Yield Reserve Program Costs in the Virginia Coastal Plain

Todd Metcalfe, Darrell J. Bosch, James W. Pease, Mark M. Alley, and Steve B. Phillips

A proposed Yield Reserve Program designed to compensate farmers for any reduced yields resulting from nitrogen (N) application rates reduced to below recommended rates is evaluated. Assuming that farmers currently follow Extension recommendations for applying N, Yield Reserve Program participation reduces expected net revenue by $10 to $13/ha. The Yield Reserve Program reduces expected net revenue by $17 to $20/ha for farmers who apply N to maximize expected net revenue. Farmers' costs of participation increase with lower probabilities of inadequate rainfall and higher corn prices and decline with higher N prices. The Yield Reserve Program can significantly reduce N applications to cropland, which may reduce N content of surface waters, but the costs to taxpayers and farmers will depend on how the program is implemented.

Key Words: compliance cost, nitrogen fertilizer, nonpoint source pollution, policy, yield response function

Agriculture is a major source of nonpoint source (NPS) pollution in the United States, "degrading 60 percent of the impaired river miles and half of the impaired lake acreage" (U.S. Environmental Protection Agency 2004). Agriculture has also been identified as the largest source of nitrogen pollution affecting the Chesapeake Bay (Chesapeake Bay Foundation 2003). Nitrogen and phosphorus nutrients that leave fields as runoff promote eutrophication and algal blooms, which create anoxic conditions damaging to aquatic species (U.S. Environmental Protection Agency 2006).

In the Chesapeake Bay Agreement of 1987, cooperating states and the District of Columbia agreed to reduce nutrient loadings to the Bay by 40 percent from the 1985 baseline (Chesapeake Bay Agreement 1987). As estimated by the Chesapeake Bay watershed model, the nutrient loadings goals were nearly achieved by 2000, but current water quality measurements indicate continued peril for the Bay's living resources such as fish and aquatic vegetation (Chesapeake Bay Program 2002). Recent model simulations indicate that only 58 percent of the phosphorus, 41 percent of the nitrogen, and 54 percent of the sediment reduction goals necessary to ensure sustainability of the Bay's living resources have been achieved (Chesapeake Bay Program 2005). The 2010 goals of the Chesapeake Bay Program include removal of the Bay and its tidal waters from the Clean Water Act 303(d) impaired waters list through achievement of established Tributary Strategies (Chesapeake Bay Program, undated).

State and federal programs seek to mitigate NPS pollution originating from farms. One type of program involves "green payments," that is, paying farmers for adoption of best management practices (BMPs) that mitigate pollution (Ribaudo, Horan, and Smith 1999). The Conservation Reserve Program bidding program uses market-determined land rental rates to pay farmers a fixed rate to remove highly erodible and other environmentally sensitive lands from production (USDA 1997). The Conservation Security Program provides incentive payments for adoption of nutrient management planning and applications (USDA 2006b). Recently, programs have provided insurance to farmers who reduce their nu-

Todd Metcalfe is Graduate Research Assistant and Darrell Bosch and James Pease are Professors in the Department of Agricultural and Applied Economics at Virginia Tech in Blacksburg, Virginia. Mark Alley is Professor in the Department of Crop and Soil Environmental Sciences, also at Virginia Tech in Blacksburg. Steve Phillips is Associate Professor in the Eastern Shore Agricultural Research and Extension Center at Virginia Tech in Painter, Virginia.

The authors express appreciation to Thomas Simpson for his research suggestions and to Karen Mundy for editorial assistance.

trient applications to levels specified in BMP guidelines (USDA 2003, BMP Challenge 2007). These programs insure against yield losses resulting from inadequate nutrient applications.

Economic analyses of green payment options have focused on types of policy instruments and methods of targeting policy instruments (Ribaudo, Horan, and Smith 1999). Wu et al. (2004) found an inelastic acreage response to payments for adoption of conservation crop rotations and tillage, implying that such programs would not be cost-effective in addressing the hypoxia problem in the Gulf of Mexico. Zhang, Horan, and Claassen (2003) found that performance-based subsidies to reduce nitrogen runoff are first-best in that subsidy rates are optimally differentiated to reflect each farm's delivery of nitrogen loads. However, targeted nutrient management subsidies, which focus directly on reducing nitrogen applications, produce almost equivalent net returns compared to performance subsidies. This result implies that altering nitrogen use directly is more efficient than altering land use as a method of achieving nutrient reduction goals. While the need to focus directly on nitrogen (or phosphorus) reductions in order to reduce nutrient pollution is becoming clear, there is less certainty as to how this reduction can be achieved most cost effectively with green payments, an issue of high importance to policymakers and water quality program leaders. Nutrient management programs which induce farmers to reduce nutrient applications to recommended rates can provide "win-win" opportunities to increase net returns and reduce pollution (VanDyke et al. 1999). However, nitrogen applications at or below recommended rates may still result in nitrogen loss, because the crop is not perfectly efficient in removing applied nitrogen (Scharf and Alley 1988).

Recently an innovative proposal has been made to reduce nutrient applications and nutrient pollution potential by compensating farmers to reduce their nitrogen applications below standard recommendations (Henry A. Wallace Center 2001). Such efforts are labeled "yield reserve" because a portion of yield production potential is retired just as land is retired under the Conservation Reserve Program. This proposal, which has yet to be approved, faces implementation challenges such as verification of farmers' nitrogen applications and yields. Nonetheless, interest in the program concept among policymakers remains high (U.S. Congress, Senate, 2002a, 2002b). While the program has not been defined for all states, an analysis of the program could help policymakers better assess costs to taxpayers and farmers as well as to assess its potential to reduce environmental damage from nitrogen applications. The purpose of this study is to examine effects of a Yield Reserve Program on costs to farmers and taxpayers and potential reductions in nitrogen applications. This study uses existing yield data extrapolated to the Virginia coastal plain to analyze costs under three scenarios for implementation of a Yield Reserve Program: insurance payments, incentive payments, and a combined set of insurance and enhanced incentive payments.

Costs of Reducing Nitrogen Applications

Farmers' potential costs of reducing nitrogen (N) applications under the Yield Reserve Program are based on the opportunity cost of foregone net revenues from the N that is not applied. Foregone net revenues are calculated from the loss of yield and the savings in N and yield-related costs relative to those that would have been obtained prior to the Yield Reserve Program. Assume that a farmer's corn yield (Y) is given by

$$Y = f(N, W, S), \tag{1}$$

where N, W, and S represent N application, weather conditions, and site-specific characteristics, respectively. Expected net revenue (NR_p) above variable costs under the prior N application strategy is

$$E(NR_p) = \sum_{i=1}^{I} pr_i \cdot P_c \cdot Y_{pi} - P_n \cdot N_p, \tag{2}$$

where N_p is the amount of N applied under the prior N application strategy; Y_{pi} is the corn yield obtained under the prior application strategy; P_n is the price of N; P_c is the price of corn (net of harvest, drying, and transportation costs per unit of yield); and pr_i is the probability of the ith weather state, which can take on I possible values (I is set to 47 in the empirical model described below). Other production costs besides N application are assumed fixed and invariant regardless of whether or not the farmer participates in the program. Under the Yield Reserve Program, a farmer's net revenue is given by

$$(3) \qquad E(NR_{yr}) = \sum_{i=1}^{I} pr_i \cdot P_c \cdot Y_{yri} - P_n \cdot N_{yr},$$

where Y_{yri} represents the yield obtained under weather state *i* and with the N application mandated by the Yield Reserve Program, N_{yr}. Assuming risk-neutrality, the farmer's potential cost of reducing N applications to comply with the Yield Reserve Program is

$$(4) \qquad E(NR_p) - E(NR_{yr}) = \sum_{i=1}^{I} pr_i \cdot P_c \cdot Y_{pi} - P_n \cdot N_p - \sum_{i=1}^{I} pr_i \cdot P_c \cdot Y_{yri} - P_n \cdot N_{yr} = \sum_{i=1}^{I} pr_i \cdot P_c \cdot (Y_{pi} - Y_{yri}) - P_n \cdot (N_p - N_{yr}).$$

Potential cost of reducing N applications depends on corn and N prices, weather event probabilities, the prior N application strategy, and the amount of N applied under the Yield Reserve Program.

