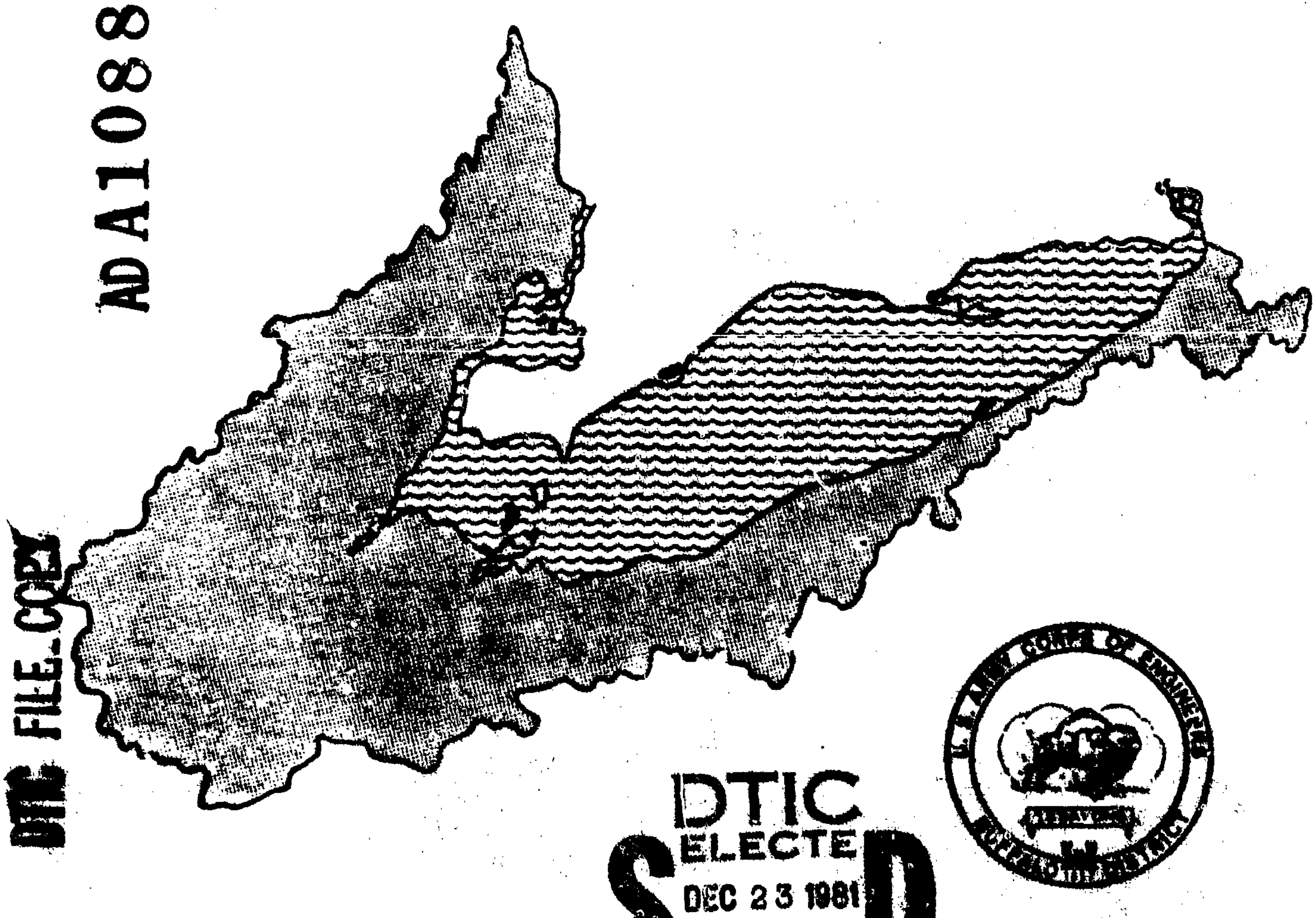
LEVEL II

TECHNICAL REPORT SERIES

SEDIMENT DEPOSITS IN DRAINAGE DITCHES



PREPARED FOR THE
LAKE ERIE WASTEWATER
MANAGEMENT STUDY
U.S. ARMY ENGINEER DISTRICT, BUFFALO

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A108 834
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Sediment Deposits in Drainage Ditches	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ohio State University, Dept. of Agricultural Economics and Rural Sociology	8. CONTRACT OR GRANT NUMBER(s) DACW-49-80-C-0016
9. PERFORMING ORGANIZATION NAME AND ADDRESS Same as #7	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Water Quality Section, NCBED-HQ, U.S. Army Engineer District, Buffalo, 1776 Niagara Street, Buffalo, N.Y. 14207	12. REPORT DATE November 1980
	13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release, Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from National Technical Information Service, Springfield, Virginia 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Lake Erie Basin
Soil Loss
Sediment Removal

