ECONOMIC and ENVIRONMENTAL IMPACTS of NUTRIENT LOSS REDUCTIONS on DAIRY and DAIRY/POULTRY FARMS

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EXECUTIVE SUMMARY

Water quality is among the most important environmental issues for the American public. Despite the anti-regulation polemic often heard from politicians, all levels of government seem willing to impose regulations to eliminate perceived threats to human health and environmental integrity. Such regulations may have serious economic impacts on livestock and poultry farm businesses in the Chesapeake Bay region. Hog lagoon spills in North Carolina and *pfiesteria pisiscida* outbreaks in Maryland have heightened public concern and may bring about regulations affecting farm production practices, costs, and profitability.

The focus of Virginia's water quality protection efforts on farms has been a largely voluntary nitrogen-based nutrient management program. With increased public concern about agriculture's impact on water quality through nutrient losses to surface and ground water, the public debate may shift to focus on a more stringent regulatory approach. The economic and environmental impacts of such an approach are not known, and those impacts are the focus of this study. In particular, the study examines the economic and environmental impacts of potential regulations affecting nutrient applications on Rockingham County dairy farms.

The study examines representative dairy and dairy-poultry farms, estimates potential nitrogen and phosphorus losses at the edge of farm fields and below the root zone, and simulates farm income effects under current practices and three possible nutrient management policies. The three policies are 1) a manure incorporation requirement, 2) a restriction on nitrogen applications to agronomic recommendation levels, and 3) a restriction on phosphorus applications to that taken up in crops harvested.

Results indicate very different environmental and economic impacts for each policy alternative. The manure incorporation requirement has only marginal impacts on potential nutrient losses and farm incomes and would be very difficult to implement on most dairies. The nitrogen application restriction is consistent with current nutrient management planning efforts and has "win-win" effects for many dairies. Potential nitrogen losses on the representative dairy farms fall by 18 to 50 percent under this policy, and income increases by as much as 5 percent. These positive economic and environmental impacts occur as farmers learn to more accurately judge the nutrient value of home-produced manures and reduce their purchases of fertilizers. These results emphasize the need for increased educational programs to help farmers more accurately allocate manure nutrients according to their economic value. However, a shortfall of the nitrogen application restriction is that concurrent potential phosphorus losses are reduced by only 3 to 15 percent. If phosphorus losses become an important environmental concern, a nitrogen application restriction will not contribute very much toward reaching phosphorus reduction goals.

The phosphorus application restriction holds the potential for the most significant decreases in potential nutrient losses and for the most serious negative impacts on dairy and dairy/poultry farm incomes. Potential nitrogen losses decrease by 21 to 56 percent, and potential phosphorus losses decrease by 28 to 43 percent under this policy. However, the farm cost imposed by such a policy is unsupportably high for most dairies. This study estimates that dairy and dairy/poultry farm incomes would fall by 11 to 23 percent if such a restrictive policy were enacted. No poultry litter could be applied to land on these representative dairy farms. If large tonnages of poultry litter had to be exported off the farm, litter prices would fall, possibly imposing additional costs on producers.

Because of the size distribution and relative animal/land ratios of Rockingham County dairies, the small and medium-sized dairies are estimated to contribute more than one-half the total potential nitrogen

losses from all dairy and dairy/poultry farms. With existing public program resources, it is not possible to reach large numbers of small farms with a nutrient management education campaign. Educational programs will need to be targeted at livestock-intensive farms according to the specific spectrum of characteristics which indicate serious potential problems for nutrient management and water quality policy.

Regulations such as those examined here are inferior mechanisms for the efficient accomplishment of societal objectives. Clearly, a need for education and nutrient management planning exists so that dairy and dairy/poultry farmers better understand the water quality implications of their farming practices. In addition, market-based nutrient trading programs, county and state-supported nutrient recycling programs, and feed technology breakthroughs should be investigated and employed along with nutrient management planning to reduce the threat of nutrient pollution while maintaining the economic vigor of the agricultural economy.

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INTRODUCTION

Risks of contamination to ground water and surface water figure prominently in public concerns about the nation's water resources. About one-half of the United States drinking water is obtained from ground water. Surface water provides an essential living environment for animals and plants and a source of recreation for humans. Agricultural impacts on surface and ground water quality are primarily through fertilizer, manure, soil erosion, and pesticides applications. The United States Department of the Interior (1995) estimated that 600 million pounds of nitrogen and 30 million pounds of phosphorus entered the Chesapeake Bay from its nine major tributaries during the period 1990-92. Agriculture contributes 50 percent of total phosphorus and 39 percent of total nitrogen entering the Chesapeake Bay (Magnien, 1996).

Agricultural nonpoint source pollution[1] concerns are focused on concentrated livestock operations, because of the production, storage, and disposal of large amounts of nitrogen- and phosphorus-bearing manure. Improper manure disposal or excessive applications to crop and pasture land pose the risk of detrimental impacts on surface and ground water. Research indicates that regions of concentrated animal production are major sources of nitrogen and phosphorus nutrients flowing into the Chesapeake Bay (Young et al.). In addition, high nitrate levels in water supplies have been directly related to regions of high animal concentration across the United States (Duda and Finan, Kingery et al., Moore et al.).

In 1987, states surrounding the Chesapeake Bay (the Bay) signed an agreement to reduce controllable nitrogen and phosphorus loadings to the Bay by at least 40 percent by the year 2000 (Chesapeake Executive Council, 1987). Using the Chesapeake Bay watershed computer simulation model, researchers estimate that phosphorus reduction goals will be met by the year 2000, but nitrogen reduction goals will not be met without additional efforts (Chesapeake Bay Program, 1997). However, because of expected population growth and increased livestock populations, maintaining nutrient loads at the year 2000 goal level will be a continuing challenge. The expectation is that nonpoint sources such as agriculture will be more closely scrutinized.

Virginia programs to protect water quality from agricultural nutrient pollution have focused on education and voluntary nutrient management planning for intensive livestock farms. However, counties such as Rockingham have been requiring nutrient management plans for new, intensive livestock operations for several years. In addition, the Virginia poultry industry is requiring all poultry production contractors to have certified nutrient management plans.

Virginia's statewide nutrient management program assists farmers in developing site-specific plans to manage nutrient applications. These plans help farmers achieve water quality protection while maintaining crop yields. Evidence shows that voluntary nutrient management plans can significantly reduce nitrogen losses from animal waste applications on cropland. Nutrient management practices such as improved manure storage and manure nutrient crediting may reduce losses and have positive effects on net farm returns (VanDyke). The four livestock farms examined in the VanDyke study decreased nitrogen losses from runoff and leaching by 23 to 45 percent,[2] while farm income increased by $400 to $4,600.

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[1] Nonpoint source pollution does not come from a specific, clearly identifiable physical location or a defined discharge.

[2] Nutrient losses to groundwater are called "leaching losses," while losses to surface water are called "runoff losses."

One alternative open to policymakers is to enact restrictions on nutrient applications to crop and pasture land. Crop farmers can adjust purchased fertilizer applications to comply with such restrictions, but livestock farmers are faced with the cost of livestock manure disposal. Many livestock farms would not be able to apply all the manure produced on the farm to their land if restrictions on phosphorus or nitrogen are established. The intent of this study is to examine the economic and environmental consequences such restrictions would have on the Shenandoah Valley's dairy and dairy/poultry farms and to provide objective information for evaluating nutrient management policies at state, regional, or county levels.

