EFFICIENCY AND EQUITY ASPECTS OF NONPOINT SOURCE POLLUTION CONTROLS

Stan R. Spurlock and Ivery D. Clifton

Achieving water quality goals will necessitate adoption of best management practices (BMP's) by some or all farmers.[1] Water quality is expected to improve as farmers adopt BMP's such as conservation cropping systems, structural measures, and conservation tillage methods. Currently, there is an absence of pollution abatement incentives strong enough to induce farmers to abate sediment, nutrients, and pesticides to desirable social levels. Although a specific socially optimal level of pollutants may be difficult (or impossible) to quantify, the U.S. Congress, by passing the Federal Water Pollution Control Act Amendments of 1972 (P. L. 92-500), has demonstrated the need for improvements in water quality. The stated goal of this legislation is to eliminate discharges of pollutants into navigable waters by 1985. This goal may not be achieved in the allotted time period unless incentives of sufficient magnitude and scope evolve. Since market forces in the private sector have not sufficiently reduced pollutant emissions, public intervention may be needed to create programs that will alleviate the non-point source pollution (NSP) problem. Possible pollution control measures include regulation, taxation, or subsidization of pollution emissions or reductions, production practices, or input usage. Educational programs geared toward informing both the public and farmers about the benefits and costs of various pollution abatement measures may also be instigated. Agricultural economists have, through various types of analyses, attempted to anticipate the economic consequences of proposed control measures. Knowledge concerning the amounts and distribution of costs and benefits of potential programs would help policy-makers determine the socially desirable program.

Restricting soil loss on each cropland acre to some specified level has generally been the most common policy studied. A policy of uniform soil loss restrictions (standards) presents two problems. First, as Hurt and Reinschmiedt among others point out, reducing erosion might reduce sediment, but may not achieve water quality goals. Second, uniform restrictions achieve a given level of total abatement at a higher resource cost than taxes on pollution emissions or subsidies on pollution abatement. The fact that soil loss standards are more costly (excluding administrative costs) than taxes or subsidies is not new (Randall, pp. 174–75). However, some states have adopted soil loss standards (some being accompanied by cost-sharing programs) and it appears that many other states may do the same (Harder et al.). An alternative policy to uniform restrictions, taxes, and subsidies which has not usually been considered is one in which restrictions are set at different levels for different polluters. The argument presented in this paper is that a policy imposing differential restrictions may, under certain conditions, be desirable when efficiency and equity aspects are considered.

One criterion for program acceptance might be economic efficiency—obtaining the most abatement per dollar of costs. The optimum level of abatement would occur at the point where marginal social cost equals marginal social benefit. Costs have previously been measured as increases in production expenditures (Alt and Heady; Nicol et al.), decreases in net farm revenue (Kasal; Forster and Becker), and changes in consumers' plus producers' surplus (Taylor and Frohberg; Osteen and Seitz). Also, direct and secondary impacts have been analyzed (Palmini et al.; Miller and Everett). Benefits derived from pollution abatement (or costs of pollution damages) have been estimated in a few studies (Lee et al., 1974a; Lee et al., 1974b; Narayanan et al., 1974b). Taylor et al, 1978, attempted to estimate administrative costs. In this study, only decreases in net farm revenue are included as costs of pollution control. No attempt was made to estimate administrative costs, abatement benefits, or secondary impacts. It is recognized, however, that proper measurement of such costs and benefits is imperative if society is to select efficient programs over more inefficient ones.

Another criterion for policy acceptance might be equity; the costs of control should be borne

---

Stan R. Spurlock is Assistant Professor of Agricultural Economics, Mississippi State University. Ivery D. Clifton is Associate Professor of Agricultural Economics, University of Georgia.

[1] BMP refers to a practice or combination of practices that is determined by a state or designated areawide planning agency to be the most efficient and practicable (including technological, economical, and institutional considerations) means of controlling point and nonpoint pollutants at levels compatible with environmental quality goals.

equally among the polluters.[2] Kasal recognized that distribution of income among farmers and various income groups is important, but did not consider this aspect in his model. Different policies could have different impacts on farmers, taxpayers, and consumers. Forster and Becker demonstrated that farmers prefer subsidies, then regulations, and finally taxes, while taxpayers prefer these policies in opposite order. Taylor and Frohberg concluded that an increase in food prices would be more harmful to low income consumers than an increase in income taxes due to the progressive nature of our tax system. Miller and Gill examined the equity consequences of applying two different NSP control policies. They found that effluent charges result in a more equal distribution of net income losses than a statewide soil loss standard applied to all farms. To the extent that equity considerations are important, the most equitable policy would be preferred over other policy alternatives, given the same level of efficiency. However, there may be trade-offs between equity and efficiency.