Prior Nitrogen Applications

Farmers' N applications are affected by their perceptions of yield risk. Several studies have concluded that N is a yield risk-increasing input, with N applications for strong risk averters falling by an estimated 2 percent (Babcock, Chalfant, and Collender 1987), 30 percent (Rosegrant and Roumasset 1985), and 80 percent (Lambert 1990) below expected profit-maximizing levels. However, these conclusions were based on production functions estimated with experimental yields. Sri-Ramaratnam et al. (1987) compared farmers' perceptions of yield risks and N applications with experimental data. While experimental results showed N to be risk-increasing, farmers viewed N as risk-reducing. Farmers' subjective yield expectations were more optimistic than comparable experimental results.

Babcock (1992) examined the effects of uncertain weather and soil N levels on N applications using a linear plateau response function. Increasing uncertainty about weather (rainfall) and soil N levels led to increased optimal N applications due to the asymmetry of losses from non-optimal N applications. Babcock (1992) demonstrated that with the plateau yield fixed at its mean level, if the price of N is less than half of its marginal product with N limiting, optimal N rates under weather uncertainty will be greater than under certainty. Similarly, uncertainty about soil N levels increases optimal N application rates when the marginal product of N is more than twice its price. While Babcock's results assume risk-neutrality, he noted that risk-aversion is likely to have little impact on N applications because, even if N is a risk-reducing input, varying N has relatively little impact on yield risk (Babcock 1992, Babcock, Chalfant, and Collender 1987).

Babcock's work implies that in many situations net revenue losses from sub-optimal N applications that are lower or higher than the optimum level are likely to be asymmetrical, meaning that net revenue losses from applying too little N are greater than net revenue losses from applying too much. Yield risks from weather uncertainty and possibly asymmetric losses need to be considered in estimating farmers' potential costs of the Yield Reserve Program. Ignoring such loss asymmetry may lead to unrealistic projections of potential Yield Reserve Program costs and adoption rates by farmers.

Farmers' applications of N also may be heavily influenced by recommended rates of the Cooperative Extension Service, state agencies, crop consultants, and other advisors. Recommended rates are particularly important under a Yield Reserve Program as they are the baseline from which a 15 percent reduction in N application is calculated (Simpson 2005).

Empirical Model

We developed an empirical model to estimate corn yields and net revenues under a prior N application strategy and with N applications constrained by the Yield Reserve Program. Expected net revenue is set equal to the yield times the price of corn, \$102/Mg (\$2.58/bu), net of transportation, drying, and marketing costs of \$7.14/Mg (\$0.18/bu), minus the N application times the price of N, \$0.62/kg (\$0.28/lb). Other costs are assumed fixed. Corn and N prices are the five-year average prices for 2000 to 2004 adjusted to 2005 dollars (USDA 2006a). Nitrogen response functions under different rainfall patterns are estimated for N experimental trials in Virginia and North Carolina. Probabilities are assigned to seasonal rainfall based on historical weather data. Two prior N application strategies are considered: (i) N applications to maximize expected net revenues, and (ii) N applications based on recommended rates of the Virginia Cooperative Extension Service. The Yield Reserve Program N application is set at 15 percent below the amount recommended by Virginia Cooperative Extension. Cooperative Extension fertilizer recommendations are often used as the target application level in nutrient management programs (Virginia Department of Conservation and Recreation 1995). Even at these recommended rates, N losses to the environment can occur because of crop inefficiencies in removing applied N (Scharf and Alley 1988).

Yield Response Curves

Experimental data representing 15 site years in North Carolina and 5 site years in Virginia were used to estimate corn yield response to N (Table 1). The North Carolina sites included the Peanut Belt Research Station (Lewiston), Haslin Farms-Organic Ridge (HSOR), located in Belhaven, Haslin Farms-Sandy Ridge (HSSR), also in Belhaven, and the Tidewater Research Station (TRS), located in Plymouth (Sripada et al. 2005). The Virginia data are from locations in Accomack, Augusta, and Charles City counties (Phillips 2005).

The data were analyzed with quadratic linear regression and nonlinear regression utilizing the Mitscherlich function (Yaron et al. 1973). The quadratic and the Mitscherlich equations produced similar results including R^2 values. The quadratic equation was selected because it is simpler to apply and interpret compared to a nonlinear regression approach, and because the quadratic equations always produced non-zero values for all of the parameters, which was not the case for all of the Mitscherlich equations. The quadratic function takes the following form:

$$Yc_j = \alpha + \beta N - \gamma N^2, \quad (5)$$

where Yc_j equals observed yield, N is applied N, N^2 is the square of N, and α, β, and γ are estimated parameters.

All of the regressions produced significant models except for 2002 TRS-ORG in North Carolina and 2002 Accomack in Virginia. Low rainfall in 2002 limited the impact of N fertilizer on yield. Three categories of yield responses were determined for the data. The data from 2003 and 2004 were used to form the high yield group, because these years gave the highest response to N. Average yield groups were formed based on the 2000 and 2001 data, and the low yield group was based on the 2002 data.

Weather Probabilities

Historical weather data were used to determine the probabilities of weather corresponding to high, average, or low yield conditions. Historic yields in Eastern Virginia for 47 years (1953–2004) were regressed against rainfall amounts during the growing season and trend. This regression facilitated grouping historical yields into three categories based on rainfall. The probabilities associated with the rainfall categories were used to weight yield response curves. The weighted yield response curves were used to determine optimal N applications and costs of restricting N applications based on weather probabilities.

Corn yield data were obtained from the National Agricultural Statistics Service from 1958 to 2004 for 28 counties in the Virginia Coastal Plain (USDA 2006a). The study area forms the southeast portion of the Chesapeake Bay drainage area (see Figure 1). Weighted average corn yield data were determined by summing the total production of corn for each year and dividing by the area harvested. Rainfall data were obtained from the Southeast Regional Climate Center's website[1] for the corresponding years. Five weather stations were chosen based on their location and completeness of their records over the 47 years of corn yields: Williamsburg 2 N, Warsaw 2 N in Richmond County, Suffolk Lake Kilby in Suffolk City, Richmond WSO Airport in Henrico County, and Painter 2 W in Accomack County. In order to mitigate spatial variability in rainfall, rainfall data from all five weather stations were averaged.

[1] See http://www.sercc.com/ (accessed July 10, 2006).

