WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

PAPERS OF THE

1989 ANNUAL MEETING

WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

COEUR D'ALENE, IDAHO

JULY 9-12, 1989

POTENTIAL OFF-SITE BENEFITS FROM TARGETING WIND EROSION IN NEW MEXICO

Paul C. Huszar
Colorado State University

INTRODUCTION

Wind erosion in the western United States represents a major soil conservation problem. Of the over two billion tons of soil eroded annually by wind on nonfederal land in the U.S., nearly 1.8 billion tons or 88 percent are eroded in the western states. Moreover, wind erosion represents about 37 percent of the total soil erosion in the U.S., so that wind erosion in the western states must represent nearly a third of the national soil erosion problem (SCS, 1984).

Besides the on-site costs of reducing production and increasing the operating and maintenance costs of farmers and ranchers, wind erosion also causes significant off-site costs. In addition to the more publicized impacts on health of particulate pollution, wind erosion results in off-site costs to individuals and firms in the form of increased cleaning, maintenance and replacement expenditures, and reduced consumption and production opportunities.

In fact, the major costs of wind erosion are likely off- site. For example, the on-site costs of wind erosion in New Mexico are estimated to be $10 million annually (Davis and Condra, 1985). These on-site costs, however, are dwarfed by the estimated off-site costs of wind erosion to New Mexico households of nearly $458 million annually (Huszar and Piper, 1986).

Annual off-site wind erosion costs in the western United States are estimated to be between $3.76 billion and $12.08 billion (Piper, 1988). By comparison, off-site water erosion costs for the U.S. are estimated to be between $3.2 billion and $13 billion per year (Clark, Haverkamp and Chapman, 1985). That is, off-site wind erosion costs maybe of equal magnitude to off-site water erosion costs.

Existence of these damage costs alone does not make wind erosion a problem requiring public action. Public action is justified only if these costs can be reduced and if the cost of reducing them is less than the damage cost reductions themselves. Farmers and ranchers have an economic incentive to control on-site costs whenever control costs are less than the damage costs, but they have no comparable incentive to control off-site costs which they do not bear (Crosson, 1986). If public action is justified, then the justification is likely to be in terms of reducing off-site costs.

In addressing erosion problems, it has been argued that targeting will increase the efficiency of soil conservation programs. It has been observed that, while U.S. Department of Agriculture (USDA) conservation efforts have been spread rather widely and uniformly throughout the country, resource problems are concentrated in limited geographic areas. In response to this argument, a national program to target conservation efforts was initiated by the USDA in 1981 (Stults, et. al., 1987).

Currently, the major criterion for targeting is tons of soil lost, with moderate emphasis on productivity and practically no emphasis on environmental and economic factors (Nielson, 1986). It maybe the case for wind erosion, as it is for water erosion, that failure to consider the off-site returns from targeting conservation programs leads to economically inefficient programs (Ribaudo, 1986).

Measurements of off-site costs of wind erosion are relatively recent. The relationship between on-site erosion and off-site costs and the implications of reducing these costs have not been explored. The purpose of this paper is to begin the exploration by developing a simple aggregate model of the damage relationship which can be used to provide, at least, the flavor of the issues. The paper examines the potential off-site returns from reducing wind erosion and the conflict between the use of economic and physical criterion for targeting wind erosion control practices. Since the only existing measurements of off-site costs of wind erosion are for New Mexico, the analysis is conducted for that state.

OFF-SITE COSTS

An empirical study of off-site costs of wind erosion in New Mexico was conducted in 1985 (Huszar and Piper, 1986). This appears to be the first and, to date, the only study to measure the off-site costs of wind erosion.

Off-site costs of wind erosion were estimated in the 1985 study using a mail survey of a random sample of households. Two mailings of the questionnaire and a reminder card were used. Respondents were asked to estimate average costs incurred by category (i.e., exterior painting, landscaping, automotive maintenance and repair, interior cleaning and laundry, health, and recreation). Questionnaires were sent to 900 households and 242 (27 percent) responded.

