Perverse Incentives with Pay for Performance: Cover Crops in the Chesapeake Bay Watershed

Darrell J. Bosch, James W. Pease, Robert Wieland, and Doug Parker

Policymakers are concerned about nitrogen and phosphorus export to water bodies. Exports may be reduced by paying farmers to adopt practices to reduce runoff or by paying performance incentives tied to estimated run-off reductions. We evaluate the cost-effectiveness of practice and performance incentives for reducing nitrogen exports. Performance incentives potentially improve farm-level and allocative efficiencies relative to practice incentives. However, the efficiency improvements can be undermined by baseline shifts when growers adopt crops that enhance the performance payments but cause more pollution. Policymakers must carefully specify rules for performance-incentive programs and payments to avoid such baseline shifting.

Key Words: baseline, Chesapeake Bay, cover crops, export, mathematical programming, nitrogen, performance incentive, practice incentive

Since passage of the Clean Water Act in 1972, policymakers have devised state and federal policies and programs in efforts to achieve the act's water-quality goals. Current efforts include establishment of total maximum daily loads (TMDLs) for waterbodies that are deemed impaired due to one or more pollutants. TMDLs establish maximum allowances of pollutant exports or processes to achieve state water-quality standards (Environmental Protection Agency (EPA) 1999, National Research Council 2001). Recently, attention has focused on motivating conservation behaviors and assessing progress toward attaining water-quality goals through payments for performance measures as an alternative to practice adoption (Winsten and Hunter 2011, Winsten 2009). With performance-incentive programs, payments to farmers or other stakeholders could be based on estimated reductions in pollutant exports rather than adoption of the practices.

Pay-for-performance programs offer potential advantages for enhancing environmental quality, engaging producers, and increasing cost-effectiveness (Winsten and Hunter 2011, Ribaudo, Horan, and Smith 1999). Cost-effectiveness may be improved by increasing farm-level efficiency and/or

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allocative efficiency (Abler and Shortle 1991). Farm-level efficiency increases because tying payments directly to pollution reductions gives an incentive to choose practices that result in greater reductions in nutrient and sediment export for a given expenditure. Allocative efficiency increases because performance incentives direct payments to farms that have the lowest cost per unit of pollution reduction.

Measuring such performance can be difficult and expensive. Pollutant exports can be estimated through direct monitoring of ambient water quality or by using watershed or field-scale models to estimate outcomes (Ribaudo, Horan, and Smith 1999, Winsten et al. 2011). A baseline estimate of the amount of pollution that would be exported in the absence of the practice or program is needed to measure changes. However, economic agents may be able to manipulate the baselines to enhance the expected effectiveness of their environmental remediation efforts. For example, an agent could adopt practices that generate more pollution during a baseline period than would otherwise be used. The agent's subsequent practices in the performance period thus would generate larger reductions and incentive payments. The same incentive to manipulate the baseline might arise under a nutrient trading market depending on how nutrient credits are estimated.

We investigate the potential for performance incentives to increase the cost-effectiveness of pollution-abatement funds relative to practice incentives in the context of Maryland's cover crop program and Chesapeake Bay. Pay for performance has not yet been institutionalized in Maryland or in Chesapeake Bay water-quality programs; however, its relevance has been highlighted by newly developed state nutrient trading programs (Hoag and Hughes-Popp 1997, Stephenson, Norris, and Shabman 1998, EPA 2012a). While other studies have analyzed performance and practice incentives (Abler and Shortle 1991, Jung, Krutilla, and Boyd 1996, Ribaudo, Horan, and Smith 1999, Hawkins 2000, Horan and Lupi 2005), we also consider the potential for baseline shifting, an issue that has received little attention.

The analysis is carried out for winter cover crops that follow summer annual row crops in Maryland. Maryland, along with the District of Columbia, Delaware, Pennsylvania, New York, Virginia, and West Virginia, must reduce nitrogen exports to Chesapeake Bay, which has been deemed impaired due to excessive nitrogen, phosphorus, and sediment loads and placed under a TMDL program (EPA 2012b). The agricultural sector in Maryland has been assigned a 23 percent reduction in nitrogen loading as a final 2025 goal. Within practices planned for achievement of the reduction, the agricultural sector is set to plant cover crops on 355,000 acres at a state-subsidized cost of $107.4 million (University of Maryland et al. 2010). The Maryland Department of Agriculture's Winter Cover Crop Program provides practice incentives for planting cover crops following the harvest of selected summer annual crops (corn, soybeans, sorghum, tobacco, and vegetables) (Maryland Department of Agriculture 2011). A cover crop during winter months is a recommended best management practice that is expected to reduce nutrient (nitrogen and phosphorus) and sediment losses from fields as cover crops hold soil and nutrients in place during the winter, when losses might otherwise occur from run-off and leaching from bare soil. Cover crops are particularly useful in reducing infiltration of nitrogen into groundwater (Staver and Brinsfield 1998). The number of acres approved for payment rose from 205,628 in 2005/06 to 607,400 in 2012/13 (Maryland Department of Agriculture 2012). However, the actual acres of cover crop planted can lag behind the approved number of acres by one third or more. This shortfall reflects the fact that some farmers may be unable to plant all of their approved acres due to weather and other factors (Powell 2008).

