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STAFF PAPER

TRADEOFFS BETWEEN WATER QUALITY AND THE ECONOMIC IMPACTS OF LOW-INPUT AGRICULTURE IN THE COASTAL PLAIN OF VIRGINIA*

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The specific objectives of this paper are to: (1) determine the profit maximizing agricultural practices under different groundwater protection policies and (2) determine the effectiveness of solutions to each policy scenario in reducing the nitrogen and chemical contributions to surface and groundwater pollution and soil erosion.

METHODS

The water quality of the Chesapeake Bay is of major concern to commercial fishermen, environmentalists, and recreationalists in Virginia. Agriculture has been identified as a major contributor of non-point source pollution to the Chesapeake Bay (Chesapeake Bay Local Assistance Board). Richmond County, Virginia was selected as the case study area. Richmond is the second largest county in the Northern Neck of Virginia. It is situated adjacent to a major tributary of the Chesapeake Bay, the Rappahannock River, and above the Columbia aquifer, which seeps into many tributaries of the Chesapeake Bay.

Profitable agricultural practices for Richmond County and the influence of agricultural and natural resource policies were determined using a multi-period, nonlinear, mathematical programming model. The model accounted for several dynamic aspects of production activities, including nitrogen and chemical residue carry-over, as well as commodity program base and yield calculations. The model maximized net returns over variable costs for a 15-year period, starting in 1988, using a 6 percent discount rate. The 15 years of weather data preceding 1988 were assumed to represent the next 15 years of weather. These weather data

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Abstract

Agricultural activities have been identified as major contributors to the non-point pollution of the Chesapeake Bay. Low-input agricultural practices are being considered to reduce pollution in areas adjoining the Chesapeake Bay. A multiperiod mathematical programming model was used to examine the potential adoption of low-input practices and to assess the environmental consequences of these activities under different policies. The results of these analyses indicate that tradeoffs exist among the types of non-point pollution produced under each policy. Only policies that retired productive agricultural land reduced all pollutant types.

Key words: environmental tradeoffs, low-input agriculture, nitrogen, pesticides.

Agent (Liddington) and Cooperative Extension Service weed specialist (Hagood). The production activities are summarized in Table 1. An activity having the suffix L used poultry litter, shipped from the Shenandoah Valley (approximately 155 miles distant) as its source of nitrogen. The number of an activity indicates a crop rotation and attendant chemical and nutrient regimes. The three organic activities (5L, 11L, and 16L) used poultry litter as their nitrogen source.

The General Algebraic Modeling System (GAMS; Brooke, Kendrick, and Meeraus) was used to solve the mathematical programming model in this study. First, a profit maximizing solution referred to as the "Base Policy Scenario," which closely approximated actual farming practices in Richmond County, was obtained. The Base Policy Scenario was constructed by imposing the litter price of $.018 per lb, yield penalties recommended by extension specialists, and a labor requirement penalty of 10 percent on organic and low-chemical activities onto a completely unrestricted model (Diebel, Taylor, and Batie 1991a). The yield penalty on both corn and soybeans in all two-year low-chemical and organic rotations (without cover crops) was 20 percent. Corn and soybean yields were penalized 20 and 25 percent, respectively, if a winter cover crop was included. Operators were assumed to account for nitrogen from crop residues, because this is a practice highly recommended by extension specialists and an important part of any LIA system.

The policies imposed individually on the Base Policy Scenario were: (1) a cost-share program for green manures, (2) surface atrazine application restriction, (3) general chemical taxation, (4) restriction

Recent studies suggest that agriculture's contribution to non-point pollution has been increasing (National Research Council, U.S. Department of Agriculture, Nielson and Lee). The U.S. Environmental Protection Agency (EPA) has determined that agriculture is the largest U.S. source of surface water contamination (National Research Council), and a major contributor to groundwater pollution. The EPA has confirmed the detection of 46 types of pesticides in groundwater (Williams, Holden, Parsons and Lorber). However, the management of agrichemical contributions to groundwater and surface water contamination is complex because agricultural sources are non-point, the pollution potentials of agrichemicals are site specific, monitoring and testing are expensive, the health implications are uncertain, and farm operators resist regulation of their practices (Batie, Cox, and Diebel). These special problems require an innovative solution, such as the adoption of low-input agriculture (LIA), to reduce the adverse environmental impacts of agriculture.