The 1985 study estimated off-site costs of wind erosion for the entire state of New Mexico and for six regions within the state. The Soil Conservation Service divides New Mexico into nine Major Land Resource Areas (MLRA's). Each MLRA consists of regions of the state with similar soil and climate characteristics. For the purposes of the study, MLRA 39 was combined with MLRA 36 and MLRA 51 was combined with MLRA 48, since in both cases these are relatively small MLRA's with similar characteristics to the larger MLRA.

Table 1 summarizes the results of the 1985 study. Total annual off-site costs from all sources of wind erosion were estimated to be $465.84 million, or approximately $340 per person. In other words, per capita off-site costs of wind erosion averaged $0.93 per day. The cost estimates for the MLRA's do not differentiate by location of the source of the blowing sand and dust, but for simplicity in the later calculations, it is assume that the origin of the costs is within the MLRA.

The question is how much of these costs could be avoided through conservation and other control activities. To answer this question, the cost estimates must be translated into returns from control practices. Necessary to this translation is a cost function which relates on-site erosion rates to off-site costs.

COST FUNCTION

It is expected that off-site costs of wind erosion will depend upon both the level of erosion and the amount of property at risk. Moreover, since a major

Table 1. Population, Income, Wind Erosion Rate, Area and Off-Site Household Costs For New Mexico MLRA's

MLRA	Population	Per Capita Income ($)	Wind Erosion (tons/acre)	Acres (million)	Off-Site Costs ($ million)
37	92,500	5,814	2.8	3.53	28.28
36/39	158,400	4,803	1.1	15.53	60.29
42	764,400	6,407	6.1	27.39	256.02
48/51	160,900	6,313	0.2	8.78	22.67
70	56,000	4,553	1.9	11.42	24.10
77	136,900	6,242	6.4	10.93	66.24
Total	1,369,100	---	---	77.58	457.60

Source: Bureau of Census (1982); Huszar and Piper (1986).

component of the off-site costs are due to interior and exterior cleaning (Huszar, 1988), attitudes of individuals towards the cleaning of blown dust should affect the level of costs incurred.

A household cost function is estimated using a multiple regression analysis of the 242 survey respondents using the rate of wind erosion, household income, whether the house is owned or rented, and the number of years at the present address. Erosion rates by MLRA were obtained from the 1982 National Resource Inventory (SCS, 1984). It would have been desirable to use erosion rates specific to each individual observation, but erosion rates by individual locations are unavailable.

Income level is used as a proxy for the value of property at risk. Respondents indicated their income as falling within one of eight levels: less than $5,000, $5,000 to $9,999, $10,000 to $14,999, $15,000 to $19,999, $20,000 to $24,999, $25,000 to $34,999, $35,000 to $50,000 and over $50,000. Income is entered as falling within levels 1 through 8.

Whether respondents own or rent their home and the number of years they have lived at their present location are used as proxy measures of attitudes towards cleaning blown dust. House owners are expected to expend more time on interior and exterior cleaning than renters, due to pride of ownership and protection of their investment. On the other hand, the more years an individual has lived in an area affected by wind erosion, the more tolerant of blowing dust they are expected to be and, thus, the less time they are expected to expend on cleaning.

The cost function derived from the regression analysis is shown in equation (1):

$$\text{(1)} \quad \ln TC = 2.98 - 0.14\, X^{-2} - 0.09\, Y^2 + 0.01 Y^3 + 2.40\, Z - 0.02\, W$$

$$(7.514) \quad (2.011) \quad (2.251) \quad (5.912) \quad (2.578)$$

$R^2 = 0.31$ D.F. = 236

where: TC = household costs from blowing soil,
X = wind erosion rate (tons/acre),
Y = household level income (1 to 8),
Z = own (2) or rent (1), and
W = years at present residence.

Equation (1) explains 31 percent of the variation in household costs due to wind erosion. The t-values, shown in parentheses, indicate that the erosion rate, years at the present residence and the dummy variable for ownership are all significant at the 0.01 level, while the income terms are significant at the 0.05 level.