Table 1. Summary of Quadratic Regressions of Corn Yields versus Nitrogen

Year	Location	Soil Prod. Grp	No. Obs.	R^2	Model Sig.	Intercept	Int. Std. Err.	N	N Std. Err.	N^2	N^2 Std. Err.
NORTH CAROLINA SITES											
2000	Lewiston	III	75	0.69	<.0001	7.7779	0.3491	0.0265	0.0033	-3.5E-05	7.0E-06
2000	HSOR	IV	73	0.43	<.0001	8.1969	0.5391	0.0199	0.0051	-2.2E-05	1.1E-05
2000	HSSR	II	73	0.45	<.0001	3.6259	0.6103	0.0198	0.0058	-1.8E-05	1.2E-05
2000	TRS	I	71	0.70	<.0001	1.8951	0.6966	0.0322	0.0064	-2.6E-05	1.3E-05
2001	HSOR	IV	45	0.72	<.0001	4.8464	0.7729	0.0414	0.0070	-4.8E-05	1.5E-05
2001	Lewiston	III	48	0.80	<.0001	3.1104	0.5386	0.0378	0.0047	-4.6E-05	9.7E-06
2001	TRS	I	47	0.38	<.0001	5.4470	0.9116	0.0183	0.0080	-1.5E-05	1.6E-05
2002	Lewiston	III	99	0.19	<.0001	2.8028	0.3404	0.0127	0.0030	-2.0E-05	5.8E-06
2002	TRS-ORG	I	59	0.05	0.2459	3.5508	0.2891	0.0043	0.0026	-7.6E-06	5.1E-06
2003	Lewiston1	I	47	0.64	<.0001	5.2024	0.5533	0.0187	0.0047	-1.4E-05	9.0E-06
2003	Lewiston2	I	48	0.56	<.0001	5.3655	0.5738	0.0237	0.0050	-2.8E-05	9.6E-06
2003	Lewiston3	I	48	0.51	<.0001	5.3125	0.6763	0.0222	0.0058	-2.3E-05	1.1E-05
2003	TRS1	I	48	0.58	<.0001	4.8644	0.5661	0.0252	0.0049	-3.1E-05	9.5E-06
2003	TRS2	I	48	0.56	<.0001	5.0916	0.5887	0.0286	0.0051	-3.9E-05	9.9E-06
2003	TRS3	I	48	0.52	<.0001	5.3291	0.5770	0.0218	0.0050	-2.6E-05	9.7E-06
VIRGINIA SITES											
2002	Accomack	III	10	0.04	0.8637	3.0523	1.3815	0.0090	0.0268	-4.4E-05	1.1E-04
2003	Accomack	III	12	0.57	0.0226	3.1321	1.3826	0.0749	0.0252	-2.6E-04	9.9E-05
2004	Accomack	III	15	0.97	<.0001	4.5867	0.3382	0.0596	0.0080	-8.9E-05	3.8E-05
2004	Augusta	IV	12	0.55	0.0263	9.8227	0.6826	0.0475	0.0219	-1.9E-04	1.4E-04
2004	Charles City	IV	15	0.90	<.0001	7.3166	0.3075	0.0381	0.0073	-8.8E-05	3.5E-05

Yields were regressed against a time trend (1958 = 1, 2004 = 47) and growing season rainfall. The regressors were each individually plotted against the response variable. The plots suggested that the regressors would have a better fit if the square root of time trend and natural logarithms of monthly rainfall were used. After the transformations were completed, a regression was run using R-square and the encyclopedic (using all combinations of the variables) selection criteria in SAS (SAS, undated). The best model, which is defined as the model that is most parsimonious, has highest R^2, and has all regressors significant, is shown below. The variables include the square root of year trend (*sqrtyear*) and natural logarithm of rainfall in centimeters for each month (*lnmay*, *lnjune*, and *lnjuly*). The adjusted R-squared value is 0.75.

(6)

$$\begin{aligned} \text{Yield} = & \underset{(<.0001)}{-54.272} + \underset{(<.0001)}{10.72239\,sqrtyear} \\ & + \underset{(.002)}{14.760\,lnmay} + \underset{(<.0001)}{20.504\,lnjune} \\ & + \underset{(<.0001)}{29.321\,lnjuly}\ , \end{aligned}$$

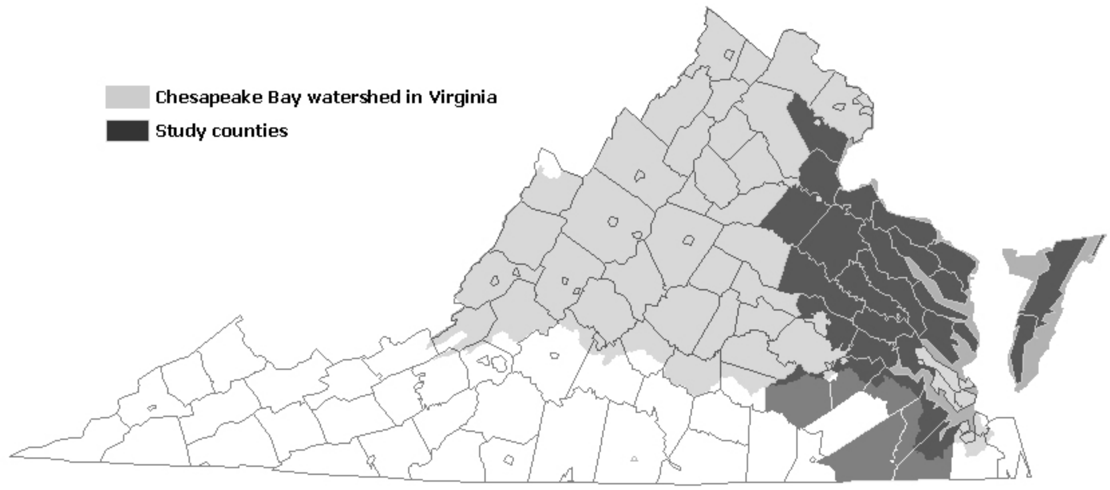

Figure 1. Study Area and Chesapeake Bay Watershed in Virginia

where yield refers to Mg of corn per hectare and coefficient significance levels are shown in parentheses.

Equation (6) was used to derive detrended yields corresponding to rainfall conditions for each weather year. Based on the application of equation (6) to the historic rainfall and yield data, the lowest yield for 2003 and 2004 (years with good growing season rainfall) is 8.3 Mg/ha. The highest yield for 2000 and 2001 (years with average growing season rainfall) is 7.9 Mg/ha. The average of these yields, 8.1 Mg/ha, is used as the boundary between good and average yields. Similarly, the lowest estimated yield for 2000 and 2001 is 7.6 Mg/ha. The estimated yield for 2002, the year with low experimental yields, is 5.6 Mg/ha. The average of the 5.6 and 7.6 yields, 6.6 Mg/ha, is used as the boundary between yields in average and poor rainfall years. There were 6 years that fell into the highest yield group, 23 in the average yield group, and 18 in the low yield group. The corresponding probabilities of these types of years occurring are 13 percent for a good (high yield) year, 49 percent for an average (average yield) year, and 38 percent for a bad (low yield) year.

