Least-Cost Supply of Nitrogen Reduction from Two Important Agricultural Non-Point Source Best Management Practices in Maryland

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of
NITROGEN REDUCTION
from
TWO IMPORTANT AGRICULTURAL NON-POINT SOURCE BEST MANAGEMENT PRACTICES IN MARYLAND

Prepared for

THE HARRY R. HUGHES CENTER FOR AGRO-ECOLOGY

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Executive Summary

This study addresses the economic supply of expected nutrient load reductions from two important non-point source nutrient pollution load reduction practices: cover crops and riparian buffers. We consider the price-quantity relationship of both practices in two different ways. First, using econometric methods, we estimate the supply response of either best management practice (BMP) as acres adopted at various prices. Since both practices are currently bought by the acre, this approach uses historical data on prices and acres and other data to test the economic expectation that higher prices call forth greater supply. Secondly, however, we estimate a marginal cost curve for either BMP measured in pounds of Nitrogen (N) reduced per dollar of implementation cost. This accounting is treated as a "per pound reduced" supply curve.

Comparing the price-quantity relationships of BMPs measured in acres versus pounds of nutrients reduced might seem at first glance an obscure, academic exercise. But the comparison reveals an important difference between these two approaches to pricing BMP implementation. It shows that expected nutrient reductions will be significantly greater at relevant levels of expenditure when they are bought by the pound, compared to buying them by the acre.

Expected load reductions from BMPs under current policy are found by averaging high reducing acres and low reducing acres within any priced class of BMP implementation. This is expected because there is no difference in the price signal going to either sort of acre. Without additional information, the best estimate for load reductions from "per acre" supply is the weighted average of high reducing and low reducing acres.

Load reductions under a "price per pound reduced" policy are estimated differently. Pricing load reductions by the pound sends a more compelling signal to high reducing acres to adopt (with high reducing practices), and they are expected to do so. Low reducing acres (with low reducing practices) would be paid less under such a policy, so, depending upon their costs and the price per pound, potential suppliers may choose not to adopt. Because of those types of decisions, total load reductions are expected to be greater at any unit price than they would be at a similar average cost under a fixed price per acre policy.

To estimate supply curves for nutrient load reductions from cover crops and riparian buffers, we use Chesapeake Bay Model (version 5.3) loading rates and Chesapeake Bay Program N reduction efficiencies, paired with BMP cost estimates from Wieland and others (2009). These accounted supply curves predict, under several different factors and assumptions, the amount of nutrient load reduction that could be achieved at different unit prices or total costs.

With respect to the original goal of this project, which was to assess the sectoral effects of implementing BMPs at the level envisioned by Maryland's Tributary Strategies, these analyses beg the question, how will that BMP implementation be paid? Will BMP implementation be motivated by a pricing policy that maximizes nutrient pollution reduction at any given level of expenditure? Or, will the current policy of buying BMPs by the acre be maintained? The answer to this question will significantly affect the sectoral impacts of the Tributary Strategies.

1. Introduction

An early objective of this study was to assess the sectoral cost impacts of implementing Maryland's Tributary Strategies (TS). Such an assessment requires information about TS-imposed cost effects on the investment returns of farms, firms, and load source sectors. Knowledge of imposed costs presupposes expectations for TS implementation – the expected pollution load reductions, the costs of achieving those reductions, and the allocation of liability for paying those costs.

Although several efforts have been made to cost TS implementation[1], none of those included serious attempts to discern the prices that might be required to achieve the adoption of Best Management Practices (BMPs) at the level envisioned in the TS. If the fundamental law of supply – that more of a good or service will be supplied at higher prices (and, less at lower prices) – holds for the supply of pollution-reducing BMPs, then in order to estimate total costs at any given level of implementation one needs to have some idea of the shape and position of the supply curve[2] for those BMPs.

Some analysis of the supply of individual BMPs in the Chesapeake Bay drainage has been undertaken (see Lynch, Hardie and Parker, 2002), but little work has been done to estimate supply responses for BMPs at different prices. This study considers two important agricultural BMPs and their respective supply responses to price. While such estimates are useful for estimating implementation costs by BMP or by load source sector, knowledge of supply response and pollution reduction at different prices also allows a comparison between the current BMP pricing policy and a "reduction-maximizing" pricing policy.

Supply of a good or service at different prices is generally an empirical question. Historical data about prices, production costs, and quantities of a good or service traded in a market provide the basic inputs for estimating supply curves. In addition to the price of the good or service itself, quantities supplied often depend on the price of alternative goods or services that could be produced with the same factor resources, and the (changing) costs of producing different quantities of the good or service. For agricultural production, weather is often an important factor in supply.

In this report, we consider supply of the cover crop BMP using Maryland Department of Agriculture (MDA) data from 1998 through 2009. Winter cover crops are expected to deliver a large portion of the nutrient pollution load reductions from Maryland's agricultural land under the TS. We also consider the supply of the riparian buffers BMP. These include both forested and grassed buffers, which are principally purchased through the US Department of Agriculture's (USDA) Conservation Reserve Enhancement Program[3] (CREP). Like winter cover crops, riparian buffers are an important nutrient load reduction practice in the TS, and there are records of prices and quantities of buffers supplied through CREP over time.

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[1] For example, Chesapeake Blue Ribbon Panel (2004), and, Chesapeake Bay Program Office (2003).

[2] A supply curve is a graph that predicts quantities of a good or service that will be supplied at various prices.

[3] Maryland Agricultural Cost Share (MACS) also provides support for CREP riparian buffers.

We undertake two different treatments of the supply of the two targeted BMPs. In the first case, we consider each BMP in terms of acres supplied under the existing payment system. This can be thought of as a "per acre" supply curve. We then relate this "per acre" supply curve to expected nutrient load reductions using Chesapeake Bay Program reduction efficiencies and loading rates.

Following the "per acre" treatment of either BMP, we consider each in terms of a unit pricing scheme, wherein specific acres are paid at a rate determined by how many pounds of Nitrogen (N) they keep from the edge of stream loads. This latter treatment can be thought of as "pounds reduced" supply curves. To the extent that our data are correct, they tell us the relationship between costs and expected load reductions, without any further analysis.

The direct calculation of a (pollution) reduction-maximizing strategy creates new opportunities and information for improving TS implementation.

Although Maryland's cover crop program uses the price mechanism to motivate more efficient nutrient reduction, CREP does not and even Maryland's cover crop pricing policy does not ensure that purchases of nutrient reduction track the efficient path. That is to say, average costs of nutrient reduction under current pricing will always be greater than average costs under a pricing scheme that takes account of how much nutrient load reduction a given BMP delivers on a specific type of acre. Whether current policy is retained or whether policy-makers shift to more targeted pricing will make a large difference in the sectoral effects of TS implementation.

2. The Cover Crop BMP

Cover crops are distinguished from normal winter grains by not being fertilized and being killed in the spring to make way for the planting of a commercial summer crop. Cover crops provide benefits to the farmer in improved soil tilth and protection from sheet erosion, but those benefits are not perceived by most farmers as sufficient to justify the cost of planting them. However, cover crops also generate the benefit of reducing nutrient loads delivered to waterways and if ecological service values are included in the calculation, planting them may be desirable from a social perspective.

Currently, cover crops are an important agricultural nutrient load reduction practice in Maryland, funded by MDA as a BMP for non-point source nutrient loads from agriculture. Maryland's cover crop program grew out of research initiated in the mid 1980s at University of Maryland's Wye Research Station (Staver and Brinsfield,1998) showing that planting a winter cover in the fall could reduce the infiltration of residual N into shallow ground water under farm fields. Since 1994, the state has provided cash incentives to encourage farmers to plant cereal grains in the fall during years in which fields would normally lie fallow in the winter. While not all winter cover crops in the state are planted under this program, the vast majority are. In 2006, increased budget resources became available and the cover crop program has expanded considerably since then.

In addition to the traditional cover crop program, under which the cover is killed in the spring, Maryland has instituted a commodity cover crop program in which the cover is allowed to grow to seed for a commercial grain crop. The difference between the commodity cover crop program and regular winter small grains is that commodity cover crops are not fertilized before March 1 of the calendar year following their (fall) planting. Since the nutrient reduction effect of commodity cover crops is not known, those acres are excluded from our analysis.

It is important to note two additional caveats to our analysis. First, the cover crop program has been variably constrained in its purchase of adoption by budget considerations. That is, in some years there may have been adequate funding to accept all the qualifying applications at some given price, while in other years, the available budget may have constrained acceptance at the price offered. When the latter was the case, the observed number of acres accepted or paid would be less than the true quantity that might have been supplied at that price. It is difficult to know, even *ex-post*, what budget was expected by MDA at the time of program sign-up for all of the years of the program.

Secondly, the large number of factors affecting adoption (in addition to price) and the short time series over which we can observe their effects limits the analysis and the robustness of the results. Our analysis should therefore be viewed as preliminary. Related to the problem of a brief data series is the issue that, until recently, prices offered for planting cover crops did not vary a great deal. Given that the observed range of the price variable is limited, it is quite possible that there is a different relationship between price and quantities supplied at radically different prices.

2.1 Supply of Cover Crop Acres and Load Reduction under Current Pricing

Our goal in this section is to describe the revealed relationship between prices offered for planting cover crops and acres of cover crop acres supplied. As both quantities of cover crop acres planted and the program's per acre prices have changed over time, we would like to apply our expectation of a positive relationship between prices and quantities supplied to these historical data to see, at the very least, whether or not that basic expectation is met. We seek to develop a schedule of expected supply of cover crop acres at different prices.

2.1.1 A Supply Equation for Cover Crop Acres

To estimate the supply-price relationship of cover crop adoption, we considered MDA data reporting annual cover crop program participation and payments (i.e., prices) offered for that participation. The data includes annual base prices and incentives for specific planting practices, average prices paid (i.e., total program payments divided by total acres paid), acres offered during summer sign-ups, acres approved by MDA, and acres actually paid. These data are reported in Table 2.1.

