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An Analysis of Public Policies for Controlling Agricultural Water Pollution: A Research Summary

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INTRODUCTION

This paper presents a summary of a recent study which evaluated alternative public policies for the control of agricultural water pollution (Kerns et al.). The study consisted of two parts. The first part, which examined the characteristics and opinions of farmers in the Nansemond-Chuckatuck Rural Clean Water Program area, is reported in a companion publication, "Nonpoint Source Pollution Management: A Case Study of Farmers' Opinions and Characteristics." The second part of the study, which investigated the potential effects of various pollution control policies on farm income and water quality is summarized in this paper.

The study focused on the area around the Nansemond River and Chuckatuck Creek, two coastal watersheds which drain into the James River near where it empties into the Chesapeake Bay. At a time of growing concern about declining water quality in the Bay, the study provides new information about the potential effectiveness of public policy actions for reducing nonpoint source pollution. A watershed model was constructed which allowed a unique opportunity for policy analysis. Unlike previous studies in other areas which generally focused on soil loss as a proxy for nonpoint source pollution, the model used in this study enabled a simultaneous analysis of policy impacts on soil, nitrogen, and phosphorus runoff. Among the polices considered in the study was the Rural Clean Water Program (RCWP), an experimental program begun recently on a pilot basis in 21 watersheds across the country. This program is administered by the Agricultural Stabilization and Conservation Service (ASCS) and provides cost-shares to encourage BMP adoption in areas with acute water quality problems.

STUDY OBJECTIVES

The overall purpose of this study was to analyze the economic relationships among agricultural production activities, nonpoint source pollution control policies, and water quality. The analysis was designed to provide information on the tradeoffs between reductions in nonpoint source pollutants and agricultural income resulting from the implementation of selected BMPs.

More specifically, the objectives of this study were:

1. To determine relevant representative loadings of soil, nitrogen, and phosphorus for principal agricultural activities based on varying soil and slope characteristics and prevailing cropping and livestock activities for the Nansemond and Chuckatuck watersheds.
2. To construct budgeting data for relevant agricultural activities with and without BMPs.
3. To develop an aggregate programming model of the Nansemond and Chuckatuck watersheds that focused on the relationships among agricultural land use practices and nonpoint source water pollution.
4. To evaluate the impacts of various public policy actions to reduce agricultural water pollution on (1) net farm income, (2) land use, (3) crop and livestock production, and (4) loadings of soil and nutrients. Environmental policy measures examined included (1) subsidies, (2) soil loss taxes, and (3) regulations.

PREVIOUS STUDIES

In general, previous economic studies of nonpoint pollution control fall into two broad categories: (1) national and regional studies, and (2) watershed and farm level studies. Most national and regional studies of nonpoint source pollution have utilized linear programming models of agricultural activities. Examples include Bogess, et al.; Wade and Heady; and Wineman et al. Typically, the studies included cropland management strategies as opposed to structural devices as a means of reducing erosion and controlling sedimentation. Wade and Heady, for example, evaluated the control of all nonpoint sediment under the assumption that sediment carries most of the pollutants to surface waters. The researchers examined the adjustments in the agricultural production sector which would result from national environmental quality goals.

The watershed and farm level studies have been more concerned with impacts on farm income and organization for a particular type of agricultural production (White and Partenheimer; Casler and Jacobs; and Walker and Timmons). For example, White and Partenheimer studied the impacts of nonpoint reductions on Pennsylvania dairy farmers. Their results indicated that of the control alternatives studied, no-till cultivation appeared to be the best approach for reducing soil loss. The results of their work demonstrated a considerable trade-off between income and soil loss control. Casler and Jacobs analyzed the costs of reducing phosphorus levels in New York's Cayuga Lake with a linear programming model. They found that a 30 percent reduction in phosphorus could be achieved with less than a 10 percent decline in net farm income. They also noted that the cost of phosphorous reductions from farming was considerably higher than the cost of phosphorous reductions from domestic sewage treatment.