Equation (1) agrees with the hypothesized relationship. Moreover, alternative functional forms representing costs increasing linearly with the level of wind erosion and at an increasing rate with the level of wind erosion were tested and found to explain significantly less variation in off-site costs and to have less significant coefficients of the independent variables than equation (1). Equation (1) is also similar to a function derived for off-site wind erosion costs by Piper (1989).

Equation (1) predicts that off-site costs will increase with the level of wind erosion, but, beyond the initial incidence of blowing dust, off-site costs will tend to increase less and less as the level of erosion continues to grow. For example, more time and effort is likely necessary for household cleaning as the amount of dust deposited in the home increases, but these costs likely increase less than proportionately with the dust level. The same amount of time and effort is likely necessary to vacuum a carpet with one millimeter of soil as with two millimeters of soil, though more vacuum bags and time to change bags are probably needed for the two millimeters of soil. But the costs do not double.

It is expected that increasing the property at risk will increase the off-site costs and that income is a good proxy for property at risk. Equation (1) predicts that off-site costs initially decrease as income increases and then eventually increases. This maybe due to income reflecting not only property at risk, but also time to engage in cleaning activities. That is, since off-site costs are largely composed of interior and exterior cleaning costs, it appears that households have less time for cleaning up to an income level of approximately $25,000 to $34,999. Beyond this income level, household incomes and off-site costs are positively correlated.

As expected, equation (1) predicts that households owning their home incur greater off-site costs than do renters. Also, the longer households have been at their current residence, the greater their tolerance to blowing dust and, thus, the smaller the off-site costs incurred.

A major shortcoming of the cost function is that it treats all wind erosion and all property at risk alike. It is likely, however, that erosion nearer population centers is responsible for greater off-site costs than erosion occurring further away and that property on the periphery of cities incurs greater costs than property more protected within the city. Moreover, the cost function ignores wind direction. But such distinctions require a transport model for the wind erosion and, while many models exist for localized soil movements, none has been found to predict the soil movements necessary for this study. Further research is needed to fine tune the damage function to account for such locational factors.

Another shortcoming of the cost function is that it is likely only a partial indicator of social costs, because it is based on estimates heavily weighted by interior and exterior cleaning costs. Health, aesthetic and other costs not adequately measured by the 1985 study are needed to fully define a social cost function. This issue also requires further research.

REDUCTION OF OFF-SITE COSTS

If income and attitudes towards cleaning are held constant, then the cost function represented by equation (1) reduces to:

$$(2) \qquad TC = e^{(A - 0.14 X^{-2})}$$

where: $A = 2.98 - 0.09 Y^2 + 0.01 Y^3 + 2.40 Z - 0.02 W$

The off-site benefits of a conservation practice (TB) which reduces the rate of wind erosion is, then, the difference between the off-site costs without a reduction and the off-site costs with the reduction:

$$(3) \qquad TB = B - e^{[A - 0.14(X_{w/o} - R)^{-2}]}$$

where:

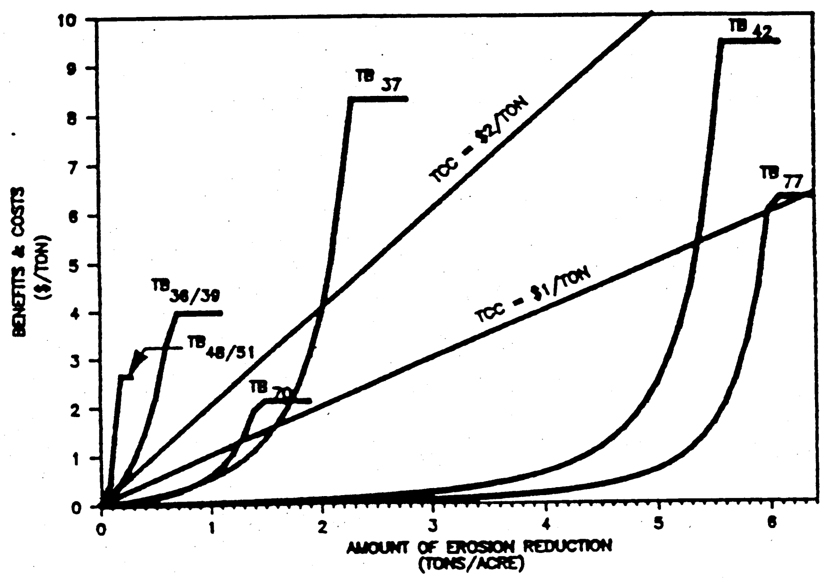
B = current level of off-site costs
R = reduction in wind erosion rate;
$X_{w/o}$ = wind erosion rate with no reduction,