Rockingham County

Virginia Department of Agriculture and Consumer Services (VDACS) reports show that Rockingham County ranks first in the production of corn silage, alfalfa, other hay, dairy cattle, and poultry, as well as farm income, making it the most important agricultural county in the Commonwealth. According to the most recent Census of Agriculture (1992), Rockingham County has experienced rapid growth in poultry numbers, with increases of 125 percent for broilers and 136 percent for turkeys from 1978 to 1992. Dairy cow numbers, however, have remained relatively unchanged. In addition, approximately 30 percent of the dairy farms also have poultry enterprises (Halstead; Bosch, et al.) The increase in poultry production has, of course, been accompanied by a corresponding increase in total litter production. Using standard manure nutrient tables, the authors estimated that nitrogen and phosphate nutrients from broiler and turkey litter increased 67 percent and 77 percent, respectively, from 1978 to 1992.

Virginia's dairy and poultry industries generate over 40 percent of the Commonwealth's agricultural sales and are concentrated in Rockingham County, the center of the Shenandoah Valley. The steep slopes of most crop and pasture land in the Valley pose a potential for soil erosion and nutrient runoff to surface waters. In addition, the hydrogeological structure underlying the Shenandoah Valley has a high potential for ground water contamination due to its karst-carbonate limestone structure (Hinkle and Sterrett). Water flow corrodes limestone, sometimes creating sinkholes that allow surface runoff to be directly introduced into underground water supplies.

Repeated applications of manure to county farmland have increased soil nutrient values to high levels. Analysis of 3,766 Rockingham County soil tests from 3 fertilizer dealers and the Virginia Tech Soil Testing Laboratory for 1993 and 1994 shows that 89 percent of all samples rated either "very high" or "high" in phosphorus (Parsons). Such soils do not require any additional phosphorus applications for optimal plant growth, either in the current year or for several years to come.

Bosch et al. estimated that 57 percent of Rockingham County's crop and pasture land received manure applications in 1990. Although dairy farms, on average, under-supplied nitrogen relative to crop recommendations, the phosphate applied in manure greatly exceeded recommended levels (Donohue and Hawkins, and Donohue). On dairy/poultry farms, both the manure nitrogen and phosphate nutrients exceeded recommended amounts. The average nitrogen and phosphorus available to crops relative to the amount recommended for the crop that was grown on surveyed fields is shown in Table 1.

Table 1. Average excess[1] plant available nitrogen and phosphorus applied on dairy and poultry farms, Rockingham County, 1990.

Farm type	Average excess N[2]	Average excess P[3]
	---------------(lbs./ac)---------------	
Dairy	-36	93
Poultry	49	137

[1]Excess application is the total amount of the nutrient applied minus the amount recommended for the crop grown on the site.
[2]N=Elemental nitrogen
[3]P= Elemental phosphorus.
Source: Bosch, et al. 1992

Two-thirds of 120 randomly selected fields used in the Bosch et al. study had high potential for runoff and leaching on or near the fields. Nevertheless, 97 percent of the livestock farmers surveyed were of the opinion that fertilizer and pesticide runoff from their fields were not contributing to nutrient pollution problems. In addition, those fields with high leaching potential were thought to have low leaching potential by 73 percent of the farmers. Apparently, farmers do not recognize the potential risk to water quality resulting from their current farming practices on environmentally sensitive land.

In order to examine the impacts of applying manure and poultry litter to fields, this study estimates tradeoffs between nutrient losses at the field level and economic returns at the farm level for Rockingham County dairy and dairy/poultry farms under current management practices and under alternative nutrient management policies which would have the effect of restricting manure applications.

HOW THE STUDY WAS DONE

Representative Dairy and Dairy/Poultry Farms

According to VDACS, in 1994 Rockingham County had 146 Grade "A" dairy farms with less than 76 cows, 92 farms with between 76 and 125 cows, and 36 farms with over 125 cows. Since it is not practical to analyze the impacts of alternative manure management policies on all 314 dairy and dairy/poultry farms in Rockingham County, 3 representative farms were constructed. The assistance of three panels of county farmers, each representing a farm size, was enlisted so that realistic physical and economic characteristics would be used in the analysis. Dairy herd sizes of 60 (representing less than 76 cows), 100 (representing 76 to 125 cows), and 150 (representing greater than 125 cows) cows were used to represent typical farms with differing milk production technology, labor requirements, acreage, and family income (Table 2).

Generally, these farms rely on homegrown corn silage and rye silage (ryelage) to meet livestock feed requirements. Cropping practices, crop and pasture acreages, nutrient applications, herd production practices, feed rations, financial structure, receipts, and manure management practices were specified by each farmer panel. Costs and additional information were obtained from Cooperative Extension budgets and from crop and dairy specialists. Predictions of milk prices, interest rates, feed concentrate costs, and other key economic variables were obtained from estimates developed by the Food and Agricultural Policy Research Institute (FAPRI). All soils were assumed to be Frederick-Lodi (the most common soil type in Rockingham County), with slopes of 7 percent (cropland), 12 percent (hay/pasture rarely tilled), and 15 percent (pasture never tilled). Complete representative farm descriptions are reported in Parsons.

Table 2. Characteristics of representative farms

	--------------Dairy-------------			-------------Dairy/poultry------------		
	60-cow	100-cow	150-cow	60-cow	100-cow	150-cow
Land						
Cropland (acres)	70	125	200	70	125	200
Hay/pasture/other (acres)	45	80	180	45	80	180
Total (acres)	115	205	380	115	205	380
Livestock production						
Milk per cow/year (lbs.)	18,000	18,000	18,400	18,000	18,000	18,400
Poultry houses	NA	NA	NA	2	2	2
Animal (units/acre)	1.1	1.0	0.8	2.5	1.8	1.2
Manure collected						
Dairy manure (‘000 gals/year)	446	704	994	446	704	994
Poultry litter (tons/year)	--	--	--	408	408	408
Family						
No. families	1	2	2	1	2	2
Beginning net worth ($)	429,000	578,000	872,000	388,000	537,000	831,000
Beginning debt ($)	185,000	305,000	465,000	458,000	579,000	739,000
Off-farm income ($)	0	18,000	0	0	18,000	0
Living expense goal ($)	16,000	49,000	52,000	16,000	49,000	52,000

Estimates by agricultural engineers and from reference materials provided manure, parlor wash, lot runoff, and surface water runoff amounts. The farmer panels agreed that the estimates were reasonable. Total manure slurry collected annually was approximately 446,000 gallons, 704,000 gallons, and 994,000 gallons for each of the three representative farms.

Since approximately 30 percent of dairy farms in the county have poultry enterprises, 3 additional representative farms were developed by adding a “hybrid” poultry enterprise of turkeys and broilers to each dairy operation. Calculations based on the 1992 Census of Agriculture data indicated 57.5 percent of county litter production was from tom/hen turkey production and 42.5 percent was from broiler production. Investment costs and litter production for representative farms with poultry enterprises were based on these proportions. Virginia Cooperative Extension budgets indicated that a $275,000 debt-financed investment at 9 percent interest was needed over 15 years to construct two poultry houses. Annual net cash poultry income, after paying all production expenses, principal payments, machinery replacements, and taxes, was approximately $11,000. Collected annual poultry litter production was assumed to be 408 tons of “turkey/broiler” litter from the two houses. Nutrient concentrations for dairy manure and poultry litter are reported in Table 3.