Table 2.1: The Maryland Cover Crop Program (Traditional), 1998 - 2008

year	Available Acres	Acres Offered	Acres Accepted	Acres Paid	Base Payment ($/Acre)	Maximum Payment ($/Acre)
1998	235,700	145,028	68,410	50,040	20	30
1999	415,000	162,328	161,667	110,605	20	25
2000	291,000	153,479	109,318	68,022	25	25
2001	314,501	157,413	155,706	99,485	20	25
2002	538,000	263,001	217,271	116,711	20	20
2003	479,000	95,487	93,245	29,584	20	20
2004	580,000	106,934	113,522	53,515	20	30
2005	547,000	210,258	205,268	126,245	25	50
2006	499,000	327,405	210,309	173,087	30	50
2007	420,000	258,321	232,676	143,794	30	50
2008	390,000	237,580	230,897	142,347	45	90

Under the cover crop program as currently implemented, in early summer MDA advertises terms for the coming fall planting of cover crops. Sign-ups are scheduled during a two week period in June. Following sign-ups, MDA staff evaluate applications (sign-ups) and accept qualifying acres. Between the time that farmers' applications are accepted and the time that payment is made, farmers plant some of the qualifying acres in cover crops.

Between acceptance and payment, there is on average a 39 percent decline in cover crop acreage. This decline is made up of acres offered and qualified, but not planted. Weather constraints, equipment constraints, or changing economic factors are the most likely causes for this decrease in acres. There is no cost to the adopter in failing to plant qualifying acres, except the revenue lost from not participating in the program.

Our selected measure for quantities supplied at different prices is “acres accepted”. This variable captures farmers’ willingness to accept the offer price(s) in a given year, constrained by MDA’s qualification of their applications. Later reductions in the actual supply of cover crop acres due to weather or production conditions are noted, but segregated from this analysis.

The price variable chosen from our analysis is the “maximum payment”, composed of the base offer price plus the premiums offered each year of the program. Alternative measures were considered as measures of farmers’ expected “price” for planting cover crops. But the maximum payment provided the best fit in the base model. MDA offer prices moved between $20 and $30 per acre for the first seven years of the program, though they have risen well above that over the past four years.

An additional factor in our model of cover crop supply is the amount of available land on which to plant them. This has changed over the years, both in terms of eligibility and with respect to cropping patterns. In the early years of the program, eligibility was limited to the Eastern Shore counties. In the 2003 program year, the program was expanded to the entire state. We develop a conservative measure of available acres based on corn (for grain) and soybean acres, from which we net out prior year barley and wheat (for grain) acres plus current year barley and wheat acres. We do this on a county basis, which allows our variable to be tailored to program eligibility.

A final variable adopted for our supply equation is early cropping season rainfall. For this we use NOAA statewide average spring rainfall data for Maryland.

Our regression for supply of cover crops as a function of price and other determinants is:

$$\text{Acres\_accepted} = \beta_0 + \beta_1 (\text{Max payment}) + \beta_2 (\text{Spring Rainfall}) + \beta_3 (\text{Spring Rainfall}^2) + \beta_4 (\text{Available Land}) + \varepsilon$$

Where:

- Acres Accepted – The number of acres that were accepted into the Maryland Agricultural Cost Share’s (MACS) traditional cover crop program (prior to certification and payment) for planting years 1998 to 2008.
- Max Payment – The advertised guaranteed payment rate ($/acre) for acreage in the traditional cover crop program, plus performance incentive payments that vary by year; in sum, the maximum ($/acre) payment available through the traditional covercrop program each year of the program.
- Spring Rainfall – average rainfall in Maryland, in inches, in March, April, and May of each crop year in the period.
- Available Land – the number of ‘potential’ covercrop acres, taken from NASS statistics for the state of Maryland as the total planted corn acreage + soybean acreage – total wheat and barley planted acreage – total previous year wheat and barley acreage.

Although we expect the relationship between producers and program designers – the supply curve for cover crop acres - to exhibit a positive slope, linearity was not assumed. Various log-linear and log-log combinations were explored in the specification, but a linear relationship between acreage and the explanatory variable proved to be the most predictive regression equation (see Figure 2.1, below)[4].

Results

Table 2.2 reports our regression results. The maximum payment variable appears to be predictive of the acres supplied into the program. An increase of $1 in the maximum incentive payment available results in a 3067 acre increase in total supply. This makes intuitive sense, because farmers are trading off the cost of growing and complying with the terms of the traditional covercrop program with their outside options; when the covercrop terms become more generous, their outside offers become less attractive and they then enroll more acres.

Spring rainfall increases acreage enrolled by over 149,000 acres per inch, but additional (too much) rainfall decreases acreage enrolled by 24,000 acres per extra inch. This effect is the inverse of the payment effect: with more spring rainfall, farmers' other options appear more attractive, and the cover crop program, less so. Finally, available land is an important determinant of covercrop acreage. Any increase in available land (or any decrease) results in 0.114 times as much land being enrolled (taken out of) the cover crop program, all else remaining equal.

Table 2.2: Cover Crop Regression Results	
Dependent Variable:	Acres Accepted
N	11
R-Squared	0.7025
Max Payment	2399**
Spring Rain	178002*
Spring Rain^2	-28857*
Land Available	0.1169
Constant	-216712
*	significant at the 90% level
**	significant at the 95% level

Because the unit of observation in this analysis is a program year, or a growing season, and the data are only available back to the 1998 planting year, a sophisticated analysis was not possible. The virtue drawn from this necessity is a simple regression equation giving meaningful, if limited results. While it is important not to over-interpret the results, our estimation provides robust estimators for supply responses to changes in the prices offered through the cover crop program over the past eleven years. Within the range, it appears to be a very flat (elastic) supply curve.

Figure 2.1, shows the cover crop regression results if all the other regressors are held at their mean value. The practical meaning of this graph is that, at any price on the vertical axis, the number of acres defined by corresponding points on this line (read off the horizontal axis) is predicted to be supplied. Placing the graph over the plot of actual observations shows that there is considerable variance between the actual outcomes and the best-fitting line, indicating that there are significant other factors affecting supply.

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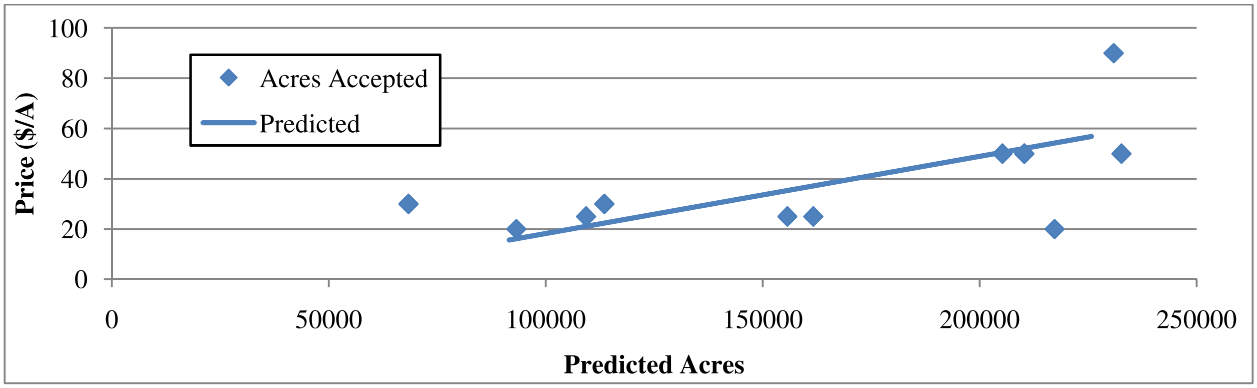
[4] Over the range of prices in our dataset, a linear estimation provides the best fitting regression line. The law of diminishing returns leads us to expect that, at some point, the increase in price needed to achieve more acres of supply will become greater, implying a supply curve that rises at an increasing rate. Therefore, extrapolating our (linear) results to vastly greater quantities of acres may underestimate the prices required to gain such adoption.

We have discussed the caveats to our estimation, above. Given those caveats, and the countervailing need to predict a price at which TS-level cover crop supply might be delivered, we estimate that a maximum price of $161.24 per acre would be required to bring forth 579,000 acres of cover crops[5] in Maryland, all other things being about average.

Figure 2.1: Graph of Cover Crop Regression Results



While our figure of $161.24 per acre provides an expected value for maximum payments required to draw forth TS levels of implementation, it does not follow that all the acres would have to be paid that price. Therefore, we cannot simply multiply $161 by 579,000 acres to estimate the total cost of such an outcome. Even so, it is likely that the costs of achieving TS levels of implementation will be quite high. If the objective in implementing this many acres of cover crops is some specific level of nutrient load reduction, the scale of the implied expenditure compared to available budgets might lead us to ask whether there is not some less expensive way to achieve this level of nutrient load reduction.

In order to quantify the amount of nutrient load reduction achieved when additional acres enter effective supply, one needs to know the nutrient loading rates of the acres to which cover crops are applied, and the specific implementation practices employed (i.e., seed type, time of planting, and planting method). In the following section, we address the nutrient load reductions achieved through the cover crop program with attention to these factors. We focus on N reduction, but with similar data, the same approach could be applied to phosphorous and other non-point pollution factors.

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[5] This expected level of implementation is taken from the Chesapeake Bay Model input file P5.3BMP Acres…, available at: ftp://ftp.chesapeakebay.net/Modeling/phase5/Phase53_Loads-Acres-BMPs/

2.1.2 Nutrient Load Reduction from Cover Crop Acres

Our estimates of edge of stream nutrient reduction by cover crops are dependent on: 1) residual nutrients available to be mitigated, 2) planting time, 3) planting method, 4) seed type, and 5) field location (hydro-geomorphic region, or HGMR[6]). Load reductions will also depend on weather and soil moisture, but those factors cannot be known beforehand and so are assumed to be averaged into estimates of the BMP's nutrient mitigation efficiency. Mitigation efficiencies for the three seed types listed, planting methods, planting times and for the two principal geomorphic regions of Maryland (i.e., coastal plain and non-coastal plain) are reported in Simpson and Weammert, 2007a. The nutrient loads available to be mitigated are drawn from input/output tables of the Chesapeake Bay Model (version 5.3, various runs).

Total nutrient reduction from the cover crop BMP is the sum of all the acres adopted, factored by the loads available and the efficiencies for each planting method, seed type, planting time, etc., for each acre. Such an accounting was undertaken in Wieland and others, 2009. That study used MDA cover crop implementation data along with Chesapeake Bay Model N loading estimates[7] and mitigation efficiencies from the Mid-Atlantic Water Program's review of the science to estimate N load reductions from cover crops planted in the fall of 2007. Because MDA data has not consistently specified what crop preceded the cover crop, reported acres were allocated proportionately across each of six different cropping systems[8].