In this study, LIA is viewed as a set of tools from which farmers can select practices that may decrease some adverse environmental impacts. LIA is defined as a farming system in which the direct or indirect use of petroleum-based inputs is reduced relative to conventional agriculture (Batie and Taylor). The potential effectiveness of groundwater protection policies to promote LIA and to reduce nitrogen and chemical contributions to surface water, groundwater, and soil erosion are examined in this paper.

Table 1. (Continued)

Production Activities[b]	Crop Rotation[c]	Special Characteristics
10	"	no metolachlor mowed rye
10L	"	no metolachlor mowed rye poultry litter
11L	"	no chemicals mowed rye poultry litter
18	"	no paraquat mowed rye
18L	"	no paraquat mowed rye poultry litter
12	C/SG-DC/FS/SG-DC(4 yr)	med. chemicals
12L	"	med. chemicals poultry litter
13	"	no atrazine
13L	"	no atrazine poultry litter
14	"	no metolachlor
14L	"	no metolachlor poultry litter
19	"	no paraquat
19L	"	no paraquat poultry litter
15	C/SG-DC-MIX(2yr)	med. chemicals/nutrients clover/rye plowed under
15L	"	med. chemicals/nutrients clover/rye plowed under poultry litter
16L	"	no chemicals clover/rye plowed under poultry litter

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[a] See Diebel, Appendix B.1 for a more detailed description.

[b] A suffix "L" indicates poultry litter is the source of nitrogen.

[c] C=corn, SG=small grains(wheat and barley), DC=double-cropped soybeans, FS=full season soybeans, MIX= rye and crimson clover.

for Richmond County were used to simulate environmental impacts. Historic rainfall patterns were used to estimate soil loss and chemical and nutrient loadings to surface and groundwater using the 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). Loading refers to the introduction of chemicals into bodies of water and soil. Coefficients of loading, as estimated by Davis, were incorporated into the mathematical programming model.

Yields and prices associated with the 15-year weather data were adjusted for inflation and technology. The model did not consider a transition period for the adoption of LIA activities, nor did individual crop yields vary under different practices within a year.

A personal survey of 30 Richmond County farm operators was conducted in the summer of 1989 to collect general information on agronomic practices (VPI & SU, Department of Agricultural Economics). These farmers were selected by the county extension agent to represent the variety of practices in the county. Based on this information, four primary crop rotations were identified. A total of 34 activities were constructed using four initial rotations identified by the Richmond County survey and were included in the mathematical programming model. 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 based on the advice of the Richmond County Farm Management Extension

Two land use policies were evaluated. Under the Conservation Reserve Program (CRP) Scenario, all eligible land, 8,252 acres, was put into the CRP program at a $70 per acre bid rate. The Buffer Strip Scenario forced the maximum amount of land (760 acres) potentially required to be put out of production to serve as buffers to major waterways under the mandate of the Chesapeake Bay Local Assistance Board. The land use policies were designed to reduce non-point pollution by idling productive land and providing filtering areas for water traveling across the surface. The CRP and Buffer Strip scenarios only accounted for the benefit from removal of productive land, because the filtering effect was not modelled.

RESULTS AND DISCUSSION

A variety of practices could be selected under each scenario, either within a single year or across the 15 years. In each case, however, one or two practices dominated the solution. The Base Scenario, representing the current situation, was dominated by activity 1, a 2-year, corn-small grain rotation with double-cropped soybeans and medium chemical use.

The Cost-Share Scenario required a 100-percent subsidization of the annual variable input costs of establishing the green manure in order for green manure to enter the solution. Activity 15, a cover crop rotation, was the only production activity selected throughout the 15 years. A rye/crimson clover crop was used as the green manure crop and

Table 1. Summary Description of the Cropping Activities Available in the Mathematical Model[a].

Production Activities[b]	Crop Rotation[c]	Special Characteristics
1	C/SG-DC(2 yr)	med. chemicals/nutrients
1L	"	med. chemicals/nutrients poultry litter
2	"	high chemicals/nutrients
2L	"	high chemicals/nutrients poultry litter
3	"	low-chemicals/nutrients
3L	"	low-chemicals/nutrients poultry litter
4	"	med. chemicals/nutrients split nitrogen application
5L	"	no chemicals poultry litter
6	"	no atrazine
6L	"	no atrazine poultry litter
7	"	no metolachlor
7L	"	no metolachlor poultry litter
17	"	no paraquat
17L	"	no paraquat poultry litter
8	C/SG-DC-RYE(2 yr)	med. chemicals/nutrients mowed rye
8L	"	med. chemicals/nutrients mowed rye poultry litter
9	"	no atrazine mowed rye
9L	"	no atrazine mowed rye poultry litter

used for two purposes: first, to evaluate the changes in non-point pollution contribution from the Base Policy Scenario and second, to compare the cost-effectiveness of each policy's non-point pollution reductions.