Table 3. Manure and litter nutrient content[1]

	Unit	Percent Moisture	Dry Weight	Mineral N[2]	Organic N[2]	P[3]
		---%---	---lbs.---	--------------lbs./unit--------------		
Dairy Manure	1,000 gal	94.5	457	8.6	12.3	5.3
Poultry Litter	ton	66.2	1323	14.6	49.0	27.8

[1]Values are mean sample values from Virginia Tech Manure Testing Lab.
[2] N = nitrogen
[3] P = phosphorus

All farms apply poultry litter to crop, hay, and pasture land in order to meet fertility needs. With current practices, the dairy-only farms import 225, 360, and 503 tons of litter for land application.[3] The 60-cow dairy/poultry farm exports 90 tons of litter with current practices, while the 100-cow dairy/poultry farms approximately meets its own needs. The 150-cow dairy/poultry farm is not self-sufficient in litter production. Its nutrient applications are the same as its dairy-only counterpart; thus, it imports an additional 95 tons of litter. A summary of crop acreage and nutrient applications on the representative dairy and dairy/poultry farms with current practices is presented in Tables 4 and 5.

Table 4. Crop acreage and nutrient applications for dairy farms[1]

Crop	Acres	Dairy manure (gals/acre)	Poultry litter (tons/acre)	N available[2] (lbs./acre)	P available[3] (lbs./acre)
60-cow					
Corn/Ryelage	50	7000	3.0	211	121
Mixed Hay	20	2600	2.5	137	83
Alfalfa[4]	20	2500	0	60	63
Pasture[5]	20	2500	2.5	137	83
100-cow					
Corn/Ryelage	50	6000	2.0	180	87
Corn/Rye	50	6000	2.0	180	87
Mixed Hay	45	2500	3.0	160	97
Alfalfa	25	0	0	0	50
Pasture[5]	25	0	2.0	92	56
150-cow					
Corn/Ryelage	60	5000	2.0	170	82
Corn/Rye	60	5000	2.0	170	82
Corn	30	5000	2.0	170	82
Grass Hay	10	3500	3.0	169	102
Mixed Hay	60	1500	1.5	82	50
Alfalfa[4]	40	2500	0	60	63
Pasture[5]	110	1500	1.5	82	50

[1]Nutrients available include manure, litter, and fertilizer. Application rates are listed for the first year of crop rotation, and total manure/litter applications are approximately equal to amount collected.
[2]N available is the amount applied as commercial fertilizer and available from current and past applications of manure.
[3]P available is inorganic phosphorus applied in commercial fertilizer and manure.
[4]Manure is only applied in the first year of a four-year alfalfa rotation.
[5]Manure or litter is applied to one-half of pasture acreage each year.

MANURE MANAGEMENT POLICIES

Three alternative nutrient management policies were examined in this study. No mandatory policies such as those examined are currently being considered in Virginia or in Rockingham County at this time. Yet, these polices form part of voluntary or mandatory nutrient management plans in regions such as the New York City watershed and Florida's Lake Okeechobee region, states such as Pennsylvania and Texas, and countries such as The Netherlands which have intensive livestock production and water quality concerns.

[3]Imported poultry litter is assumed to have the same nutrient content as that produced on the dairy/poultry farms.

Table 5. Crop acreage and nutrient applications for dairy/poultry farms[1]

Crop	Acres	Dairy manure (gals/acre)	Poultry litter (tons/acre)	N available[2] (lbs./acre)	P available[3] (lbs./acre)
60-cow					
Corn/Ryelage	50	7000	4.6	283	121
Mixed Hay	20	2600	3.0	161	83
Alfalfa[4]	20	2500	0	60	63
Pasture[5]	20	2500	3.0	160	83
100-cow					
Corn/Ryelage	50	6000	3.0	226	87
Corn/Rye	50	6000	2.0	180	87
Mixed Hay	45	2500	3.0	160	97
Alfalfa	25	0	0	0	50
Pasture[5]	25	0	2.0	92	56
150-cow					
Corn/Ryelage	60	5000	2.0	170	82
Corn/Rye	60	5000	2.0	170	82
Corn	30	5000	2.0	170	82
Grass Hay	10	3500	3.0	169	102
Mixed Hay	60	1500	1.5	82	50
Alfalfa[4]	40	2500	0	60	63
Pasture[5]	110	1500	1.5	82	50

[1]Nutrients available include manure, litter, and fertilizer. Application rates are listed for the first year of crop rotation, and total manure/litter applications are approximately equal to amount collected.
[2]N available is the amount applied as commercial fertilizer and available from current and past applications of manure.
[3]P available is inorganic phosphorus applied in commercial fertilizer and manure.
[4]Manure is only applied in the first year of a four-year alfalfa rotation.
[5]Manure or litter is applied to one-half of pasture acreage each year.

"BASE" represents current practices as defined by the farmer panels. The three alternative policies analyzed focus on different environmental concerns. "INCORP" examines the impact of a manure/litter incorporation requirement, which responds to odor, air quality, and surface runoff concerns. "NLIMIT" focuses on concerns about nitrogen as a potential contaminant of surface and ground water by limiting nitrogen applications to Virginia Agronomic Land Use Evaluation System (VALUES) recommendations. "PLIMIT" limits phosphorus applications to the amount removed by crops, and thereby addresses concerns about phosphorus as a potential water contaminant (Box 1).

Assumptions

All farms are assumed to have a structure to store dairy manure for at least 120 days. Both the 100-cow and 150-cow dairy farmers buy poultry litter to apply on their crop or pasture land. Under both NLIMIT and PLIMIT, it was initially assumed that export of any excess poultry litter by dairy/poultry farms is costless. Currently, poultry farms can sell litter for $6 to $10 per ton. But with a general restriction on application rates, there would be a much larger supply of litter in the region, and a sharp drop in the market price would be expected. The sensitivity of farm returns to the manure restrictions depends critically on the disposal conditions for poultry litter.

Box 1. What is a manure management policy?

INCORP would require soil incorporation of surface-spread manure applications within 48 hours. Working manure into the soil removes manure from the soil surface, decreases volatilization of nitrogen compounds, and reduces the likelihood that nitrogen and phosphorus are carried away from the site by rainfall.

NLIMIT would limit nitrogen applications on crop and pasture land to the amount specified in the VALUES nutrient recommendations (Donohue *et al.*). Nutrient recommendations are based on maximum economic crop yields, but not necessarily maximum potential yields. By limiting nitrogen applications to crop nutrient requirements, nitrogen losses to ground and surface water should be minimized.

PLIMIT would limit phosphorus applications to the amount removed through crop harvest. Estimated phosphorus removal by crops follows nutrient management recommendations. By limiting phosphorus applications to crop removal, phosphorus concentrations in the soil should not increase, and phosphorus losses to ground and surface water should be minimized.

EPIC and FLIPSIM

Crop yields and potential nutrient losses[4] under current and alternative manure management practices were estimated with the Erosion Productivity Impact Calculator (EPIC), a biological soil/crop growth simulation model (Box 2). The EPIC simulation for each field/crop/management alternative requires several hundred detailed parameter values which were drawn from Bosch et al., expert judgement of a soil scientist, Natural Resource Conservation Service soil database files, and VALUES (Donohue et al.). Initial phosphorus levels were set at the median level of soil test results reported in Parsons.