Soil Productivity Groups

The soil on which each experiment was conducted is classified in a Soil Productivity Group as defined in the Virginia Nutrient Management and Standards Criteria (Criteria) (Virginia Department of Conservation and Recreation 1995). The potential yields assigned to each Soil Productivity Group in the Criteria were used to apply yield response curves from the experiments to other soils. An adjustment percentage was calculated, which equaled the ratio of potential yield for each Soil Productivity Group relative to the Productivity Group on which the experiment was conducted (Table 2). Adjustment percentages were multiplied by the linear and quadratic terms in each yield response curve to obtain estimated yield responses to N for the soil groups not included in the field experiments. The intercepts were not adjusted because yields on different soils in the study area are not expected to vary greatly at low levels of fertilizer application.

Total areas in Soil Productivity Groups I, II, and III in the Virginia Coastal Plain (Table 2) were quantified using soil profiles obtained from the Soil Data Mart of the Natural Resource Conservation Service, U.S. Department of Agriculture (USDA, undated). The corn acreage in each Soil Productivity Group was estimated by multiplying its percentage share of the total area in groups I, II, and III by the average amount of corn acreage for the Virginia Coastal Plain for 2000–2004 (USDA 2006a). Although the Criteria define 5 soil productivity groups, only Soil Productivity Groups I, II, and III are included be-

Table 2. Soil Productivity Areas in Virginia Coastal Plain and Yield Adjustments

Soil Productivity Groups	Estimated Corn Area in Virginia Coastal Plain (ha)	Realistic Corn Grain Yield (Mg/ha)	Yield Ratio Relative to Soil Productivity Group I (%)
I	13,300	11.0	100
II	32,798	9.7	89
III	40,193	8.5	77
IV	NA	6.9	63

Source: Soil types and corresponding areas were obtained from USDA (undated). Classifications of soil types into productivity groups and realistic grain yields are from Virginia Department of Conservation and Recreation (1995).

cause they account for almost all corn production in the study area.

Nitrogen Applications

Two prior N application strategies, the first based on Cooperative Extension recommendations and the second based on expected net revenue maximization, were considered. Cooperative Extension recommendations are 196, 174, and 152 kg N/ha, respectively, for Groups I, II, and III, based on yields shown in Table 2. Cooperative Extension N fertilizer recommendations are based on an efficiency of 0.02 kg N/kg grain (1.0 lb N/bu) of corn grain production potential for individual soil series (Virginia Department of Conservation and Recreation 1995). Yield potential for each soil series is established from yield records over several years (usually 5) from research and on-farm trials. Virginia corn yield potential levels for individual soils were updated in 2005 (Baker 2006). The N fertilizer recommendations will generally be the rate that will achieve 90 to 95 percent of maximum yield potential based on corn yield response to N fertilization trials.

The N application that maximizes net revenue on each of k = 3 soil productivity groups is estimated as follows:

(7)

$$\text{Max } NR_{ik} = \sum_{j=1}^{20} Y_{ijk}(N_{ik}) P_c pr_{jk} - N_{ik} P_n : i = 1...41 \, ,$$

where pr_{jk} is probability of obtaining a yield response of Y_{ijk} for an application rate of N_{ik} on the kth Soil Productivity Group. For the ith N application on Soil Productivity Group k there are j = 20 possible yield responses (depending on weather and site conditions) corresponding to the 20 yield response equations shown in Table 1 as applied to the kth Soil Productivity Group. For a given Soil Productivity Group, the composite, weighted-average yield response function (Figure 2) is obtained by summing the yield response of each equation in Table 1 (as applied to that Soil Productivity Group) multiplied by its probability. The probability of each yield response equation is related to growing season rainfall (good rainfall probability = 0.13, average rainfall probability = 0.49, and poor rainfall probability = 0.38) as follows. Each yield response estimated for a given type of rainfall year is assumed to be equally likely. Each of the 10 equations estimated for good rainfall years (2003 and 2004) is given a probability of 0.13/10 = .013. Each of the 7 equations estimated for average rainfall years (2000 and 2001) has a 0.49/7 = 0.07 probability, and each of the 3 equations estimated for low rainfall years (2002) has a 0.38/3 = 0.127 probability.

The expected net revenue maximizing strategy is found by searching over 41 potential application rates varying in 9 kg/ha (8 lb/ac) increments from 0 to 360 kg/ha (320 lbs/ac). Expected net revenue maximization occurs at N applications of 225, 216, and 207 kg/ha for Soil Productivity Groups I, II, and III, respectively.

Farmer Compensation and Taxpayer Costs

Farmers' expected costs of the Yield Reserve Program are equal to estimated expected net revenue in the baseline using the prior N application strategy minus expected net revenue under the Yield Reserve Program prior to compensa-

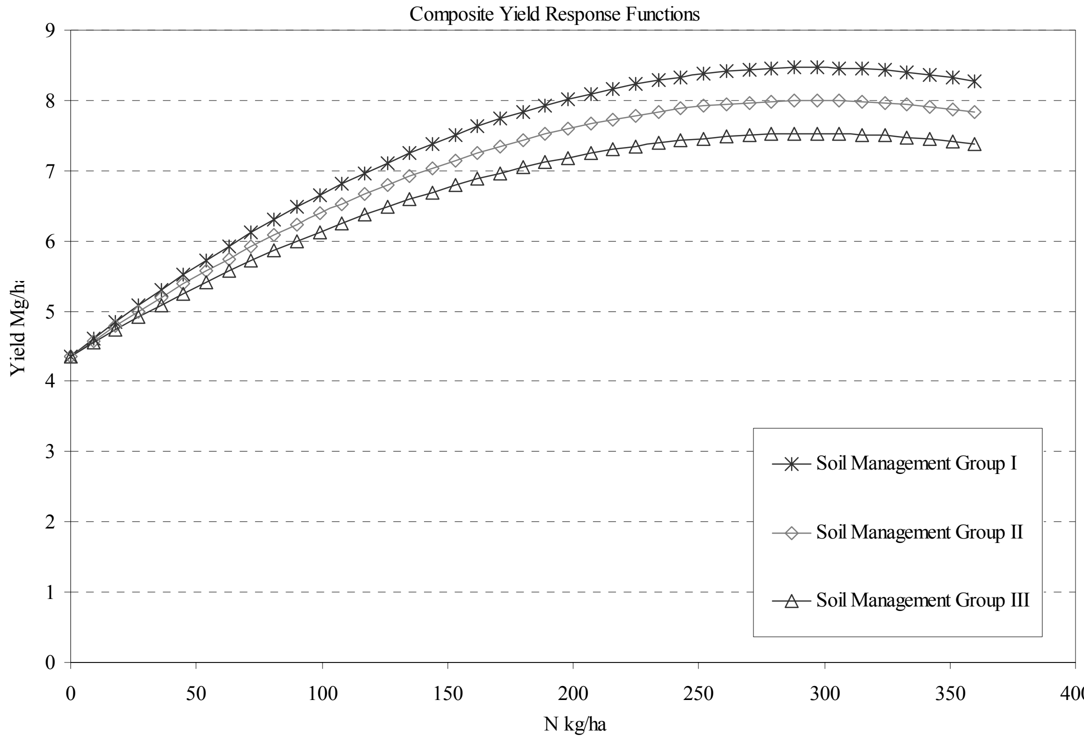

Figure 2. Composite Yield Response to Nitrogen Functions by Soil Productivity Group

tion. Expected costs may be offset by compensation. Three compensation scenarios are investigated: insurance-only, incentive-only, and a combined set of insurance and enhanced incentive payments. The insurance-only scheme provides compensation to the participating farmer during a year when yield losses occur due to applying N below recommended rates. Losses are compensated at the assumed market price. Losses are certified by planting check strips in the field, which are fertilized at recommended rates. The incentive-only scheme provides the farmer a fixed annual payment equal to the expected value of net revenue losses from applying N at a rate 15 percent below the Extension-recommended levels. There is no insurance adjustment for yield losses under this scheme. The incentive scheme takes account of savings realized by a farmer from reduced N applications and reduced harvest, transportation, and marketing costs for the lower yield.

