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Abstract:

This paper examines the potential for nonadditional nonpoint loadings in the Chesapeake Bay as a result of institutions in the new Maryland Nutrient Trading program. The analysis uses real land/agronomic data from a survey of Eastern Shore fields—that are below-baseline—to run BMP scenarios in the trading interface. Results show 36.8% of acres are estimated to be below-baseline, suggesting the Maryland performance-based baseline may be "looser" than many might think. Regression models isolate the marginal impact on average of seven BMPs, individually adopted, using a sample of 77 below-baseline fields. The results suggested that six BMPs generate nitrogen offsets, while four BMPs generate substantively significant phosphorus offsets. Coupled with potentially permissive rules about additionality for annual practices and monitoring costs, the analysis suggests that annual practices pose viable avenues for nonadditional loadings. The analysis concludes with an estimation of the possible impact on the Bay if 50% of below baseline fields have a BMP currently in place. The analysis shows that for some structural BMPs, the impact of one BMP can be at a level that is 3.0 - 8.3% of the current N and P load for agricultural in the Eastern Shore.

Introduction

Institutions affecting Chesapeake Bay water quality are currently undergoing significant change. New federal and state policies, including nutrient trading, will affect point and nonpoint nutrients sources over the entire Bay watershed. Under the Clean Water Act (CWA), federal agencies are largely unable to exert direct regulatory control over nonpoint sources, like (non-CAFO) agriculture. The federal government, however, can regulate the nutrient loadings allocated to Bay states in the form of a total maximum daily load (TMDL). State TMDL compliance plans—the Watershed Implementation Plans (WIPs)—will likely include a variety of state-level nutrient trading programs. Trading is deemed necessary because point sources like municipal waste facilities, which are constrained by a TMDL-allocated cap, will have to offset future load increases that come with population growth, but their abatement costs are higher than nonpoints (Van Houtven, et al. 2012). The conventional wisdom is that trading will: (1) incentivize the participation of agriculture sources in meeting the TMDL, as agriculture contributes substantively to nutrient loads but is unregulated by the CWA; (2) create a "win" for participating farmers, who will access a new revenue source to pay them for adopting best management practices (BMPs); and (3) create a "win" for point sources who can buy offsets below their cost of abatement.

Economic research on nonpoint source pollution is extensive and rich (see Shortle and Horan 2001 for a synthesis). The literature on Bay water quality policy is substantive and growing, and a large share of studies examines least-cost abatement solutions that, in a sense, mimic where trading might reallocate abatement if transaction costs are low. Catma and Collins (2011) focus on optimizing manure relocation in the watershed via transport, arriving at estimates of least-cost forestland application and higher cost energy processing. Hanson and McConnell (2008) propose a trading-like policy in which "Flush Tax" revenue redirects abatement from sewage plants to agriculture through cover crops, saving 17-44% of abatement costs. Van Houtven et al. (2012) conducted a Bay-wide optimization analysis that reallocates abatement to the least-cost sources under a variety of institutional assumptions; they estimate that agriculture-to-point-source trading produces abatement cost savings of 21% in Maryland, assuming only in-state trades are allowed. Wainger et al. (forthcoming) offers another optimization model, and extends the results of Van Houtven et al. (2012) by recognizing and measuring the uncertainty of load reductions when reallocated from certain (point sources) to uncertain (nonpoint sources). Wainger et al. (forthcoming) find that trading ratios help address uncertainty, but they also have significant impacts on the least cost solution. One consistent result from these studies is that market institutions about permissible trades will have substantive efficiency and environmental implications.

The design of trading markets is ongoing, and so comprehensive economic evidence about the actual performance of these markets is unavailable. That said, there is quite a bit of questioning and skepticism among some economists about the ability of these emerging markets to function as hoped. For instance, Stephenson and Shabman (2010) outline a series of serious market challenges for nutrient trading in the Bay watershed. To interpret the policy process in a positive light, one might perceive the states as test-bedding a series of variations on nutrient trading institutions. Experience with what may be the largest water quality trading experiment in history will provide evidence over time as to how best to design these markets to achieve efficiency, fairness, participation, and low transaction costs.

This paper contributes to the literature and policy debate by presenting an exploratory analysis of a market under construction, using real field data to investigate a single economic concern (nonadditional loadings) in the context of a current program (Maryland's nutrient trading market) with the institutions in place as of spring 2012. Although all programs have institutions in flux, it is hoped that this economic research will help in the design of efficient institutions for trading in the face of information asymmetry.

The broad research purpose is to examine Maryland's trading program for evidence that the nutrient trading market could actually lower water quality, relative to the TMDL expected quality. Evidence shows this is possible, and this occurs because nonadditional offsets arise from the fundamental nonpoint pollution information asymmetry; a regulator cannot readily monitor the behavior of nonpoint sources. Research results focus on institutional and empirical evidence. A secondary purpose is to demonstrate how the results can be used by policymakers to predict the possible extent of nonadditionality relative to the total load coming from agricultural sources.