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study is to estimate one of the off farm costs of cropland soil loss, sediment removal from drainage ditches. Information is compiled about the cost of sediment removal, characteristics of the drainage ditch and land area draining into the ditch.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

410294

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Sediment Deposits in Drainage Ditches

by

D. Lynn Forster

and

Girmai Ibrahim

Department of Agricultural Economics
and Rural Sociology

The Ohio State University
and
Ohio Agricultural and Research Development Center

Prepared for:
Buffalo District
U.S. Army Corps of Engineers
November, 1980

TABLE OF CONTENTS

ABSTRACT

The purpose of this study is to estimate one of the off-farm costs of cropland soil loss, sediment removal from drainage ditches. Also, the relationship between sediment deposits and soil loss is estimated. Six counties are selected to represent western Lake Erie Basin agriculture. For selected drainage ditches in these counties, information is compiled about the cost of sediment removal, characteristics of the drainage ditch and land area draining into the ditch, and estimated gross soil loss. Results indicate that about 8 percent of the gross erosion is later removed as sediment from nearby drainage ditches. Annual costs of sediment removal are approximately $0.45 per acre. The marginal benefit of reducing annual gross soil loss by one ton per acre is about $0.10.

Introduction

Previous studies have addressed the economic impacts of reducing soil loss in the Lake Erie Basin (Forster and Becker; Forster). Economic analysis of soil loss reduction have been conducted for many cropland areas throughout the United States (e.g. Kasal; Nagadevara, Heady, and Nicol; Taylor and Frohberg; Wade and Heady). Each of these studies has investigated the economic impacts of reducing soil loss to some rather arbitrary level (e.g. soil loss tolerance factor). Soil loss has been computed by the Universal Soil Loss Equation (Wischmeier and Smith) which is a widely accepted mathematical model for predicting gross soil erosion.

The Universal Soil Loss Equation (USLE) says nothing about net soil loss from an area. That is, rainfall may erode soil particles and move them from one point in a field to another without any externality occurring. Also, soil particles may be deposited on another's property and create a positive externality or benefit to another.

Certainly, soil loss results in costs to others as it is deposited in drainage ditches and other water bodies, but these costs are largely undefined. These costs are incurred through the removal of sediment from drainage ditches, reservoirs, and harbors; damage to fisheries; damage to recreational sites; and increased water treatment; and reduced soil productivity for future generations. The cost of sediment removal from water ways is probably the most obvious and easy to measure of the many externalities that exists, and some sediment removal cost estimates have been made (Lee, et al.).

The objectives of this study are two fold. The first is to test the relationship between USLE gross soil erosion estimates and actual sediment deposition in drainage ditches. The second objective is to measure one of the downstream costs of soil loss, sediment removal from drainage ditches. These results would provide a partial estimate of the sediment removal cost from downstream water bodies and a partial estimate of the externalities emanating from cropland.

Procedure

Six counties were selected to represent Western Lake Erie Basin agriculture. These counties include Seneca, Wyandot, and Crawford counties in North Central Ohio; and Paulding, Wood, and Fulton counties in North Western Ohio. In each of these counties, a systematic drainage ditch maintenance program has been in effect, and drainage ditch data have been kept by the Soil and Water Conservation District or by the County Engineers Office. These data include physical characteristics of the ditch and year, costs and quantities of sediment removal.

Drainage ditches were selected for the analysis which met the following restrictions: (a) sediment had been removed during the past seven years, (b) no sediment from outside an identifiable watershed could have been deposited in the drainage ditch, (c) soil survey maps were available to assist in estimating gross soil erosion, and (d) agriculture was the principal land use in the watershed. The first restriction assured that most of the sediment deposited in the ditch was caused by recent (post 1970) cropping patterns in the watershed. The second restriction assured that all sediment in the ditch came from the watershed and not from another upstream area. It necessitated omitting several secondary ditches that received water from a number of upstream ditches. The third restriction removed several counties with sizable ditch systems from consideration and removed a few ditches in the sampled counties where soil surveys were incomplete. Finally, areas with housing developments or other non-agricultural land uses were omitted due to the final restriction.