The mass measurement of load reductions from cover crops is a function of so many factors (i.e., loads, practices, timing, and seeds), the vector of load reductions by each factor is quite long. Table 2.3 reports a partial summation of estimated load reductions from the 2007 cover crop planting wherein the effects of planting method and the different cropping systems to which cover crops are applied have been captured in a prior step (those calculations are shown in Appendix 1). This table breaks out acres and load reductions by time of planting, seed type, and whether the BMP acre was on the coastal plain or the non-coastal plain. Because per acre payments were staggered by time of planting, it is possible to price load reductions by this factor and specify price efficiencies, or dollars per pound of N reduction for various classes of the BMP. Early planting was paid $50/acre, normal planting $40/acre and late planting, $30/acre.

To interpret Table 2.3, consider the first row of data -- rye planted early on the coastal plain. Some of that rye was planted by airplane on corn or soybeans, some was drilled and some was broadcast. Drilling gives the highest N reduction efficiency, but in this presentation, that efficiency has been averaged with the less efficient planting methods to provide a single measure for early rye. Likewise, cover crops inserted into a hi-till with manure cropping system will reduce more N than cover crops planted on nutrient management lo-till without manure by virtue

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[6] Cover Crop Efficiencies and available acre loading rates are disaggregated by coastal plain and non-coastal plain.

[7] Wieland and others used loading rates as estimated for the Chesapeake Bay Model version 5.1. Because efficiencies are not given for several cover crops planted in 2008, those acres (approximately 12,000) are excluded from the analysis.

[8] There are six relevant cropping systems, but since there are four with manure and two without manure, it was possible to disaggregate acres among those two characteristics and do the proportional placement independently for each set.

of the greater amount of residual N available to be mitigated in the former. Land use (cropping system) effects have been estimated in the proportional manner described above.

Table 2.3: 2008 Cover Crop Edge of Stream Load Reductions by Time, Seed, Place and Price

		Acres Planted	Total Load Reduction (lbs N)	Load Red./A (lbs N)	$/lb N
Coastal Plain	Early Planting ($50)				
	Rye	6,884	44,370	6.45	$7.76
	Barley	17,939	92,576	5.16	$9.69
	Wheat	57,249	247,473	4.32	$11.57
	Sum/Avr	82,071	384,419	4.68	$10.67
	Normal Planting ($40)				
	Rye	1,639	10,455	6.38	$6.27
	Barley	3,221	13,813	4.29	$9.33
	Wheat	15,355	66,702	4.34	$9.21
	Sum/Avr	20,215	90,970	4.50	$8.89
	Late Planting ($30)				
	Rye	2,037	5,816	2.86	$10.51
	Barley				
	Wheat	7,611	15,951	2.10	$14.31
	Sum/Avr	9,647	21,767	2.26	$13.30
Non Coastal Plain	Early Planting ($50)				
	Rye	4,254	71,304	16.76	$2.98
	Barley	6,468	88,177	13.63	$3.67
	Wheat	8,848	104,438	11.80	$4.24
	Sum/Avr	19,570	263,920	13.49	$3.71
	Normal Planting ($40)				
	Rye	1,863	28,205	15.14	$2.64
	Barley	1,983	20,675	10.43	$3.84
	Wheat	5,467	58,717	10.74	$3.72
	Sum/Avr	9,313	107,597	11.55	$3.46
	Late Planting ($30)				
	Rye	1,489	11,299	7.59	$3.95
	Barley				
	Wheat	2,574	13,010	5.05	$5.94
	Sum/Avr	4,063	24,309	5.98	$5.01
	Total/Avr	144,879	892,981	6.16	$7.47

Sources: MDA data, and CBPO.

Early rye has the highest "pounds per acre" load reduction for either coastal plain or non-coastal plain cover crop acres. While the cover crop reduction efficiencies on the non-coastal plain are somewhat lower than those for the same practice on the coastal plain, Chesapeake Bay Model estimates for nutrient loading rates are much higher on the non-coastal plain and that generates the higher pounds per acre N reduction by cover crops there.

In Table 2.3 we can see that, in 2008, a total of 144,879 acres of cover crops reduced total N loads by about 0.89 million (eos) pounds, at a cost of about $6.67 million. At the highest level of aggregation, we see that the BMP delivered N reduction for an average cost of $7.47 per pound and that, on average, per acre N reduction was about 6.16 (eos) pounds.

While useful in a very general sense for estimating the amount of nutrient reduction obtained at some given level of program spending, these averages conceal important information. They obscure the calculated prices per pound of nutrients reduced, depending upon practices, loading rates and seed type. The differences in the price per pound of N reduced are of interest because they track price efficiencies for buying nutrient reduction from cover crops. This aspect of the price paid for implementing cover crops is taken up in the following section.

2.2 An Alternative View for Supply of Nitrogen Reduction from Cover Crops

In this section we show the implied delivery of N reduction at a range of relevant prices, if it were bought by the pound. We will focus on our mathematical calculations and results, except for this brief introductory intuition.

Most markets operate on the basis of payment for the desired good. With respect to trade in apples, people enjoy apples and, in response to that, producers grow apples. Producers invest in apple orchards because they expect to earn some positive return by selling apples. At the other end of the market, people either buy apples or they don't depending on how much they want them and the price for which apples can be had.

The key to this scenario is that the thing being traded – apples – is priced. Price carries information to the consumers about the producers' (and intermediaries') costs in producing (and marketing) apples. And, whether or not consumers buy at some retail price conveys information back to producers about their prospects for earning a positive return from their enterprise. Consumers prefer to buy their apples based on some unit price, because that gives them a more certain outcome than if they were to be offered apples by the acre.

Current BMP payments (or, adoption incentives) are based on the number of acres qualifying, and not the number of pounds of nutrient reduced. Even though the service sought through the planting of cover crops is nutrient pollution reduction, this goal is poorly signaled to the adopter with respect to payments. A system of premiums is used to motivate desired planting practices, but the basic unit for pricing cover crops is, still, acres adopted.

If nutrient load reduction were priced by "units reduced", per acre payments would communicate a great deal more information to suppliers of cover crops. A farmer with a cropping system that generates higher expected nutrient load exports would know under such a scheme how valuable it is to get cover crops on those acres. She would know this by virtue of the higher price offered for planting them there (i.e., pounds reduced per acre times some fixed price per pound). And, another farmer who employed practices that leave lower expected nutrient export loads would know that it is not worth all that much – in terms of nutrient load reductions – to put cover crops on those acres.

The obvious reason that cover crops are bought by the acre and not by the pounds of nutrients reduced is that policy-makers have not felt competent to attribute unit load reductions across different acres of cropland or different planting practices[9]. An acre of cover crop can be certified, visually, whereas the number of pounds of N reduced by planting cover crops cannot be seen. However, to the extent that research on agricultural nutrient load export has generated estimated loading rates for various sorts of cropland and, to the extent that there is 20 years of scientific data focused specifically on load reductions from cover crops under variable

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[9] This is a simplification. As noted, policy-makers have employed premiums for some factors important to load reductions. But they have not used expected load reductions as the basis for pricing those premiums, and their approach leads rapidly to a trade-off between complexity and precision.

conditions, it is possible to estimate actual pounds of N reduced by cover crops, given a specific type of cropping system, a specific planting practice and seeds used.

2.2.1 Accounting Supply of Nutrient Reduction from Cover Crops on a Marginal Cost Basis

In this sub-section we create a marginal cost relationship between N reduction and cover crop installation. This relationship will allow us to assess the number of pounds of nitrogen that can be reduced at any given cost. It is then assumed that farmers will be willing to install cover crops if the benefits of doing so (the price they are paid) are greater than the costs. This allows us to create an accounting supply curve for nutrient reductions.

Our approach for creating a supply relationship for N reduction from cover crops begins with a vector of costs per acre for all planting practices (i.e., planting methods, time of planting and seed types). These values are initially based on estimates made by Wieland and others, 2009. However, here we add $14 per acre as a suppositional returns to management[10] (See Appendix 2a). Adding this additional amount to costs provides a more conservative estimate of the supply of nutrient reductions at any given price.

The vector of per acre costs by practice is factored by the expected reduction efficiency for each planting practice in each of two hydro-geomorphic regions (HGMRs) – the coastal plain and the non-coastal plain. This provides an intermediate vector of costs per reduction efficiency rate. Each planting practice has a different N reduction efficiency (measured as percent of exported pounds reduced) but, since we want to know the number of pounds reduced, we must factor those percentages by the pounds of N available to be reduced. For those values, we use per acre Chesapeake Bay Model version 5.3[11] edge of stream loads for each land use and by coastal plain and non-coastal plain.

Factoring per acre costs by reduction efficiencies and per acre loading rates gives us a measure of dollars per pound reduced by planting practice and by cropping system. The final step in estimating the supply of N reduction from cover crops, is to factor costs (by practice and cropping system) by the acres available in each cropping system. The number of available acres in each cropping system is taken from the Chesapeake Bay Model (version 5.3, 2009 Progress Run) input data.

There are a number of different cover crop planting practices that might be employed on acres in any given cropping system and HGMR. The assumption that we use to predict which cover crop planting practices will be employed is that adopters would like to maximize their returns from participation in the program. If that is true, and if our estimates of unit reduction costs track closely with actual costs, then the planting practice employed across land uses will be the ones

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[10] While arguably arbitrary, this imputed cost amounts to 30 percent of the average estimated resource cost for cover crop BMP implementation – a not unreasonable premium that can be accounted as returns to management.

[11] The data used were generated by a model run of nutrient loads without BMPs, except those BMPs measured as a land use change (i.e., nutrient management, manure use, and tillage practices).

that bring the greatest returns per acre. Under that assumption, we can model the supply of N reduction from cover crops as a function of the dollar costs per pound reduced.

Figure 2.2 shows the number of pounds of N reduction that would be supplied at different prices ($/lb N reduction) if adopters could shift costlessly among planting practices and if there were no short term input supply effects. At any given price per pound on the vertical axis, the supply curve identifies the pounds of N reduction that might be expected at estimated (2007) costs. Because we have assumed away some potential costs[12] and implicitly employed the expectation that input costs remain the same even if everyone plants rye, we treat this scenario as "unconstrained". Data for this figure and the next are supplied in Appendix 2b.

