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Project Summary

Effect of Agricultural Land Use Practices on Stream Water Quality: Economic Analysis

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Since nonpoint source pollution from agricultural lands is to be controlled by best management practices (BMPs), a good understanding of the response of farmers to incentive and regulatory policies is needed if there is to be effective implementation. This report provides an economic analysis of agricultural production activities and farmer response to water quality controls using the Four Mile Creek Watershed in Iowa as a case study.

To address some of the limitations of the existing information base on the efficiency of BMPs, the investigation included four components. First, a watershed survey provided a profile of the farmers and the necessary data for the empirical analysis. Second, a BMP cost-effectiveness evaluation framework was developed and applied. Third, factors that are important in explaining the adoption of BMPs, such as perceived risk, were identified. Fourth, the impact of increasing relative energy prices on crop management practices and on the effectiveness of nonpoint source pollution control policies was assessed.

The analysis showed that secondary tillage practices are important in designing cost-effective control strategies. Knowledge of perceived risk associated with practices is critical in determining farmer adoption of BMPs and response to control policies. Also, data on perceived opportunity costs of certain practices provided additional understanding of farmers' reluctance to adopt those practices. A BMP evaluation framework that accommodated the scaling up from fields to watersheds was ultimately developed. This analysis showed that the marginal cost of soil loss control increases significantly as more stringent limits are adopted. Also, it was determined that higher energy prices are likely to enhance the effectiveness of soil loss control policies.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Society's concern for improving water quality is reflected in the Federal Water Pollution Control Act Amendments (FWPCA) of 1972 (PL 92-500) and in the Rural Clean Water Program (RCWP) of 1977 (PL 95-217). Section 208 of FWPCA-1972 requires states to develop areawide plans for controlling nonpoint sources of water pollution (including agricultural sources) and the RCWP has provided a framework and funding mechanism for implementing the program. Since the control or prevention of nonpoint source pollution from agricultural land is directed at site-specific management (implying that compliance monitoring will be conducted on land rather than water), it is essential that economically feasible land use practices or Best Management Practices (BMPs) be selected. The Four Mile Creek evaluation project is an attempt to develop the necessary information base.

Previous nonpoint source (NPS) pollution control evaluation projects, based on linear programming models designed to maximize profits or minimize costs of control, have utilized secondary data sources in developing coefficients for the model and have assumed constant input prices. Little attention has been given to the actual information or data used by farmers in forming their perceptions of profitability. If farmers' yield expectations for new crop management practices differ from those employed in the model coefficients, the actual responses of farm operations to public incentives and regulations may be significantly understated or overstated. Likewise, if the secondary data sources used in establishing the costs and returns coefficients do not represent the actual production environment, further bias will be introduced into the programming model results.

Past evaluations based solely on linear programming models also suffer from the assumption that only profitability matters to farm operators. Other factors, such as risk, however, may play an important role in farm management decisions. If other objectives enter into the farm operator's decision function and if these factors are ignored, the linear programming results will not be accurate and may not be reliable for planning purposes.

In any modeling effort, the investigator must choose a set of input and output prices that reflect farmer expectations or professional judgment. Yet, relative price patterns, especially for inputs, typically change over time and affect the relative profitability of different crop management practices. For example, reduced tillage practices may become more profitable relative to moldboard plowings as energy prices rise over time. Such changes in relative prices, and in turn profitability, may induce adjustments in tillage practices that have favorable environmental impacts. It is important not only to identify the environmental consequences of relative price changes but to recognize these adjustments when designing incentives and regulations to induce the adoption of BMPs.

In an effort to address some of the limitations of the existing information base on the efficiency of BMPs, this investigation includes four major components. First, the watershed survey provides a profile of the farmers and the necessary data for the empirical analysis. Second, a BMP cost-effectiveness evaluation framework is developed and an application is illustrated. Third, factors that are important in explaining the adoption of BMPs are identified. Finally, the impact of increasing relative energy prices on crop management practices and on effectiveness of NPS pollution policies is assessed.

Profile of Four Mile Creek Watershed

To establish a primary data base for the analysis, a survey of farmers in Four Mile Creek, Iowa, was undertaken. A five-section questionnaire designed to inventory machinery, crop management practices, livestock management practices, risk attitudes, and background information was administered. The objectives of the survey were to determine (1) existing management practices, (2) how farmers would adjust their production practices given incentives, and (3) coefficients for BMP evaluation and programming models.

A few findings of the survey, crucial to the economic analysis conducted, should be highlighted. First, as more erosive primary tillage practices were reduced, secondary tillage practices increased in the watershed. Thus, the potential soil loss reduction attributed to the reduction of primary tillage operations may be somewhat overstated when farmers shift to conservation tillage. Second, watershed farmers expected the highest yields from fall tillage activities, followed by spring tillage, and then no-till. In addition to having the lowest expected yield, no-till had the highest risk rating assigned by farmers. Knowledge of perceived yield impacts of different tillage systems as well as perceived risk associated with practices is critical in determining farmer adoption of BMPs and response to NPS pollution control policies. Third, the data suggest that Four Mile Creek farmers tend to be risk neutral to risk averse in their behavioral preferences. Different formulations of risk questions were employed and relatively consistent responses were received. Finally, data on perceived opportunity costs of terracing, including both time and yield reduction costs, provided further understanding of farmers' reluctance to terrace cropland.

BMP Cost-Effectiveness Evaluation Framework

To evaluate the cost-effectiveness of alternative BMPs, an activity analysis framework was developed. The framework accounts for the various costs associated with different management practices and levels of residual control. The impacts of scaling-up from fields to farms, farms to subwatersheds, and subwatersheds to watersheds can be evaluated.