Reductions in Non-Point Pollution

The values presented in Table 2 are the changes from the Base Policy Scenario results, listed in the first line. Atrazine is the only chemical accounted for in this paper, although other levels of chemicals were affected. For a more detailed listing of scenario results, including other chemicals, see Diebel.

Nitrogen. Nitrogen contributions to surface water and sediment contamination were reduced the most in the Cost-Share Scenario. The nitrogen content in runoff was reduced by 120,787 pounds and the nitrogen content in sediment by 6,257,458 pounds. The presence of a winter cover crop promoted greater retention of nutrients and moisture, which, in turn, was associated with greater percolation of nitrogen and most agrichemicals. Therefore, reductions in nitrogen percolation were not found in the Cost-Share Scenario but only in the CRP and Buffer Strip Scenarios. In these scenarios, idled land promoted reductions in nitrogen application.

Atrazine Reductions. Atrazine was completely removed under both the No Atrazine and Chemical Taxation Scenarios. Atrazine was absent under the 300 percent tax because the production activity selected was organic. Without complete removal of atrazine, the 1/3 Atrazine and of chemical loading to runoff and groundwater, and (5) land use restrictions. Ex ante calculations indicated that without a cost-share program, the benefits of using green manures as nitrogen sources and a winter cover crop did not provide the profits needed for inclusion in the optimal solution of any scenario.

Two scenarios were analyzed that restricted the use of atrazine, the chemical found consistently at the highest levels in groundwater. A complete removal of atrazine from production practices was imposed in the No Atrazine Scenario. A less severe one-third reduction of permissible application levels was imposed in the 1/3 Atrazine Scenario.

A commonly used economic incentive to discourage excessive use or misuse of inputs is taxation. By raising the price of all chemicals by an equal percentage, the level of tax was determined that would "force" the conversion to a chemical free, organic activity.

The final restrictions on chemical use were two policies restricting the loading of all chemicals into non-point pollutant pathways. The first policy, the 40% Percolation Reduction Scenario, restricted all chemical levels in percolation to less than 40 percent of their total level under the Base Policy Scenario over the 15-year period. The second policy, the 40% Runoff/Percolation Reduction Scenario, restricted runoff and percolation chemical contributions to less than 40 percent of their initial levels. These types of restrictions are politically popular but are expensive to enforce and are often shrouded by debate over the time period within which the goal should be reached.

Cost Share Scenarios had the greatest atrazine reduction in runoff, percolation, and sediment. The reduction in atrazine pollution was greater under surface restriction policies than policies regulating the loading of bodies of water.

Soil Erosion. The Cost-Share Scenario also produced the greatest reduction in soil erosion. The use of a rye/clover, winter, cover crop had two purposes: to provide a green manure in the spring and to control soil erosion in the winter months. Therefore, it is not surprising that the reduction in soil erosion under this scenario is the largest, 527,626 tons.

Cost-Effectiveness

A standard approach for cost-effectiveness comparison is to divide the cost of a policy by the achieved reduction in a targeted pollutant. In this analysis, however, many pollutants are being affected by the various policies. Cost-effectiveness analysis is further complicated by the fact that, in some scenarios, some pollutants decrease, while others increase. A relative measurement of cost-effectiveness was determined by dividing the total cost of each policy by the total 15-year change in individual pollutants. These measures appear in parentheses under the loading changes in Table 2. For example, in the Cost-Share Scenario, the per unit cost of nitrogen reduction in runoff was $53 per pound.

The cost-effectiveness measure represents the cost per unit of pollutant reduction. A positive sign on that unit cost indicates that was disked under in early spring. The two surface restriction scenarios were both driven to select activities using less or no atrazine. Activities 5L and 6 dominated both the No Atrazine and the 1/3 Atrazine Scenario. Activity 5L is completely organic and activity 6 uses no atrazine. Atrazine was the limiting chemical in conventional practices, therefore, the 1/3 reduction in application forced the use of practices with no atrazine. The limitation of atrazine use induced the substitution of higher levels of currently used chemicals and the introduction of substitute chemicals such as 2-4D and cynazine (Diebel, Taylor and Batie, 1991b).