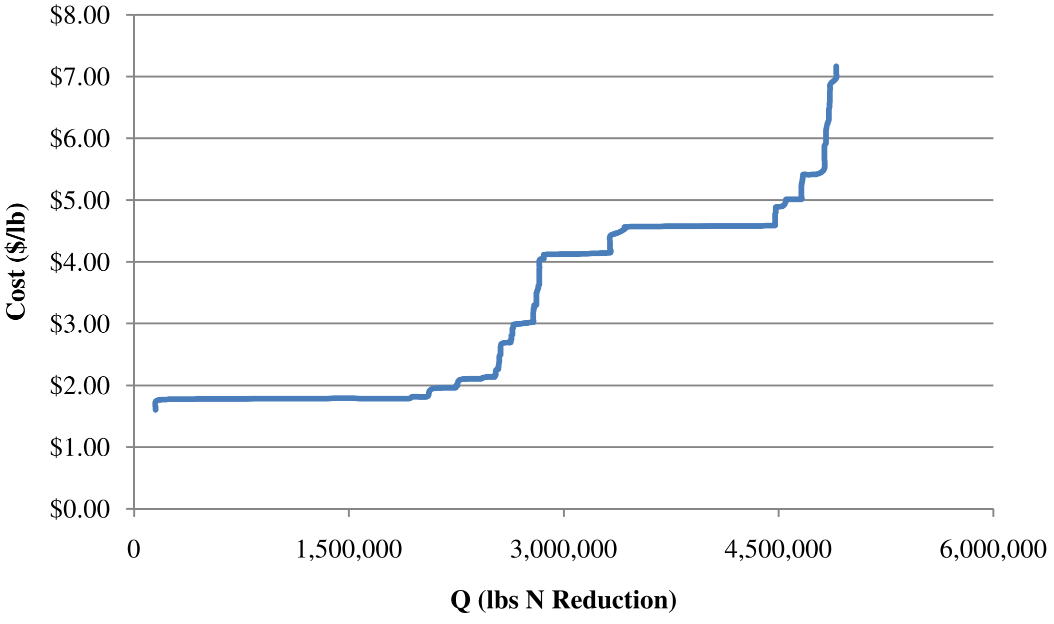

Figure 2.2: Supply of Nitrogen Load Reduction From Cover Crops (MD - Unconstrained)

The deterministic model that generates this graph relates estimated costs of achieving N reductions with prices that might be paid, per unit reduction, given our assumed constraints on production, available acres, loads and reduction efficiencies. It tells us that at a price of $4.00/lb, we can expect N load reduction from cover crops of 2.83 million pounds at a total cost of $11.39 million ($4.00 * 2.83 million). At $6.00/lb it tells us to expect 4.83 million pounds of reduction at a total cost of $28.62 million. At a total cost similar to that of the 2007 cover crop program (traditional cover crops only), expected reduction would more than double the estimated actual, falling in the range of 2.56 million pounds.

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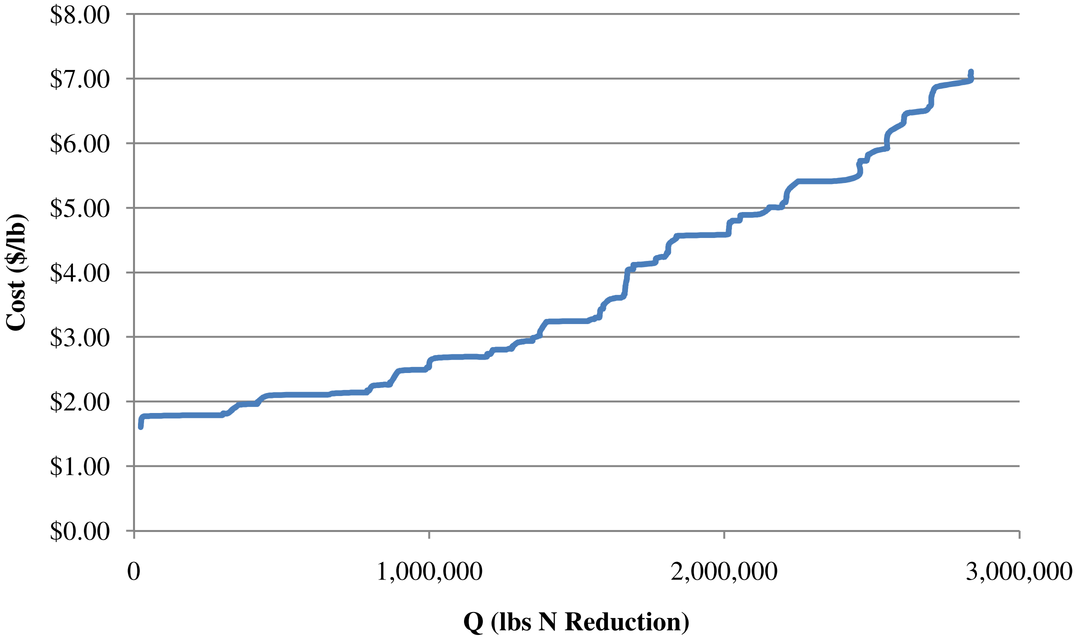
[12] Our cost model assumes the same resource cost if the cover crop is planted early, versus standard or late. In many cases, this may not be true, but accounting the potential differences is impractical with available data and methods.

Clearly, the foregoing predictions for supply at different prices are only as accurate as our estimates for the parameters. Estimates for loading rates, reduction efficiencies, and implementation costs all carry unknown error. On the other hand, our sources for some of the estimates are the same as can be expected to provide estimates for the Chesapeake Bay TMDL and, in that case, their accuracy will be independent of achieving the regulatory requirement. The model also allows us to estimate supply at various prices if we change the underlying assumptions.

In Figure 2.3, we show a supply curve in which available acres have been constrained to ensure that adopters employ practices in the same proportions that they did in the 2007 planting year. The model assumes that planting of cover crops will be split between the three major seed types in the following ratios: Barley – 20%, Rye – 40%, and Wheat – 40%. With respect to timing: 70% is planted early, 20% normal, and 10% late. And, with respect to planting method: 20% is aerial, 40% is drilled, and 40% is “other” (primarily, broadcast).

Figure 2.3: Supply of Nitrogen Load Reduction From Cover Crops (MD - Constrained)



Although reductions shown in Figure 2.3 are proportionate to the actual implementation of planting practices in the 2007 planting year, the graph shows that greater reductions are possible, even while holding these historical proportions constant. The difference between the supply curve depicted in Figure 2.3 and outcomes as reported in Table 2.3 is that supply in the figure is sorted according to costs per pound reduced. We expect this as a response to unit pricing.

If, at some fixed price per pound, a potential adopter sees that his per acre costs are covered given price and pounds per acre, he is expected to adopt. Furthermore, if he has some choice about planting practice, seed type and time of planting, he is expected to shift to the choice that brings the greatest net income. Current price policy does not track nutrient load reductions in this manner because for any specific planting practice, the load reduction achieved is a result of a random draw from high reducing and low reducing acres for which the price is fixed.

Table 2.4 compares outcomes estimated for the current cover crop program (first row) against expected outcomes if nutrient load reductions from cover crops were priced by the pound. In the first comparison, we assume that policy-makers like the current average price for nutrient reduction from cover crops and we consider the level of load reduction implied by that average price under both the unconstrained and constrained "unit-pricing" scenarios. Total cost is also noted. In the second instance, we assume that policy makers wish to keep the level of nutrient reduction about the same and we show the price and total cost implied by that assumption. And, in the third pair of rows, we assume that policy makers have a budget that doesn't change, and show what might be achieved for a similar level of total expenditure.

Table 2.4 Comparison of Expected Outcomes Under Unit Pricing

	Program/ Scenario	Marginal/Av. Price	Expected N Reduction (Million lbs)	Total Cost (million $)
	2007 Program	$7.47	0.893	$6.67
≅ Price per lb	Unconstrained	$7.43	4.759	$35.35
	Constrained	$7.43	2.960	$21.99
≅Load Reduct.	Unconstrained	$1.79	1.199	$2.14
	Constrained	$2.47	0.899	$2.23
≅ Total Cost	Unconstrained	$2.53	2.559	$6.48
	Constrained	$3.90	1.670	$6.51

2.2.2 Supply of CC Nutrient Reduction in Terms of Delivered Loads

The model of supply of N reduction from covercrops described above uses edge of stream loads from version 5.3 of the Chesapeake Bay Model. This measure of N reduction is relevant to what happens in tributaries of the Chesapeake Bay, as opposed to the main stem. If those tributaries are not impaired by excess N loads, and if the target is reduced N load in the main stem of the Bay, "delivered loads" may be more appropriate than the "edge of stream" measure.

The model is adapted here to give us costs for delivered loads by substituting average per acre delivered loads from a version of the 5.3 model that incorporates agricultural BMPs that are counted as changes in land use. This mirrors the process described in the preceding section except that instead of using edge of stream loads, we substitute delivered loads. Acreage by land use and region is taken from the 2009 progress run (version 5.3).

Per acre costs are independent of our measurement of per acre nutrient loads and they remain the same. However, since delivered loads are attenuated relative to edge of stream loads, it is implied that the per pound costs of delivered load reduction will rise relative to costs of edge of stream loads. Figure 2.4 bears this out.

Measuring unit-priced load reduction from covercrops on a delivered load basis, unit costs are higher than they were for the edge of stream accounting. The unconstrained scenario tells us that it would take a total cost of $30.45 million to get 3.85 million pounds of delivered load reduction. Measuring reduction as edge of stream loads, the unconstrained scenario reported in the previous section suggested load reductions of a similar amount (3.43 million pounds) for about $16 million.

The appropriate measurement for a units-reduced pricing system will be determined by the Chesapeake Bay TMDL. This model is equally capable of providing supply estimates using either measure. Notably, the delivered load measure levels out some of the difference between per acre edge of stream reductions on the coastal plain versus the non-coastal plain.