The combined set of enhanced incentive and insurance payments is expected to provide the highest overall level of compensation to farmers and, therefore, to induce the widest level of participation. This option provides an enhanced incentive payment of $74 per hectare ($30 per acre), which is higher than the expected level of the incentive payment under option 1. In addition, the program provides an insurance payment, which covers yield losses in years when yields are reduced due to lower fertilizer rates (Sweeney 2005). For all three compensation schemes, yield losses are calculated relative to the yields that would have been earned from applying N at the level recommended by Extension. If net revenue maximizing N applications are higher than Extension recommendations, farmers' losses may be higher.

Cost of the program to taxpayers under each payment scenario (assuming 100 percent farmer participation) is estimated by summing farmer incentive and insurance payments plus administrative costs times the estimated number of hectares of corn produced in the Virginia Coastal Plain. Administrative costs for verifying N applications and yield losses under the Yield Reserve Program are estimated as $7.40/ha (Simpson 2005).

Results

Assuming that farmers currently follow Extension recommendations in applying N, the estimated cost to farmers of the Yield Reserve Program (reduction in expected net revenue) ranges from $13 (Soil Group I) to $10 (Soil Group III) per hectare (Table 3). Costs are incurred because of yield reductions averaging 0.3 Mg/ha. The costs are lowered somewhat by savings from reduced N applications, which fall by 29, 26, and 23 kg/ha on Soil Groups I, II, and III, respectively. Costs are higher on higher productivity soil groups because they have slightly greater yield losses from reduced N applications.

If current N applications are based on net revenue maximization, farmer costs per hectare of the Yield Reserve Program are higher: $17 (Soil Group I) to $20 (Group III) (Table 3). Costs are higher because the Yield Reserve Program imposes larger restrictions on N applications by net revenue maximizers. When farmers apply N to maximize expected net revenue, N application rates are higher compared to Extension recommendations. For example, N application on Soil Group I increases from 196 to 225 kg/ha, a 15 percent increase (Table 3, row 1). The 15 percent reduction in N application under the Yield Reserve Program is computed based on Extension recommendations; consequently, the N application on Soil Group I is reduced by 58 kg/ha (compared to a 29 kg/ha reduction for those farmers following Extension recommendations). However, expected costs of the Yield Reserve Program are still not large—the largest cost of $20 for Soil Group III is less than 4 percent of baseline expected net revenue. N applications higher than Extension recommendations bring only modest yield increases—0.2, 0.3, and 0.4 Mg/ha on Soil Groups I, II, and III, respectively—and net revenue increases—$4, $8, and $10/ha, respectively (Table 3, rows 2 and 3). Consequently, the reductions in net revenues from the Yield Reserve Program are not much larger (in absolute terms) for net revenue maximizers than for those following Extension recommendations.

Yield reserve compensation and mean net revenue with compensation (Table 4) are the same for both N application strategies because N applications are restricted to the same level, 15 percent below Cooperative Extension recommendations. The Yield Reserve Program compensation under the incentive-only scheme is set equal to the expected cost of the program with N applications restricted to 15 percent below Extension recommendations (Table 4). Incentive-only compensation of $10 to $13/ha (Table 4) covers only one-half to three-fourths of the $17 to $20 costs of the Yield Reserve Program for net revenue maximizers (Table 3). Insurance-only compensation ($27 to $39/ha) is up to three times larger than incentive-only compensation. With insurance, all reductions in yield from the Extension baseline are compensated at the market price. Savings from reduced N applications and reduced yield transportation costs are not deducted from compensation paid to farmers as is the case under the incentive-only scheme. Compensation under the enhanced-incentive plus insurance plan is highest of the three plans evaluated, three to four times higher than the insurance-only plan (Table 4). Compensation includes coverage of yield losses relative to yields under the Extension baseline plus an enhanced incentive of $74/ha. The $74 enhanced incentive is larger than expected costs of the Yield Reserve Program.

After factoring in the Yield Reserve Program compensation, expected net revenue per hectare is generally larger under the Yield Reserve Program compared to the baseline for all soil groups (Table 4 versus Table 3). The one exception is incentive-only compensation under the net revenue maximizing baseline, for which expected net revenues decline by $4 to $10/ha. Farmers seeking to maximize expected net revenues should have incentives to participate if their prior probabilities of yield reductions under the Yield Reserve Program match those used in this study.

Sensitivity Analysis

Farmers may tend to forget the bad years and overestimate the response of yields to N (Sri-Ramaratnam et al. 1987, Pease 1992), which would increase the perceived costs of the Yield Reserve Program. The sensitivity of expected costs of the program to perceived yield probabilities is examined under two additional weather probability scenarios. In the first scenario, farmers are assumed to forget all but the most extreme bad years. The year 2002 is the most recent drought year with poor yields and has the seventh lowest predicted yield in the past 47 years based on the

Table 3. Effects of Yield Reserve Program Scenarios on Nitrogen Applications, Mean Yields, and Mean Farmer Net Revenues

		Nitrogen Applications Based on ...					
		... Cooperative Extension Recommendations			*... Maximizing Expected Net Revenue*		
	Units	Soil Prod. Group I	Soil Prod. Group II	Soil Prod. Group III	Soil Prod. Group I	Soil Prod. Group II	Soil Prod. Group III
BASELINE							
1. Nitrogen application	kg/ha	196	174	152	225	216	207
2. Mean yield	Mg/ha	8.0	7.4	6.8	8.2	7.7	7.2
3. Mean net revenue	$/ha	639	593	550	643	601	560
COSTS OF REDUCED NITROGEN APPLICATIONS UNDER YIELD RESERVE PROGRAM							
4. Nitrogen application	kg/ha	167	148	129	167	148	129
5. Mean yield	Mg/ha	7.7	7.1	6.5	7.7	7.1	6.5
6. Mean net revenue	$/ha	626	582	540	626	582	540
7. Mean cost (row 3 – row 6)	$/ha	13	12	10	17	19	20

Table 4. Compensation and Farmer Net Revenue under Yield Reserve Program[a]

	Soil Prod. Group I	Soil Prod. Group II	Soil Prod. Group III
1. Mean net revenue before compensation	626	582	540
YIELD RESERVE PROGRAM COMPENSATION ($/HA)			
2. Incentive only	13	12	10
3. Insurance only[b]	39	33	27
4. Enhanced incentive + insurance[c]	113	107	101
MEAN NET REVENUE WITH YIELD RESERVE PROGRAM COMPENSATION ($/HA)			
5. Incentive only (row 1 + row 2)	639	594	550
6. Insurance only (row 1 + row 3)	665	615	567
7. Enhanced incentive + insurance (row 1 + row 4)	739	689	641

[a] Compensation and net revenues apply to both nitrogen application strategies.
[b] Amounts shown are mean payments. Payments vary from 0 to a maximum of $115 (Group I), $98 (Group II), and $81 (Group III).
[c] Amounts shown are the mean insurance payment (row 3) plus an enhanced incentive payment of $74/ha (Simpson 2005). Payments per hectare vary from a minimum of $74 to a maximum of $189 (Group I), $172 (Group II), and $155 (Group III).

trend model [equation (6)]. Predicted yields for 2002 [equation (6)] are used as the cutoff for low yield years. Only years with yields lower than those predicted for 2002 are included as low yield years, with other years being reclassified as average years. The resulting probabilities are 72, 15, and 13 percent for average, bad, and good years, respectively. In the second scenario, farmers are assumed to forget all bad years, which are reclassified as average years. Resulting probabilities for average and good years are 87 percent and 13 percent, respectively. In this scenario, equations for 2002 in Table 1 are not used in estimating yield losses under the Yield Reserve Program.