The objectives of this paper are: (1) to demonstrate graphically that restrictions such as uniform soil loss standards are less efficient *and* equitable than some other NSP control measures; and (2) to empirically investigate efficiency and equity impacts from various policies for a river basin in Georgia.

THEORETICAL CONSIDERATIONS

The efficiency and equity aspects of restrictions, taxes, and subsidies are illustrated in Figure 1 for three hypothetical farms in a river basin. Farms having different topographic features, soil types, and management systems generate different amounts of soil loss. These factors are also important in determining the amounts of sediment delivered to waterways. Initially, with no sediment abatement (the origin), Farms 1, 2, and 3 deliver OD_1, OD_2, and OD_3 tons/acre of sediment, respectively.[3] Total basin delivery, OD_b, is the sum of the individual farm deliveries. Assume each farm can, by adopting BMP's, reduce all sediment deliveries and that the incremental costs of abating sediment are directly related to the quantity of sediment abated.[4] The marginal costs of abatement for the three farms are the curves MC_1, MC_2, and MC_3. The horizontal summation of these curves is the basin marginal cost of abatement, MC_b.

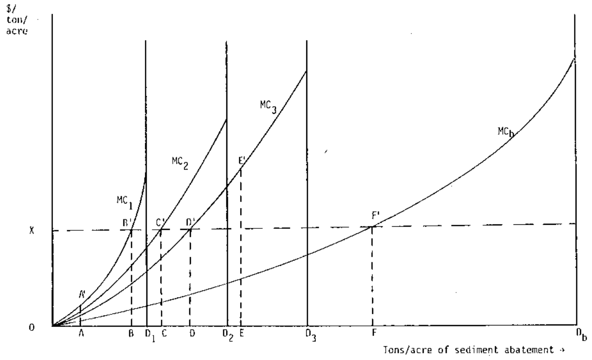


FIGURE 1. Efficiency and Equity Aspects of Restrictions Versus Taxes-Subsidies

One policy may be to restrict per acre deliveries of sediment to some specified amount (one-half ton per acre, for instance). If the standard is less than the quantity being delivered, then the farm will have to reduce deliveries. The restriction level is met when Farm 1 abates OA (delivers AD_1) tons, Farm 2 abates OC (delivers CD_2) tons, and Farm 3 abates OE (delivers ED_3) tons. Distances AD_1, CD_2, and ED_3 are equal and represent the uniform sediment delivery restriction level applied to each farm. The total cost of abatement for any farm is the area under the marginal cost curve between the origin and the level of abatement. Thus, Farm 1 has the lowest total costs (OAA′) and Farm 3 has the highest total costs (OEE′) under a uniform restriction policy.

Within the basin, OF tons of sediment have been abated, leaving deliveries of FD_b, an acceptable level. The quantity OF equals the sums of OA, OC, and OE while FD_b equals AD_1, CD_2, plus ED_3. Efficiency and equity can, however, be improved by applying a tax per unit of delivery or subsidy per unit of abatement. The appropriate tax-subsidy rate is the vertical distance between F and F′. A tax of OX \$/ton/acre will induce farmers to abate sediment as long as the tax rate is greater than the marginal cost of abatement. A subsidy of OX \$/ton/acre will induce farmers to abate as long as the marginal cost of abatement is less than the subsidy rate. Thus, the equilibrium levels of abatement are identical under either the tax or subsidy policy provided there are no differences in transaction costs or income effects. In this example, Farms 1, 2, and 3 would abate OB, OC, and OD tons, respectively.

Comparison of a tax-subsidy policy with a regulation policy reveals some important results. Farm 1 abates more (delivers less) sediment, Farm 2 abates an equal amount of sediment, and

---

[2] The definition of equity used assumes only one type of societal value judgment. In some instances, equity may imply that the costs of abatement should accrue to those who benefit from the improvement in water quality. In other cases, an equitable policy is one that distributes costs either in proportion to damages or by ability to pay. Much debate centers on the definition of equity when dealing with economic policies. Just, Hueth, and Schmitz state that ". . . equity has to do with how equitable goods are distributed among individuals." This circular definition is of little value in forming a precise meaning of equity. In this paper, however, the most equitable policy is defined as the one resulting in the most equal cost distribution among farmers. This definition is implied by Miller and Gill, also. The authors realize that other distributional impacts may be important, but identifying them is beyond the scope of this research.

