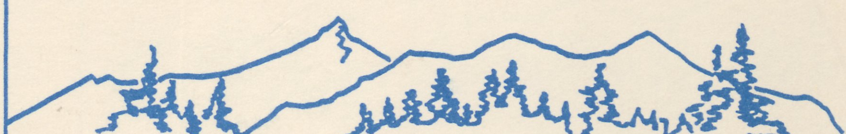
Papers of the 1991 Annual Meeting

Western Agricultural Economics Association



Portland, Oregon
July 7 – 10, 1991

LOW-INPUT AGRICULTURE AS A GROUNDWATER PROTECTION STRATEGY

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ABSTRACT

Protection of groundwater quality is of great importance to local, state, and federal governments. This study uses mathematical programming to evaluate the effectiveness of low-input agriculture as a groundwater quality management strategy. The results indicate that low-input agriculture alone may not be an effective protection strategy.

INTRODUCTION

Groundwater is an important source of water for our nation. Approximately 97 percent of rural America's tap water is groundwater (Nielson and Lee). In the 19 western states, groundwater sources supply about 38 percent of all water uses (Smith). Furthermore, in six of these western states, more than 90 percent of the population depends on groundwater for drinking water (U.S. EPA). Protection of the quality of groundwater is thus of primary importance to local, state, and federal agencies.

Low-input agriculture is a voluntary tool being proposed as a part of the solution to agricultural contamination of groundwater. Low-input agriculture is defined in this study as a farming system in which the direct or indirect use of petroleum-based inputs are reduced relative to conventional agriculture (Batie and Taylor).

The objectives of this paper are to evaluate: (1) the ability of low-input agricultural activities to control groundwater contamination, and (2) the profitability of these practices. Mathematical programming is employed to model the decision-making of farmers in terms of their selection of low-input versus conventional production activities under a variety of policy scenarios.

THE STUDY AREA

The county selected for this study was Richmond County, the second largest county in the Northern Neck of Virginia. While Richmond County does not directly front on the Chesapeake Bay, it does lie above a large aquifer which flows into the Chesapeake Bay and is adjacent to the Rappahannock River, a major tributary of the Chesapeake Bay. Nearly 68 percent of Richmond County's farmland is cropland (U.S. Department of Commerce). This study area merits particular attention because of the 1987 Chesapeake Bay Agreement which has as one of its specific objectives the design of a groundwater management strategy to control agricultural discharges of contaminants.

METHODS

To achieve this study's objectives, an economic optimization model was developed which incorporates the results of two non-point pollution simulation models. The economic analysis used a multiperiod, nonlinear dynamic optimization model which maximized net returns to the county by selecting production activities which met the policy and physical restrictions imposed upon the model. The mathematical programming model contained 4,745 equations and 6,976 variables. There were 180 nonlinear equations which calculated the moving average of yield and base hectares. The model accounted for several dynamic aspects of production activities, including nitrogen and chemical residue carry-over, as well as the dynamic aspects of base and yield calculations under the federal commodity programs.

A personal survey of thirty Richmond County farm operators was conducted in the summer of 1989 to collect information on typical agronomic practices (VPI & SU, Department of Agricultural Economics). Based on this information, four primary crop rotations emerged: (1) corn/small grain-double cropped soybeans (2 years), (2) corn/small grain-double cropped soybeans/full season soybeans/small grain-double cropped soybeans (4 years), (3) corn/small grain-double cropped soybeans-rye (2 years), and (4) corn/small grain-double cropped soybeans-rye and crimson clover (2 years). Based on the advice of the Richmond County Farm Management Extension Agent (Liddington) and a Cooperative Extension Service weed specialist (Hagood), thirty-four potential agricultural activities were constructed from the four initial rotations. Different fertilization rates, chemical types and application rates, nitrogen sources (commercial nitrogen and poultry litter), and non-chemical weed control practices were added to the initial rotations. There were three completely organic activities. Extension Specialists and the surveyed farmers provided information on expected changes in the labor requirements, yields, and variable costs of low-chemical applications and completely organic activities. Corn and soybean yields were penalized by 20 percent in two-year low-chemical or organic rotations without a cover crop. If a cover crop or green manure was used in these low chemical and organic activities, the penalty which was assessed to soybean yields rose to 25 percent but the corn penalty remained at 20 percent. In addition, labor requirements in low-chemical and organic production activities were increased 10 percent. Poultry litter, used as the organic nitrogen source, was assumed to be trucked into the county at a price of $.018 per lb. (Napit; and Diebel).

Chemical and nutrient loading of groundwater were obtained from the results of Davis. Davis used two simulation models: CREAMS (Chemical, Runoff, and Erosion from Agricultural Management Systems)(Knisel) and GLEAMS (Groundwater Loading Effects of Agricultural Management Systems)(Leonard, Knisel, and Still). A mass balance approach to the estimation of chemical loading was facilitated by the ability of these two models to account for virtually every dispersal path of chemicals and nutrients. Levels of percolation of chemicals and nutrients provided an estimate of potential groundwater contamination (Davis).