Conceptual Model

We assume that a representative grain farmer has the objective of maximizing total gross margin from crop production.

(1) $$Max\ (\sum_{r=1}^{R} CR_r^{NS} \cdot GR_r - \sum_{r=1}^{R} CR_r^{NS} \cdot TC_r)$$

where CR_r^{NS} is total acres of crop rotation *r*, which may include both spring- and fall-planted crops. The *NS* superscript indicates that the crops were selected when there was no subsidy available for cover crops. GR_r represents weighted average gross revenue per acre from crop rotation *r* (crop price multiplied by crop yield for each crop in the rotation and by the proportion of each acre that produced that crop each year). TC_r equals the weighted average variable cost per acre of crop rotation *r* (variable cost per acre for each crop in the rotation multiplied by the proportion of each acre that produced that crop each year).

If a cover crop subsidy program is available, the farmer's objective function is expanded to include the subsidy income from cover crops:

(2) $$\text{Max}\ (\sum_{r=1}^{R} CR_r^{S} \cdot GR_r + \sum_{rcc=1}^{Rcc} CR_{rcc}^{S} \cdot GR_{rcc} - \sum_{r=1}^{R} CR_r^{S} \cdot TC_r - \sum_{rcc=1}^{Rcc} CR_{rcc}^{S} \cdot TC_{rcc})$$

where CR_r^S and CR_{rcc}^S refer to rotations without and with cover crops, respectively, selected when a cover crop subsidy is available. Cover crops vary by species, time of planting, and method of planting. GR_{rcc} refers to gross revenue that includes subsidies from cover crops while TC_{rcc} refers to total cost and includes the cost of the cover crops in the rotation. The grower also can harvest and market the cover crops. The following two sections describe optimal behavior of a farmer who maximizes the net subsidy with practice and performance incentives.

Practice Incentive

The subsidy for the practice incentive is calculated as

(3) $$S = \sum_{rcc=1}^{Rcc} CR_{rcc}^{Rcc} \cdot s_{rcc}$$

where s_{rcc} is the incentive payment per acre for rotation *rcc* based on the type of cover crop grown and the proportion of each acre on which the practice is applied each year. The payment per acre can be based on the perceived effectiveness of the particular combination of planting time, species planted, and planting method chosen in reducing nitrogen export. Practice payments differ from a traditional cost share in that the payment is not tied to actual or estimated costs incurred by the farmer. Instead, practice payments that are tied to *perceived* effectiveness are similar to performance incentives but with an important difference—the performance of a practice is not measured or estimated in determining payments.

Inclusion of a number of rotations that involve alternative commodities and cover crop combinations provides the farmer with flexibility to choose the rotation(s) that best achieve(s) the farmer's objective: maximize the net subsidy (NetSub) received from acres enrolled in the cover crop program subject to the constraint of available land (L) for rotations involving cover crops.

(4) $$Max\ NetSub = \sum_{rcc=1}^{Rcc} CR_{rcc} \cdot s_{rcc} - \sum_{rcc=1}^{Rcc} CR_{rcc} \cdot TC_{rcc} - \lambda\left(L - \sum_{rcc=1}^{Rcc} CR_{rcc}\right)$$

A farmer's decision to plant cover crops could be affected by other factors, including the effect of cover crops on yields of the commodity crop planted in the rotation. However, results from Maryland's cover crop program indicate that the subsidy is the primary factor in many farmers' decisions to plant cover crops. For that reason, and to keep the model tractable, we specify the model objective as net subsidy maximization.

If the opportunity cost of land for cover crops is positive ($\lambda > 0$), NetSub is maximized under the following first-order conditions.

(5) $$\frac{\partial NetSub}{\partial CR_{rcc}} = s_{rcc} - TC_{rcc} - \lambda = 0\ \forall\ CR_{rcc} > 0$$

(6) $$\frac{\partial NetSub}{\partial \lambda} = L - \sum_{rcc=1}^{Rcc} \cdot CR_{rcc} = 0$$

Equation 5 requires that NetSub for the cover crops chosen (subsidy – cash costs (TC) – opportunity cost of land for cover crops (λ)) equals zero. Equation 6 requires that the land constraint for cover crops be exhausted. Because the payments for cover crops are given regardless of any actual change in nitrogen export, there is no incentive to adjust the way harvested crops are managed to increase cover-crop efficiency, which is defined as the amount of nitrogen removed per acre. However, a cover crop program could affect the choice of crops planted. For example, a program might specify that cover crops can be planted only following summer annual row crops. In that case, if cover crop payments were sufficiently high, farmers could shift out of hay crops into row crops to qualify for payments, a case of baseline shifting. And if row crops generate more pollution than hay, nitrogen export could increase under the cover crop subsidy. Such behavior is not considered in this study.

Performance Incentive

Under a performance incentive, the subsidy, S, is estimated based on pounds of nitrogen load reduced by use of a cover crop.