[3] In this graph, movements from left to right represent increases in abatement and decreases in emission. As abatement increases, emission decreases.

[4] Costs of abatement for this example are defined as losses in net farm revenue accompanying adoption of BMP's. These costs do not include administrative costs or regional income impacts. They only represent the costs to the farm firms of undertaking pollution control practices.

Farm 3 abates less (delivers more) sediment under a tax-subsidy policy than under a uniform regulation policy. Also, the increased costs of Farm 1 are less than the reduced costs of Farm 3 (AA'B'B<DD'E'E). Thus, efficiency is increased with a tax-subsidy policy because the total basin abatement costs are reduced. Also, the tax-subsidy policy is more equitable since costs are distributed more evenly among the farms. Applying a tax-subsidy policy (identical to applying the equi-marginal principle) is more efficient and equitable than applying a restriction policy as long as there are differences in either quantities of pollution delivered or marginal costs of abatement among farms.

In discussing the tax-subsidy policies, a second aspect requires consideration. A tax policy imposes additional costs to farmers above the abatement costs for those units of pollution not abated. Thus, farmers must pay taxes for the quantities of pollution delivered. With a subsidy, taxpayers must pay for the quantities of pollution abated, providing a net gain to farmers. These additional costs to either farmers or taxpayers may be substantial. An alternative policy that would avoid these additional costs may be needed. One possibility, imposing differential standards at tax-subsidy equilibrium levels, could be feasible if individual marginal cost curves could be estimated. In this example, Farm 1 would be restricted to BD_1 tons/acre, Farm 2 to CD_2 tons/acre, and Farm 3 to DD_3 tons/acre. This solution would maintain the efficiency and equity properties of tax-subsidy policies without imposing additional costs to farmers or taxpayers. Farmers would, however, pay the associated pollution abatement costs unless cost-sharing was made available.

Iowa has enacted a sediment control law which sets different soil loss limits for different land classes. However, cost-sharing assistance is made available to the landowner to cover at least 75 percent of the cost of installing permanent soil and water conservation practices (Greiner). Forster and Becker used differential soil loss restrictions based on the soil loss tolerance factor (T-value) in their model. These T-values vary between soil types and are used to approximate the ideal standard which equates marginal costs across all producers. Soil loss standards set according to T-values would be more efficient and equitable than uniform standards. However, the problem of actual sediment delivery and other forms of pollutants still remains. As noted before, restricting soil loss may not necessarily achieve the optimal level of water quality.

Differential restrictions could be structured so that all farmers pay identical pollution abatement costs. This plan would be less efficient than the equi-marginal restrictions policy but might be desirable if equi-marginal restrictions resulted in "too wide" a cost distribution. Policy-makers need to evaluate the relative trade-offs between efficiency and equity. The preceding discussions do demonstrate that differential restrictions applied equi-marginally are more efficient and equitable than uniform per acre restrictions applied to all farms. Administrative costs may be different under these two policies. Both policies would require monitoring and enforcement at the firm level but differential restrictions would require the identification of restriction levels for each farm. As this may require substantial costs, farms of similar erosion potential could be aggregated into separate classifications. Then only marginal cost of abatement functions for each classification would be estimated to obtain equi-marginal restriction levels. This is, in fact, the procedure used in the empirical analysis of this study.