A 300 percent tax on all chemicals was needed in the Chemical Taxation Scenario before the conversion to an organic activity occurred. This activity, 5L, used poultry litter as a source of nitrogen and cultivation for weed control. The results of the 40% Runoff/Percolation and 40% Percolation Reduction Scenarios were virtually the same. Both practices used the "conventional" practice, activity 1, as well as activity 6, which controlled the introduction of atrazine to runoff and groundwater.

Finally, the CRP and Buffer Strip scenarios, which accounted only for the benefit from removal of productive land. These policies proved to be the only strategies that reduced all types of pollution. The primary production activity selected was the conventional practice of the Base Scenario, activity 1.

Each policy considered in this study was then evaluated with respect to its effectiveness in reducing non-point pollution. Table 2 is and serve only as relative comparisons within a pollutant type across scenarios.

Costs. The cost figures in the second column of Table 2 are the changes in net returns to the farmer or government. The negative sign proceeding the cost figure represents a decrease in income, whereas a positive sign represents an increase in income. The only positive change in net returns was in the Cost-Share Scenario, where the cost of using a rye/clover cover crop was completely subsidized by the government. The increase in income was due to estimating the cost of the winter cover crop activity 15, before adjustments were made in the model, e.g., organic penalties and low-input. These penalties induced the use of 15L rather than 15 which produced some further savings for the farmer.

Table 2 shows that in the Cost-Share Scenario includes costs to the government of $53 per pound of nitrogen removed from runoff and $1 per pound of nitrogen removed from sediment. These reductions occurred simultaneously with increased nitrogen in percolation, for which the government paid $2 per pound. All other scenarios caused a reduction in farmers' net returns.

Nitrogen. No single policy consistently produced the highest or lowest nitrogen reduction costs in all non-point pollution categories. The Chemical Taxation Scenario, with organic practices, was the least cost-effective for reducing nitrogen levels in runoff, at a cost of $250 per pound. The 1/3 Atrazine Scenario produced the most cost-effective

TABLE 2. Fifteen-year Total Nitrogen and Chemical Loadings and Cost-Effectiveness Groundwater Protection and Low-Input Adoption[a]

		Nitrogen (lbs)			Atrazine (lbs)			Soil Erosion
Scenario	**Cost (dollars)**	**Runoff**	**Percolation**	**Sediment**	**Runoff**	**Percolation**	**Sediment**	**(tons)**
Base Policy	31,199,006	226,547	7,024,204	6,309,252	172	253	3	882,772
Cost-Share	+6,468,129 (government)[b]	-120,787 (+53)[c]	+2,687,430 (-2)	-6,257,458 (+1)	-114 (+56,738)	-23 (-281,223)	-3 (+2,156,043)	-527,626 (+12)
No Atrazine	-1,351,301 (farmer)	-7,920 (+171)	+1,372,309 (-.98)	-1,811,038 (+.75)	-172 (+7,856)	-253 (+5,341)	-3 (+450,434)	-920 (+1,469)
1/3 Atrazine	-848,033 (farmer)	-16,845 (+50)	+754,648 (-1)	-1,437,414 (+.60)	-114 (+7,439)	-170 (+4,988)	-2 (+424,016)	-12,661 (+67)
Chemical Taxation	-12,699,213 (farmer)	-50,855 (+250)	+2,373,756 (-5)	-6,237,438 (+2)	-172 (+73,833)	-253 (+50,194)	-3 (+4,233,071)	-124,022 (+102)
40% Percolation Reduction	-1,708,619 (farmer)	-8,287 (+206)	+201,106 (-8)	-389,983 (+4)	-49 (+34,870)	-98 (+17,435)	-1 (+1,708,619)	-6,095 (+280)
40% Runoff/ Percolation Reduction	-3,068,786 (farmer)	+24,858 (-123)	+1,133,671 (-3)	-944,552 (+3)	-84 (+36,533)	-106 (+28,951)	-1 (+1,708,619)	-31,169 (+98)
CRP	-1,800,335 (farmer)	-51,157 (+35)	-1,619,565 (+1)	-1,430,449 (+1)	-40 (+45,008)	-58 (+31,040)	-1 (+1,800,335)	-200,520 (+9)
	-5,937,961 (government)	(+116)	(+4)	(+4)	(+148,449)	(+102,379)	(+5,937,961)	(+30)
total		(+151)	(+5)	(+5)	(+193,457)	(+133,419)	(+7,738,296)	(+39)
Buffer Strip	-599,944 (farmer)	-4,165 (+144)	-129,468 (+5)	-116,307 (+5)	-3 (+199,981)	-5 (+119,989)	[c]	-16,270 (+37)

[a] A "+" indicates the amount of increase and a "-" the amount of decrease in a measure of change from the Base Policy Scenario. A blank indicates no change. Relative cost effectiveness measures are in parentheses: these are the total costs of each policy divided by the 15-year total change in each individual pollutant. A positive sign indicates the policy reduced loadings at a cost; a negative sign indicates a pollutant loading increased and a payment was made to permit increase.