All nitrogen and phosphorus loss estimates by EPIC occur at the lower edge of the root zone and at the edge of the field. Such field losses may or may not end up in ground or surface water. A number of intervening factors, such as buffer strips, wooded areas, and the distance to ground and surface water are critical in determining whether these estimated nutrient losses have a detrimental effect on water quality.

Initial soil nitrogen levels were set by running a four-year startup period at current nutrient application rates prior to running the five-year simulations.[5] The farmer panels specified all mechanical operations performed on the site, dates of those operations, and quantities of fertilizer, manure, and pesticide applied. Dairy and poultry manure nutrient content was based on manure test results reported by the Virginia Tech manure testing laboratory. County weather station data from 1949 to 1992 (daily rainfall and daily high and low temperature) provided input for weather simulation.

Using the input data provided, the model simulated crop and pasture growth on a daily basis for each farm. For each field/crop/management alternative on each representative farm under BASE, INCORP, NLIMIT and PLIMIT, 100 5-year EPIC simulations were generated giving field-level crop yield and nutrient losses. Crop and soil science experts reviewed and recommended modifications and assessed all model outputs.

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[4] Crop yields are estimated from above-ground biomass and converted to harvestable material by the model. Nutrient losses, as estimated by EPIC, occur when nutrients travel beyond the field edge or below the root zone.

[5] Five years is the length of the longest rotation on the representative farms.

Box 2. What is EPIC?

The Erosion Productivity Impact Calculator (EPIC), a computer model, used to simulate multi-year interactions of weather, hydrology, erosion, nutrient cycling, plant growth, pesticide fate, soil temperature, economics, and soil tillage. It was developed by USDA through the combined efforts of specialists in hydrology, soil science, botany, and soil and plant biochemistry (Williams et al., 1990, Jones et al. 1991). EPIC has been widely tested and used throughout the United States and other countries. Williams et al. (1989) reviewed 227 studies of EPIC-simulated yields of 6 major crops, and found that simulated yields were always within 7 percent of mean measured yields and that none was significantly different from measured yields. In other studies, the nutrient cycling predictions have shown good agreement for nitrogen and phosphorus (Jones *et al*., 1984, 1985; Smith *et al*., 1990). EPIC simulated yields provided statistically identical estimates of actual yields from Virginia experiments with commercial fertilizer and manure nutrient applications (Parsons et al.).

Crop yields from EPIC determine the amount of farm-produced feed available for consumption by the dairy herd, and, hence, the level of feed purchases required. Estimated crop yields and representative farm costs of production and financial data were used as input for simulation of financial performance with the Farm Level Income Policy Simulation Model (FLIPSIM) (Box 3). Expected future prices were obtained from the FAPRI's long range forecasts. FLIPSIM then predicted annual financial performance for 100 simulated 5-year periods for each representative farm.

Box 3. What is FLIPSIM?

The Farm Level Income Policy Simulation Model (FLIPSIM), a computer simulation model, is used to estimate annual farm financial performance over a multi-year planning period. Given initial state financial information, FLIPSIM produces estimates of farm income, taxes, cash flow, probability of survival, return on assets, and debt levels over time. Congressional committees use FLIPSIM to examine the potential impacts of alternative policies on United States farms (Richardson and Nixon). Previous studies have used FLIPSIM to estimate financial impacts of nutrient and manure management policies (Boggess et al., Allen et al.).

RESULTS

Estimated nutrient losses using BASE and associated farm financial returns were analyzed and compared to the corresponding outcomes under the potential nutrient management policies INCORP (required manure incorporation), NLIMIT (nitrogen applications limited to agronomic recommendations), and PLIMIT (phosphorus applications limited to crop uptake). Average nutrient losses per acre for each representative farm are presented in Table 6, and percentage changes in Figures 1A, 1B, 2A, and 2B.

Financial returns for each representative farm are presented in Table 7 and percentage changes in Figures 3A and 3B. Predicted net cash incomes consider cash receipts minus all cash expenses, including principal payments on debt and replacement capital purchases. The number of families involved in each operation and their living expense goals differ, as does the income earned off the farm (Table 2). The 60-cow farm designed by the farmer panel reflects the small, intensive, primarily Mennonite farms of the county. Such families are very frugal, which explains much of their relatively high rate of net worth growth. On the other hand, the 150-cow farm is operated by 2 families, each with much higher living expense goals and, consequently, a slower rate of net worth growth.

BASE

Average soil nitrogen losses for BASE range from 20.5 to 40.9 pounds per acre on the representative dairy farms. Phosphorus losses (primarily through soil erosion) for BASE are 4.0 to 5.3 pounds per acre. Since a dairy/poultry farm applies the same amount of dairy manure as its dairy-only counterpart plus some poultry litter, its nutrient losses are as high or higher than its dairy-only counterparts.

The 60-cow dairy/poultry farm has the highest nitrogen and phosphorus losses per acre of all farms because it has much less land area on which to spread dairy manure and poultry litter. Despite cropping practices such as conventional tillage with no cover crop (which increases the potential for soil erosion and nutrient losses), the 150-cow farm (with or without poultry) has lower per acre losses than other farms, primarily because it has relatively more land on which to spread the nutrients.

The 60-cow dairy is not likely to generate enough net cash return to support a family, unless the operators of such farms have a very low expenditure pattern. With family living expenses already at such a low level, these farms have limited flexibility to meet rising family living and production costs and to replace aging machinery. The net returns of the 100-cow dairy provide a little more opportunity for 2 families to live at the standard of their urban neighbors or to reinvest in the business, but the longer term competitiveness of a dairy with this herd size also seems doubtful. Only when 2 families milk 150 cows do net cash returns reach a level which seems to offer some promise for investment and growth of the farm business. It is clear from these results that there is considerable financial incentive to increase herd size.

Net returns are increased considerably by adding a poultry enterprise to a dairy farm. The 60-cow dairy has relatively little land to expand the dairy operations. By adding a poultry enterprise, net cash returns increase by 41 percent and the rate of return on farm net worth doubles. Thus, the 60-cow dairy-only farm could expand to a 100-cow dairy-only operation or add poultry and achieve approximately the same net cash income and net worth as the 100-cow dairy-only operation. When a poultry enterprise is added, substantial increases in net returns also occurred for the 100-cow dairy (+49 percent) and the 150-cow dairy (+14 percent), and their rates of return on farm net worth are nearly doubled in both cases (Table 7).

Table 6. Predicted nutrient losses per acre[1]

	Policy							
	BASE		INCORP		NLIMIT		PLIMIT	
Farm type	N loss[2]	P loss[3]	N loss	P loss	N loss	P loss	N loss	P loss
Dairy	--------------------------(lbs./acre)--------------------------							
60-cow	26.8	4.7	27.1	4.4	18.7	4.4	18.1	3.0
100-cow	30.5	5.0	30.9	4.7	20.9	4.7	20.1	3.3
150-cow	20.5	4.0	21.1	3.7	16.9	3.9	16.1	2.9
Dairy/poultry								
60-cow	40.9	5.3	41.5	4.8	20.6	4.5	18.1	3.0
100-cow	32.2	5.2	32.7	4.7	23.5	4.9	20.1	3.3
150-cow[4]	20.5	4.0	21.1	3.7	16.9	3.9	16.1	2.9

[1]Predicted nutrient losses are estimated at the edge of the field and the bottom of the root zone.
[2]Nitrogen soil losses include nitrogen dissolved in surface water runoff, attached to eroding sediment, dissolved in subsurface lateral water flow, and leached through the soil profile.
[3]Phosphorus losses include such nutrients attached to soil particles and carried off the site by soil erosion as well as soluble phosphate carried off the surface by surface runoff.
[4]The 150-cow dairy/poultry farm applies more litter than it produces; therefore, its application rates and losses are the same as the 150-cow dairy.

