. While erodible land may or may not earn lower revenue over the long term, incentives required to restrict production in the short term must be based on current productivity. Since current productivity is uncorrelated with erodibility, idling some highly erodible land may also idle some of our most productive and valuable cropland. If so, retirement incentives may have to be made larger than originally thought.

Table 1-- Correlation Matrix and Statistics for Productivity, Erodibility, and Land Classification Variables on Cropland, United States, 1982

Variables	RKLS/T	Corn Yield	Net Crop Revenue	Land Capability	Prime Farmland
RKLS/T 1/	1.000	-	-	-	-
Corn Yield	-.088	1.000	-	-	-
Net Crop Revenue	-.029	.332	1.000	-	-
Land Capability	.298	-.363	-.316	1.000	-
Prime Land	-.179	.334	.345	-.618	1.000
Mean	5.58	90.72	2.82	2.65	.45
Standard Deviation	55.61	100.52	188.51	4.10	1.89
Minimum	0	40.00	-254.14	1.00	0
Maximum	1,535.56	163.00	246.57	8.00	1.00

- indicates symmetrical entries across the main diagonal of the matrix.

1/ Continuous variable computed using USLE parameters at each 1982 NRI sample point.

Table 2--Mean Net Crop Revenue and Distribution of Cropland Acreage by Net Crop Revenue and Erodibility, United States, 1982

Net Crop revenue	Erodibility Class: Non-erodible	Moderately below T	Erodible above T	Highly erodible	Wind erodible	All cropland
	Dollars per acre					
Mean	.89	14.52	20.67	1.41	-26.93	2.85
	Thousand acres					
No yield	950	293	98	289	641	2,271
(dol/ac)						
<-50	23,250	8,150	5,295	5,040	18,130	59,865
-50--26	31,462	8,370	4,445	3,817	19,168	67,262
-25-0	23,519	15,874	10,048	7,549	14,216	71,206
1-25	27,596	24,365	19,482	6,632	9,458	87,533
26-50	25,216	17,368	14,907	4,470	4,036	65,997
51-75	13,467	9,097	8,013	2,747	1,252	34,576
> 75	11,456	9,043	8,082	2,742	497	31,820
All	156,914	92,561	70,368	33,287	67,398	420,528
	Percent of acreage					
No yield	0.6	0.3	0.1	0.9	1.0	0.5
<-50	14.8	8.8	7.5	15.1	26.9	14.2
-50--26	20.0	9.0	6.3	11.5	28.4	16.0
-25-0	15.0	17.1	14.3	22.7	21.1	16.9
1-25	17.6	26.3	27.7	19.9	14.0	20.8
26-50	16.1	18.8	21.2	13.4	6.0	15.7
51-75	8.6	9.8	11.4	8.2	1.8	8.2
> 75	7.3	9.7	11.5	8.3	0.8	7.6
All	100	100	100	100	100	100

Detail may not add to totals due to rounding.
1/ Area-weighted averages of average net revenue from major field crops for which yields were recorded.
2/ Mean revenue for erodibility groups is statistically different according to the Waller-Duncan k-ratio test with k = 100, approximately equivalent to the .05 significance level.

Table 3--General Linear Model Estimates of Contributions to Cropland Productivity, United States, 1982 1/

Variable	Corn Grain Yield		Net Crop Revenue	
	Parameter (Bi)	Std. Error	Parameter (Bi)	Std. Error
Erodibility				
Nonerodible	120.6	1.80	-18.05	2.23
Moderately <T	118.5	1.80	- 2.16 *	2.23
Moderately >T	124.3	1.80	6.40	2.23
Highly	127.5	1.80	10.54	2.24
Wind	111.3	1.80	-31.39	2.23
Land Capability				
I	-12.6	1.80	27.96	2.24
II	-16.5	1.80	30.00	2.23
III	-32.8	1.80	19.37	2.23
IV	-41.4	1.80	8.81	2.23
V	-37.0	1.82	- .95 *	2.25
VI	-31.8	1.80	- 3.72 *	2.24
VII	-28.4	1.83	- 9.80	2.25
VIII	.0	na	.00	na
Land Subclass				
c	-40.1	.09	-33.96	.10
e	-11.8	.04	-25.30	.06
s	-24.5	.06	-27.18	.08
w	.0	na	.00	na
Prime Farmland				
prime	2.1	.04	14.61	.06
not prime	.0	na	.00	na
R-Square	.938		.258	

* Parameter is not significantly different from zero at the 99 percent confidence level.

1/ SAS GLM procedure with categorical variables produces a singular X'X matrix and uses a generalized inverse to solve the normal equations. All parameter estimates are biased but are best linear unbiased estimates (BLUE) for some linear combination of the parameters (SAS, p.161).

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