For each drainage ditch the following information was obtained: cost of sediment removal, length of time since previous sediment removal or ditch construction, quantity of sediment removed, land area draining into the ditch, ditch length and slope of ditch. Gross soil erosion was then calculated for the land area draining into the ditch. The USLE was used to estimate the annual gross erosion for a number of random points in the area draining into the ditch. Each random point represented 23 acres. Thus, for example, a 230 acre watershed would have had 10 gross soil erosion calculations, and the mean gross erosion would have been used to represent the annual soil loss in the watershed.

The annual deposition (tons) of sediment in a ditch is expected to be a function of the area which drains into the ditch and the average soil loss from the area. The use of the USLE, of course, incorporates not only rainfall, topography of the land, and the inherent erodibility of the soil but the prevailing cropping and management factors as well. Also, deposition is expected to be affected by the physical dimensions of the drainage area. The drainage area which has a long ditch draining a narrow strip of cropland is expected to have relatively higher sediment deposition than another with equal area but with shorter ditch length and wider drainage area.

The model used to test this physical relationship is shown in equation (1).

$$SED = a_o \, SL^{a_1} \, WDTH^{a_2} \qquad (1)$$

where SED is the annual sediment deposition per acre in the watershed (tons/acre), SL is the average annual gross soil erosion per acre in the watershed (tons/acre), and WDTH is the average width of the watershed (feet). The properties of the Cobb-Douglas function in equation (1) are desirable for estimating this relationship which is expected to be nonlinear. Multiple regression analysis was used to estimate the coefficients of equation (1) after converting the equation to its logarithmic form. Several other nonlinear models also were estimated but performed much poorer in terms of their goodness of fit (R^2).

It is expected that estimates of equation (1) would show a_1, the coefficient relating gross erosion to sediment deposition, to be positive. That is, the higher the annual gross erosion per acre, the more soil would be deposited in drainage ditches. On the other hand a_2, the coefficient relating the average width of the watershed to sediment deposition, would be negative. The closer a given point of cropland is located to the drainage ditch, the more likely it is for eroded soil particles to enter the ditch. Thus, the wider the watershed, the less the quantity of sediment deposition per watershed area.

The cost of sediment removal ($ per ton) is expected to be a function of the amount of sediment removed and the year in which the sediment removal occurred. For each ditch, sediment removal costs were updated to 1979 prices. A mean estimate of sediment removal cost ($ per ton) then was calculated. Other models relating cost to the quantity of sediment removed were estimated, but the simple linear model was found to be the most satisfactory.

Results

The sample consists of 44 drainage ditches. Each ditch averages 1.4 miles in length and drains a watershed of about 730 acres. The USLE estimates of annual gross soil erosion in these watersheds averages 2.85 tons per acre (Table 1). About 8 percent of this gross erosion (.24 tons per acre) is later removed as sediment from the drainage ditch. Costs of sediment removal total $1.87 per ton. Thus, annual costs of sediment removal are approximately $0.45 per acre. Sample results are provided for each county in Appendix 1.

Table 1. Mean and Standard Deviation for Characteristics of Sampled Watersheds and Drainage Ditches (N=44)

	Mean	Standard Deviation
Ditch Characteristics - Length (feet)	7251	4694
Annual Sediment Deposition (tons per acre in watershed)	0.24	0.30
Cost of Sediment Removal (1979 $ per ton of sediment removed)	1.87	0.94
Watershed Characteristics Area (acres)	730	395
Annual Gross Soil Erosion (tons per acre)	2.85	1.29

The estimate of equation (1) in the log form is:

$$\text{Log (SED)} = -4.975 + \underset{(2.03)}{0.650}\ \text{Log (SL)} - \underset{(-4.56)}{0.890}\ \text{Log (WDTH)}$$

where t-statistics are in parentheses below the regression coefficients. Both coefficients have the expected signs and are significant at the 0.01 level. R^2 of the equation is 0.34 and the F value is 10.50.