Under scenarios 1 and 2, expected costs of the Yield Reserve Program are almost double and triple, respectively, compared to cost estimates based on initial probabilities (compare Table 5,

Table 5. Expected Cost of Participation in the Yield Reserve Program with Reduced Probability of Low Yield Years

		SCENARIO 1 Reduced Probabilities of Low Rainfall Years[a]			SCENARIO 2 No Probability of Low Rainfall Years[b]		
	Units	Soil Prod. Group I	Soil Prod. Group II	Soil Prod. Group III	Soil Prod. Group I	Soil Prod. Group II	Soil Prod. Group III
BASELINE							
1. Nitrogen application	kg/ha	196	174	152	196	174	152
2. Expected yield	Mg/ha	9.4	8.6	7.8	10.4	9.4	8.5
3. Expected net revenue	$/ha	778	713	652	868	790	717
COSTS OF REDUCED NITROGEN APPLICATIONS UNDER YIELD RESERVE PROGRAM							
4. Nitrogen application	kg/ha	167	148	129	167	148	129
5. Expected yield	Mg/ha	9.0	8.2	7.5	9.8	9.0	8.1
6. Mean net revenue	$/ha	752	691	633	834	761	693
7. Mean cost (row 3 − row 6)	$/ha	26	22	19	35	29	24

[a] Rainfall year probabilities reclassified as average, 72 percent, low, 15 percent, and good, 13 percent. Nitrogen applications are based on Cooperative Extension recommendations.
[b] Rainfall year probabilities reclassified as average, 87 percent, and good, 13 percent.

scenarios 1 and 2, with Table 3, Extension recommendations). Costs of the Yield Reserve Program are low or even negative in drought years because there is little or no crop response to N and farmers save money by applying less N. Lowering the probability of drought years reduces this advantage of the Yield Reserve Program and increases the expected cost. However, under both scenarios, expected costs are only 3–4 percent of baseline expected net revenues.

Increases in the cost of N would lower costs of the Yield Reserve Program as farmers save more money from lowering their N applications. A Sensitivity Index [percentage change in net cost/ percentage change in N price (corn price)] was formulated to examine the response of farmer net cost to changes in N or corn prices. A 25 percent increase in the price of N (to $0.77/kg) lowers the expected cost of the Yield Reserve Program by $5, $4, and $3 on Soil Groups I, II, and III, respectively (Table 6). The Sensitivity Index is greater than 1 in absolute value, indicating sensitivity of the Yield Reserve Program costs to N price.

Increased corn prices raise the value of yield losses from lowering N applications and increase the costs of the Yield Reserve Program. The Sensitivity Index for corn price (percentage change in net cost/percentage change in corn price) is greater than two for all soil groups, indicating that a 25 percent increase in corn price raises expected cost of the Yield Reserve Program by more than 50 percent, to $17–$21/ha (Table 6).

Taxpayer Costs

Taxpayer costs of the Yield Reserve Program in the Virginia Coastal Plain vary significantly by compensation scheme. The lowest cost plan is incentive-only with a total cost of approximately $1.6 million (Table 7). Costs are low because savings from reduced N and crop transportation costs are accounted for and reduce the amount of payment. Based on the estimates presented here, farmers following Extension recommendations would just break even with no additional compensation for bearing risk. The insurance plan would be twice as expensive as the incentive-only plan because farmers are compensated for yield losses, while savings from reduced N and reduced crop harvest costs are not deducted from farmers' compensation. The cost of the proposed enhanced

Table 6. Effects of Increased Nitrogen and Corn Prices on Farmer Net Costs of Yield Reserve[a]

	Mean Net Costs of Yield Reserve[b]		
	Soil Group I	Soil Group II	Soil Group III
Base scenario	13	12	10
Nitrogen price = $0.77/kg	8	8	7
Sensitivity index[c]	-1.5	-1.3	-1.2
Corn price = $128/Mg	21	19	17
Sensitivity index[c]	2.5	2.3	2.8

[a] Nitrogen and corn prices in the base scenario are $0.62/kg and $102/Mg, respectively.
[b] Nitrogen applications are based on Cooperative Extension recommendations.
[c] Sensitivity index = percentage increase in farmer net cost/percentage increase in Nitrogen (corn) price.

Table 7. Reduced Nitrogen Applications and Mean Taxpayer Costs of Yield Reserve

	Soil Group I	Soil Group II	Soil Group III	Total
RESIDUAL NITROGEN REDUCTIONS (KG)				
Extension recommendation baseline	321,823	702,360	751,539	1,775,722
Maximum revenue baseline	658,021	1,894,917	2,663,981	5,216,919
TAXPAYER COSTS ($)				
Incentive only				
Total cost	$266,000	$623,162	$723,474	$1,612,636
Cost/ha	$20	$19	$18	$19
Cost/kg residual N reduction (Extension baseline)	$0.83	$0.89	$0.96	$0.91
Cost/kg residual N reduction (maximum revenue baseline)	$0.40	$0.33	$0.27	$0.31
Insurance only				
Total cost	$611,800	$1,311,920	$1,406,755	$3,330,475
Cost/ha	$46	$40	$35	$39
Cost/kg residual N reduction (Extension baseline)	$1.90	$1.87	$1.87	$1.88
Cost/kg residual N reduction (maximum revenue baseline)	$0.93	$0.69	$0.53	$0.64
Enhanced incentive + insurance				
Total cost	$1,596,000	$3,738,972	$4,381,037	$9,716,009
Cost/ha	$120	$114	$109	$113
Cost/kg residual N reduction (Extension baseline)	$4.96	$5.32	$5.83	$5.47
Cost/kg residual N reduction (maximum revenue baseline)	$2.43	$1.97	$1.64	$1.86

[a] Costs are mean values for the Virginia Coastal Plain assuming 100 percent participation on corn acres. Costs include farmer compensation plus a $7.40/ha administrative cost.

incentive plus insurance plan, $9.7 million, is six times more expensive than the incentive-only plan, because it includes an insurance payment plus an enhanced incentive payment, $74/ha, which is higher than the estimated expected cost of the Yield Reserve Program to farmers.

McCann and Easter (2000) estimate an average transaction cost of $30.94/ha for all agricultural conservation programs, which is almost four times higher than the $7.40 rate used in this study. If the $30.94 rate were used, taxpayer costs would increase to $3.6, $5.4, and $11.8 million, respectively, for incentive, insurance, and enhanced-incentive plus insurance compensation schemes.