Equation (3) indicates that off-site benefits increase at an increasing rate with the amount wind erosion is reduced up to an erosion rate near zero. That is, small reductions in wind erosion rates yield relatively small off-site benefits, but the off-site benefits increase more than proportionately as the reduction in the wind erosion rate increases. Contrary to most conventional benefit curves, the off-site benefits of wind erosion reductions demonstrates significant increasing returns, as shown by the graphs of equation (3) for each MLRA in Figure 1.

OPTIMAL LEVEL OF CONTROL AND TARGETING

The optimal level of erosion control maximizes net benefits. The off-site benefits of varying levels of erosion control are estimated by equation (3). The costs of reducing erosion on such a broad scale, however, may be impossible to determine. Reducing wind erosion on rangeland, for example, may cost practically nothing or as much as $20 per acre [4,10]. Conservation tillage for reducing erosion on cropland may actually cost less than

Figure 1. Projected Off-Site Benefits by MLRA & Hypothetical Costs of Reducing Wind Erosion in New Mexico



conventional tillage on an annual basis and the initial conversion costs may be covered in as little as one year [2, 12]. Moreover, the available cost estimates cannot be expressed in terms comparable with the benefits estimated by equation (3).

The costs of controlling wind erosion likely increase at an increasing rate with the level of control. That is, the marginal cost curve for reducing wind erosion is likely upward sloping. But the marginal benefit curve is also upward sloping, so that the conventional method of equating marginal benefits to marginal costs may not maximize net benefits. Due to this possibility, it is easier, especially with a computer, to determine the optimum level of control in terms of total benefits and costs, rather than in marginal terms. Moreover, for simplicity in illustrating the nature of the optimal level of erosion control, it is assumed that the cost of controlling wind erosion is the same for all MLRA's and increases at a constant rate.

Suppose the total cost of controlling wind erosion (TCC) is the same for all MLRA's and is equal to $2 per ton per acre. As can be seen from Figure 1, the total costs of control are greater than the total off-site benefits for all control levels in MLRA's 42, 70 and 77. Only in MLRA's 36/39, 48/51 and 37 do total benefits exceed total control costs.

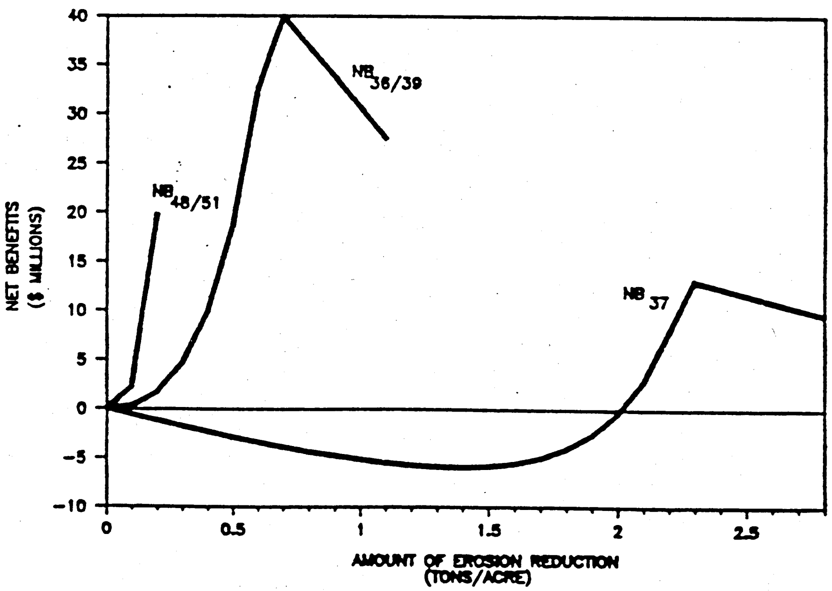
Total benefits exceed total control costs for all levels of wind erosion reductions in MLRA's 36/39 and 48/51, but the costs of control initially exceed the benefits in MLRA 37. That is, any level of erosion control pays in MLRA's 36/39 and 48/51, but erosion control only breaks even at approximately 2 tons per acre in MLRA 37.