The preliminary results indicated that contouring is the most cost-effective BMP of the subset considered. Yet, contouring is only effective as an erosion management practice over a relatively narrow range of residual control. In other words, contouring can reduce gross soil loss in the Four Mile Creek Watershed from 17 to 9 tons per acre per year but no further. The same soil loss reduction with terracing or pasturing is far less cost-effective. Also, as supported by other studies, the marginal cost of additional increments of soil loss (residual) control increases significantly regardless of the BMP imposed.

To compare and contrast the imposition of BMPs at different levels of aggregation, the Four Mile Creek Watershed was divided into five subwatersheds based on differences in soil type and erosion potential. Supporting the argument frequently made for targeting soil conservation funding, the average cost of reducing soil loss is significantly higher in subwatersheds with less serious erosion hazards. Put another way, specific BMPs are more cost-effective in areas with greater erosion hazards, other things equal. Further investigation of the implications of BMP targeting is needed.

Adoption of Conservation Tillage Practices

Given the emphasis that EPA has placed on management practices for the improvement of water quality, it is important to understand why farmers do or do not adopt particular BMPs. Specific attention was given to the conservation tillage practice adoption decision. To isolate the factors that influence the adoption of conservation tillage practices (i.e., a BMP), a linear probability model of tillage choice was developed. The probability that a farmer will choose a tillage practice other than moldboard plowing is related to characteristics of the farm operator, including experience, tenure, education, and risk perceptions, and to characteristics of the farm, including field topography, crop rotation, and farm size.

The adoption model was fitted to 238 observations of primary tillage choice from the Four Mile Creek Watershed survey. The results should be useful in the design of more effective soil loss control policy. First, farmers with more education and experience had a higher probability of adopting conservation tillage practices. These results point to the importance of considering the human capital characteristics of farmers when designing education, incentive, and targeting programs to induce soil conservation practices.

Second, the structural characteristics of the farm operation produced some surprising results. Farm size proved to be a negative factor in the adoption decision, i.e., the probability of adoption was inversely related to the size of farm operation. Even though larger scale operations generally would be expected to have an incentive to acquire and adopt improved technology because they can spread the costs over more units, the smaller operations actually exhibited a higher probability of adoption. Only if adoption of conservation tillage practices had negative scale effects or if it were generally less economical would this result be expected. Existing experimental and survey data do not support these contentions. Also contrary to the findings of some previous studies as well as to a popularly held belief, a more tenured operator (i.e., a larger share of owner-operated land) was not more likely to adopt conservation tillage practices than a less tenured operator. Economic theory supports the hypothesis that tenure should not matter if landowners are attempting to maximize the long run net returns to their investment.

Third, potential erosivity or field topography was also found to be a strong factor in explaining the probability of adoption. As was to be expected, farm operators on hilly land had a higher probability of adopting conservation tillage practices. Additionally, failure to account for potential erosion problems may explain why previous studies found a significant positive relationship between tenure and conservation practice adoption.

Finally, differences in risk perceptions and expected yields were considered. Differences in risk perceptions influenced the probability of adoption but the statistical significance of the result was somewhat weak. The result suggests that improved information directed toward developing more accurate perceptions of the riskiness of reduced tillage may be useful. Expected yield differences were not significant in explaining adoption, but this result may be due to the small expected variation in yields in the region.

How far the results from the Four Mile Creek Watershed can be generalized is open to question, but they do indicate some potentially important factors that should be considered in designing future soil conservation programs.

Effects of Rising Energy Prices on Nonpoint Source Pollution and Its Control

Changing relative input prices may confound the implementation of NPS pollution control options. Such price changes may complement the desired policy impacts, or alternatively, may compete with the policy objectives. Rising relative energy prices are of particular interest because of the impact of energy prices on the choice of tillage, rotation, and cultural practices. Thus, the formation of NPS pollution control policies should be cognizant of the impacts of increasing relative prices of farm fuel and other energy related inputs.

To assess the impacts of rising energy prices on soil loss and on the potential effectiveness of NPS pollution control policies, a linear programming model for the Iowa River Basin was used. Department of Energy 1985 and 1990 price projections for fuels were used to generate model solutions to compare with the 1978 baseline case.

The overall policy implications were that higher energy prices tended to bring about shifts to practices that decrease both soil erosion and the amount of fertilizer used by farmers, even without encouragement from NPS pollution policies. These reductions are caused by a projected shift from continuous corn to corn-beans rotation and by a partial shift from fall chisel to no-till planting. Significant changes occurred in both soil loss and net farm income by 1985, with 22 and 19 percent decreases, respectively. Little additional adjustment occurred between 1985 and 1990.

Combining the impacts of increasing energy prices and per acre soil loss restrictions, soil loss restrictions are only effective if the average annual is set at less than 10 tons per acre. Subsidies for soil loss abatement combined with increasing energy prices do provide ambiguous results. At lower subsidy levels, increasing energy prices will enhance the effectiveness of the subsidy policy, but at higher subsidy levels increasing energy prices may weaken the impact of the abatement subsidy. Generally, in the politically relevant range of subsidies as well as over the likely range of soil loss restrictions, higher energy prices will likely enhance the effectiveness of soil loss control policies.

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The complete report, entitled "Effect of Agricultural Land Use Practices on Stream Water Quality: Economic Analysis," (Order No. PB 83-217 836; Cost: $14.50, subject to change) will be available only from:
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