DESCRIPTION OF THE STUDY AREA

Virginia's Nansemond River and Chuckatuck Creek watersheds comprised the study location, primarily because parts of these watersheds were approved in 1981 for a Rural Clean Water Program. The Nansemond River and Chuckatuck Creek are situated on the coastal plains of southeast Virginia. Within the RCWP area, there are 825 farms producing primarily peanuts, corn, soybeans, small grains, and hogs (RCWP Local Coordinating Committee). The study area contains seven water supply reservoirs for nearby municipal areas, and the Virginia State Water Control Board has classified water quality in the area as poor.

DESCRIPTION OF WATERSHED MODEL

A computerized model of the Nansemond and Chuckatuck watersheds, which focused on the relationships among agricultural land use practices and nonpoint source water pollution was used to analyze policy alternatives. A linear programming algorithm was used to solve for the maximum value of the objective function, which reflected the assumed profit maximizing behavior of farmers attempting to earn the maximum possible income given the various physical, financial, and institutional constraints they face. The technical coefficients were developed primarily from farm enterprise budgets. Constraints on resource use reflected the maximum available amounts of various inputs such as land, labor, and capital. The model also contained pollution constraints based on pollutant loading factors. These factors reflected estimated per acre runoff of nitrogen, phosphorus, and sediment for each production activity. It was assumed that reductions in pollutants would translate into improved water quality.

Cost of production data were estimated for each of the major crop and livestock activities in the study area. Using statewide enterprise budgets as guidelines, area specific crop and livestock budgets were developed with information provided by the Cooperative Extension Service, Soil Conservation Service (SCS), and ASCS personnel familiar with local farming practices. Cost data for the BMPs included in the model were obtained from ASCS and SCS personnel involved with designing farm water quality plans for the RCWP. For a given activity, these budgets indicated the quantity of each input utilized, the prices of the inputs, and the variable costs of producing the activity. The costs were subtracted from sales revenue to determine net revenue for each activity. No allowance was made for fixed costs, so the net revenue figures should be viewed as net returns to operators' land, capital, labor and management.

Production activities in the model allowed for the selection of corn, soybeans, wheat, peanuts, and hogs. Variations of each of these enterprises were included to reflect some of the BMPs recommended for use in the area. For example, corn production activities included: conventional tillage corn, conventional tillage corn with sod filter strips, conventional tillage corn with a cover crop, conventional tillage corn with both sod filter strips and a cover crop, and no-till corn. Soybeans and peanuts had the same variations except that no-till soybeans were assumed to be double-cropped with wheat, and there was no conservation tillage activity for peanuts. The various hog enterprises included: pasture finishing, pasture farrow to finish, confinement finishing, confinement farrow to finish, confinement finishing utilizing a Cargill floor, and confinement farrow to finish utilizing a Cargill floor.

Policy alternatives were included in the model in a variety of ways. For example, the effects of regulation were simulated by constraining soil, nitrogen, and phosphorus loadings. Cost-sharing was simulated by decreasing the production cost of activities such as conventional tillage corn with sod filter strips and conventional tillage peanuts with a cover crop. One policy alternative, a tax on soil loss, was included as a separate activity. Parameterizing the objective function value of this activity provided the means by which the effect of the tax was analyzed.

The universal soil loss equation (USLE) was used to provide soil loss coefficients for the model (Wischmeier and Smith). Briefly, the USLE is an equation that predicts gross soil loss per acre as the product of various erosion related factors. Most previous watershed studies have assigned each factor in the USLE equation a weighted mean value for the entire watershed. A shortcoming of this approach is that it fails to recognize that the implementation of a BMP may not significantly affect the mean soil loss factor and thus sensitivity could be lost. As a consequence, this method requires subjectivity and can place model results in question.

A less subjective approach to the use of the USLE was utilized in this study based on a random sample of watershed fields. The study area was segmented into 13 subsheds, with two subsheds broken down further into critical and noncritical areas. From the ASCS county records, a random sample of 10 farms was selected from each subshed or area. Each farm was further divided into parcels where a parcel was defined as a field or part of a field with the same cover and soil type. Soil loss was then determined for all sampled parcels. Finally, the mean USLE value for all field parcels within a subshed or area and with a particular cover became a particular loading factor for use in the model.

The simulated implementation of BMPs was accomplished by recalculating soil loss for all parcels. In the recalculation, however, each parcel was evaluated against BMP design criteria. If the parcel met the criteria, the BMP was assumed implemented for the parcel.