Without a budget constraint, the optimum level of control is equal to the maximum amount of erosion in the three MLRA's. That is, erosion should be controlled at 0.2 tons per acre in MLRA 48/51, 1.1 tons per acre in MLRA 36/39 and 2.8 tons per acre in MLRA 37. Erosion control would not pay for itself in any of the other MLRA's.

With a budget constraint, the optimum level of control is between the breakeven level, where benefits equal costs, and the maximum possible level of control, or it is zero. In MLRA 48/51, the constrained optimum level of control will be between 0 and 0.2 tons per acre and in MLRA 36/39 it will be between 0 and 1.1 tons per acre, but in MLRA 37 it will be between 2.0 and 2.8 tons per acre.

If the budget is insufficient to attain positive net benefits in all regions, then it should be allocated between regions in order to maximize total net benefits. This requires that the sizes of the regions also be considered. Figure 2 shows the total, net benefits of erosion reduction for MLRA's 48/51, 36/39 and 37. A limited budget should be allocated to the MLRA with the greatest positive net benefit until the budget is exhausted.

Figure 2. Total Net Benefits With Erosion Control Costs Equal to $2 Per Ton



For example, with a budget of $38 million, net benefits will be maximized by treating the 8.78 million acres of MLRA 48/51 to the maximum reduction level of 0.2 tons per acre and the 15.53 million acres of MLRA 36/39 to the maximum reduction level of 1.1 tons per acre. This would exhaust the budget and maximize net benefits at $45.3 million, yielding a benefit/cost ratio of over 2.

It is important to recognize that Figures 1 and 2 imply that no control may be better than some erosion control. Clearly, no control is optimum in MLRA's 42, 70 and 77 when the average cost of control is $2 per ton per acre. And no control is better than a control level less than the breakeven level of 2.0 tons per acre in MLRA 37.

By comparison, targeting erosion control on the basis of the level of erosion would yield much different results. For example, if the erosion rates shown in Table 1 are used to rank the MLRA's for erosion control, then MLRA 37 would rank third behind MLRA's 77 and 42, MLRA 36/39 would rank fifth, and MLRA 48/51 would rank last. But at an average erosion control cost of $2 per ton per acre, any erosion control level in MLRA's 42, 70 and 77 will yield a negative net return.

If a lower cost of erosion control is considered, then the feasible set of regions increases. Suppose erosion control costs average $1 per ton per acre, then erosion control is feasible in all of the MLRA's, as shown by Figure 2. All levels of erosion control yield positive net benefits in MLRA's 36/39 and 48/51. The breakeven levels of control are approximately 1.6 tons per acre in MLRA 37, 1.2 tons per acre in MLRA 70, 5.4 tons per acre in MLRA 42 and 6.0 tons per acre in MLRA 77. Again, however, some control is not necessarily better than no control.

CONCLUSIONS AND LIMITATIONS

Off-site costs of wind erosion dwarf the on-site costs. In New Mexico, the off-site household costs are estimated to be $458 million per year, while the on-site costs are only $10 million. Moreover, the farmer has no economic incentive to reduce off-site costs, while there is an economic incentive for farmers to reduce on-site costs. There is a strong rationale for public action to be directed towards reducing the off-site costs.

The off-site costs of wind erosion are a decreasing function of the erosion rate. The implication is that off-site returns from erosion control are small from relatively low levels of control and that significant returns will only be realized once nearly all the erosion is controlled.