(7) $$S = p_N \cdot TNred$$

where p_N is the per-pound price for the reduction in nitrogen load, which typically is set by policymakers based on their nitrogen-reduction goals. *TNred*, the total reduction in nitrogen export from a cover crop practice, is estimated as

$$(8)\qquad TNred = \left(\sum_{r=1}^{R} CR_r^{NS} \cdot NE_r^{NS}\right) - \left(\sum_{r=1}^{R} CR_r^{S} \cdot NE_r^{S}\right) - \left(\sum_{rcc=1}^{Rcc} CR_{rcc}^{S} \cdot NE_{rcc}^{S}\right)$$

where CR_r^{NS} represents harvested crop rotations grown without a subsidy and NE_r^{NS} represents nitrogen export per acre of crop without a subsidy. When the subsidy is available, NE_r^S and NE_{rcc}^S represent per-acre nitrogen exports without and with cover crops, respectively. The nitrogen reduction is estimated as the difference between nitrogen export under the baseline when no subsidy is available (term in the first set of parentheses in equation 8) and nitrogen export after planting a cover crop (terms in the second and third sets of parentheses in equation 8).

The cost of growing the cover crops is expressed as

$$(9)\qquad CovCost = \sum_{rcc=1}^{Rcc} CR_{rcc}^{S} \cdot TC_{rcc} \cdot prop_{rcc}$$

where $prop_{rcc}$ represents the proportion of the total cost of growing the crops (TC_{rcc}) incurred for the cover crop.

Under the performance standard, maximization of the net subsidy is expressed as

$$(10)\qquad Max\ NetSub = p_N \cdot TNred - CovCost + \lambda\left(L - \sum_{rcc=1}^{Rcc} CR_{rcc}^{S}\right).$$

Assuming that λ is positive, the first-order conditions require that

$$(11)\qquad \frac{\partial TNred}{\partial CR_{rcc}^{S}} \cdot p_N - \frac{\partial CovCost}{\partial CR_{rcc}^{S}} - \lambda = 0$$

for any CR_{rcc}^S that is positive and

$$(12)\qquad L - \sum_{rcc=1}^{Rcc} CR_{rcc}^{S} = 0.$$

Farmers will choose types of cover crops for which

((reduction in nitrogen export/acre) × (price of nitrogen export reduction))
– cover crop costs – shadow price for land in cover crops = 0.

Assuming that the land for cover crops has a positive shadow price, all of a farmer's land that is available for rotations with cover crops will be used because the farmer maximizes the subsidy. If the shadow price of land for cover crops is not positive, some land will not be planted with cover crops. This could occur, for example, on lower-quality land for which the reduction in nitrogen export and resulting payment are not adequate to offset the cost of planting cover crops. In reality, other factors, such as producer preferences and rotational constraints, also may prevent farmers from planting cover crops.

Equation 8 assumes that the baseline for calculating nitrogen reductions is the set of crops that would have been grown in the absence of the subsidy. This baseline is unobservable. One way to impute a baseline is to use the set of crop rotations, some of which include cover crops, adopted by the farmer under the subsidy and estimate the amount of nitrogen exported from the rotations if no cover crops had been planted. This option has the advantage of being easy to observe. A disadvantage is that farmers would have an incentive to adapt their choices for rotations that include cover crops to increase nitrogen exports:

$$\frac{\partial\left(NE_r^S\right)}{\partial\left(CR_{rcc}^S\right)} > 0. \tag{13}$$

The strategic behavior referred to here as baseline shifting results in crop changes that (i) increase credited nitrogen exports and, consequently, the performance-based incentive payment but (ii) decrease the realized reduction in nitrogen export and the cost-effectiveness of the performance incentive.

Crop changes can involve the types of crops grown or production methods. For example, a farmer could switch from soybeans to corn because corn crops export more nitrogen. The change in crop is easily observed. However, changes in production methods, either for new crops or for existing crops, are less readily observable but could have equally important implications for nitrogen export. Some changes in production methods might be controlled by requiring farmers to have a nutrient management plan for any rotation that involves cover crop subsidies, as is the case in Maryland. However, since nutrient management plans apply only to rotations involving cover crops, the plans would provide no information about prior rotations, leaving open the possibility of baseline shifting. Baseline shifting can be viewed as a moral hazard problem brought about by the inability of resource managers to establish a readily observable baseline. The issue also can be viewed in terms of additionality since it calls into question the actual amount of pollution reduction brought about by a measure.

Empirical Model

We evaluate practice and performance incentives for representative farms in the coastal and noncoastal plains of Maryland using linear programming models (GAMS Development Corporation 2011). The coastal plain refers to flat, low-lying areas along the coastline of Chesapeake Bay. The noncoastal plain refers to upland Piedmont and ridge-and-valley regions. We estimate the amount of subsidy earned and reductions in nitrogen export for each incentive.

The performance incentive in Maryland consists of a payment per pound of estimated nitrogen export reduction. Given the goal of reducing nitrogen exports to Chesapeake Bay, a performance incentive is tantamount to pricing the desired environmental impact. Our model incorporates payments that vary from \$1 to \$12 per pound in \$1 increments made for estimated reductions in the export of nitrogen. A change in nitrogen export is calculated as the difference between the estimated amount of nitrogen exported from a crop rotation that included cover crops and the amount of nitrogen exported under a pre-cover-crop baseline.