Yield Reserve Program costs per kg of N reduction depend on how N reductions are defined and the baseline from which reductions are measured. Here, N reductions are defined as reductions in residual N, which is defined as the amount of applied N not removed by the crop. Crop removal is estimated as crop yield for the given N application amount (Table 3) times N removal per unit of yield. Corn removes an estimated 16.1 kg N per Mg of grain harvested (Virginia Cooperative Extension Service 2000).

Bosch et al. (1992) conducted a survey of farmers' nutrient application practices in a portion of the study area. They concluded that most surveyed farmers applied close to Extension-recommended levels of N. If this finding holds generally true in the study area, total residual N reductions are an estimated 1.8 million kg, and costs per kg of N reduction are $0.91, $1.88, and $5.47 per kg, respectively, for incentive-only, insurance-only, and enhanced-incentive plus insurance plans (Table 7). If farmers apply N to maximize expected net revenue, the estimated reduction is almost 3 times larger, 5.2 million kg. Compared to the Extension baseline, estimated costs per kg of residual N reduction are one-third as high—$0.31, $0.64, and $1.86 per kg, respectively, for incentive-only, insurance-only, and enhanced-incentive plus insurance plans.

Summary and Conclusions

Policymakers are searching for ways to reduce nonpoint source pollution from farms. A Yield Reserve Program proposal would compensate farmers for reducing N applications by 15 percent below Extension recommendations. This study analyzes the policy proposal for the Virginia Coastal Plain under three compensation plans: incentive-only, insurance-only, and enhanced-incentive plus insurance.

Assuming that farmers follow Extension recommendations in applying N, expected costs of the Yield Reserve Program (reductions in expected net revenue from limiting N applications) are $10 to $13/ha or 3 to 4 percent of baseline expected net revenue. Costs are somewhat higher for farms that apply N to maximize expected net revenue, $17 to $20/ha, but still less than 4 percent of expected net revenue. Reducing the probability of low rainfall years increases the expected cost of the Yield Reserve Program because yield penalties from limiting N applications are highest under average to good rainfall years. However, even with all low rainfall years removed, costs are $35/ha or less. Yield Reserve Program costs are sensitive to N and corn prices. Increasing the N price lowers program costs because farmers save more money from the lower N applications. Increased corn prices increase program costs because of the higher value of yield losses from lower N applications.

Taxpayer costs would be lowest under the incentive-only plan, which limits compensation to expected costs of Yield Reserve Program participation. Insurance-only and enhanced-incentive plus insurance plans would have higher costs due to higher compensation paid to farmers and costs of administration. The taxpayer cost per kg reduction in residual N is sensitive to the incentive scheme and the assumed N application in the baseline prior to the Yield Reserve Program. If farmers follow Extension recommendations, average costs per kg reduction in residual N vary from $0.91 to $5.47/kg, depending on compensation.

The Yield Reserve Program can potentially reduce nutrient pollution in waterways. The level of farmer participation and costs to taxpayers and farmers will depend on how the program is implemented. Whether the Yield Reserve Program is implemented and at what level will depend on perceived benefits of nutrient reduction, costs of alternative programs for reducing nutrient pollution, and other factors. Several issues related to the economic viability of yield reserve for nutrient pollution control require further study, including the following.

Transaction costs. McCann and Easter (2000) estimate that transaction costs are 38 percent of total conservation program costs. The transaction costs of yield reserve and other approaches to reducing nutrient pollution should be compared.

A yield reserve program may offer opportunities to economize on overall transaction costs by obtaining larger individual reductions in N applications per contracting farmer compared to the N reductions obtained in a standard nutrient management program.

Program targeting. Targeting program payments at farmers with lowest costs per unit of pollution reduction may greatly reduce costs of achieving nutrient control objectives (Carpentier, Bosch, and Batie 1998, Zhang, Horan, and Claassen 2003). The potential to enhance the cost-effectiveness of yield reserve by targeting payments should be investigated. This study would require the use of site-specific models that link reductions in N applications to changes in N loadings to water bodies (Ribaudo et al. 2001).

How frequently must nitrogen recommendations be updated? The Yield Reserve Program targets a 15 percent reduction in fertilizer applications from Extension-recommended levels. If new hybrids of corn have a greater yield response to N, and the optimal (net revenue maximizing) levels of fertilization increase without the Extension recommendations also increasing, the program's costs to farmers could increase. In Virginia there were approximately 10 years between the most recent updates in Extension fertilizer application recommendations (1995 to 2005).

Sensitivity of farmer participation to recent weather. The effect of recent weather on farmers' perceived yield risk and perceived costs of the Yield Reserve Program deserves more study. Changes in farmers' subjective yield probabilities as a result of recent weather experiences could change their perceived costs of program participation and willingness to participate under alternative compensation rules.

Other production costs. The Yield Reserve Program could affect other crop production costs besides N application. For example, with land area held constant, lower yields raise farmers' machinery costs and land rent costs per unit of yield. Because land and machinery costs are variable in the long run, farmers' costs of participation could rise as these costs are spread over lower yields. Higher land and machinery costs may discourage participation in some cases. These costs should be estimated to determine if they present significant barriers to participation.

Government subsidy payments. Farmers whose yields decline as a result of the Yield Reserve Program will also get lower loan deficiency payments when prices fall below the loan rate. This potential disincentive should be quantified.

Residual nitrogen effects. The potential effects of drawing down soil residual N levels on Yield Reserve Program participation and costs should be examined further. There is evidence of high levels of residual N in many crop fields (Brown 1996, Yadav, Peterson, and Easter 1997). Reductions in yields from reduced N applications may increase over time in such fields, thus increasing farmers' participation costs and perhaps the compensation necessary to induce farmers to participate.

References

Babcock, B.A. 1992. "The Effects of Uncertainty on Optimal Nitrogen Applications." *Review of Agricultural Economics* 14(2): 270–280.

Babcock, B.A., J.A. Chalfant, and R.N. Collender. 1987. "Simultaneous Input Demands and Land Allocation in Agricultural Production under Uncertainty." *Western Journal of Agricultural Economics* 12(2): 207–215.

Baker, J.C. 2006. Personal communication. Virginia Tech Department of Crop and Soil Environmental Sciences, Blacksburg, Virginia (January 25).

BMP Challenge. 2007. "Take the BMP Challenge." Available at http://www.bmpchallenge.org/index.htm (accessed March 6, 2007).

Bosch, D.J., J.W. Pease, S.S. Batie, and V.O. Shanholtz. 1992. "Crop Selection, Tillage Practices, and Chemical and Nutrient Applications in Two Regions of the Chesapeake Bay Watershed." Report No. VPI-VWRRC-BULL 176, Virginia Water Resources Research Center, Blacksburg, VA.

Brown, H.M. 1996. "Evaluation of Nitrogen Availability Indices." Ph.D. thesis, University of Illinois at Urbana-Champaign.

Carpentier, C.L., D.J. Bosch, and S.S. Batie. 1998. "Using Spatial Information to Reduce Costs of Controlling Agricultural Nonpoint Source Pollution." *Agricultural and Resource Economics Review* 27(1): 72–84.

Chesapeake Bay Agreement. 1987. Chesapeake Bay Program Office, Annapolis, MD. Available at http://www.chesa[-]peakebay.net/pubs/1987ChesapeakeBayAgreement.pdf (accessed April 8, 2006).

Chesapeake Bay Foundation. 2003. "Water Pollution in The

Chesapeake Bay." Chesapeake Bay Foundation, Annapolis, MD. Available at http://www.cbf.org/site/PageServer?page[-]name=resources_facts_water_pollution (accessed September 20, 2006).