Targeting erosion control practices based upon the amount of erosion does not guarantee economic efficiency. Economic efficiency exists when net benefits are maximized. In New Mexico, depending upon the costs of control and the available budget, net benefits maybe maximized by targeting MLRA's with relatively low erosion levels.

Moreover, it appears that breakeven levels of erosion control exist such that levels less than this threshold cost more than the benefits produced. That is, some erosion control is not always better than none at all.

Finally, these are admittedly crude approximations. Major limitations to assessing the off-site returns from erosion control are the absence of a suitable dust transport model and the lack of sufficient erosion control cost data. Moreover, computations of returns on such a broad scale as MLRA's clearly are likely to miss significant returns from targeting within the MLRA's. Before this approach can be made operational, these deficiencies must be rectified. But as stated at the outset, the purpose of this paper is to provide the flavor of the issues and, hopefully, to stimulate further research.

REFERENCES

Clark, Edwin H., Haverkamp, Jennifer A. and Chapman, William. 1985. Eroding Soils: The Off-Farm Impacts. Washington, D.C.: The Conservation Foundation. 174.

Crosson, Pierre R. 1986. "Soil Erosion and Policy Issues," in Agriculture and the Environment, ed. by Tim T. Phipps, Pierre R. Crosson and Kent A. Price. (Washington, D.C.: Resources for the Future). 35-73.

Crosson, P., Hanthorn, M. and Duffy, M. 1986. "The Economics of Conservation Tillage," in No Tillage and Surface Tillage Agriculture, ed. by M.A. Sprague and G.W. Triplett. (New York: John Wiley and Sons). 409-436.

Davis, Robert and Condra, Gary D. 1985. The On-Site Costs of Wind Erosion in New Mexico. Final Report to Soil Conservation Service, U.S.D.A., Albuquerque, New Mexico. Department of Agricultural Economics, Texas Tech University, Lubbock, Texas.

Dawson, George. 1983. An Assessment of Best Management Practices For Controlling Non-Point Pollution of New Mexico Rangelands. Draft of Final Report. New Mexico State University, Agricultural Experiment Station, Las Cruses, New Mexico. January.

Huszar, Paul C. and Piper, Steven L. 1986. "Estimating the Off- Site Costs of Wind Erosion in New Mexico." Journal of Soil and Water Conservation. 41(6): 414-416.

Huszar, Paul C. 1988. "Economics of Off-Site Damages and Control of Wind Erosion." Proceedings of 1988 Wind Erosion Conference. Sponsored by Texas Tech University, Soil Conservation Service and Monsanto. Lubbock, Texas. April.

Nielson, James. 1986. "Conservation Targeting: Success or Failure?" Journal of Soil and Water Conservation. 41(2): 70-76.

Piper, Steven L. 1988. "Measuring the Particulate Pollution Damages from Wind Erosion in the Western United States". Journal of Soil and Water Conservation. (forthcoming).

Piper, Steven L. 1989. "Estimating the Offsite Benefits from a Reduction in Wind Erosion and the Optimal Level of Wind Erosion Control: An Application in New Mexico." Journal of Soil and Water Conservation. (forthcoming).

Ribaudo, Marc O. 1986. "Consideration of Offsite Impacts in Targeting Soil Conservation Programs". Land Economics. 62(4): 402-411.

SCS. 1984. 1982 National Resource Inventory. USDA, Washington, D.C.

SCS. 1986. "State Average Cost Data. New Mexico SCS Handbook. November.

Stults, Harold; Dawson, Robert; Raitt, Daryll; and Williams, Jerry. 1987. Targeting Erosion Control: Economic Effects. Economic Research Service, U.S.D.A, Conservation Research Report No. 36.

Troeh, F.R., Hobbs, J.A. and Donahue, R.L. 1980. Soil and Water Conservation: For Productivity and Environmental Protection. New Jersey: Prentice Hall. 616.

U.S. Bureau of the Census. 1982. Statistical Abstract of the United States: 1982-1983. Washington, D.C