Nine scenarios were examined. The Base Scenario had no external policies enforced except for the existing provisions of the commodity and conservation reserve programs. A Cost-Share Scenario included a 100 percent subsidization for the establishment of a green manure cover crop. Two policies limited the surface application of Aatrex, one of the most widely used chemicals in Richmond County. The No Aatrex Scenario banned Aatrex use, and the 1/3 Aatrex Scenario required a one-third reduction in the quantity of applied Aatrex. A Chemical Taxation Scenario imposed a 300 percent tax on chemicals, which was the magnitude of tax that was found to be the necessary incentive for farmers to stop using all chemicals. Two policy scenarios consisting of a 40 Percent Percolation Reduction and 40 Percent Percolation/Runoff Reduction, regulated chemical levels in groundwater; and in groundwater and runoff, respectively. Finally, two land use policy scenarios comprised of the Conservation Reserve Program (CRP) and Buffer Strips, required that all land eligible for each land retirement program (1,574 acres and 190 acres, respectively) be removed from production.

RESULTS

The Base Scenario reflected the current practices in Richmond County. A two-year corn/small-grain-soybean rotation using a medium level of chemicals and commercial nitrogen was used throughout the 15 years. Table 1 shows the total net returns, and nitrogen and selected chemical leaching levels for the entire 15 years. Aatrex, Dual and Chlorimuron (one of the two active ingredients in Gemini) are shown in Table 1 because they consistently appeared in groundwater at the high levels relative to other chemicals. Alternative chemicals, 2-4D and Bladex, are also presented in Table 1 to show the impacts of substituting chemicals[1] for Aatrex in non-organic protection activities. All five chemicals in Table 1 are herbicides. The results of the other scenarios are presented in Table 1 as changes from the Base Scenario.

Low-Input Adoption

In only two scenarios were low-input practices the only practice selected throughout the entire 15 years. The Cost-Share Scenario "encouraged" the use of low-input production activity A15L[2]; the Chemical Taxation Scenario "forced" the use of low-input production activity A5L. The No Aatrex and 1/3 Aatrex scenarios restricted the surface application of Aatrex so severely that a completely organic activity, A5L, was used over part of the 15 years to meet these restrictions. In both surface restriction scenarios, activity A6 was selected; A6 did not use Aatrex, but did substitute 2-4D and Bladex for Aatrex. In the 40 Percent Percolation Reduction Scenario and the 40 Percent Percolation/Runoff Reduction Scenario activity, A6 was also used, but it was not used in combination with an organic activity. Rather, A6 was used with the "conventional" production practice, A1, of the Base Scenario and activity A4. Activity A4 is the same as A1 except that the nitrogen applications, which were split into two applications in A1, are further split into 3 applications in activity A4. Activity A4 generally created lower nutrient and chemical leaching levels. Since the CRP and Buffer Strip Scenarios only reduced productive acreage, there was no incentive to adopt low-input practices.

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[1]All chemicals could not be listed due to space limitations.

[2]Production Activity A15L was considered to be low–input because of the use of a legume winter cover crop, which could reduce the need for nitrogen supplements, and because of the use of the organic nitrogen source, poultry litter.

Table 1. Summary of the Fifteen-Year Total Net Returns and Potential Leaching of Chemicals and Nitrogen to Groundwater.

Scenario[a]	Net Returns (dollars)	POTENTIAL GROUNDWATER POLLUTION (lbs)					
		Nitrogen	Aatrex	2-4D	Bladex	Dual	Chlorimuron
Base (A1)	31,199,006	10,163,881	1,223	0	0	31	72
Cost-Share (A15L)	+6,468,129	+5,205,704	+575	0	0	+84	-72
No Aatrex (A5L,A6)	-1,351,301	+193,778	-1,223	+56	+23	+11	+1
1/3 Aatrex (A5L,A6)	-848,033	+841,249	-819	+28	+16	+10	+4
Chemical Taxation (A5L)	-12,659,213	+3,088,397	-1,223	0	0	-31	-72
40% Percolation Reduction (A1,A4,A6)	-1,708,619	+2,996,440	-489	+8	+6	-11	-29
40% Percolation/ Runoff Reduction (A1,A4,A6)	-3,068,786	+881,360	-489	+20	+11	-4	-29
CRP (A1)	-1,800,335	-2,356,556	-281	0	0	-7	-16
Buffer Strip (A1)	-559,944	-677,120	-19	0	0	-0.48	-1

[a] The notation in parentheses under the policy scenarios indicates the production activities selected. These activities are defined as follows:

A1 Corn/Small Grain-Double Crop Soybeans(2 yr), med. chemicals/nutrients;
A4 Corn/Small Grain-Double Crop Soybeans(2 yr), med. chemicals/nutrients, nitrogen application split into three;
A5L Corn/Small Grain-Double Crop Soybeans(2 yr), no chemicals, poultry litter as a nutrient source;
A6 Corn/Small Grain-Double Crop Soybeans(2 yr), no Aatrex (2-4D and Bladex substituted), med. chemicals/nutrients;
A15L Corn/Small Grain-Double Crop-Mixed Cover Crop(2 yr), no Gemini (Chlorimuron), med. chemicals/nutrients, clover/rye cover crop, poultry litter as a nutrient source.