[b] Who pays for the policy is indicated in parentheses under the cost.

[c] Less than 1 pound difference.

the extent of land needed to be set aside. The costs of all policies are high per unit of pollutant reduction; however, these estimates may be biased upward. In cases where increases as well as decreases in pollutants were observed, several policies may have to be combined to obtain reductions in all pollutants. For example, the Cost-Share Scenario produced large reductions in runoff and sediment levels of nitrogen and in soil erosion. However, the retention characteristics of a winter cover crop, which make it a good soil erosion control strategy, also create greater potential for percolation of agrichemicals. In this case, a cost-share program and restriction of atrazine surface application could be employed. Even then, the result of this combination of policies on pollutant levels is unknown, and the cost per unit of pollutant reduction would probably increase.

General banning of a targeted chemical may be cost-effective, but the possibility exists for substitutions of other chemicals. The toxicity, persistence, and cost of the substitute chemicals must be considered. The surface application restrictions on the whole were more cost-effective than loading restrictions. The relative cost of surface restrictions would have been greater, if the expense of monitoring for loading restrictions had been included in its per unit cost. Except under land retirement policies, reductions in chemical contributions to groundwater were often associated with large increases in nitrogen losses and soil erosion. Many of the LIA practices included the use of organic sources of nitrogen, such as poultry litter, which showed the potential to pollute as much as or more than inorganic sources of the policy reduced the pollutant loading. A negative sign on the cost-effectiveness measure indicates that the policy increased the pollutant and a payment was made by government and/or farmer per unit of the increase. All chemicals could have been evaluated in this manner. However, because of the variety of chemicals only a few are presented. Atrazine was examined, along with its common substitute 2-4D, because of its consistent appearance in runoff, percolation, and sedimentation and its widespread use among farmers. Note that these costs do not include the costs of clean-up, health effects, or detection--only direct costs to the income of the government and farm operator.

Note that if the increase (a negative cost-effectiveness value) in a contaminant is large, the payment is small. This is not realistic, because payment should rise as more contaminant is found in the environment. This counter-intuitive result is strictly a function of the mathematical derivation of these cost-effectiveness figures. Therefore, the payments are not used for comparison as much as the positive cost-effectiveness figures.

Factors such as active ingredients, toxicity, and persistence, which influence the overall effectiveness of a policy, are not easy to combine in one overall measurement. As a result, the cost-effectiveness measurement in this study is biased because each pollutant reduction is divided into the entire cost of the policy, when if aggregation were feasible, each pollutant would actually bear a smaller proportional share of the cost. Therefore, estimates of cost-effectiveness are high pollution. This alternative does not abandon the idea of LIA but enhances its scope. All LIA practices should be associated with the same type of information gathering relied on by Integrated Pest Management. This type of program will require more time spent in management of the farm, perhaps assisted by computer programs designed to assist the farmer in this task. Additional research will also be needed to develop better procedures for testing soil and plant tissues for nutrient levels and prescribing necessary actions to the farmer.

reductions in both runoff and sediment levels of nitrogen. The CRP and Buffer Strip Scenarios were the only ones producing reductions in nitrogen percolation, and, therefore, the only scenarios with positive values for cost effectiveness.

Atrazine. The CRP and Buffer Strip Scenarios consistently produced the most expensive reductions in atrazine levels. The expense was due to removal of land from production. The surface application scenarios, No Atrazine and 1/3 Atrazine, were the most cost-effective at reducing atrazine levels in runoff, percolation, and sediment. General banning of a targeted chemical may be cost-effective, however, the possibility exists for substitutions of other chemicals. The relative cost of surface restrictions may have been higher if monitoring costs had been included.

Soil Erosion. The Cost-Share Scenario was the most cost-effective for controlling soil erosion. The No Atrazine Scenario, which included no specific element for soil erosion control, was the least cost-effective scenario for soil erosion reduction.