METHODOLOGY

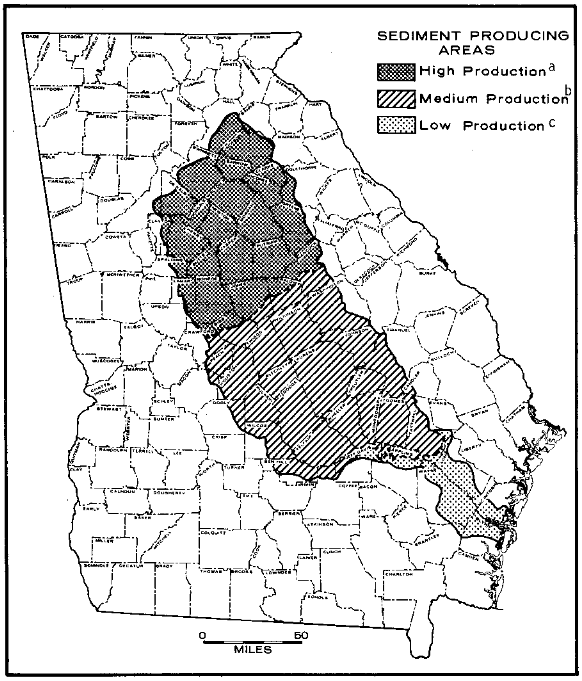
A linear programming model was developed to quantify the economic and environmental quality impacts from equal restrictions versus differential restrictions. Analysis of both solutions reveals the efficiency and equity aspects of the proposed policies.

The model includes an objective function to maximize annual returns to land, management, overhead, and risk. Activities were either crop production, crop selling, or terrace construction. Objective function coefficients for the crop production activities were the negative total costs of producing one acre of that crop.[5] The yields for these crop production activities were transferred to the selling activities and sold at 1979 prices. Unterraced land could become terraced at a specified cost through use of transfer rows. Objective function coefficients for the terrace construction activities were negative, and represented the cost of converting unterraced land to terraced land on a per acre basis. Cost and yield estimates were developed from information provided by the Cooperative Extension Service, University of Georgia, and the Soil Conservation Service.

The study area was the Altamaha River Basin in Georgia (Figure 2). Sediment delivery is more likely to occur in the Piedmont than in the Coastal Plains because the Piedmont has more erosive, steeper sloping soils and a larger sediment delivery ratio. This basin was classified into seven soil resource groups (SRG's) on the basis

---

[5] This analysis is based on the requirement that the firm invest in equipment. The ownership costs of equipment were computed on an annual basis taking into account its expected life. These costs plus variable operating expenses equal the total cost of producing one acre of each activity. The programming solution assumes that the optimal farm organization will remain unchanged over the lifespan of the equipment.



[a] Piedmont
[b] Upper Coastal Plains
[c] Lower Coastal Plains

FIGURE 2. Sediment Producing Areas Within the Altamaha River Basin in Georgia

of comparable agronomic and erodibility characteristics.[6] Two of the SRG's (A and B) were located in the Piedmont province and five of the SRG's (C through G) were in the Coastal Plains region. The crops considered were corn, cotton, peanuts, and soybeans. Alternative BMP's available in the model included straight or contour row farming with or without terraces under conventional or conservation tillage methods. Only corn and soybeans could be grown under conservation tillage methods. Conservation tillage yields were assumed to equal 95 percent of conventional tillage yields. Also, alternative two-year crop rotation systems were available. Corn and peanuts could have a winter grass cover of rye while soybeans could have been double-cropped with wheat. A total of 464 cropping activities were included in the model. Crop acreages within each SRG were constrained to levels established in 1979. If environmental constraints become stringent, cropland could be taken out of production.

Erosion rates for each production activity were estimated by using the Universal Soil Loss Equation (Wischmeier and Smith). Then these erosion rates were multiplied by a sediment delivery ratio (SDR). The SDR's for the Piedmont and Coastal Plains SRG's were .24 and .10, respectively (Georgia Agriculture/Irrigation Technical Task Force Report, 1978). Information concerning the actual levels of sediment in waterways that occur when selected BMP's are used on farms was not available. Thus, the results derived from these models may over- or under-estimate the economic and environmental impacts attributed to each policy.

The model was applied to three situations. First, a baseline solution was obtained by leaving sediment delivery unconstrained. Second, sediment delivery in each SRG was constrained to an average of one-half ton per acre.[7] This situation represents the equal restriction policy.[8] Third, sediment delivery in the whole basin was constrained to an average of one-half ton per acre to represent the equi-marginal restriction policy. In the study by Alt and Heady, one policy was to set maximum limits on gross erosion per acre while another policy was to limit the total amount of sediment delivered to the reservoir. They noted that limits on total sediment delivery would result in a more efficient solution.

Efficiency of a policy can be measured in terms of total basin net income per unit of sediment abatement. That is, given alternative policies which generate equal abatement, the one providing the largest net income for the whole basin is the most efficient policy. The distribution of costs provides the means by which equity can be measured. In this study, the distribution of costs imposed on each SRG is developed for both policies. Using the standard deviation of the cost distributions, the most equitable policy is the one which results in the lowest standard deviation.