Potential Pollution

Nitrogen. Only the two land retirement policies resulted in reduction of nitrogen levels in groundwater from the Base Scenario. These reductions were strictly due to the removal of land from production. All other scenarios resulted in increased nitrogen loadings to groundwater. Even those scenarios which completely or partially converted to the low-input activities had increased nitrogen loadings. For example, in the Cost-Share Scenario an activity A15L using a winter legume crop was selected. This production activity was designed to partially eliminate the need for additional nitrogen applications and to prevent runoff and soil erosion. However, these beneficial table characteristics are accompanied by an increase in nitrogen percolation, of 5,205,704 lbs from the Base Scenario. The increase in nitrogen loadings is because moisture is retained on the field by the crop, and it percolates rather than running off.

The use of poultry litter in production activities generally did not reduce nitrogen percolation. Poultry litter often had higher percolation levels than commercial nitrogen because of its slow release of nutrients (Diebel). The release of usable forms of nitrogen often occurred when plant uptake was low, thereby losing nitrogen to percolation.

Chemicals. The No Aatrex and Chemical Taxation Scenarios completely removed Aatrex; however, in the No Aatrex Scenario, 2-4D and Bladex, and appeared in percolation. Levels of 2-4D and Bladex were also found with low levels of Aatrex in the 1/3 Aatrex, 40 Percent Percolation Reduction, and 40 Percent Percolation/Runoff Reduction Scenarios. Reducing the loading or application of Aatrex thus still resulted in some Aatrex use as well as its substitutes. Substitute chemicals may have different toxicity and persistence levels, as well as other characteristics, which may be higher or lower than the original chemical.

The Cost-Share Scenario had the only increase in Aatrex levels, 575 lbs, from the Base Scenario. This increase was due to the reduction in runoff associated with the winter cover crop. The use of activity A15L in the Cost Share Scenario resulted the highest levels of Dual loadings at 84 lbs above the Base Scenario.

The greatest reduction in the level of Dual loadings, 31 lbs less than the Base Scenario, occurred with the organic production activity, A5L, in the Chemical Taxation Scenario. The smallest decrease in Dual, .48 lbs less than the Base Scenario, was found under the Buffer Strip Scenario. The CRP, 40 Percent Percolation Reduction, and 40 Percent Percolation/Runoff Scenarios also produced reductions in Dual levels.

Chlorimuron levels were decreased in all but two of the scenarios. Both surface application restriction policies had slight increases in Chlorimuron levels from the Base Policy Scenario, with a 1 lb increase for the No Aatrex Scenario and a 4 lb increase for the 1/3 Aatrex Scenario. The greatest reduction in Chlorimuron, 72 lbs, was under both the Cost-Share Scenario, with activity A15L, and the Chemical Taxation Scenario, with activity A5L. This result occurred because neither of these activities used Gemini.

Economic Impacts

The Base Scenario had a 15 year total net returns, over variable costs, of $31,199,006. All of the other scenarios reduced net returns from the Base Scenario level, except for the Cost-Share Scenario. The Cost-Share Scenario increased farmer income because of the 100 percent subsidization of establishing the winter cover crop. The net returns increase of $6,468,129 would be the cost to the government of this policy.

The chemical Taxation Scenario had the greatest reduction in net returns from the Base Scenario of $12,659,213. This decrease in net returns was due to the yield penalty on organic production activities and their increased labor requirements. The Buffer Strip Scenario had the smallest reduction in net returns at $559,944.

DISCUSSION AND CONCLUSIONS

Production activities in this study included a range of production practices from "conventional" to organic. Complete conversion to any low-input activity was not achieved without government involvement in the form of taxes or subsidies. Partial adoption of low-input activities occurred throughout many of the policy scenarios. The ability to use organic or low-chemical activities on some of the acreage provided a mechanism to reduce county level chemical leaching which permitted conventional production on the remainder of the land and county level compliance with the imposed policies.

This study shows that even if low-input agricultural practices are adopted the potential for chemical and nutrient leaching can still be substantial. In addition, some policies may reduce or remove one agrichemical from percolation, but through substitutions introduce other chemicals. The tradeoffs between the properties of a banned chemical and its substitutes must be considered, beginning with a thorough evaluation of their relative toxicity and persistence levels.

The only scenarios under which all nutrient and chemical percolation levels were reduced were those in which land was retired from production. Surface application restrictions showed more potential to reduce a targeted chemical, while loading restrictions provided more overall chemical reductions.

The results of this study provide insights for states which are considering low-input agricultural practices as a mechanism to address their groundwater quality problems. Low-input agriculture may be an attractive voluntary tool for reducing groundwater contamination but designing low-input systems which will lead to overall improvements in groundwater quality would appear to be a complex and challenging endeavor.

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