Most previous economic studies of nonpoint source pollution control policy have focused on one pollutant; usually sediment. In this study, loading factors were developed for nitrogen and phosphorus in addition to soil. Phosphorous and nitrogen loadings were estimated using the concept of potency factors and the sediment load obtained from the USLE calculations. These calculations followed procedures outlined in detail by Novotny and Chesters. As the sediment loading factor was modified by BMPs, so were the nutrient loadings. Because of a lack of water quality monitoring data for the Nansemond and Chuckatuck watersheds, statistical relationships developed for another geographic area were used in the calculations. Although ideally one would prefer to use statistical relationships developed for the study area, it is believed that the existing statistical relationships should yield adequate information for determining the relative effects of BMPs on nutrient loadings.

RESULTS

Results from the watershed policy analysis are discussed in this section. The results of twelve different policy scenarios are discussed including a base run of no government pollution policy for comparison purposes. The results include information concerning net farm income, crop and livestock production, soil loss, nitrogen runoff, and phosphorus runoff under each policy scenario. It should be emphasized that the intent here is to indicate the relative impacts of alternative government actions, rather than changes in absolute magnitudes.

The first alternative is the base run of no government induced practices. Next, several regulatory alternatives are examined including a solution each for 25, 50, and 75 percent simultaneous reductions in all three pollutants, and 50 percent reductions in soil, phosphorus, and nitrogen, individually. The effects of three different levels of cost-sharing, 50, 75, and 100 percent, are presented next. Finally, the impacts of a \$0.50 and then a \$1.00 tax per ton of soil loss are presented. Information is given in Table 1 on net farm income and total loadings of soil, nitrogen and phosphorus under the different policies. Effects of the policies on crop and livestock production are shown in Table 2.

Base Run Results. Under the no pollution policy, results in Table 1 indicate a net farm income of \$14,560,670 for the Nansemond and Chuckatuck watersheds. Pollution loadings total 621,116 tons of soil, 61,517 lbs. of nitrogen, and 8,582 lbs. of phosphorus. Table 2 shows the following pattern of agricultural production: 49,247 acres of conventional tillage corn, 2,952 acres of double-cropped soybeans, 8,945 acres of quota peanuts, 29 confinement swine finishing operations (9,686

TABLE 1

Net Farm Income and Pollution Loadings Under Alternative Policies

Policy Alternative	Total Net Farm Income ($)	Total Soil Loss (tons)	Total Nitrogen Loss (lbs.)	Total Phosphorus Loss (lbs.)
Base Run	14,560,670	621,116	61,517	8,582
25% Reduction in all NPSP	14,481,341	465,839	45,517	5,036
50% Reduction in all NPSP	14,377,385	310,561	31,196	2,890
75% Reduction in all NPSP	14,101,442	155,280	20,050	1,609
50% Reduction in Soil Loss	14,386,822	310,558	34,062	3,428
50% Reduction in Nitrogen	14,379,298	327,794	30,759	3,189
50% Reduction in Phosphorus	14,446,901	476,829	43,018	4,291
50% Cost Share	14,959,958	246,348	22,078	1,723
75% Cost Share	14,976,851	246,348	22,078	1,723
100% Cost Share	14,993,744	246,348	22,078	1,723
$0.50 Tax on Soil Loss	14,254,080	457,245	46,195	5,585
$1.00 Tax on Soil Loss	14,110,736	248,848	26,798	2,183