Figure 2.4 : Supply of Nitrogen Delivered Load Reduction from Cover Crops (MD - Unconstrained)

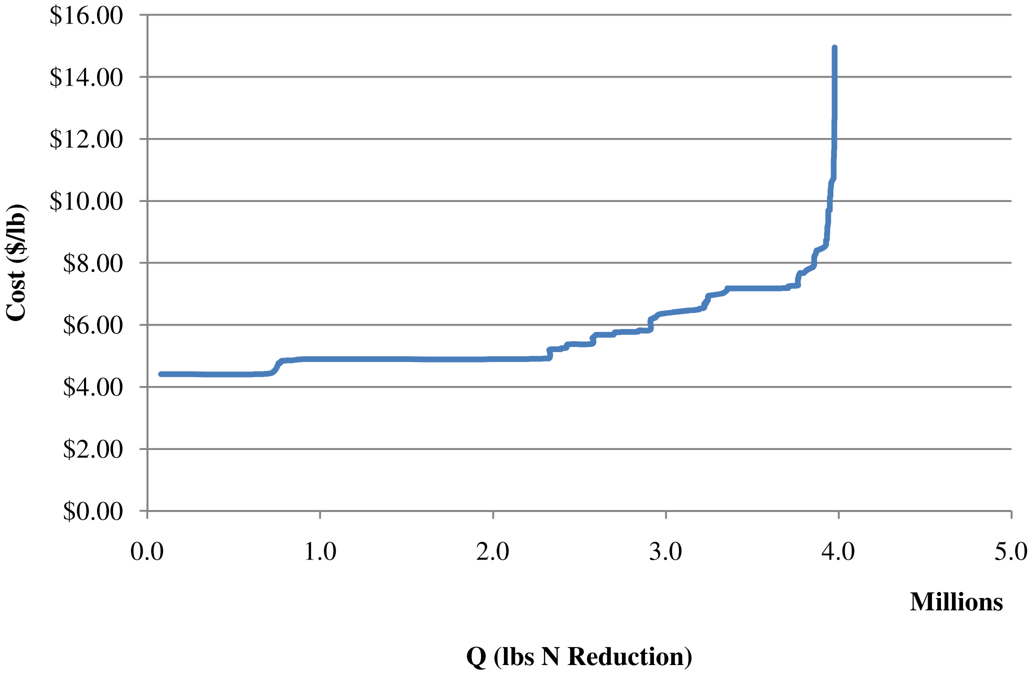


Figure 2.5 shows expected supply of delivered load reductions under the constraint that adopters implement practices and seed types in the same proportions as they did under 2007 program

pricing. As in the previous example, the supply curve shifts up, relative to the edge of stream measurement.

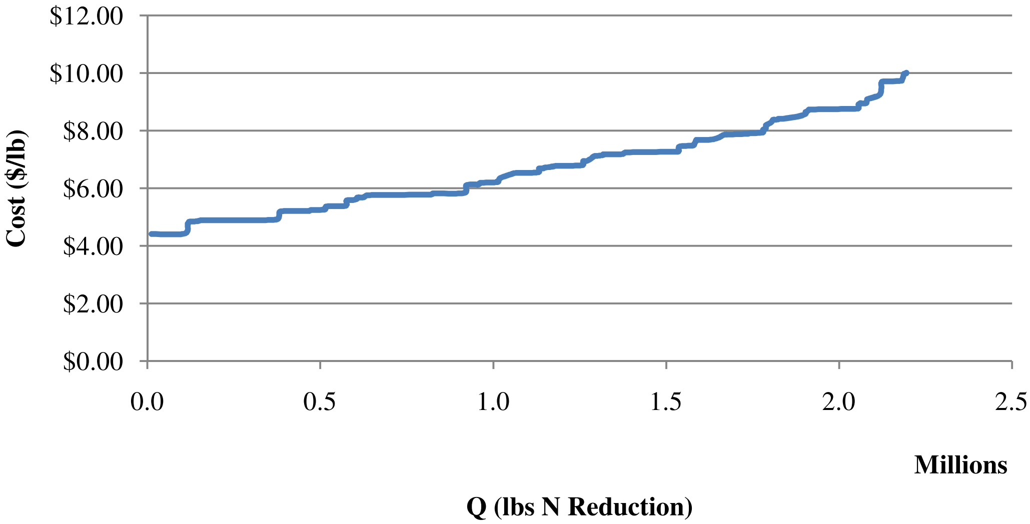


Figure 2.5 : Supply of Nitrogen Delivered Load Reduction From Cover Crops (MD - Constrained)

3 The Riparian Buffer BMP

Riparian buffers are either grassed or wooded strips 35 feet or more in width, but adjacent to and up-gradient of qualifying waterways of the state. In general, forested buffers are allowed on streams, but not constructed ditches. Grassed buffers are allowed on constructed ditches, under a 35 foot maximum width limitation[13]. Except for the additional supply of land made available to grassed buffers by constructed ditches, riparian grassed buffers (RGB) and riparian forested buffers (RFB) are both drawn from the same supply of land.

While some land-owners construct or maintain riparian buffers along waterways passing through or by their land on their own account, much of the additional riparian buffer acreage created over the past 13 years has been financed through USDA's Conservation Reserve Enhancement Program (CREP). This program pays landowners to take land bordering qualifying streams out of agricultural uses (i.e., crops or pasture) and to manage it for either grass or trees.

The expected benefit of taking land along stream edges out of production and putting it into grass or trees is improved ecosystem function, in part through reductions in nutrient loads. Since this benefit accrues more broadly than the landowner(s), improved ecosystem function can be thought of as a social benefit to buffers. Simpson and Weammert (2007) outline the current consensus values for N and phosphorous reduction efficiencies for RB applied on different HGMRs.

Chesapeake Bay Program (CBP) accounting for nutrient reduction from RB entails two calculations. First, there is a reduction from the difference between the existing loading rates of crop or pasture land and the loading rates for grassed or forested land. Secondly, there is a nutrient reduction benefit derived from the effect of the buffer on water flowing through it (both surface and sub-surface) from uphill. CBP assumes that one linear unit of grassed or forested buffer treats four up-gradient units with respect to N loads[14].

The costs of adopting RB can be usefully decomposed into several classes. First, there are costs of creating and maintaining a buffer. Those costs tend to be highly variable[15], particularly for forested buffers. But, in general, forest buffers carry higher establishment costs than grassed buffers. Under the approach employed below, CREP and MACS establishment cost-share records are used as the basis for estimating establishment costs.

Secondly, there is the annual (re-occurring) loss from not using the land for production. We approximate this cost by using the soil rental rate of the land taken out of production and put into riparian buffers. The rental rate approximates the net value that the owner might expect to make from the land if it remained in its agricultural use.

Finally, landowners may perceive costs to adopting riparian buffers in: 1) the time and effort required to participate in the program; 2) loss of landowner decision-authority over the ten (grassed buffers) and 15 (forested buffers) years of the contract; 3) and/or wildlife and

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[13] Prior to 2004, RFB were allowed on ditches as were wider buffers.

[14] In other words, one acre of RB affects four additional up-gradient acres of nitrogen.

[15] See the discussion in Wieland and others (2009).

environmental effects of the buffers on remaining agricultural land. These latter costs, by their nature, are difficult to quantify. However, the CREP program has employed significant premiums over the establishment and opportunity costs of buffers and, in our estimates below, we use those premiums as an approximation of the value of these other adoption costs to landowners.

Below, we develop models of supply of RB, first using the metric of additional acres adopting the practice and then using the metric of pounds of N reduced, assuming a fixed price per unit of nutrient load reduction from RB.

3.1 Supply of Forest and Grass Buffers under Current Pricing

We use CREP program data from the state of Maryland for the years 1998-2009, to estimate a supply curve for acres of RB enrolled in the program over that period. As was the case for the cover crop program, RFB (CP-22) and RGB (CP-21) eligibility and payment terms changed almost each year of the program. These changes, along with several simplifying assumptions, give some idea of the supply-price relationship of RB. We consider acres enrolled and signup terms annually over the period.

To establish a forest or grass buffer, the farmer plants the approved seed or stock along the streamside, to a distance no less than 35 feet inland. In some, but not all years, there was a maximum qualifying width as well. The land enrolled is then under contract for the term specified, and penalties apply if the land is withdrawn. CREP RB terms vary by year, by location and by program. A summary of Maryland CREP prices, terms and conditions for CP 21 and 22 is provided in Appendix 3.

The RGB contract, under which the participant plants and maintains approved grasses, has a 10 year term. The establishment costs are lower (as are the incentive payments) than for RFB, although federal and state signing bonuses, when they exist, are the same for both buffer types. The RFB program has a 15 year term and, at the end of that period, there should be a well established stand of young trees on the land. The soil rental rate payments are identical for both programs, although they vary by county, according to the market conditions.

The Maryland CREP program can be broken into three separate phases in terms of payment structure. In phase 1, from 1998 – 2000, there were no establishment incentives or signup bonuses. An annual incentive payment was made, on top of an annual soil rental rate, but that was the extent of the reward for buffer participation. In phase 2, which lasted from 2001-2004, payment terms were more generous. State and federal signup bonuses of $100 each were introduced, paid at the initiation of the contract. In addition, a mixture of state and federal establishment incentives were offered, which typically exceeded the cost of establishment of the buffer. Finally, in phase 3, from 2005 – 2009, the state signup bonuses were dropped[16], so only $100 in federal incentive payment was received at project implementation. The establishment and annual incentives remain, although the terms vary by year.[17]

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[16] They were re-introduced in 2009.

[17] CREP average costs and acreages by year are taken from Wieland and others, 2009 and are based on Maryland FSA data.

The term and value of CREP contracts are assumed to be important considerations for adopters. Grass buffers are less permanent than RFB and they only carry 10 year terms. They also contribute less to crop effects and are less expensive to maintain and install. This is reflected in the lower incentive payments for RGB relative to RFB. RFB carry a longer term and survival requirements that may require more active (and, costly) management. And it is clearly more difficult (costly) to convert RFB back to a crop use upon completion of the term. Consequently, CREP incentives are significantly higher for RFB.

To estimate the number of acres enrolled into the program, we consider both the terms of the contract and the number of acres already in the program. We estimate separate equations for grass and forest, using the same variables but estimating them differently.