The practice incentive in our model reflects Maryland's current cover crop program and consists of a payment per acre of cover crop planted. The payments can differ based on the species of cover crop planted, time of planting, method of planting, and whether the cover is harvested. We consider five types of unharvested cover and one harvested cover (see Table 1) (Maryland Department of Agriculture 2011).

Maryland farmers receive up to $100 per acre for traditional cover crops that are left unharvested and are killed by tilling or herbicides prior to spring planting. The base rate for certified cover crops is $45 per acre with additional incentive payments for desirable practices associated with type of seed, time and method of planting cover crops, the type of the other crop used in the rotation, and whether manure was applied to that crop. Farmers who want to harvest a commodity cover crop agree to withhold fertilization until March 1. They receive $25 per acre as a base rate plus an additional $10 per acre when the commodity cover crop is rye. Growers are allowed to sign up for both unharvested and commodity cover crops and to alter the number of acres certified for each option after the crop is established.

Crop Yields, Budgets, and Farm Constraints

In accord with Maryland's program (Maryland Department of Agriculture 2012), we consider only crop rotations that involve nutrient management. Planning yields for the crops are estimated from the distribution of historic county yields for 2000 through 2009 (National Agricultural Statistics Service (NASS) 2010a). Using county yields for coastal and noncoastal plain counties, we estimate planning yields as the 95th percentile of the distribution (see Table 2). Yields for double-cropped soybeans are lower than yields for full-season soybeans, reflecting the effect of later planting (University of Maryland Extension 2010).

With the yield estimates, we adapt crop enterprise costs and returns from University of Maryland Extension budgets (Table 2). The $85-per-acre land charge is removed from the cost figures since the farmer is assumed to maximize returns to management, risk, and land. Nitrogen application costs are adjusted based on the rates appearing in the budget (one pound of nitrogen per planned bushel yield of corn or wheat). For rotations with soybeans, a nitrogen carryover of 0.5 pounds per bushel of soybean yield is assumed (Virginia Department of Conservation and Recreation 1995). We do not adjust the phosphate and potash applications by planned yield for corn, wheat, or soybeans. Manure applications (poultry litter costing $15 per ton applied) are allowed up to the phosphate requirement of the crop with supplemental applications of

Table 1. Cover Crops and Payments

Cover Crop Identifier	Description	Per-Acre Payment ($)[a]
WTDE	Wheat drill-seeded by October 1	65
WTDN	Wheat drill-seeded between October 2 and October 15	55
WTBE	Wheat broadcast-seeded by October 1	55
WTBN	Wheat broadcast-seeded between October 2 and October 15	50
WTBL	Wheat broadcast-seeded between October 16 and November 5	45
WTCOM	Wheat cover grown for commodity	25

[a] Payments are increased by $5 per acre if the cover crop follows corn and by $10 per acre if the cover crop is planted on fields that received a spring application of manure (Maryland Department of Agriculture 2011).

Table 2. Estimated Crop Yields, Gross Receipts, Variable Costs, and Gross Margins

Crop Type	Yield (bushels/acre)	Gross Receipts[a] ($/acre)	Total Variable Cost[b] ($/acre)	Gross Margin[a] ($/acre)
		Coastal Plain		
1. Corn, no till	155.9	617.36	450.11	167.25
2. Corn, conventional till	155.9	617.36	454.94	162.42
3. Corn, conventional till, manure	155.9	617.36	424.49	192.87
4. Soybeans, full-season, no till	42.0	390.18	272.08	118.10
5. Soybeans, full-season, conventional till	42.0	390.18	322.08	68.10
6. Double-cropped soybeans / wheat	71.8/30.0	638.42	560.51	77.91
		Noncoastal Plain		
7. Corn, no till	150.5	595.98	445.06	150.92
8. Corn, conventional till	150.5	595.98	449.89	146.09
9. Corn, conventional till, manure	150.5	595.98	419.71	176.27
10. Soybeans, full-season, no till	42.0	390.18	272.08	118.10
11. Soybeans, full-season, conventional till	42.0	390.18	321.88	68.30
12. Double-cropped soybeans / wheat	71.6/30.0	637.42	560.51	76.91

[a] Amount includes income from sale of crops but not cover crop subsidies.
[b] Includes a cost for writing a nutrient management plan of $4.33 per acre.
Note: All crops are grown under nutrient management.

commercial nitrogen and potash as needed. Allowing for nitrogen volatilization with surface application and no incorporation, we assume that a ton of litter as applied has a plant-available nutrient concentration of 44 pounds of nitrogen, 40 pounds of phosphate, and 51 pounds of potash during the first year after application (Mid-Atlantic Water Program 2006). The cost of nutrient management planning is estimated as $4.33 per acre (Dill 2011).

The total land area for crops for the representative farm is set at 2,000 acres. The total number of acres of each crop is limited based on planting machinery capacity and estimated suitable days for field work (see Table 3).

Cover Crops

In this analysis, a cover crop can be planted following corn and soybeans. Cover crop payment rates (Table 1) differ by planting method (drilled or broadcast), timing (early is before October 1, normal is between October 2 and October 15, and late is between October 16 and November 5), and whether the cover crop is harvested. Wheat, rye, and barley can be used as cover crops, but we consider only wheat since it is most widely grown as a cover crop in Maryland.