Table 7. Annual net cash income and net worth change for representative farms

	Policy							
	BASE		INCORP		NLIMIT		PLIMIT	
Farm type	Net Cash Income[1]	Net Worth Growth[2]	Net Cash Income	Net Worth Growth	Net Cash Income	Net Worth Growth	Net Cash Income	Net Worth Growth
Dairy	$	%	$	%	$	%	$	%
60-cow	24,400	3.8	24,600	3.8	24,700	3.9	20,200	3.5
100-cow	30,100	3.6	30,500	3.6	31,800	3.7	24,900	3.4
150-cow	52,700	2.6	52,600	2.6	53,700	2.7	46,900	2.3
Dairy/poultry								
60-cow	34,500	7.7	34,800	7.8	34,500	7.8	26,700	7.4
100-cow	44,800	7.1	45,100	7.1	46,100	7.1	35,300	6.7
150-cow	60,100	4.7	59,900	4.7	61,200	4.7	51,400	4.2

[1] Total cash receipts minus total cash expenses, including principal payments, capital replacement, and taxes. Family living expenses must be paid from net cash income.
[2] Average percent change over the five-year planning period, market basis, unadjusted for inflation. Net worth is the wealth of the owners if all the business obligations were paid.

Policy Alternatives

The three alternative policies--INCORP, NLIMIT, and PLIMIT--were explained to the farmer panels. They expressed the opinion that farmers, if faced with such restrictions, would apply all dairy manure to their own farm, supply as much crop nutrients as needed from poultry litter, and then supplement any plant nutrient needs with commercial fertilizer. In moving from the INCORP to the NLIMIT and finally to the PLIMIT policy, it becomes increasingly difficult to use poultry litter for fertilizer, because nutrient limits are reached primarily through dairy manure applications. Under PLIMIT, no poultry litter can be applied by any farm. Dairy/poultry farmers must find other farmers willing to take their litter production. Litter use on all farms under current practices and alternative manure management policies is shown in Table 8.

Table 8. Poultry litter applications with current practices and alternative policies[1]

	Policy			
	BASE	INCORP	NLIMIT	PLIMIT
Farm	----Tons----			
Dairy				
60-cow	225	225	195	0
100-cow	360	360	298	0
150-cow	503	503	454	0
Dairy/poultry				
60-cow	318	318	215	0
100-cow	410	410	388	0
150-cow	503	503	454	0

[1]All dairy/poultry farms produce 408 tons of litter/year. Any litter application exceeding production is obtained from other farms. Litter production greater than application must be exported from the farm.

INCORP Policy Impacts

- Nitrogen losses decrease slightly
- Phosphorus losses decrease 6 to 10 percent
- Income increases slightly
- Implementation difficult

The policy requirement INCORP does not restrict the quantity of manure or litter that can be applied to the land. While significantly decreasing nitrogen volatilization into the atmosphere, incorporation of manure increases the nitrogen in the soil. However, this reduction in surface loss is more than off-set through subsurface losses resulting from leaching and percolation (Figures 1A and 1B and Table 6). Phosphorus losses are decreased 6 to 10 percent with INCORP (Figures 2A and 2B). Relatively little difference in nitrogen- or phosphorus-loss reductions across farm types and sizes occurs. Furthermore, the farm-level income and wealth effects of INCORP are negligible (Figures 3A and 3B, Table 7).

Clearly, these results show that INCORP by itself is not a policy that could make a significant difference in nutrient losses. The nutrient loss impacts of such a policy when applied to farmland with varying soils and slopes are not easily predicted, nor would implementing this policy on many rocky soils in Rockingham County be possible.

Figure 1A. Dairy only: percent change in nitrogen losses compared to BASE by manure management policy.

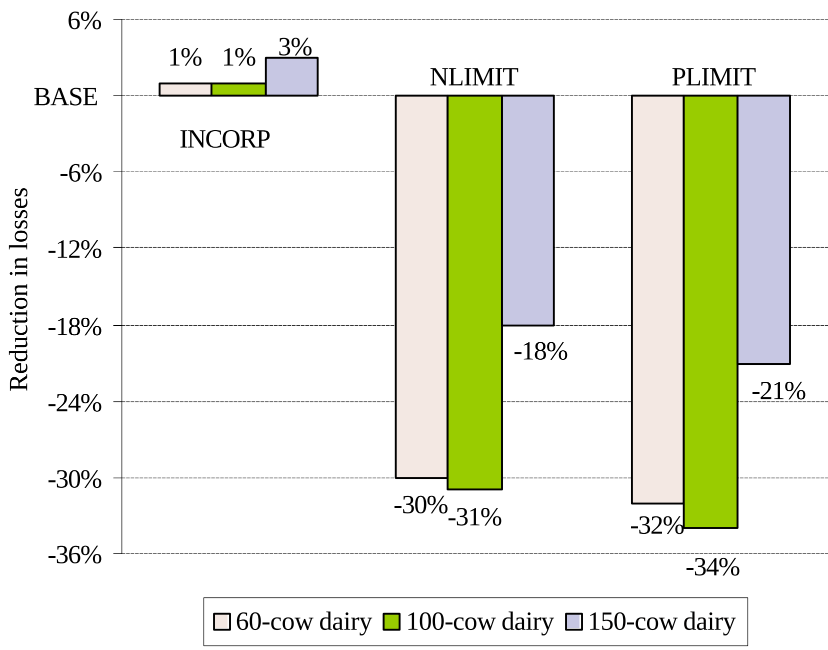


Figure 1B. Dairy/poultry: percent change in nitrogen losses compared to BASE by manure management policy.

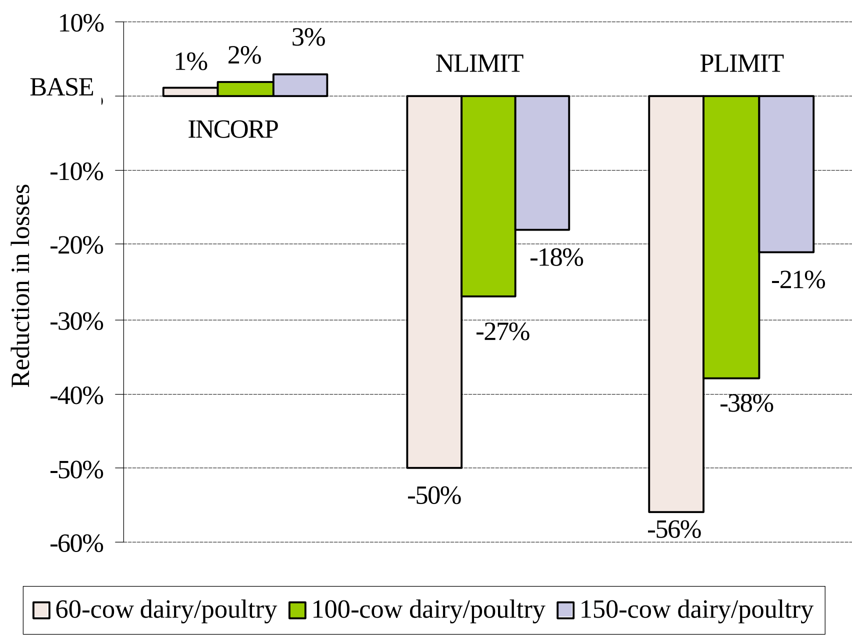


Figure 2A. Dairy only: percent change in phosphorus losses compared to BASE by manure management policy.