Some sediment is deposited in drainage ditches regardless of cropland soil loss. Drainage ditch bank erosion, erosion from construction in the watershed, and other erosion from non cropland acres are expected to deposit some sediment in drainage ditches. Thus, the marginal change in sediment deposition associated with a decrease in soil loss from cropland is expected to be less than the average sediment deposition per unit of soil loss. Results support this expectation. A one ton per acre decrease in annual gross erosion would be accompanied by a .055 ton per acre decrease in sediment deposits[1]. The average sediment deposition per unit of gross erosion is .08. At the mean sediment removal cost of $1.87 per ton, the marginal benefit of reducing annual gross erosion by one ton per acre is $0.10.[2]

These results support the hypothesis that USLE estimates are related to sediment deposition in drainage ditches. In the watersheds analyzed in this study, only a small portion of cropland gross erosion is deposited in nearby drainage ditches. Most of the gross erosion remains unaccounted for. Soil particles move to another part of the field, they move to downstream sites, or they are suspended in the water. However, the results indicate that changes in gross soil erosion are closely related to changes in drainage ditch sediment deposition. Results indicate that a one percent change in gross soil erosion is associated with a .650 percent change in sediment deposition.

Externalities from soil loss in the form of sediment in drainage ditches are small when compared to the direct costs of crop production. An estimate of $0.45 per acre as the annual cost of sediment removal is less than one half percent of the fixed costs of land in this crop production area and a very small fraction of total costs. Sediment is a classic case of an environmental externality as Seitz says,

> "...the economic value of each pollutant is often small relative to the value of the normal good with which the pollution is associated. In addition, each contributor to the pollution problem often adds but a small portion of the total. It is through processes of aggregation and accumulation that a problem becomes large enough to warrant attention." (p. 818)

The costs of removing sediment deposition may be substantial in the aggregate. In Ohio there are at least 3,650 miles of drainage ditches under collective maintenance programs which include regular sediment removal.[3] Extrapolating the results of this study to these ditches results in costs of nearly $1 million per year in Ohio for sediment removal. Costs for many miles of drainage ditches are excluded from this estimate since the amount of privately maintained ditches is unknown. In addition, costs are incurred for harbor dredging in Lake Erie and other water bodies.

Conclusions

Researchers have long relied on the USLE to provide a measure of cropland soil loss. Studies have estimated the economic impacts of reducing soil loss and have implied that external costs would be reduced as soil loss is reduced. Results of this study support the use of USLE gross erosion estimates as a proxy for one external cost, sediment removal from drainage ditches. The analysis finds a significant statistical relationship between USLE gross erosion estimates and actual sediment deposition in drainage ditches.

External costs associated with soil loss include downstream damage of sediment and other pollutants in water bodies and the reduced productivity of the soil resource incurred in future years. Estimates of these externalities are seldom used in analyses since little data exists on the quantities of pollutants produced or the extent of damages done. One of the most obvious sources of damage is the cost of sediment removal in drainage ditches. In order to maintain the productivity of nearby cropland, these ditches must be regularly dredged to remove sediment deposits. These deposits are a function of soil loss in the drainage area and physical characteristics of the drainage area. Results indicate that costs of $0.45 per acre of cropland draining into ditches are being incurred annually to remove sediment. In Ohio, costs of sediment removal are at least $1 million annually.

Conservation practices such as reduced tillage, contouring, and other practices which reduce gross erosion can be expected to reduce sediment removal costs. It is estimated that using practices which reduce USLE estimates of gross erosion by one ton per acre would reduce sediment removal costs by $0.10 per acre. Results of this study support the contention that gross erosion near water bodies causes more sediment deposition than distant soil erosion. Conservation practices used in proximity to drainage ditches (e.g. grass filter strips) are expected to be especially effective in reducing sediment deposition.

References

Forster, D. Lynn, "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," Technical Report Series, Corps of Engineers, Buffalo District, 1978.

Forster, D. Lynn and G. S. Becker, "Costs and Income Effects of Alternative Erosion Control Strategies: The Honey Creek Watershed." North Central Journal of Agricultural Economics, 1 (1979): 53-60.

Kasal, James, "Trade-Offs Between Farm Income and Selected Environmental Indicators: A Case Study of Soil Loss, Fertilizer, and Land Use Constraints." Technical Bulletin No. 1550, Economic Research Service, USDA, 1976.