In the model, the commodity cover crops are harvested and do not qualify for a premium for the planting date or method. Maryland farmers generally view wheat as the best option for a harvested cover crop. For this analysis, commodity wheat cover is planted via drilling prior to October 15 as those practices result in the best crop stand.

Cover crop establishment costs vary by seeding method (drilled or broadcast) (Table 4). We obtain cost information from the Cover Crop Cost Efficiency Calculator (Wieland et al. 2010). We consider five types of unharvested wheat cover that can potentially follow corn or soybeans. In addition, commodity wheat cover can follow corn in a corn-wheat-soybean rotation with the restriction that no fertilizer can be applied to the wheat prior to March 1.

Table 3. Crop Planting Capacity Based on Suitable Field Days

Crop	Planting Window	Suitable Field Days	Planting Capacity/Season (acres)
Corn	April 30 – May 20	10.2	1,352
Soybeans, full-season	May 28 – June 26	11.5	1,524
Soybeans, double-cropped	July 5 – July 12	6.5	862
Wheat early	Sep. 22 – Oct. 1	5.2	690
Wheat normal	Oct. 2 – Oct. 15	8.8	1,166
Wheat late	Oct. 16 – Nov. 5	11.9	1,577

Notes: The data on planting windows come from the National Agricultural Statistics Service (2010b). Estimated suitable field days for each planting window are based on the minimum number of suitable field days recorded for that period for 2009 through 2011 (NASS various years). The estimated seasonal capacity is based on a 30-foot-wide planter, a 200-horsepower tractor, planting efficiency of 0.675, an average speed of 4.5 miles per hour, and 12-hour work days.

Table 4. Cover Crop Nitrogen-removal Efficiencies and Total Variable Costs

Crop	Nitrogen Removal Efficiency (percent)		Total Variable Cost ($/acre)
	Coastal Plain	Noncoastal Plain	
Wheat, drilled, early	31.2	24	33.40
Wheat, broadcast, early	26.6	20	33.55
Wheat, drilled, normal	28.6	22	33.40
Wheat, broadcast, normal	24.3	18	33.55
Wheat, broadcast, late	11.4	9	33.55
Wheat commodity	28.6	22	—

Notes: The nitrogen removal efficiencies are from Simpson and Weammert (2007). Commodity wheat is assumed to have been drill-seeded by the normal deadline. The commodity wheat costs are described in Table 3.

Commodity wheat cover is assumed to have the same yield as commodity wheat grown as the primary crop. Unharvested wheat cover can follow soybeans in the modeled rotation; however, only late-planted wheat is a cover crop option due to the harvest period of late-planted soybeans. The amount of wheat that can be planted by the early and normal deadlines of October 1 and 15 (Table 3) is constrained by machinery capacity and suitable working days during the fall planting period.

Reduction in Nitrogen Export

We estimate reductions in nitrogen export as a *calculated* reduction and as a *credited* reduction. The *calculated* reduction is based on equation 8: amount of nitrogen export under cover crop rotations minus amount of nitrogen export from rotations grown prior to the performance or practice subsidy program and without cover crops. There is no baseline shift.

The baseline nitrogen exports (see Table 5) are based on version 5.3 of the Chesapeake Bay Model (Wieland et al. 2010). Nitrogen exports for noncoastal farms are much larger than exports from coastal farms because noncoastal farms have steeper slopes and are more prone to run-off. We then estimate total nitrogen exports for the set of crops grown under the performance and practice scenarios. The degree to which nitrogen exports decline in rotations that include cover crops depends on the nitrogen removal efficiency of the cover crop (Table 4) (Simpson and Weammert 2007). We subtract the total amount of nitrogen exported from all of the crops grown on the farm from the baseline export amount to arrive at the *calculated* reduction in nitrogen export. This method eliminates incentives for baseline manipulation described in equation 13 but the baseline export amount is difficult to determine. For example, it might be necessary for participating farmers to document the crops they grew prior to signing up for the cover crop program.

Table 5. Nitrogen Losses from Crops without Cover

	Nitrogen Loss to Edge of Stream without Cover Crop (pounds per acre)	
Crop Type	**Coastal Plain Farm**	**Noncoastal Plain Farm**
Corn, no till, nutrient management[a]	15.36	51.67
Corn, conventional till, nutrient management[b]	23.31	50.86
Corn, conventional till, nutrient management, manure[c]	16.98	51.67
Soybeans, full-season, no till[a]	15.36	51.67
Soybeans, full-season, conventional till[b]	23.31	50.86
Wheat/soybeans, nutrient management[a]	15.36	51.67
Commodity cover wheat / soybeans[a]	15.36	51.67

[a] Losses are based on nutrient management low-till.

[b] Losses are based on high-till without manure.

[c] Losses are based on nutrient management, high-till, and with manure.

Notes: Nutrient losses are based on runs of the Chesapeake Bay Model for coastal and noncoastal plains. The land-use categories used to estimate nutrient losses for each crop-tillage combination are reported in the footnotes.