TABLE 2

Crop and Livestock Production
Under Alternative Policies

Policy Alternative	PCNCL[a]	PCNNT[b]	PSBNT[c]	PQNCL[d]	PQNCV[e]	PFDCF[f]	PFFCF[g]	PFDCG[h]	PFFCG[i]	WWSM[j]
Base Run	49,247	0	2,952	8,945	0	29	160	0	7	0
25% Reduction in all NPSP	31,627	13,771	3,800	8,945	0	29	160	0	7	0
50% Reduction in all NPSP	17,055	25,484	6,660	8,945	0	29	160	0	7	0
75% Reduction in all NPSP	3,744	34,515	10,588	8,945	0	29	160	0	7	0
50% Reduction in Soil Loss	17,642	26,901	3,811	8,945	0	29	160	0	7	0
50% Reduction in Nitrogen	16,353	24,133	8,216	8,945	0	29	160	0	7	0
50% Reduction in Phosphorus	28,958	16,643	3,596	8,945	0	29	160	0	7	0
50% Cost Share	3,260	40,877	5,061	8,945	0	29	160	0	7	0
75% Cost Share	3,260	40,877	5,061	8,945	0	29	160	0	7	0
100% Cost Share	3,260	40,877	5,061	8,945	0	29	37	8	30	0
$0.50 Tax on Soil Loss	31,327	14,919	2,952	8,945	0	29	160	0	7	0
$1.00 Tax on Soil Loss	11,968	32,124	4,866	7,361	1,584	29	160	0	7	6,016

[a]PCNCL denotes total watershed acreage of conventional tillage corn.

[b]PCNNT denotes total watershed acreage of no-till corn.

[c]PSBNT denotes total watershed acreage of soybeans double-cropped with wheat.

[d]PQNCL denotes total watershed acreage of conventional tillage quota peanuts.

[e]PQNCV denotes total watershed acreage of quota peanuts with a winter cover crop.

[f]PFDCF denotes total number of confinement swine finishing operations in the watershed, at 334 market hogs, 220 lbs. slaughter weight, per operation.

[g]PFFCF denotes total number of confinement farrow to finish swine operations in the watershed, at 334 market hogs, 220 lbs. slaughter weight, per operation.

[h]PFDCG denotes total number of confinement swine finishing operations with Cargill Floor in the watershed, at 1336 market hogs, 220 lbs. slaughter weight, per operation.

[i]PFFCG denotes total number of confinement farrow to finish swine operations with Cargill Floor in the watershed, at 1336 market hogs, 220 lbs. slaughter weight, per operation.

[j]WWSM denotes total number of acres protected by grassed waterways. (Note: it does not represent the total acreage in grassed waterways.

hogs), and 160 confinement farrow to finish swine operations (53,440 hogs). As expected no BMPs come into this solution. Note that peanut acreage is only 8,945. This represents the maximum acreage consistent with maintaining federally regulated poundage quotas. Peanut acreage remains constant across all policy scenarios at this maximum level.

Impact of Regulatory Programs. The second row of Table 1 shows that a regulatory program requiring a 25 percent reduction in all 3 pollutants results in a decline in net farm income of $79,239 (from $14,560,670 to $14,481,341). As shown in Table 2, the 25 percent reduction in pollutants is primarily achieved by a shift from conventional till to no-till corn. No-till corn acreage (PCNNT) increases from 0 in the base run to 13,771 acres. There is also a small increase in the acreage of soybeans double-cropped with wheat (PSBNT), an activity that is only slightly erosive. Nitrogen and phosphorus are actually reduced by more than 25 percent in this case, apparently because the change in cropping activities necessary to bring about the 25 percent reduction in soil loss results in cropping patterns that reduce nitrogen and phosphorus runoff by a greater proportion. This is also true under the 50 and 75 percent reductions described below.

A regulatory program that requires a 50 percent reduction in all three pollutants further diminishes net farm income. Compared to the base run, net farm income would fall $183,285. No-till corn acreage (PCNNT) is almost twice that under the 25 percent reduction and double-cropped soybean acreage (PSBNT) also increases dramatically.

A 75 percent reduction in the three pollutants leads to a decline in net farm income of $459,228, which is 3.2 percent of the base run net farm income. This would be accompanied by decreases in conventional tillage corn (PCNCL), by increases in no-till corn (PCNNT) and double-cropped soybeans (PSBNT), and by no change in peanut or hog operations.

The results for a required 50 percent reduction in soil loss have similar effects to the 50 percent reduction in all pollutants. Income declines by $173,848 as compared to the base run and considerable acreage shifts from conventional till (PCNCL) to no-till corn (PCNNT). This is one of only two alternatives under which grassed waterways enter the solution. Sufficient amounts are planted to protect 647 acres of cropland.