Chesapeake Bay Program. Undated. "What are Tributary Strategies?" Chesapeake Bay Program Office, Annapolis, MD. Available at http://www.chesapeakebay.net/comet_[-]uploads/7154/tribstrats_backgrounder_final.pdf (accessed March 22, 2007).

____. 2002. "The State of the Chesapeake Bay." Chesapeake Bay Program Office, Annapolis, MD. Available at http://www.chesapeakebay.net/pubs/sob/sob02/sotb_2002_final.pdf (accessed March 22, 2007).

____. 2005. "State of the Chesapeake Bay and Its Watershed." Chesapeake Bay Program Office, Annapolis, MD. Available at http://www.chesapeakebay.net/indicators.htm (accessed April 6, 2006).

Henry A. Wallace Center for Agricultural and Environmental Policy at Winrock International. 2001. "Making Changes: Turning Local Visions into National Solutions." Agriculture and rural development policy recommendations from the Agriculture Policy Project. Winrock International, Arlington, VA. Available at http://www.farmfoundation.org/projects/00-50.pdf (accessed March 26, 2007).

Lambert, D.K. 1990. "Risk Considerations in the Reduction of Nitrogen Fertilizer Use in Agricultural Production." *Western Journal of Agricultural Economics* 15(2): 234–244.

McCann, L., and K.W. Easter. 2000. "Estimates of Public Sector Transactions Costs in NRCS Programs." *Journal of Agricultural and Applied Economics* 32(3): 555–563.

Pease, J.W. 1992. "A Comparison of Subjective and Historical Crop Yield Probability Distributions." *Southern Journal of Agricultural Economics* 24(2): 23–32.

Phillips, S. 2005. Unpublished data. Eastern Shore Agricultural Research and Extension Center (Virginia Tech), Painter, VA.

Ribaudo, M.O., R. Heimlich, R. Claassen, and M. Peters. 2001. "Least-Cost Management of Nonpoint Source Pollution: Source Reduction Versus Interception Strategies for Controlling Nitrogen Loss in the Mississippi Basin." *Ecological Economics* 37(2): 183–197.

Ribaudo, M.O., R.D. Horan, and M.E. Smith. 1999. "Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice." Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Rosegrant, M.W., and J.A. Roumasset. 1985. "The Effect of Fertiliser on Risk: A Heteroscedastic Production Function with Measurable Stochastic Inputs." *Australian Journal of Agricultural Economics* 29(2): 107–121.

SAS. Undated. "SAS/STAT® Software." Available at http://www.sas.com/technologies/analytics/statistics/stat/index.html (accessed September 20, 2006).

Scharf, P.C., and M.M. Alley. 1988. "Nitrogen Loss Pathways and Nitrogen Loss Inhibitors: A Review." *Journal of Fertilizer Issues* 5(4): 109–125.

Simpson, T. 2005. Personal communication. College of Agriculture and Natural Resources, University of Maryland, College Park, MD (November 9).

Sripada, R.P., R.W. Heiniger, J.G. White, and R. Weisz. 2005. "Aerial Color Infrared Photography for Determining Late-Season Nitrogen Requirements in Corn." *Agronomy Journal* 97(55): 1443–1451.

SriRamaratnam, S., D.A. Bessler, M.E. Rister, J.E. Matocha, and J. Novak. 1987. "Fertilization Under Uncertainty: An Analysis Based on Producer Yield Expectations." *American Journal of Agricultural Economics* 69(2): 349–357.

Sweeney, J. 2005. Personal communication. University of Maryland, College Park, MD (October 7).

U.S. Congress, Senate. 2002a. "Agriculture, Conservation, and Rural Enhancement Act of 2001." *Congressional Record*, 107th Congress (February 13). Available at http://thomas.loc.gov/home/r107query.html (accessed June 10, 2006).

____. 2002b. "Farm Security and Rural Investment Act of 2002." *Congressional Record*, 107th Congress (May 8). Available at http://thomas.loc.gov/home/r107query.html (accessed June 10, 2006).

U.S. Department of Agriculture. 1997. "Fact Sheet: Conservation Reserve Program." Farm Service Agency, USDA, Washington, D.C. Available at http://www.fsa.usda.gov/pas/publications/facts/crp1.pdf (accessed July 9, 2006).

____. 2003. "Nutrient Best Management Practice Underwriting Guide." Risk Management Agency, USDA, Washington, D.C. Available at http://www.rma.usda.gov/FTP/Poli[-]cies/2003/n-bmp/pdf/N-BMP_ur.pdf (accessed June 10, 2006.)

____. 2006a. "U.S. and All States County Data." National Agricultural Statistics Service, USDA, Washington, D.C. Available at http://www.nass.usda.gov:8080/QuickStats/Create_County_All.jsp (accessed June 10, 2006).

____. 2006b. "Conservation Security Program." Natural Resources Conservation Service, USDA, Washington, D.C. Available at http://www.nrcs.usda.gov/Programs/csp/ (accessed September 18, 2006).

____. Undated. "Soil Data Mart." Natural Resources Conservation Service, USDA, Washington, D.C. Available at http://soildatamart.nrcs.usda.gov/ (accessed June 10, 2006).

U.S. Environmental Protection Agency (U.S. EPA). 2004. "Nonpoint Source Pollution: The Nation's Largest Water Quality Problem." Pointer No. 1, EPA841-F-96-004A. U.S. EPA, Washington, D.C. Available at http://www.epa.gov/owow/nps/facts/point1.htm (accessed July 9, 2006).

____. 2006. "Mid-Atlantic Integrated Assessment Nitrogen." U.S. EPA, Washington, D.C. Available at http://www.epa.gov/maia/html/nitrogen.html (accessed July 9, 2006).

VanDyke, L.S., J.W. Pease, D.J. Bosch, and J. Baker. 1999. "Nutrient Management Planning on Four Virginia Livestock Farms: Impacts on Net Income and Nutrient Losses." *Journal of Soil and Water Conservation* 54(2): 499–505.

Virginia Cooperative Extension Service. 2000. "Agronomy Handbook." Publication No. 424-100. Virginia Cooperative Extension Service, Blacksburg, VA.

Virginia Department of Conservation and Recreation. 1995. *Virginia Nutrient Management Standards and Criteria*. Virginia Department of Conservation and Recreation, Richmond, VA.

Wu, J., R.M. Adams, C.L. Kling, and K. Tanaka. 2004. "From Microlevel Decisions to Landscape Changes: An Assessment of Agricultural Conservation Policies." *American Journal of Agricultural Economics* 86(1): 26–41.

Yadav, S.N., W. Peterson, and K.W. Easter. 1997. "Do Farmers Overuse Nitrogen Fertilizer to the Detriment of the Environment?" *Environmental and Resource Economics* 9(3): 323–340.

Yaron, D., G. Strateener, D. Shimshi, and M. Weisbrod. 1973. "Wheat Response to Soil Moisture and the Optimal Irrigation Policy under Conditions of Unstable Rainfall." *Water Resources Research* 9(5): 1145–1154.

Zhang, W., R.D. Horan, and R. Claassen. 2003. "The Economics of Green Payments for Reducing Agricultural Nonpoint Source Pollution in the Corn Belt". Michigan State University, East Lansing, MI.