Under the *credited* reduction, the set of crops grown under the practice or performance incentive determines the baseline amount of nitrogen exported. Using Tables 4 and 5, we calculate nitrogen exports with and without cover-crop reductions for the set of crops used in the program rotations. The difference between the baseline export (without reductions from cover crops) and the program export is the *credited* reduction. Estimating reductions in this manner is less work for program administrators and participants because the assumed baseline is readily observable. The drawback is that farmers may use baseline shifting when they select crops to maximize the amount of nitrogen reduction obtained from cover crops.

Because the estimates calculate the amount of nitrogen exported to the edge of a stream rather than to tidal waters of Chesapeake Bay, nitrogen losses and reductions in losses for farms in coastal and noncoastal plains cannot be compared. The two regions' nitrogen loss-attenuation functions are different and affect the final amount of nitrogen that reaches the bay.

Results

On the coastal farm (Table 6), the practice incentive induced adoption of a wheat cover crop on the entire 2,000 acres (last line of Table 6) with 690 acres planted by the early deadline, 1,166 acres planted by the normal deadline, and 144 acres planted by the late deadline (commodity wheat is considered a cover crop planted by the normal deadline). On the noncoastal farm (Table 7), the practice incentive (last line of Table 7) induced full adoption of cover crops with an identical distribution of planting times. Cover crops under both programs were planted following continuous conventionally tilled corn, a no-till corn/soybean rotation, and a conventionally tilled corn/wheat/soybean rotation.

For the coastal farm, the performance incentive induced adoption of cover crops on between 648 and 1,856 acres that generated payments of $2 to $12 per pound of *credited* nitrogen export reduced. As the rate granted per pound of nitrogen increased, the crop rotation shifted from no-till corn/soybeans to conventionally tilled corn/wheat/soybeans. Since the maximum area placed under cover crops was 1,856 acres, the shadow price on land for cover crops (equation 10) reached zero even with the highest payment per pound of nitrogen reduction. The reason is that only 1,856 acres can be planted by the early or normal planting deadlines due to limited machinery capacity (Table 3). Cover planted late does not reduce nitrogen export enough (Table 4) to be profitable.

The noncoastal farm (Table 7) was more likely to be converted to cover crop rotations than the coastal farm since cover crops were adopted at a smaller threshold payment ($1 per pound rather than $2 per pound). The maximum number of acres converted to a cover crop rotation was also greater (2,000 compared to 1,856). Under the performance incentive, unharvested cover was grown with continuous, conventionally tilled corn and with a no-till corn/soybean rotation. Commodity wheat cover was grown following continuous corn production while unharvested wheat cover followed soybeans in a corn/wheat/soybean rotation.

Both coastal and noncoastal farms recorded reductions in estimated nitrogen export as the acres of cover crop increased. Compared to the scenario with no cover crop subsidy, nitrogen export dropped by almost 22 percent on the noncoastal farm when cover crops were planted on all acres and by almost 28

Table 6. Coastal Plain Farm Crop Rotations and Cover Crops with Performance and Practice Incentives

N Reduction Price per Pound	Acres of Cover Crop	Estimated N Exports (pounds)	*Credited* N Reduction (pounds)[a]	*Calculated* N Reduction (pounds)[b]	Total Gross Margin (dollars)	Avg Cover Payment ($/acre)	N Reduction Unit Cost ($/pound)[c]
Baseline Rotations: CCT corn with manure, no cover (704 acres) • NT corn/soybeans, no cover (1,296 acres)							
$0–1	0	31,860	—	—	331,482	—	—
Rotations Chosen at Subsidy Price: CCT corn with manure, no cover (704 acres) • CT corn with manure / CM wheat, NT DC soybeans (1,296 acres)							
$2	648	29,913	2,997	1,947	331,726	9	3
$3	648	29,913	2,997	1,947	334,723	14	5
$4	648	29,913	2,997	1,947	337,720	18	6
$5	648	29,913	2,997	1,947	340,716	23	8
$6	648	29,913	2,997	1,947	343,713	28	9
Rotations Chosen at Subsidy Price: CCT corn with manure, CV DR wheat, early (690 acres) • CCT corn, CV DR wheat, normal (14 acres) • CT corn with manure / CM wheat, NT DC soybeans (1,296 acres)							
$7	1,352	26,190	6,720	5,670	349,260	35	8
$8	1,352	26,190	6,720	5,670	355,981	40	9
$9	1,352	26,190	6,720	5,670	362,701	45	11
$10	1,352	26,190	6,720	5,670	369,421	50	12
$11	1,352	26,190	6,720	5,670	376,141	55	13
Rotations Chosen at Subsidy Price: CCT corn, CV DR wheat, normal (704 acres) • CT corn/soybeans, CV DR wheat, early (690 acres) • CT corn/soybeans, CV DR wheat, normal (318 acres) • CT corn with manure / CM wheat, NT DC soybeans (288 acres)							
$12	1,856	26,663	10,254	5,197	383,781	66	24
Rotations Chosen: CCT corn, CV DR wheat, normal (704 acres) • NT corn/soybeans, CV DR wheat, early (690 acres) • NT corn/soybeans, CV DR wheat, normal (318 acres) • CT corn with manure / CM wheat, NT DC soybeans, CV BR wheat, late (288 acres)							
Practice Incentive[d]	2,000	23,040	9,054	8,821	394,572	63	14

[a] *Credited* reduction: (nitrogen export from rotation with no cover crop) – (nitrogen export on rotation with a cover crop).