RESULTS

Net revenues and sediment deliveries derived using the linear programming model for each of the three situations are presented in Table 1. Impacts from both the equal and equi-marginal restrictions were more severe in the Piedmont SRG's (A and B). This is because the Piedmont is more erosive and delivers a higher percentage of sediment than the Coastal Plains.

Overall efficiency between the equal restrictions and the equi-marginal restrictions can be

---

[6] An SRG is not necessarily a continuous or contiguous land area. Each SRG corresponds to a major soil type found within the basin. These soil types occur somewhat haphazardly throughout the basin, making it difficult to delineate each one on a map such as the one in Figure 2. The major soil types within each SRG are: A-Cecil; B-Pacolet; C-Norfolk; D-Dothan; E-Cowarts; F-Chewacla; and G-Lakeland.

[7] There is nothing "special" about restricting sediment delivery to one-half ton per acre. In fact, other restriction levels were analyzed and results from those models demonstrate that equi-marginal restrictions are more efficient and more equitable than equal restrictions. To conserve space, only the one-half ton per acre restriction results are presented.

[8] Applying the restriction to a whole SRG assumes that all land within that SRG is identical in terms of erosion potential as well as costs of abatement. In aggregate models such as this one, however, it is necessary to make this assumption because focusing on individual production units (or on each acre within the basin) would be prohibitively costly. Soils within an SRG do have similar environmental characteristics such as slope, erodibility, and productivity. It may be useful to consider the river basin as being composed of seven "farms." Soil similarities are found within an SRG, but soil differences occur between SRG's.

TABLE 1. Net Revenue and Sediment Delivery Per Acre for Soil Resource Groups and for the Altamaha River Basin, 1979

	Policy[a]		
SRG	Unconstrained	Equal	Equi-marginal
A	71.65 (4.557)	44.47 (.500)	57.95 (1.117)
B	34.11 (9.028)	9.58 (.500)	11.35 (.618)
C	142.92 (.483)	142.92 (.483)	140.92 (.240)
D	119.25 (.695)	118.36 (.500)	117.25 (.345)
E	68.50 (1.090)	65.47 (.500)	66.50 (.542)
F	52.78 (.555)	52.37 (.500)	50.78 (.333)
G	30.33 (1.605)	20.77 (.500)	26.08 (.782)
Basin[b]	94.74 (1.546)	88.87 (.496)	90.40 (.500)

[a] The top number in each row is net revenue per acre. Sediment delivery per acre is in parentheses. Both net revenue and sediment delivery per acre are averages. Revenue and delivery for each acre within a particular SRG will deviate from these averages.

[b] These basin averages are weighted by the number of acres in each SRG.

TABLE 2. Per Acre Cost Distributions from Equal Versus Equi-marginal Restrictions

	Policy[a]	
SRG	Equal	Equi-marginal
A	27.18	13.70
B	24.53	22.76
C	0.00	2.00
D	0.89	2.00
E	3.03	2.00
F	0.41	2.00
G	9.56	4.25
Basin	5.87	4.34
Standard deviation[b]	11.42	8.01

[a] These costs are derived by subtracting the net revenue of a policy from the net revenue of the baseline solution.

[b] This value was obtained by using the basin cost as the mean.

$$\text{Specifically, s.d.} = \sqrt{\frac{\sum_{i=1}^{n} (C_i - C_b)^2}{n}} \quad \text{for } i = 1, \ldots, 7$$

where C_i is the cost for the ith SRG and C_b is the total basin cost.

TABLE 3. Land Use Under Equal Versus Equi-marginal Restrictions[a]

SRG	Straight Rows, Conventional Tillage	Contour Rows, Conventional Tillage	Contour Rows, Conservation Tillage	Unused Land
	---------------------(acres)	-----------------	-----------------	-------------
A	0 (0)	11,200 (26,095)	70,031 (93,250)	38,069 (0)
B	0 (0)	3,000 (3,000)	4,405 (6,500)	28,395 (26,300)
C	253,500 (0)	0 (253,500)	0 (0)	0 (0)
D	151,957 (0)	123,343 (275,300)	0 (0)	0 (0)
E	0 (0)	170,700 (170,700)	0 (0)	0 (0)
F	41,743 (0)	10,857 (52,600)	0 (0)	0 (0)
G	0 (0)	44,562 (102,000)	62,038 (4,600)	7,500 (7,500)