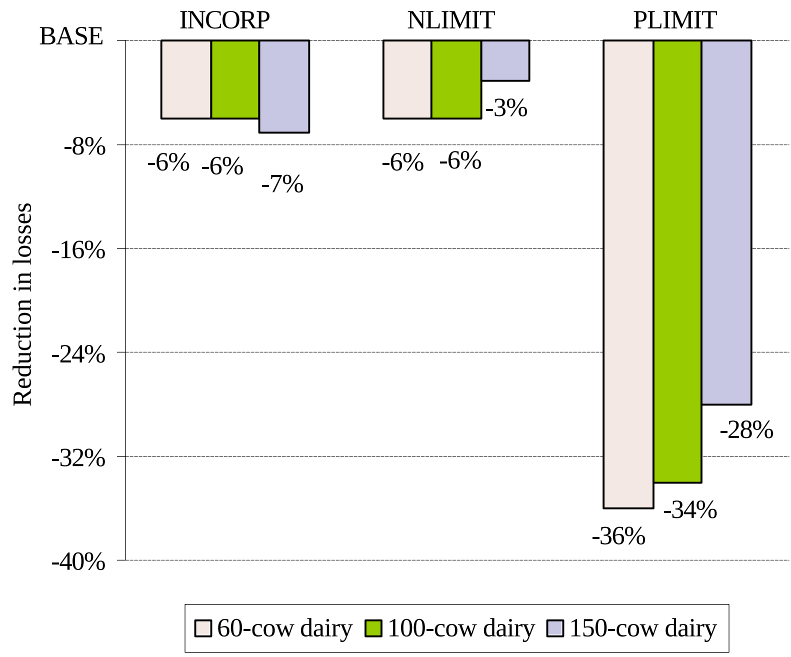


Figure 2B. Dairy/poultry: percent change in phosphorus losses compared to BASE by manure management policy.

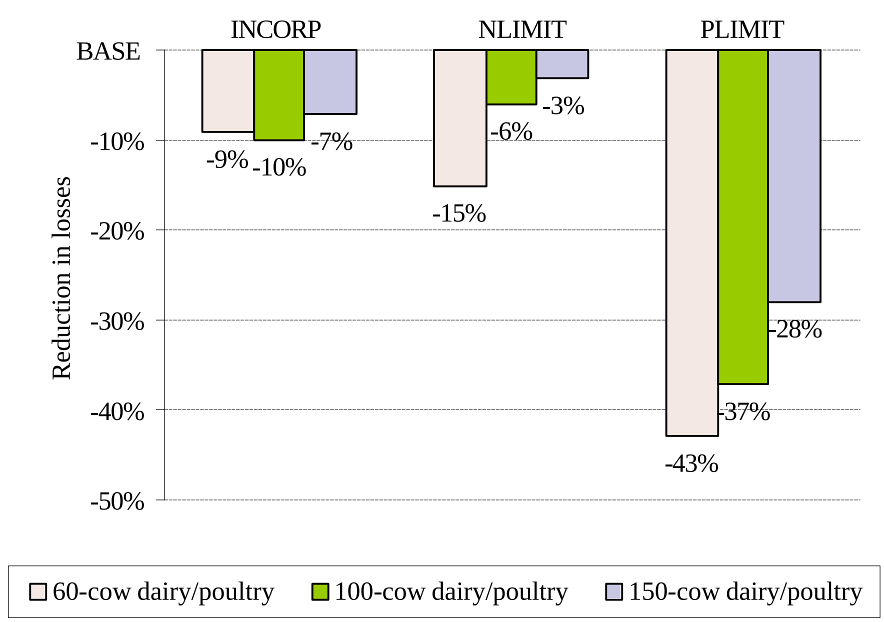


Figure 3A. Dairy only: percent change in net income compared to BASE by manure management policy.

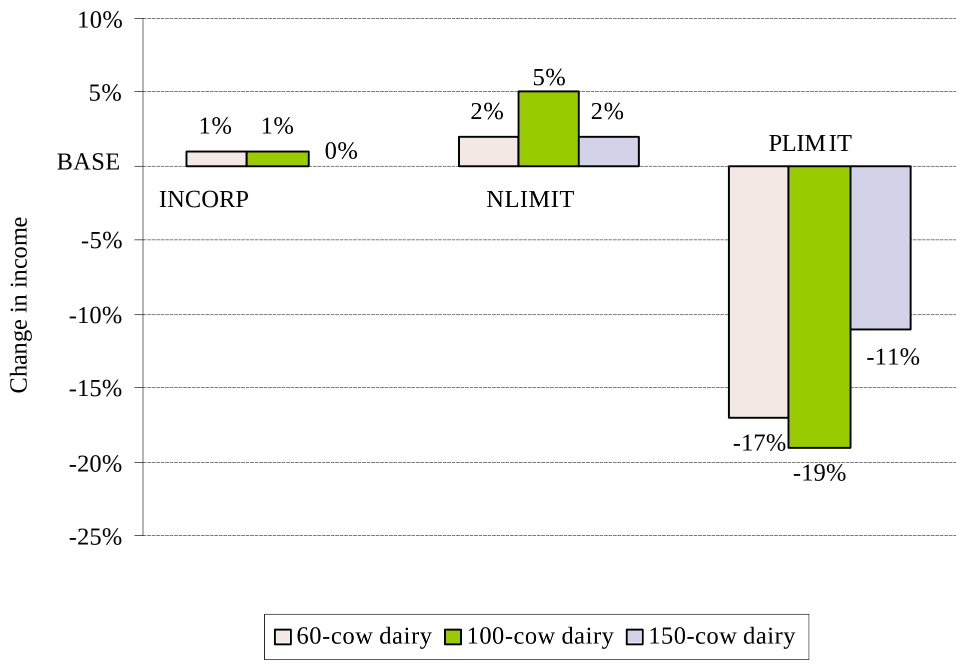
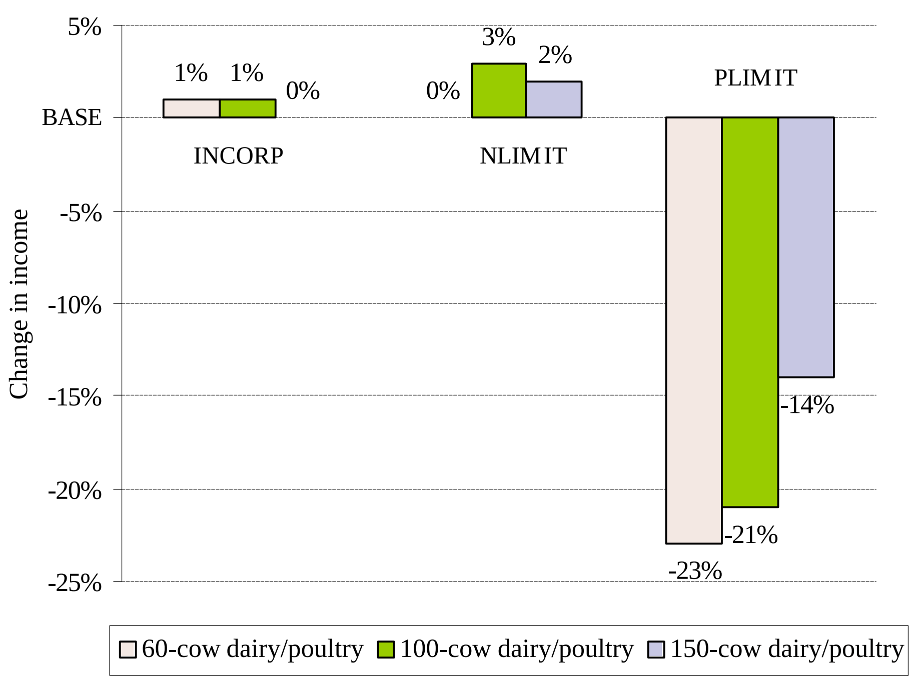


Figure 3B. Dairy/poultry: percent change in net income compared to BASE by manure management policy.