[b] *Calculated* reduction: (nitrogen export from rotation grown with no subsidy) – (nitrogen export from rotation following subsidy).

[c] Unit cost = subsidy cost per unit of *calculated* N reduction.

[d] Practice incentive subsidy is paid at a fixed rate per acre of cover crop.

Notes: All rotations include nutrient management.

Abbreviations:

CCT: continuous conventionally tilled (corn).
CT: conventionally tilled (corn).
NT: no till.
CM: commodity (normal cover).
CV: cover.
BR: broadcast-seeded.
DR: drill-seeded.
DC: double-cropped.

Table 7. Noncoastal Plain Farm Crop Rotations and Cover Crops with Performance and Practice Incentives

N Reduction Price per Pound	Acres of Cover Crop	Estimated N Exports (pounds)	*Credited* N Reduction (pounds)[a]	*Calculated* N Reduction (pounds)[b]	Total Gross Margin (dollars)	Avg Cover Payment ($/acre)	N Reduction Unit Cost ($/pound)[c]
Baseline Rotations: CCT corn with manure, no cover (704) • NT corn/soybeans, no cover (1,296)							
$0	0	103,340	—	—	309,208	—	—
Rotations Chosen at Subsidy Price: CCT corn with manure, no cover (704) • CT corn with manure / CM wheat, NT DC soybeans (1,296)							
$1	648	95,974	7,366	7,366	310,001	11	1
$2	648	95,974	7,366	7,366	317,367	23	2
Rotations Chosen at Subsidy Price: CT corn with manure / CV DR wheat, early (690), NT DC soybeans (1,296) • CCT corn with manure, CV DR wheat, normal (14) • CT corn with manure / CM wheat, NT DC soybeans (1,296)							
$3	1,352	87,258	16,082	16,082	327,366	36	3
$4	1,352	87,258	16,082	16,082	343,448	48	4
Rotations Chosen at Subsidy Price: CT corn with manure / CV DR wheat, early (690), NT DC soybeans, CV BR wheat, late (288) • CCT corn with manure, CV DR wheat, normal (14) • NT corn/soybeans, CV DR wheat, normal (1,008) • CT corn with manure / CM wheat, NT DC soybeans (288)							
$5	1,856	81,529	21,811	21,811	359,621	59	5
$6	1,856	81,529	21,811	21,811	381,432	71	6
$7	1,856	81,529	21,811	21,811	403,243	82	7
Rotations Chosen at Subsidy Price: CT corn with manure / CV DR wheat, early (690), NT DC soybeans, CV BR wheat, late (288) • CCT corn with manure, CV DR wheat, normal (14) • NT corn/soybeans, CV DR wheat, normal (1,008) • CT corn with manure / CM wheat, NT DC soybeans, CV BR wheat, late (288)							
$8	2,000	80,859	22,481	22,481	425,580	90	8
$9	2,000	80,859	22,481	22,481	448,061	101	9
$10	2,000	80,859	22,481	22,481	470,541	112	10
$11	2,000	80,859	22,481	22,481	493,022	124	11
$12	2,000	80,859	22,481	22,481	515,502	135	12
Practice Incentive[d]	2,000	80,859	22,481	22,481	372,115	63	6

[a] *Credited* reduction: (nitrogen export from rotation with no cover crop) – (export on rotation with a cover crop).

[b] *Calculated* reduction: (nitrogen export from rotation grown with no subsidy) – (nitrogen export from rotation following subsidy).

[c] Unit cost = subsidy cost per unit of *calculated* N reduction.

[d] Practice incentive subsidy is paid at a fixed rate per acre of cover crop.

Notes: All rotations include nutrient management.

Abbreviations:
- CCT: continuous conventionally tilled (corn).
- CT: conventionally tilled (corn).
- NT: no till.
- CM: commodity (normal cover).
- CV: cover.
- BR: broadcast-seeded.
- DR: drill-seeded.
- DC: double-cropped.

percent on the coastal farm when cover crops were planted on the maximum number of acres.

For the noncoastal farm, corresponding *credited* and *calculated* nitrogen reductions were equal under both incentives (see Table 7). For the coastal farm, the *calculated* reductions lagged slightly behind the *credited* reductions under the practice incentive because the coastal farmer replaced a no-till corn and soybean rotation on 288 acres with conventionally tilled corn, commodity wheat, and soybeans. The rotation was chosen because of the profitability of commodity wheat cover grown following corn. However, the new rotation exports more nitrogen than the baseline one.