[a] The top number in each row corresponds to equal restrictions. The number in parentheses corresponds to equi-marginal restrictions.

determined by observing the basin net revenue per acre values. An average savings of $1.53/acre can be obtained by applying restrictions equi-marginally. Farmers in the basin aggregate could save over 1.5 million dollars with equi-marginal restrictions. Equity aspects between the two policies are revealed by analyzing costs for each SRG (Table 2). The equi-marginal restrictions benefit SRG's A, B, E, and G. However, SRG's, C, D, and F must incur greater costs. The cost distribution among the SRG's is more even with the equi-marginal restrictions, as evidenced by the lower standard deviation. Thus, the results suggest that equi-marginal restrictions create a more efficient and equitable solution to the NSP problem than uniform restrictions.

It is interesting to note what BMP's were incorporated to meet sediment delivery restrictions (Table 3). In the baseline solution, all land was planted in straight rows with conventional tillage. A one-half ton per acre restriction applied to each SRG resulted in conservation tillage methods being used as well as land being taken out of crop production in SRG's A, B, and G. Contour rows with conventional tillage were present in all areas except SRG C. Soybeans-wheat double cropping was used extensively but winter covers of rye were only used in SRG E. Equi-marginal restrictions allowed more land to stay in production and caused all land to be under contour rows. Two-year crop rotations were used whenever possible and terraces were not constructed in any solutions.[9]

CONCLUSIONS

Given that policy-makers strive for efficiency and equity, economists must consider both aspects when analyzing a proposed policy. In this

---

[9] Other solutions which allowed cost-sharing for terrace construction were obtained. As the cost-sharing rate increased, more terraces were constructed, especially under the equal restriction policy.

study, theory was reviewed and analysis was conducted demonstrating that in the absence of administrative costs, an equi-marginal approach is more efficient and equitable than equal per acre restrictions. When compared to an equal restriction policy, an equi-marginal restriction policy allows high-level polluters to deliver more sediment, but requires low-level polluters to deliver less sediment. If differential restrictions which equate marginal costs could be determined at the farm level (or even at a sub-basin level), then costs would be distributed more evenly among the polluters, and aggregate basin costs would decline. Administrative costs, although not estimated in this study, could be different under these two policies. Information concerning administrative costs could help policy-makers decide on the most desirable policy.

In this research, two assumptions were implicitly used which, if false, could alter the empirical results. These assumptions were: (1) damages from a unit of sediment in one location are equal to damages from other units of sediment in any other location, and (2) each acre of cropland within the basin causes sediment damage. Possibly, in a large river basin, sediment damage would occur unevenly. Also, the sources of the damage would vary from location to location. In this situation, the most efficient solution would be to locate the damaged areas, locate the sources of those damages, and restrict sediment delivery from those sources. As Moldenhauer and Onstad point out, pollution control may be required at watershed outlets, farm boundaries, or the farm itself. Depending on the circumstances, levels of control at these three locations could vary. Efficient minimization of offsite damages from NSP requires knowledge concerning the pollutant source. Any NSP control policy should require only sources causing damages to incur costs. Results from this study would be different if locations of damaged areas and sources of that damage had been incorporated in the model. The theoretical conclusions, however, would still be valid. That is, equi-marginal restrictions applied to sources causing damages would be more efficient and equitable (for that subset of sources causing damages) than equal per acre restrictions. Certainly, more effort is needed in determining areas where water quality damage is present, quantitatively or monetarily measuring the damage, and locating the sources of damage. These activities might require substantial administrative costs, but could reduce aggregate pollution control costs borne by farmers.

REFERENCES

Alt, Klaus F. and Earl O. Heady. "Economics and the Environment: Impacts of Erosion Restraints on Crop Production in the Iowa River Basin." Iowa State University, Center for Agricultural and Rural Development, CARD Report No. 75, Ames, December 1977.

Forster, D. Lynn and Gary S. Becker. "Costs and Income Effects of Alternative Erosion Control Strategies: The Honey Creek Watershed." *North Central J. of Agr. Econ.* 1(1979):53–60.

Forster, D. Lynn and Gary S. Becker. "Georgia Agriculture/Irrigation Technical Task Force Report." 1978.