NLIMIT Policy Impacts

- Nitrogen losses decrease by 18 to 50 percent
- Phosphorus losses decrease by 3 to 15 percent
- Income increases by 0 to 5 percent
- Litter applications decrease, cutting imports, increasing exports

Reductions in nitrogen losses under NLIMIT range from 18 to 50 percent across all representative farms. These reductions are comparable to the estimates obtained by VanDyke in her study of before-and-after nitrogen losses on four Virginia livestock farms which adopted nutrient management plans. Reductions in losses are smallest on the 150-cow farms where nitrogen applications are already more consistent with crop and pasture requirements. The largest nitrogen-loss reduction (50 percent) occurs on the 60-cow dairy/poultry farm (Figure 1B). These loss reductions are achieved through reducing nitrogen availability--from new applications and, over time, from residual nitrogen--by 57 pounds per acre on hay/pasture, 100 pounds per acre on pasture, and 52 pounds per acre on corn silage/ryelage. Notwithstanding the dramatic decrease in nitrogen available to the crops/hay/pasture, yields do not change under NLIMIT, because applications under BASE exceed plant requirements for all farms.

Even though phosphorus applications in manure and litter are cut by 20 to 45 percent, high soil residual phosphorus levels cause phosphorus losses to continue almost at BASE levels for several years. The largest reductions in phosphorus losses occur on the 60-cow dairy/poultry farm, and are primarily attributable to reductions in poultry litter applications (Figure 2B).

Litter applications under NLIMIT must be cut by 30 to 103 tons depending on farm size, and 193 and 20 tons of litter must now be exported from the 60-cow and 100-cow dairy/poultry farms, respectively. The 150-cow dairy/poultry farm continues to import litter, but the quantity is reduced by 49 tons.

Four of the six farms show a slight improvement in net income and net worth under NLIMIT (Figure 3A, Table 7). These farms cut litter applications to some corn, hay, and pasture land, resulting in lower fertilization costs from poultry litter acquisition or spreading or both. In some cases, nitrogen fertilizer purchases are reduced. Thus, a nitrogen-limiting policy could increase the net income of farms such as these while reducing nitrogen losses by 18 to 50 percent. This “win-win” result from reducing nitrogen losses was also found by VanDyke.

PLIMIT Policy Impacts

- Nitrogen losses decrease 21 to 56 percent
- Phosphorus losses decrease 28 to 43 percent
- Income decreases sharply by 11 to 23 percent
- No litter applications
- Cost of PLIMIT policy to farmers is very high

PLIMIT reduces phosphorous losses by 28 to 43 percent below BASE, a much greater decrease than with other policies. Because of the high phosphorus levels shown by county soil tests, no additional phosphorus applications are necessary to sustain optimal yields, and only phosphorus from dairy manure applications is added to soil reserves. The 60-cow dairy/poultry farm is the only farm which reduces losses from BASE by at least the 40 percent target of the Bay protection efforts. This reduction is accomplished by exporting the entire 408 tons of poultry litter produced (Figure 2B).

Nitrogen losses under PLIMIT are reduced by 21 to 56 percent from BASE, but are only slightly greater than those under NLIMIT. This result occurs because commercial nitrogen is purchased to offset the decreased litter applications, and, hence, soil nitrogen losses are nearly the same as with the NLIMIT manure and litter applications. Again, these shifts in nutrient practices are accompanied by little change in crop yields because BASE nutrient applications exceed crop needs.

The financial impacts of PLIMIT are much more severe than those of other policies (Figures 3A and 3B, Table 7). Additional costs are incurred by all farms under PLIMIT, as dairy manure applications must be supplemented with additional nitrogen and potash commercial fertilizer to meet crop and pasture nutrient requirements. Net income decreases range from -11 percent to -23 percent. Net worth growth is also significantly slower because of the management changes required under the policy.

Cost Impact of Litter Removal

The simulated income and net worth results shown in Table 7 assume that litter disposal cost is zero. If all farms were subjected to a policy like PLIMIT, it is unlikely that all poultry-producing farms would be able to dispose of their litter without cost. Economic returns would decrease if poultry farms were required to pay in order to remove litter from their farms. If litter disposal costs were $10 per ton, net cash income for all dairy/poultry farms would decrease from the BASE level by 45 percent (60-cow), 42 percent (100-cow), and 24 (150 cow) percent.

County Nutrient Losses by Farm Type

Assuming that the representative farms analyzed depict the entire range of dairy and dairy/poultry farm sizes in Rockingham County, total county nutrient losses can be estimated. This estimate is made by multiplying the average nutrient loss per acre on each representative farm by the number of dairy and dairy/poultry farms of that size. The number of dairy and dairy/poultry farms represented by each model farm and the associated total nutrient loss under BASE are shown in Table 9.

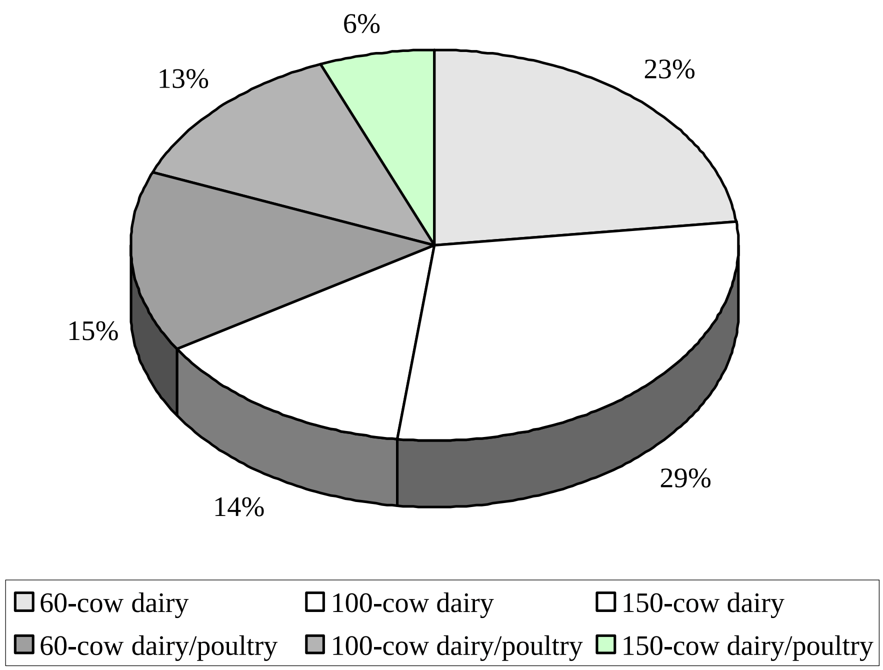
Table 9. Potential Rockingham County nutrient losses from dairy and dairy/poultry farms[1,2]