3.1.1 A Supply Equation for Acres of Riparian Buffers

Two different regression equations for RB were estimated as follows:

A. Acres $= \beta_0 + \beta_1$ (Lag cumulative acres) $+ \beta_2$ (NPV) $+ \beta_3$ (width) $+ \varepsilon$
B. Acres $= \beta_0 + \beta_1$ (Lag cumulative acres) $+ \beta_2$ (Upfront) $+ \beta_3$ (Annual) $+ \beta_4$ (width) $+ \varepsilon$

Variable Selection

- Acres – The total number of acres enrolled in the buffer program (grass or forest) in a given year (from MDFSA Data).
- Lagged Cumulative Acres – The cumulative number of acres enrolled, lagged by one period: the value for 2001 would be the sum of enrolled buffer acres in the years 1998, 1999, and 2000. This variable captures the effect on enrollment of reduced available acreage.
- Net Present Value (NPV) – The sum of the current (upfront) payments and all the annual future payments discounted back to the present at 4 percent.
- Upfront – The total upfront payments, in any given year, awarded to the participating landowner. This is a combination of establishment costs and incentives – payments to cover the cost of building a buffer – as well as signup bonuses – made for adopting a buffer.
- Annual – The total annual payments made to landowners as part of the buffer contract. Annual payments are a combination of soil rental rates, which are established at the county level (the statewide average was used in the data), and annual incentive payments.
- Width – The average width of newly-signed RFB in any given year from MD DNR monitoring data. No corollary data are available for RGB, so RFB buffer width is used as a proxy for that. This variable tracks response to constraints imposed between 2005 and May of 2009 aimed at limiting buffer widths. Since, for any length of stream, narrower buffers allow more extensive stream coverage, this policy provided bonuses for narrower buffers and limited incentive payments for portions of buffers wider than 100 feet. *NB*: Because of this width basis for payments, an estimate of annual buffer widths is required for estimating the NPV and Annual variables in those years.

Linearity was not assumed in our regression analysis, but the best results were found using a linear specification. This may be due to limited range of the variables (see discussion in covercrops) or for other reasons. Nevertheless, linear regressions, with robust covariance treatment to account for heteroskedasticity in the errors, were used in all cases.

Regressors other than those listed above were explored. Disaggregated payments, such as signup bonus, annual incentive payment, soil rental rate, and establishment cost, were used individually as regressors to capture the variability in each of the different terms by year. However, the combined upfront and annual costs were nearly as predictive and much easier to interpret.

Lagged acres and land available were also explored as potential regressors. The lagged acre variable was constructed as the prior year's buffer enrollment. This variable captured some of the depletion effect of enrollment on supply acreage, but lagged cumulative acreage proved to be a much better variable. Similarly, available land was approximated by using GIS categories for the state of Maryland. The data were generated using an algorithm which classifies satellite imagery according to color – approximately, blue is water, and green next to blue is potential buffer land. Using this value to approximate the entire state supply of potential buffer land (crop land, as opposed to wetland, urban, forest, or grass/shrub), the cumulative buffer acreage enrolled was then differenced every year. The result was meant to be an estimate of supply remaining (streamside cropland not enrolled in buffer). However, this estimate also proved inferior to the simple lagged cumulative acreage.

The width variable was used with some hesitation. Although it captures some of the program limitations, it is also endogenous to the program participation for the current year – it reflects both program restrictions on width of buffers as well as choices for the program participants in the width of buffers they want to enroll. It proved to be more useful in the grass buffer regressions, but it must be interpreted with care.

Results

Table 3.1 clearly shows the differences between grass and forest buffers. RFB acreage is predicted reasonably well with financial variables: the significance of the *upfront* and *annual* payments can be taken to reflect a decision process that weighs the monetary returns of participation. This may be a reflection of the longer term of RFB and the more generous financial rewards to enrollment. *Width* does not appear to be a determining factor in the RFB regression, partly due, perhaps, to the issues just mentioned and to the fact that forest buffers are more difficult and costly to establish and remove than grass buffers. *NPV* appears to be a predictive regressor, but disaggregation of the upfront and annual payments provides a better fit.

The grass buffer regressions tell a different story. In both specifications, as well as those tried but not listed, *width* was a predictive regressor[18]. This suggests that participants enrolling grass buffers are less deterred by the costs of installing the buffer, but are rather more motivated at the idea of being compensated for a very wide buffer. As a result, when the *width* variable takes on small values, indicative of sharp limits on buffer widths, grassed buffer enrollment declines. Running the RGB regression without a width variable, as in A, generates strange results. The

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[18] Recall that width of RGB is predicted using RFB widths. Direct data for RGB widths is not available.

coefficient on annual payments, although not significant, becomes negative. The coefficient on lagged cumulative acres in A is also insignificant, whereas in other regressions which include *width*, the coefficient is significant.

Table 3.1: Regression Results (Robust Standard Errors)

Dependent Var:	Grass Buffer (Acres)		Forest Buffer (Acres)	
	A	B	A	B
N	11	11	11	11
R-Squared	0.6534	0.8764	0.7381	0.7140
Lagged CA	-0.08	-0.27**	-0.40**	-0.40**
NPV		17.71**		4.53*
Upfront	36.09*		6.08**	
Annual	-41.57		37.78*	
Width		89.92**		-6.21
Constant	4078*	-27713**	-2199	-2598
*	significant at the 90% level			
**	significant at the 99% level			

Our preferred specifications are equation B for RGB and equation B for RFB. In equation B, the *lagged cumulative acres* variable is negative and significant. For every additional acre enrolled in the past, there is a 0.27 acre decline in current enrollments, all else being equal. Every additional dollar in *NPV* is associated with an additional 17.71 acre increase in acres enrolled. Finally, for every foot in average *width* increase, there is an associated increase in enrollment. The meaning of the coefficient is not easy to interpret because width is constructed, partially, from acres enrolled. The endogeneity bias tends to overstate the importance of the variable. Regardless, it appears that width restrictions have a downward effect on RGB enrollment.

As in equation B for RGB, equation B for RFB resulted in significance for the *lagged cumulative* variable, but at a higher level: one past acre depressed current enrollment by 0.4 acres. Every additional $1 to incentive payments increased enrollment by 6 and 38 acres for *upfront* and *annual* payments, respectively.

In sum, it appears that CREP RB participation is a competition between compensation and cost. Forest buffers, which are more costly, demand higher compensation to implement. The variability of supply is largely dependent on the specific terms which are offered. Grass buffers, which are less costly, are more affected by the revenue opportunities – how much acreage (width) a farmer can enroll seems to have a large effect on participation and supply.

3.1.2 Nutrient Load Reduction from Riparian Buffers

Data for variables important to the estimation of nutrient load reduction from RB are, unfortunately, not as readily available as those for the cover crop load reduction estimates. In particular, other than the general categories "cropland and pastureland", we do not know to which types of land uses acres of RB were applied. And, while adoption data is broken out by county, we do not know the specific HGMR acres that received RB. Perhaps most limiting, data describing the width of RGB are not available.

In the absence of data on these variables, we are left to generate our estimates of the nutrient load reductions from RB by making assumptions about the distribution of RB by land use and by HGMR. We do know how many acres of RB were grassed buffers and how many were forested. Unless there is some reason to believe that some land uses or particular HGMRs were targeted for adoption, it is reasonable to assume that RGB and RFB are distributed randomly across land uses and HGMR. If RB are randomly distributed across available cropland or pasture land and HGMRs, then a weighted average of nutrient load reductions based on: available supply of RB acres by HGMR, land use and buffer type will provide us with serviceable nutrient load reduction estimates from RB.

We use a model developed for the following section of the report to estimate average load reduction by buffer type. The part of the model employed here is based on: (i) the estimated available supply of RB acres, assuming 100-foot buffers and USGS stream edge mile estimates by HGMR and, (ii) agricultural land uses and their loads, based on the Chesapeake Bay Model (version 5.3) edge of stream loads. Table 3.2 reports the number of acres of either buffer type reported in USDA CREP (CP21 and CP22) data, and average load reduction per acre for RGB and RFB based on the assumptions above. Total reductions are the product of per acre reduction times acres.

Table 3.2: Nutrient Load Reduction by Buffer Type

Buffer Type	Acres	Average LR/A (lbs)	Total Load Reduction (lbs)
RFB	16,301	57.00	929,157
RGB	36,336	43.56	1,582,796

(Source: Acres FAS data; Average load reduction Chesapeake Bay Model Version 5.3)

Average load reduction (LR/A) estimates are based on Chesapeake Bay modeling expectations that load reductions are generated from both the change in land use on buffered acres plus the effect of the buffer on water flowing through it from up-gradient acres. At estimated annual prices for RGB and RFB, these 2.51 million pounds of N load reductions cost $11.10 million per year.

3.2 An Alternative View for Supply of Nitrogen Reduction from Riparian Buffers

As was argued for cover crops, there is a disjunction between what is desired from RB and what is priced. Although nutrient reduction is the desired service in RB, they are paid by the acre. Different prices are paid for grassed as opposed to forested buffers, but excepting that distinction, RB are paid by the acre. The regression results reported in Table 3.1, above, use estimates of prices paid to predict quantities of RB acres supplied. It was argued in the preceding section that our best statistical estimator for the amount of N load reduction achieved through RB adoption on those acres is a weighted average including all the land uses and HGMR in the available set.

It is possible to sort the load reductions expected from various categories of RB acres by their mass, from greater to less. That implies a rank ordering of types of acres by pounds of N reduced with either a RGB or a RFB. If we then divide the dollar cost of installing and maintaining a given acre by the pounds N reduced on it, we establish a cost per pound of N reduced. With those values and information about the distribution of available riparian acres across land uses and HGMR we can estimate an accounting supply curve based on pounds of N reduced from RB (see cover crop discussion).

3.2.1 Accounting the Supply of Nutrient Reduction from RB on the Basis of Marginal Costs

As we did for cover crops, our estimation of a nutrient load reduction supply curve for RB starts with a vector of costs per acre for the various planting practices. In this case the vector is only two rows long; one for RFB and the other for RGB. We use an average value based on historical CREP establishment cost share information[19], and CREP annual incentive information[20]to construct an average price paid per acre for either RFB or RGB in Maryland.