A regulation requiring a 50 percent reduction in nitrogen reduces income by $181,372. Soybean acreage (PSBNT) is much greater for this option than the previous one (8,216 acres vs. 3,811 acres), because soybeans are a legume, requiring no application of nitrogen fertilizers.

The 50 percent reduction in phosphorus alternative results in a net farm income loss of $113,769. As compared to the 50 percent reduction in either soil loss or nitrogen, this policy scenario causes a much greater area to be devoted to conventional till corn (PCNCL) as opposed to no-till corn (PCNNT). The phosphorus reduction also requires a much smaller decline in income than do the comparable reductions in nitrogen and soil. Thus, depending on which pollutant is regulated, quite different impacts on farmers could result.

Impact of Cost Sharing Programs. The next set of policies considered were the cost-sharing programs. Under the first cost-share alternative, a 50 percent subsidy was assumed on all BMPs except for no-till which was assigned a $15 per acre cost-share. The $15 payment reflects ASCS policy in the area. Income increased by $399,288 compared to the base run because of the $15 per acre payment on no-till acreage. This subsidy lowers the per acre cost of producing no-till versus conventional till and since both were assumed to have equal yields, net returns increase. In terms of reducing pollution, this alternative appears quite effective, since it leads to larger reductions in all three pollutants than any other alternative examined except for the 75 percent regulatory case. This is an expensive approach in terms of government expenditures since more than $650,000 is spent on cost-shares in each of the cost-share runs.

The higher levels of cost-shares, 75 and 100 percent, lead to no further reduction in loadings or changes in crop planting. This is because the cost-share on the most economically feasible BMP, no-till corn was held constant at $15 per acre. After the initial change to no-till (PCNNT) with the 50 percent cost share, there is no opportunity to shift further acreage into no-till because of model restrictions. However, dramatic changes in hog production practices occur when the cost-share is increased from 75 to 100 percent. Swine finishing operations with Cargill floors (PFDCG with 1,336 hogs each) increase from 0 to 8. The number of farrow-to-finish hog operations with Cargill floors (PFFCG with 1,336 hogs each) increases from 7 to 30. The number of confinement farrow to finish operations without Cargill floors (PFFCF with 334 hogs each) remains the same and the number of finishing operations without Cargill floors (PFDCF with 334 hogs each) declines from 160 to 37.

Impact of Soil Loss Taxes. The final category of policies examined with the model was a soil loss tax. A $0.50 tax per ton of soil loss reduces net farm income by $306,590. Compared to the 25 percent regulated reduction, a $0.50 per ton tax would have about the same effect on soil loss and nitrogen and phosphorus loadings, but there would be a greater negative impact on farm income. When the tax is raised to $1.00 per ton, income falls by another $143,344 and soil loss is reduced to 248,848 tons, which is almost 75 percent less than in the base run. This has considerable impact on pollution generation as well as on farm income. The tax induces the use of grassed waterways, to the extent that 6,016 acres in the watersheds are protected by them. Furthermore, a winter cover crop (PQNCV) BMP is employed for 1,584 acres of peanuts.

CONCLUSIONS

The impacts of regulatory, cost-sharing, and soil loss tax programs have been explored with a watershed model of the Nansemond and Chuckatuck watersheds. While no model can capture all of the parameters affecting economic decision making, the model used in this study has been carefully constructed to reflect the general characteristics of the agricultural sector of the area. Soil loss was calculated based on a random sample of farms in the watersheds. Additional loadings were estimated for nitrogen and phosphorus.

The results indicate that a regulatory program could have a very different effect on cropping patterns and farm income depending on which pollutant is targeted for reduction. A 50 percent reduction in nitrogen induces a much greater acreage of soybeans than a 50 percent reduction in soil loss or phosphorus. A soil loss regulation results in two-thirds of the corn acreage being planted no-till, but a phosphorus regulation results in two-thirds being planted by conventional tillage methods. This implies that a program with explicit water quality goals could have a different impact on land use practices than a program that emphasized erosion control. This also suggests that studies of nonpoint control which use soil loss as a proxy for nutrient loadings may yield misleading information.