Nagadevara, V. S., Earl O. Heady, and K. S. Nicol, "Implications of Application of Soil Conservancy and Environmental Regulations in Iowa Within a National Framework." Report No. 57, Center for Agricultural and Rural Development, Iowa State University, 1975.

Taylor, C. Robert and K. K. Frohberg, "The Welfare Effects of Erosion Controls, Banning Pesticides and Limiting Fertilizer Applications in the Corn Belt." American Journal of Agricultural Economics, 59 (1977): 25-35.

Wischmeier, W. H. and D. W. Smith, Predicting Rainfall - Erosion Losses from Cropland East of the Rocky Mountains. Handbook No. 282, Washington, D.C.: USDA Agricultural Research Service, 1965.

Lee, M. T., A. S. Narayanan, and E. R. Swanson, "Economic Analysis of Erosion and Sedimentation, Upper Ambarras River Basin." AERR 135, Department of Agricultural Economics, University of Illinois, 1975.

Seitz, Wesley D., "Environmental Regulation: A Framework for Determining Research Needs." American Journal of Agricultural Economics, 61 (1979): 818-823.

Footnotes

Support from the U.S. Army Corps of Engineers, Buffalo District is gratefully acknowledged. Terry Logan and James Wade provided helpful comments on an earlier draft.

[1] $$\frac{\partial SED}{\partial SL} = a_1 \frac{SED}{SL}$$

At the mean values for SED (0.24) and SL (2.85),

$$\frac{\partial SED}{\partial SL} = 0.650 \left(\frac{.24}{2.85}\right) = .055$$

[2] $$\frac{\partial \text{ Benefit}}{\partial SL} = \frac{\partial SED}{\partial SL} \cdot \frac{\partial Cost}{\partial SED} = (.055)(1.87) = \$0.10$$

[3] Estimate from Dr. Byron Nolte, Department of Agricultural Engineering, The Ohio State University.

Appendix I. Mean and Standard Deviation for Characteristics of Sampled Watersheds and Drainage Ditches by County.

	Mean	Standard Deviation
I. Crawford County (N=8)		
Ditch Characteristics - Length (feet)	7149	5712
Annual Sediment Deposition (tons per acre in watershed)	0.35	0.52
Cost of Sediment Removal (1979 $ per ton of sediment removed)	2.40	0.84
Watershed Characteristics - area (acres)	814	398
Annual Gross Soil Erosion (tons per (acre)	2.90	1.34
II. Fulton County (N=16)		
Ditch Characteristics - Length (feet)	7208	4733
Annual Sediment Deposition (tons per acre in watershed)	0.16	0.12
Cost of Sediment Removal (1979 $ per ton of sediment removed)	2.40	0.97
Watershed Characteristics - area (acres)	768	428
Annual Gross Soil Erosion (tons per acre)	3.02	1.37
III. Paulding County (N=7)		
Ditch Characteristics - Length (feet)	8719	3118
Annual Sediment Deposition (tons per acre in watershed)	0.20	0.067
Cost of Sediment Removal (1979 $ per ton of sediment removed)	1.33	0.36
Watershed Characteristics - area (acres)	545	207
Annual Gross Soil Erosion (tons per acre)	1.59	0.50

Appendix I (continued)

	Mean	Standard Deviation
IV. Seneca County (N=4)		
Ditch Characteristics - Length (feet)	8441	2929
Annual Sediment Deposition (tons per acre in watershed)	0.44	0.37
Cost of Sediment Removal (1979 $ per ton of sediment removed)	1.23	0.49
Watershed Characteristics - area (acres)	744	621
Annual Gross Soil Erosion (tons per acre)	2.91	1.32
V. Wood County (N=3)		
Ditch Characteristics - Length (feet)	8510	8499
Annual Sediment Deposition (tons per acre in watershed)	0.14	0.19
Cost of Sediment Removal (1979 $ per ton of sediment removed)	1.59	1.03
Watershed Characteristics - area (acres)	489	358
Annual Gross Soil Erosion (tons per acre)	2.92	1.92
VI. Wyandot County (N=6)		
Ditch Characteristics - Length (feet)	4583	5247
Annual Sediment Deposition (tons per acre in watershed)	0.28	0.45
Cost of Sediment Removal (1979 $ per ton of sediment removed)	0.97	0.24
Watershed Characteristics - area (acres)	799	362
Annual Gross Soil Erosion (tons per acre)	3.76	0.72