Cost share for establishment costs reported in the CREP data is multiplied by 2.27 to account for the full value paid by all buyers[21]. This value is annualized by dividing it by the life of the respective contracts. This annualized establishment value is summed with annual incentive payments and annual rental and maintenance payments. The average annual price paid per acre under this estimation is $249.63 for RFB and $193.60 for RGB.

We then factor appropriate costs by the N load reductions expected from either RFB or RGB on each of the various HGMRs and land uses (as defined by the Chesapeake Bay Model version 5.3). This provides a vector of costs per pound of N reduced by HGMR and land use. Our vector is limited by the simplifying assumption that up-gradient land-uses are the same as those on the acres that became buffers. This simplifies from the large number of combinations feasible (if not likely). In order to complete the journey to the supply curve, it is necessary to know how

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[19] http://content.fsa.usda.gov/crpstorpt/r7crepyr/md.htm

[20] http://content.fsa.usda.gov/crpstorpt/r1meprtx/MD.HTM

[21] This includes 50% - USDA, 37.5% MACS, and an additional 40% Practice Incentive Payment (USDA), for a total reimbursement of 127%.

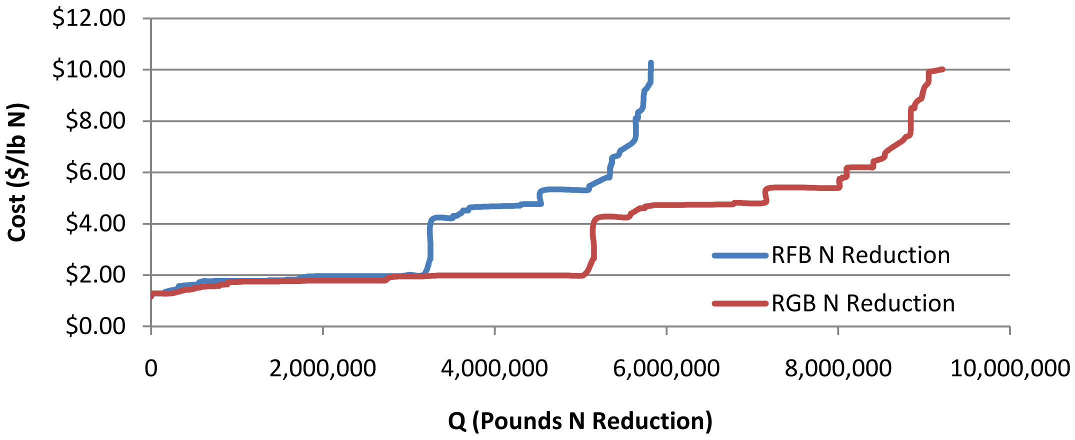
the available supply of riparian acres is distributed across HGMR and land uses. In order to know that distribution, it is necessary to know the available supply of riparian buffer acres.

To estimate the number of acres of potential supply by HGMR, we use data generated by USGS – Chesapeake Bay Program Office (see Appendix 4). Those data were compiled from GIS stream edge data at the 100K scale. We estimate buffer acreage on those miles of stream edges at a width of 100 feet. We narrow the available set by netting out stream miles passing through all land uses except agricultural uses – cropping and pasture. Stream miles are then apportioned to relevant land uses based on their share in each HGMR.

Our method for calculating potential RB supply generates an estimate of 336,195 acres. Given Chesapeake Bay Model estimates for acres in relevant land uses in Maryland (approximately 1.161 million acres) the riparian portion at 100 ft. widths constitutes about 29 percent of the total. Taking this amount of land out of agricultural production for RB is likely to have a considerable economic impact. In terms of what has been achieved so far, the 52,637 CREP acres (CP-21 & CP22) in RB constitutes about 17 percent of estimated available riparian land.

The data reported in Table 3.2, above, in conjunction with our cost data, generates an average cost for N reduction from RB of $4.42 per pound. That is the level of cost efficiency that would be expected under a random draw of riparian acres (under agricultural land uses) implied by the "per acre pricing" of current programs.

Figure 3.1: Supply of N Load Reduction From RFB and RGB



In Figure 3.1, we show supply at marginal costs of nutrient reduction from RFB and RGB, truncated at $10/lb. This curve shows the N reduction expected if available acres were sorted on their cost per pound of N reduced. Both curves represent N reduction supplied at any price in the range. Total RB N reduction is the sum of the quantities supplied from both curves. At a price of approximately $4.40/lb N reduction, our supply curves tell us to expect 3.61 million lbs N reduction from RFB and 5.59 million lbs of N reduction from RGB for a total N reduction of 9.20 million lbs of reduction. The total cost of this nutrient load reduction would be $40.49

million. It would require RB adoption on 88,186 acres of agricultural land. These data are reported in more detail in Appendix 5.

Another way to compare the results of the current program with what is predicted by the constructed marginal cost curves for RFB and RGB is to ask how much N reduction we might get if N reduction were bought by the pound but we still only had $11.1 million per year to pay for riparian buffers. Using our model's expectation at a total expenditure of $11.64 million, the supply curve suggests that 5.92 million pounds of reduction could be had if units of N reduction were bought by the pound. This compares well with the 2.51 million pounds of reduction estimated to have been generated by spending $11.1 million on a "per acre" basis.

Figure 3.1 would overstate available supply of N reduction, if our estimate for the available supply of riparian agricultural land is greater than the actual. We have assumed that all agricultural stream edge miles are available for RB. But it could be that fragmentation of the land leaves many individual owners with such a small segment of stream edge that it will never be worth their while to enroll their land. Perhaps potential adopters are concerned about resale value, adding a cost factor that has not been incorporated into our cost estimate. It could be that owners simply do not want to participate in publicly supported programs to plant RB or that they are not aware of the opportunity.

We can use our model to test what a reduction of potential RB acreage would mean to nutrient load reduction from cover crops under a "price per pound reduced" payment scheme. Figure 3.2 shows N reduction at various prices if 40 percent of the riparian acres that we estimate as being available are taken away.

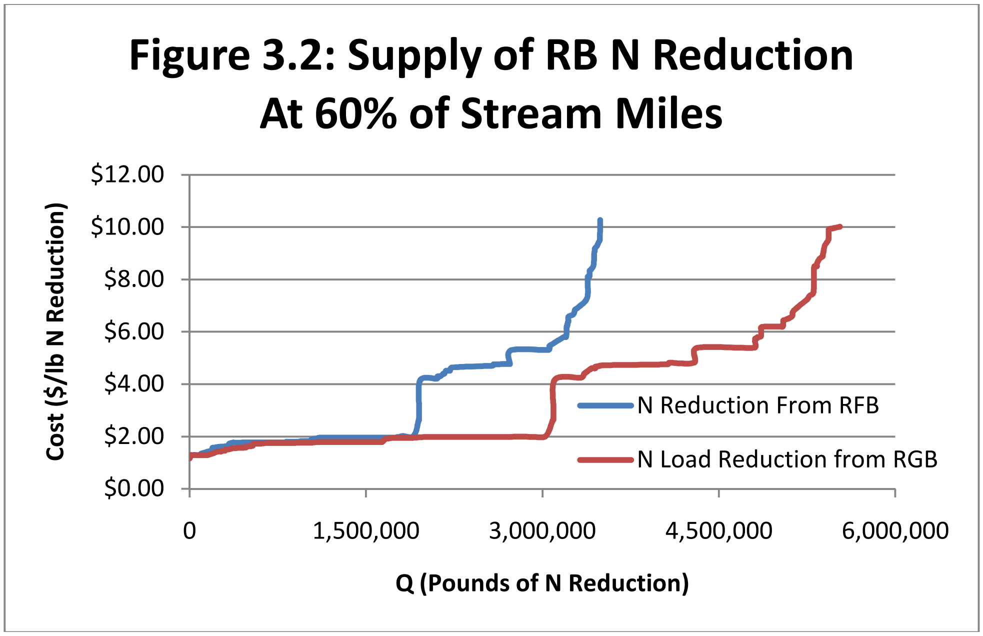


Figure 3.2 indicates that, even with significantly reduced supply, one could achieve greater N reduction at lower total budgets if price is based on the N load reduction achieved under the practice. At a price of $4.40 per pound N reduced, even in this reduced supply situation, the

supply curves tell us that about 5.52 million pounds of N reduction (the sum of RFB and RGB reductions at that price) would be delivered at a total cost of $24.29 million. This reduction would require 52,911 acres of RB adoption.

We summarize these scenario results in Table 3.3. If the goal is to maintain the average price implied by the current program, then significantly more N reduction will be obtained, and the total cost will be much greater. If, on the other hand, the goal is to maintain the same level of N reduction as estimated for the current program, then unit pricing would result in a much lower total cost, for both the optimistic estimate of supply, and the 60 percent estimate. And, finally, if the goal is to maintain the same total cost, more than twice the amount of nutrient reduction is predicted for a unit pricing scheme under the optimistic estimate and a 96 percent increase even under the pessimistic estimate of supply.