Greiner, William H. "Iowa's Experience with a Mandatory Sediment Control Law." *J. of Soil and Water Conservation,* 30(1975):132–34.

Harder, S. M., T. C. Daniel, and F. W. Madison. "Guidelines for Mandatory Erosion Control Programs." *J. of Soil and Water Conservation,* 33(1978):80–84.

Hurt, Verner G. and Lynn L. Reinschmiedt. "Impacts of Non-Point Source Pollution Regulations on Mississippi Agriculture." *S. J. Agr. Econ.,* 11(1979):1–9.

Just, R. E., D. L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy.* New York: Prentice-Hall, 1982.

Kasal, James. "Trade-offs Between Farm Income and Selected Environmental Indicators: A Case Study of Soil Loss, Fertilizer, and Land Use Constraints." Washington: ERS, USDA, Technical Bulletin No. 1550, August 1976.

Lee, M. T., A. S. Narayanan, Karl Guntermann, and E. R. Swanson. "Economic Analysis of Erosion and Sedimentation: Hambaugh-Martin Watershed." University of Illinois at Urbana-Champaign, Dept. of Ag. Econ., Ag. Exp. Sta., AEER 127, July 1974a.

Lee, M. T., A. S. Narayanan, and E.R. Swanson. "Economic Analysis of Erosion and Sedimentation: Sevenmile Creek Southwest Branch Watershed." University of Illinois at Urbana-Champaign, Dept. of Ag. Econ., Ag. Exp. Sta., AERR 127, July 1974b.

Miller, W. L. and H. W. Everett. "The Economic Impact of Controlling Non-Point Pollution in Hardwood Forestland," *Amer. J. Agr. Econ.* 57(1975):576–83.

Miller, William L. and Joseph H. Gill. "Equity Considerations in Controlling Nonpoint Pollution From Agricultural Sources." *Water Resources Bull.* 12(1976):253–61.

Moldenhauer, W. C. and C. A. Onstad. "Achieving Specified Soil Loss Levels." *J. of Soil and Water Conservation,* 30(1975):166–68.

Narayanan, A. S., M. T. Lee, Karl Guntermann, W. D. Seitz, and E. R. Swanson. "Economic Analysis of Erosion and Sedimentation: Mendota West Fork Watershed." University of Illinois at Urbana-Champaign, Dept. of Ag. Econ., Ag. Exp. Sta., AERR 126, April 1974a.

Narayanan, A. S., M. T. Lee, and E. R. Swanson. "Economic Analysis of Erosion and Sedimentation: Lake Glendale Watershed." University of Illinois at Urbana-Champaign, Dept. of Ag. Econ., Ag. Exp. Sta., AERR 131, December 1974b.

Nicol, Kenneth J., Earl O. Heady, and Howard C. Madsen. "Models of Soil Loss, Land and Water Use, Spatial Agricultural Structure, and the Environment." Iowa State University, Center of Agricultural and Rural Development, CARD Report 49T, Ames, July 1974.

Osteen, Craig and Wesley D. Seitz. "Regional Economic Impacts of Policies to Control Erosion and Sedimentation in Illinois and Other Corn Belt States." *Amer. J. Agr. Econ.* 60(1978):510–17.

Palmini, D. J., C. R. Taylor, and E. R. Swanson. "The Potential Economic Impact of Selected Agricultural Pollution Controls on Two Counties in Illinois." University of Illinois at Urbana-Champaign, Dept. of Ag. Econ., Ag. Exp. Sta., AERR 154, December 1977.

Randall, Alan. *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy.* Columbus, Ohio: Grid Publishing, 1981, pp. 174–75.

Taylor, C. Robert, Duane R. Reneau, and B. L. Harris. "An Economic Analysis of Erosion and Sedimentation in Lavon Reservoir Watershed." Texas A&M University, Texas Water Resources Institute, Technical Report No. 88, May 1978.

Taylor, C. Robert and Klaus K. Frohberg. "The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt." *Amer. J. Agr. Econ.* 58(1977):25–36.

U.S. Congress. Federal Water Pollution Control Act Amendments of 1972. 92nd Congress 2nd Session, Washington: U.S. Government Printing Office 1972.

Wischmeier, Walter H. and Dwight D. Smith. *Predicting Rainfall Erosion Losses.* Washington: USDA, Agricultural Handbook No. 537, 1978.