		Nitrogen losses[3]			Phosphorus losses[4]		
		---lbs.---					
Farm type	No. of farms	BASE	NLIMIT	PLIMIT	BASE	NLIMIT	PLIMIT
Dairy							
60-cow	102	300,700	209,800	203,100	52,700	49,400	33,700
100-cow	64	380,700	260,800	250,900	62,400	58,700	41,200
150-cow	25	189,700	156,300	148,900	37,000	36,100	26,800
Dairy/poultry[5]							
60-cow	44	198,000	99,700	87,600	25,700	21,800	14,500
100-cow	28	175,800	128,300	109,800	28,400	26,800	18,000
150-cow	11	83,400	68,800	65,500	16,300	15,900	11,800

1 Nitrogen and phosphorus losses measured to edge of field or root zone.
2 Results with the INCORP policy are omitted for clarity.
3 Nitrogen soil losses include nitrogen dissolved in surface water runoff, attached to eroding sediment, dissolved in subsurface lateral water flow, and leached through the soil profile.
4 Phosphorus losses include such nutrients attached to soil particles and carried off the site by soil erosion as well as soluble phosphate carried off the surface by surface runoff.
5 30 percent of all dairy farms assumed to also have poultry.

To appropriately target programs to reduce nutrient losses from livestock-intensive farms, the contribution that small and mid-sized farms make to total loses and the importance of poultry imports must be taken into account. The 60- and 100-cow dairy farms represent the largest number of farms and consequently, are the source of over half the total nitrogen losses (Table 9). The 100-cow dairy and dairy/poultry farms are the source of 42 percent of the nitrogen losses, while the 150-cow dairy and dairy/poultry farms contribute only 20 percent to the total losses. The losses of each representative farm type as a proportion of total county nitrogen losses from dairy and dairy/poultry farms are shown in Figure 4. Farm shares of county phosphorus losses, using BASE practices, are essentially the same as the nitrogen losses shown in Figure 4.

Figure 4. Farm share of county nitrogen losses, BASE practices.



CONCLUSIONS AND IMPLICATIONS

- Current nutrient applications exceed recommended amounts on many livestock farms
- INCORP policy has small economic and environmental impacts
- NLIMIT policy reduces nitrogen losses significantly and increases income slightly
- PLIMIT reduces nitrogen, phosphorus losses and income considerably

As potential policies are reviewed, a critical assumption must be remembered: ***nutrient losses are estimated at the edge of the field or the root zone and do not necessarily result in water pollution***.

Of the three policies considered by this study, INCORP as a regulatory policy has unforeseen impacts on water quality goals. Because a substantial proportion of nitrogen in unincorporated manure is volatilized into the atmosphere, a requirement that manure be incorporated within 48 hours decreases surface but increases sub-surface nitrogen losses. Given the difficulty of incorporating manure and of enforcing such incorporation, it appears that INCORP is an inadequate policy for water quality protection.

The NLIMIT policy may present a win-win situation for many farmers as well as for water quality protection programs. Nitrogen and phosphorus losses are decreased, and farm level income and wealth are increased slightly. Improved income and wealth occur because BASE practices identified by the farmer panels do not correctly assess the value of manure nutrients available from current and past applications. A more careful assessment of manure nutrient value as would be required under NLIMIT could result in slightly higher profits and business net worth. These results are consistent with those of VanDyke, who estimated that income on four Virginia livestock farms increased from $400 to $4,600 after implementing a nutrient management plan, while nitrogen losses decreased 23 to 45 percent. Such results emphasize the clear need for educational efforts to allocate manure nutrients according to their economic value. However, since phosphorus losses are reduced only marginally by farming practices designed to reduce nitrogen losses, a policy such as NLIMIT would probably not be sufficient to achieve existing water quality protection goals from nonpoint source pollution.

However, for litter producing farms, the farm level income effects of both NLIMIT and PLIMIT depend on an aspect of the poultry litter market not studied here. At an assumed zero disposal cost, the two smaller dairy/poultry farms export 193 and 20 tons of litter, respectively, under NLIMIT, and each exports 408 tons of litter under PLIMIT. If a policy such as NLIMIT or PLIMIT creates a surplus of litter for the county or region, it may be necessary for some poultry farms to pay for litter disposal. The further development of litter markets and farm financial risk implied by increased litter disposal costs should be the object of future study.

PLIMIT substantially decreases both nitrogen and phosphorus losses, but at the expense of 11 to 23 percent of net cash income from base. Low-cost litter fertilization of crops and pastures is not possible, since phosphorus requirements are met solely with dairy manure. For Rockingham County, approximately 34,000 tons of additional litter would have to be transferred off farms of these types if a policy such as PLIMIT were instituted, and county dairy farms could not import any litter. The impact on litter prices would be substantial. If litter disposal cost $10 per ton, net cash income would decrease by over 8 percent or approximately $1.2 million for all dairy/poultry farms in the county.

In general, many educational programs concentrate on reaching larger farms, under the premise that a ripple effect will result from innovations by the larger, “better educated,” and “more progressive farmers.” In addition, an underlying assumption is that such programs can affect “more acres” or “more animals” by working with the larger operations. This study shows that the majority of county nutrient losses come from small to mid-sized dairy and dairy/poultry farms. With existing public program resources, it is not possible to reach large numbers of small farms with a nutrient management education campaign. Educational programs will need to be targeted at livestock-intensive farms according to the specific spectrum of characteristics which indicate serious potential problems for nutrient management and water quality policy. Farm-level data, like as soil types and slopes, livestock numbers, and manure import/export, needed to target such programs are not readily available. Related watershed-level data, which research models might use to predict potential water quality problems such as location of farms with high livestock density within the watershed, are also not widely available. If water quality goals are to be met with regard to agricultural nonpoint source pollution, more ambitious private and government efforts in these areas will be necessary.

The Valley’s hydrogeologic structure for potential water quality pollution, its increasing population, and its expanding poultry industry make water quality an increasing concern. Poultry production in

Rockingham County has grown by 5 to 7 percent per year in recent years. If the same proportion of litter stays within the county each year, then manure nutrients applied to the soil are increasing rapidly. Bosch et al. and soil test results (Parsons) support the position that nitrogen and phosphorus nutrients have been "banked" in Rockingham County soils.

Serious financial impacts could result from mandatory phosphorus restrictions on Virginia's livestock industry. Clearly, a need for education and nutrient management planning exists so that dairy and dairy/poultry farmers understand the water quality implications of their farming practices. However, evidence shows that education and nutrient management efforts may not be sufficient to achieve existing water quality goals. Market-based nutrient trading programs show some promise in this regard (Jacobson et al.). Another possibility is for state government to give incentives for recycling nutrients from the four poultry-producing Valley counties. Public/private cooperative efforts have been initiated to incorporate new feeding technology which lowers nutrient concentrations in manure. The greatest environmental benefits are likely to be achieved through a combination of voluntary and regulatory measures. Further research is needed on farm-level effects of those policies aimed at reducing the threat of nutrient pollution while maintaining the economic vibrancy of the agricultural economy. Innovative, voluntary programs to accomplish environmental objectives should be investigated.

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