<u>Table 3.3</u>: Riparian Buffer N Reduction by Marginal Costs, Total Supply, and Total Cost

	Scenario	Average/ Marginal Cost	Expected N Reduction (Million lbs)	Total Cost (Million)	Acres Adopted
	Current Program	$4.42	2.51	$11.10	52,637
≅ Price per lb	N Reduction Supply @ 336,195 available acres	$4.40	9.20	$40.49	88,186
	N Reduction Supply @ 201,717 available acres	$4.40	5.52	$24.29	52.911
≅ Load Reduction	N Reduction Supply @ 336,195 available acres	$1.77	2.52	$4.48	19,172
	N Reduction Supply @ 201,717 available acres	$1.80	2.57	$4.63	20.290
≅ Total Cost	N Reduction Supply @ 336,195 available acres	$1.97	5.92	$11.64	47,509
	N Reduction Supply @ 201,717 available acres	$2.02	4.92	$9.95	42,021

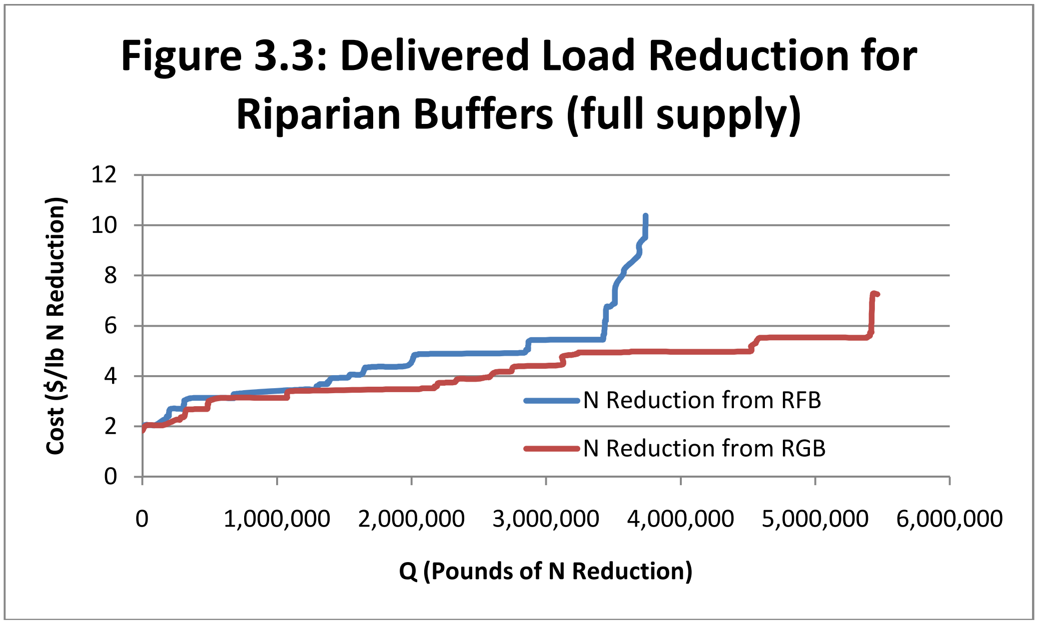
3.2.2 Supply of RB Nitrogen Reduction in Terms of Delivered Loads.

As was done for the cover crop example, it is possible to develop corollary supply estimates using delivered loads in place of edge of stream loads. Using the same assumptions that we used to generate Table 3.2, we estimate the average N load reduction from RB in terms of delivered loads. These estimates are reported in Table 3.4. Using delivered loads by land segment, and average load reductions for both grassed and forested buffers, we estimate that 1.56 million pounds of delivered load N reduction were achieved up to 2008. Costs and acres remain as they were under the existing (CREP) program. The average cost for the reductions reported in Table 3.4 is $7.09/lb.

Table 3.4: Nutrient Load Reduction by Buffer Type (Maryland Delivered Loads)

Buffer Type	Acres	Average LR/A (lbs)	Total Load Reduction (lbs)
RFB	16,301	35.48	578,359
RGB	36,336	27.15	986,522

The graph for riparian buffers using delivered loads shifts up, compared to edge of stream estimates. This is shown in Figure 3.3.



By the estimates on which Figure 3.3 is built, at a total cost similar to that of the current program ($11.05 million), 2.94 million pounds of N reduction would be possible from the combination of RFB and RGB under per pound reduced pricing. This reduction could be achieved with a unit price for N reduction of $3.76/lb. This level of predicted unit priced reduction compares favorably with the current program, which is estimated to achieve 1.56 million pounds of delivered N reduction at a slightly higher total cost ($11.1 million).

4 Getting from Here to There

In this paper, we have paired Chesapeake Bay Model (5.3) estimates of N export loads by land use and hydro-geomorphic region with corresponding efficiencies for load mitigation practices to develop estimates of unit (i.e., pounds per year) N reduction for two BMPs across all their possible applications[22]. The resulting schedule of expected load reductions, when factored by a fixed value per pound reduced, provides a means for improved pricing of N load reduction practices. The improvement in this shift in pricing derives from avoiding paying more for nutrient reduction than it is worth and providing an incentive for N reduction suppliers to adopt the practices that generate greater load reduction. The paper provides examples of how, at any given budget, more N reduction could be obtained by unit pricing than current pricing policy.

While the differences between unit-priced versus per acre-priced outcomes at current levels of implementation are considerable, as levels of implementation rise so do those differences – to a point. The two outcomes will ultimately converge when all the available acres are bought. The important consideration for that outcome, however, is that budgets are never likely to be sufficient to buy all the available acres of cover crops. Prior to reaching the end of supply, pricing that tracks the number of pounds of N reduced will achieve greater reduction at any price or total cost than pricing that does not.

If the improved pricing of nutrient reduction could truly deliver significant additional load reductions for the same total cost, policy makers seeking to increase nutrient load reductions at a time of increased expectations and limited budgets should have an obvious interest. Moreover, if policy-makers are seeking “market-based” policies for nutrient load reductions, pricing the desired service rather than a proxy for that service seems a prerequisite for achieving efficiency gains[23].

The economics of the proposed pricing scheme for N reduction are fundamental and, to the extent that producers are believed to respond to price signals, settled. There are, however a number of other issues to resolve before implementing a shift to N reduction pricing. Are the technical estimates employed in our model to capture differences in load reductions across practices, land uses and HGMRs appropriate? Are there other ways to slice the data that improve the precision of the estimates of N reduction by acre, practice and location? Beyond BMPs that can be counted as land use changes, how should reductions be discounted when they are layered on the same acres?

Additional institutional costs may be implied by a shift to unit reduction pricing. Whether or not it is practical for a unit pricing scheme to be implemented and supervised under the existing institutional framework and what this might cost are important. And, while improved pricing can be shown to be more efficient in a closed context, it would be prudent to consider potential adverse behavioral responses by adopters in the wider context of total loads.

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[22] Excepting alternate up-gradient land uses for Riparian Buffers.

[23] It is noteworthy in this respect that Maryland’s policy statement on nutrient trading (MDE, 2009) presumes mass measurements of nutrient load reductions per unit time as the thing being traded. This raises the question, why are current programs not based on similar measurements?

4.1 Determining the Appropriate Efficiency Model

The accuracy of the estimates of $/lb N reduced in our model are dependent on the accuracy of the estimated loading rates in the absence of the practice and the estimated reduction efficiencies of the BMPs. Although final publication of this paper has awaited Chesapeake Bay Model (version 5.3) output that was expected to be definitive, some important decisions for agricultural input data were deferred and the data on which our results are based are therefore provisional. However, processing the 5.3 data for the final draft was not overly difficult. Part of the usefulness of our constructed supply curves and pricing models is that the efficiency models that generate them can easily accept new data.

Whether the supply models developed for this paper compile available data appropriately is a question for technical staff. If there is a better way to parse available data such that more precise estimates of N reduction per acre can be generated, then a similar process of transforming that reduction efficiency matrix by some unit price can be substituted for the model employed here. It should still be possible to construct cost estimates for such a revised model, allowing the construction of a supply curve and informing the question, what price to pay per pound reduced.

With respect to stacked BMPs, the efficiency matrices for the two BMPs targeted in our paper only took account of agricultural BMPs that are measured as land-use changes in the Chesapeake Bay Model. If cover crops are stacked on acres that enjoy riparian buffers, then in those years that cover crops are planted the riparian buffers will be reducing less N export. This effect is not captured in our pricing models. A more precise pricing tool would take account of this effect, and will thereby be more complicated than the models described in this paper.

With respect to both establishing a standard reduction efficiency matrix for BMPs and improving them as better information becomes available, it would seem reasonable to assign the task to a team of technically qualified researchers. This team might be charged with establishing the best available estimators for nutrient load reductions by BMP and providing estimates of supply mapped to prices at industry marginal costs (a supply curve). Their mandate might also include explaining their estimates in a way that allows other researchers to replicate and test their results. It would be important that this group be independent of agencies that represent specific sectors or implementers, although those agencies would ultimately act on their findings.

An argument that adequate data do not exist for employing a model such as we have proposed presumes that scientists cannot predict nutrient loads and nutrient load reductions from BMP adoption. This is a difficult argument to disprove, and beyond the scope of this economic analysis to assess. However, if a TMDL for the Chesapeake Bay is based on the input-output data of the Chesapeake Bay Model, whether the data are accurate or not is obviated by the fact that they are factors in the regulation. Any state wishing to comply with the regulation in a least-cost manner would therefore be best served by reducing loads along the efficiency matrices of Chesapeake Bay Model.

4.2 Institutional Issues

Cover crops are implemented in Maryland by MDA soil conservation district staff. Given a pricing tool (i.e., a simple means for determining the dollar value of a given type of acre with a given cover crop practice applied), what would the responsible staff need to do differently to ensure the smooth function of a new cover crop pricing scheme with particular regard to supervision and certification? Are there significant new costs, foreseeable in a shift to unit-reduced pricing?

Riparian buffers are funded by both the federal and the Maryland state governments, with the bulk of the funding being provided by USDA. Determining the practicality of shifting RB to a unit-reduced pricing scheme requires a study of CREP program requirements. It could be within the scope of the existing regulations to allow a more efficient pricing mechanism for N load reduction from RB. On the other hand, shifting to unit reduced pricing could require re-writing the underlying regulations.

As noted in the preceding section, it matters how the nutrient load reduction model is compiled and it is important that this process be both independent and transparent. In assessing potential institutional or regulatory reforms implied by a shift to unit-reduced pricing, where to house the keepers of the reduction equations is clearly an important issue.

4.3 Knock-on Effects to Improved Nutrient Reduction Pricing

Because greater returns are available from acres with greater nutrient export under a unit pricing system, adopters may face an incentive to use farming practices that generate greater nutrient export. For this to be the case, the returns to cover crops or RB would have to be great enough to affect the commercial cropping decisions of the adopter. The unit reduction price at which the adopter is better off choosing a more nutrient-polluting practice can be estimated with crop budgets and estimates of net returns to adopters from BMP implementation.

It would be prudent to test these potential consequences to a unit-reduction pricing scheme before it is implemented. Armed with an understanding of when such consequences might obtain, it should be possible to develop mechanisms to avoid them.

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5 Appendices

Appendix 1: MDA cover crop data and load reduction calculations

Appendix 2a: Costs and cost efficiency calculations for cover crops

Appendix2b: Marginal Cost Supply Estimations for Cover Crops

Appendix 3: MD CREP History (Provided by Economic and Policy Analysis Staff, Farm Service Agency, Washington)

Appendix 4: Available Riparian Agricultural Land (Provided by USGS-CBPO staff)

Appendix 5: Riparian Buffer Marginal Cost Calculations and Results