SUMMARY AND CONCLUSIONS

Although the land use scenarios, CRP and Buffer Strips, did not consistently produce the highest reduction in non-point pollution, they were the only scenarios in which all non-point pollution sources were reduced. Land retirement programs may be attractive to farmers attempting to meet conservation compliance requirements, depending on

Diebel, P.L., D.B. Taylor, and S.S. Batie. *Low-Input Agriculture as a Groundwater Protection Strategy*. Staff Paper No. 92-6, Department of Agricultural Economics, Kansas State University, 1991b.

Hagood, S.E. Extension Weed Scientist, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Personal communication with Penelope L. Diebel, September 1990-December 1990.

Knisel, W.G. (ed). CREAMS: A Fieldscale Model for Chemical, Runoff, and Erosion from Agricultural Management Systems. Washington, DC: USDA, Science and Education Administration, Conservation Report No.26, 1980.

Leonard, R.A., W.G. Knisel, D.A. Still. "GLEAMS: Groundwater Loading Effects of Agricultural Management Systems." *Trans. ASAE* 30(1987):1403-1418.

Liddington, K.J., Virginia Cooperative Extension Service Agent, Agriculture/Unit Director. Personal communication to Penelope L. Diebel. Warsaw, Virginia, May-December 1989.

National Research Council. *Alternative Agriculture*. Washington, DC: National Academy Press, 1989.

Nielsen, E. and L.K. Lee. "The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals: A National Perspective." Washington, DC: USDA. Agr. Econ. Report No. 576, 1987.

U.S. Department of Agriculture. "Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals. A National

nitrogen. In this study, poultry litter consistently leached more than inorganic nitrogen because of the physical characteristics of its nitrogen.

LIA has promised reductions in chemical contamination of groundwater and runoff. This study showed that although this promise is indeed fulfilled, tradeoffs exist among reduced chemical contamination, nitrogen losses, and soil erosion. All tradeoffs should be considered when examining the cost-effectiveness of any policy or LIA practice. Comparisons between chemical levels are not straightforward because of the variety of units used and toxicity levels and the uncertainty of contamination concentrations in depository bodies of water. However, a cost-effectiveness measurement, such as the one used in this study, brings attention to the complexity of the problem and the sometimes contradictory solutions created by a single policy.

Perhaps the most important caveat to add is that agricultural practices are site-specific and so are the environmental loadings created from them. A national endorsement of a limited number of LIA practices would be too restrictive; federal support for LIA use should include research and demonstration of economic and environmental impacts of many different combinations of practices under various physical conditions. State enforcement of LIA adoption policies is, perhaps, more feasible than a national approach.

If LIA is not the best solution, then what is the alternative? An information- and management-intensive approach to production may be what is needed to solve the unique problems of agricultural groundwater

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REFERENCES

Batie, S.S., and D. B. Taylor. "Widespread Adoption of Non-Conventional Agriculture: Profitability and Impacts." *Amer. J. Alt. Ag.* 4(1989):128-134.

Batie, S.S., W.E. Cox, and P.L. Diebel. *Managing Agricultural Contamination of Ground Water: State Strategies.* Washington, DC: National Governors' Association, State Policy Report, 1989.

Brooke, A., D. Kendrick, and A. Meeraus. *GAMS: A User's Guide.* Redwood City, CA: The Scientific Press, 1988.

Chesapeake Bay Local Assistance Board. Chesapeake Bay Preservation Area Designation and Management Regulations. VR 173-02-01, 1989.

Davis, P. "Simulated Effects of Agricultural Management Systems on Potential Non-Point Source Loading of Nitrate and Pesticides," M.S. Thesis, Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 1991.

Diebel, P.L. "An Economic Analysis of Low-Input Agriculture as a Groundwater Protection Strategy." Ph.D. dissertation, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA, 1990.

Diebel, P.L., D.B. Taylor, and S.S. Batie. *Barriers to Low-Input Agricultural Adoption: A Case Study of Richmond County, Virginia.* Staff Paper No. 91-13, Department of Agricultural Economics, Kansas State University, 1991a.

Perspective." ERS, Staff Report AGES870318, Washington, DC: USDA, 1987.

Virginia Polytechnic and State University, Dept. of Agricultural Economics. "A Survey of Richmond County Farmers." Unpublished survey. Contacts: Sandra S. Batie and Daniel B. Taylor. 1989.

Williams, W.M., P.W. Holden, D.W. Parsons, and M.N. Lorber. *Pesticides in Ground Water Data Base: 1988 Interim Report*. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs, 1988.