The regulatory approaches, while effective in reducing pollution, decrease net farm income in the watershed. The declines in farm income are substantial, but in no case exceed four percent of the base run income. Yet, even these modest declines in income could have severe impacts on farmers, particularly during periods of financial stress for agriculture. Of course, a regulatory program would be objectionable to many people because of its interference with farmer decision making. Nor does it encourage greater pollution reduction for those farms who can abate pollution more cheaply than others. The regulatory approach would be difficult to implement since estimation of pollutant loadings on a farm by farm basis would be required.

Soil loss taxes are another method of encouraging the adoption of BMPs. The $0.50 per ton tax has a modest effect on pollution generation in the model, primarily by encouraging a shift to no-till. With a $1.00 per ton tax, it becomes economical to avoid part of the tax by planting no-till corn, using a cover crop with peanuts, and installing grassed waterways. Like the regulatory program, a soil loss tax would be unpopular with farmers and difficult to implement. Soil loss would have to be estimated for each farm.

The cost-share alternatives appear effective in reducing pollutant loadings and have the political advantage of raising farm income. In this study, cost-shares greater than 50 percent had little effect on generated soil, nitrogen or phosphorus, but did encourage use of annual waste BMPs on hog farms. However, these results should not be interpreted as exact representations of existing ACP or RCWP programs. No limits were placed on the availability of cost-share funds. As a result government cost-shares in all three of the cost-share alternatives analyzed far exceed the funds currently available for ASCS cost-sharing in a given year in the watershed. Thus, in order to achieve the reductions in agricultural nonpoint source pollution indicated by the model, additional cost-share funds would be needed.

REFERENCES

Bogess, W., J. McGrann, M. Boehlje, and E. Heady. "Farm Level Impacts of Alternative Soil Loss Control Policies." *Journal of Soil and Water Conservation*. 34(1979):177-183.

Casler, G. and J. Jacobs. "Cost of Altering the Quality of Water in Cayuga Lake by Reducing Phosphorus Losses From a Rural Watershed." *Journal of the Northeast Agricultural Economics Council*. 4(1975):174-184.

Kerns, W. R., R. A. Kramer, W. T. McSweeny, and R. W. Stavros. *An Economic Evaluation of the Impacts of Reducing Nonpoint Source Pollution with Alternative Control Procedures on an Agricultural River Basin in Virginia*. Final Project Report to the Virginia State Water Control Board, September 1982.

Kerns, W. R., R. A. Kramer, and R. Greenough. "Nonpoint Source Pollution Management: A Case Study of Farmers' Opinions and Characteristics." Virginia Tech, Department of Agricultural Economics, A.E. 51, August 1983.

Novotny, V. and G. Chesters. *Handbook of Nonpoint Pollution: Sources and Management*. New York: Van Nostrand Reinhold Company, 1981.

RCWP Local Coordinating Committee, County of Isle of Wight and the City of Suffolk. *Nansemond-Chuckatuck Rural Clean Water Project*. Project proposal, 1981.

Wade, J. and E. Heady. "Controlling Non-Point Sediment Sources With Cropland Management: A National Economic Assessment." *American Journal of Agricultural Economics*. 59(1977):13-24.

Walker, D. and J. Timmons. "Costs of Alternative Policies for Controlling Agricultural Soil Loss and Associated Stream Sedimentation." *Journal of Soil and Water Conservation*. 35(1980):177-183.

White, G. and E. Partenheimer. *Economic Impact of Sedimentation- and Erosion-Control Plans on Selected Commercial Dairy Farms in Pennsylvania*. Pennsylvania State University, Agricultural Experiment Station Bulletin 330, January 1980.

Wineman, J., W. Walker, J. Kuhner, D. Smith, P. Ginberg, and J. Robinson. "Evaluation of Controls for Agricultural Non-Point Source Pollution." *Best Management Practices for Agriculture and Silvaculture*, ed. R. C. Loehr, D. A. Haith, M. F. Walter, C. S. Martin, pp. 599-624. Ann Arbor, Michigan: Ann Arbor Sciences Publications, 1980.

Wischmeier, W. H. and D. D. Smith. *Predicting Rainfall Erosion Losses- A Guide to Conservation Planning* U. S. Department of Agriculture, Science and Education Administration, Handbook 537, 1978.