Under a performance incentive on the coastal farm (Table 6), the *calculated* reductions lagged further still. A $2 payment induced adoption of 648 acres of cover, 2,997 pounds of credited reduction, and 1,947 pounds of calculated reduction. The difference increases with the subsidy rate. The $12 payment produced a calculated reduction of 5,197 pounds and a credited reduction of 10,254 pounds. The difference is due to baseline shifting, in this case adoption of cover crops in rotations of continuous conventionally tilled corn and conventionally tilled corn and soybeans. These rotations generate almost 50 percent more nitrogen export than the no-till corn and soybean rotation (see Table 5) adopted when no subsidy is given. By adopting the conventional-till rotations, farmers shift from the baseline to higher levels of nitrogen export and obtain a greater performance incentive payment. For example, if a wheat cover crop is drill-seeded by the normal deadline in rotation with a no-till continuous corn crop, the *credited* export reduction is 4.39 pounds (0.286 × 15.36 pounds). For the same cover crop rotated with continuous conventionally tilled corn, the credited reduction is 6.66 pounds (0.286 × 23.31 pounds), an increase of 2.17 pounds. With payments of $2 to $12 per pound for export reductions, the shift from no-till to conventional-till production increases the performance payment by approximately $4 to $26 per acre.

The results for baseline shifting depend somewhat on the fact that conventional-till corn is only slightly less profitable than no-till corn ($5 per acre) (Table 2). A larger difference in profitability between the two systems would reduce the tendency to shift to conventionally tilled corn. Further investigation of differences in profit between the two systems would be useful for analyzing the potential for baseline shifting. For the example cited in the previous paragraph, a $4 to $26 per-acre increase in the profitability of no-till cultivation of corn would eliminate the baseline shift.

Baseline shifting is not evident for the noncoastal farm because estimated exports from no-till and conventional-till corn are nearly the same (Table 5). Compared with the coastal farm, the noncoastal farm recorded larger increases in the total gross margin, higher average payments per acre of cover crop, and smaller unit costs for nitrogen reduction. The noncoastal farm is more effective at reducing nitrogen exports to the stream edge with cover crops because the baseline export level is significantly greater and baseline shifting does not occur (Table 7). The coastal farm, on the other hand, less effectively reduces nitrogen export to the stream edge with cover crops. Baseline shifting increases the unit cost of nitrogen reduction. Our conclusion that noncoastal farmers pay less per unit for nitrogen reduction applies to nitrogen export to the edge of the stream but does not necessarily apply to nitrogen export to tidal waters of Chesapeake Bay. Exports from the noncoastal farm would be subject to greater attenuation than exports from the coastal farm, thus reducing the relative advantage of nitrogen control efforts on the noncoastal farm.

Conclusions

Performance incentives can increase the cost-effectiveness of expenditures for pollution control by directing payments to farms and practices that offer the greatest potential reductions in pollution per dollar. However, the method of determining the baseline is critical. Performance incentives may induce baseline shifts in which farmers alter their practices to increase the amount of estimated pollution reductions from their practices and thus boost their payments, potentially at the expense of actual nitrogen reduction. We compare performance and practice incentives for use of cover crops for two representative grain farms in Maryland, one in the coastal plain and one in the noncoastal plain.

The practice incentive induced adoption of cover crops on all 2,000 acres of each farm. Under the performance incentive, adoption of cover crops depended on the level of the incentive payment. Maximum cover crop adoption was achieved at a payment of $8 per pound for the noncoastal farm and $12 per pound for the coastal farm. Nitrogen export dropped 22 percent on the noncoastal farm and 28 percent on the coastal farm under the practice incentive. Under the maximum performance incentive, the nitrogen export dropped 22 percent for the noncoastal farm and 16 percent for the coastal farm.

For the noncoastal farm, the *credited* reductions in nitrogen export were the same as the *calculated* reductions for both the performance and the practice incentive. However, for the coastal farm, baseline shifting steered the crop rotations to a conventional-till corn/soybean rotation, which would export a greater quantity of nitrogen. This shift increased the farmer's performance payment for adoption of cover crops but also caused the *calculated* reductions in nitrogen export (which were based on a comparison with the no-subsidy baseline) to lag behind the *credited* reductions.

While performance incentives have potential to decrease the cost of pollution abatement measures relative to practice incentives, the cost savings may be undermined partially or wholly by baseline shifting. Policymakers will need to consider how a performance incentive might induce participants to alter their crop patterns and production practices in ways that will increase rather than decrease nitrogen exports. Similar concerns could arise under a nutrient trading market depending on how trading credits are estimated. Policymakers should establish baselines for agricultural operations that participate in performance-based programs to reflect agricultural practices without the subsidy. It may be desirable to document participants' farm practices prior to their adoption of program measures for purposes of determining conservation payments. This may be more time-consuming and costly for program administrators and participants but also may lead to more effective environmental protection.

Further research to extend both the theoretical and empirical models in this study would be useful. The theoretical analysis assumed separability of input levels from cover crop choices. In fact, these could be linked. For example, a cover crop rotation could improve yields on fields that are deficient in organic matter and reduce the need for applied nutrients. Other incentives for cover crop adoption, such as increases in yields and reductions in the cost of fertilizer, could be considered in addition to the subsidy incentive. Studies also could analyze the potential for baseline shifting under performance incentives and a broader menu of nutrient-control practices that could include soil/tissue testing, reduced fertilizer applications, changes in tillage methods, and adjustments in animal rations. Another direction would be to look at alternative ways of structuring performance incentives. For example, payments could be tied to farmers reaching specified levels of estimated loss per acre rather than to total reductions. Such a scheme might be less cost-effective but also could be more equitable and less prone to baseline shifting.[1]

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