Defining Additionality and Nutrient Trading Institutions in Maryland

Institutions determine what loadings are additional, so this section will define what nonadditional loadings are possible with reference to the specific trading institutions in the Maryland program in place in spring 2012. Additionality is the idea that an ecosystem service from a management practice—say one that sequesters carbon or reduces nutrient load—currently is not provided or would not have been provided in the absence of a new policy institution seeking to increase service provision. Nonadditionality, then, will be defined as an ecosystem service provided prior to the policy, but that is claimed to be an environmental-improvement outcome of the policy. This is not of environmental quality concern if the nonadditional load is not used to create offsets. However, the danger of nonadditional load reductions is that policymakers perceiving them to be additional, may design institutions that allow these "reductions" to be traded as offsets and then emitted by another source. In such cases, environmental quality can actually decrease because loadings increase.

This is an original definition of nonadditionality derived in light of an assessment of the trading program under consideration. It is important to recognize that a TMDL restricts point sources to loading below the status quo and, thus, some policymakers may anticipate that the loading reductions gained from a point-source cap will be greater than losses associated with nonadditionality among nonpoint sources. The relative magnitude of these gains and losses is a researchable question, but the purpose here is to show that nonadditionality will result in loadings above the anticipated TMDL level—a level one presumes from the language in the law that is necessary to attain the water quality society needs. In other words, if nonadditionality among nonpoint sources allows point sources to exceed the TMDL, then this institution may be in violation of the CWA.

The Economics of Nonadditionality in Nutrient Trading

For concreteness, consider farm fields A and B in the Bay watershed, where field A currently has a forested riparian buffer and field B does not. Current Bay water quality reflects the BMP on field A and the lack of BMP on field B. Policy intervention X that incentivizes the owner of field B to adopt the BMP will produce an additional load reduction. But the load reductions from field A cannot be attributed to policy X as they would be nonadditional. If policy X pays the owner of field A, then one may find that some standards of fairness to the early adopter are satisfied—indeed paying early adopters for their ecosystem services rather than allowing them to undercut the additionality of an offset program seems to be a sensible policy solution. This research is based on the recognition that in a trading regime, the issue of nonadditionality extends beyond fairness. If field A's load reductions are tradable to a point source, then water quality will actually decline (all else equal). That is because current water quality reflect field A's abatement and allowing a point source to emit even a fraction of field A's abatement will lower quality below the regulated standard (or cap) imposed by the TMDL.

An economist immediately recognizes that this incentive problem shares characteristics of adverse selection. This incentive problem involves information asymmetry and high monitoring costs. A policy that pays for any BMP is most likely to first attract all those that provide these services already. This is because the early adopter's costs are zero (simply the transaction costs associated with garnering the incentive payment), and these costs by definition will be lower than those who have not yet adopted. The ecosystem services supply function is private information held by landowner and operators, and the policy administrator cannot observe types costlessly. At best, the administrator can monitor existing practices.

A final step in this economic argument involves the specific set of institutions forming trading. Nutrient trading markets establish a single price for pound of offset pollution. In sum, this means that a trading market will send the same revenue incentives to all parties but the underlying costs will be biased toward those with existing practices (because their adoption costs are lower). Thus, those with existing practices will systematically have greater incentives to participate in a program than those without practices currently in place.

The Role of the Baseline

Baselines are likely the most important institutional choice in the design of water quality trading. A baseline is a minimum level of performance or practice that a nonpoint source must meet before additional abatement can be used to generate offsets. Ghosh, Ribaudo, and Shortle (2011) assessed a time-based (D-type) and a practice/performance based (M-type) baseline. D-baselines credit offsets for any BMP that occurs after a given date. Under D-baselines, early adopters are penalized, but any BMP they adopt after the date qualifies for offsets. M-baselines require that a set of BMPs and/or an estimated load level be achieved prior to offsets being generated. To the extent that they are already below baseline, early adopters benefit from M-baselines in that all their marginal BMPs fully generate offsets. However, if an existing BMP helped achieve below-baseline status, these early adopters cannot gain offsets for the level they are below baseline. Ghosh, Ribaudo, and Shortle (2011) conclude that baseline choice affects efficiency; specifically, a M-baseline provides a disincentive for above baseline farms to deliver their low marginal cost BMPs because these owners will bear abatement costs simply to meet baseline without generating offsets. This article will extend the Ghosh, Ribaudo, and Shortle (2011) assessment of efficiency problems with M-baselines by suggesting how below-baseline farms may sell nonadditional offsets for existing BMPs because they can be implemented at zero cost.

Nutrient Trading Institutions in Maryland

With the goal of meeting the TMDL, Maryland has a baseline load allocation for agriculture, which to an economist is similar to a nonpoint "cap". Nonpoint loadings are unobservable to the regulator, for practical purposes, but they can be estimated (the accuracy of the estimates is an area for future scientific research). The Maryland baseline consists of a minimum set of practices (such as complying with nutrient management regulations and having a nutrient management plan) and achieving a minimum level of estimated performance (i.e., N and P loadings to the Bay). Baseline performance consists of an adjusted agricultural load (from the TMDL) distributed among farm fields by different watershed segments, and then specifically allocated to a given field using Maryland's Nutrient Trading Tool (MDNTT, at http://www.mdnutrienttrading.com/).

Walker, et al. (2012) explain how MDNTT works, and a summary of their work is provided here. A user identifies his or her field in MDNTT's dynamic GIS map, which reveals underlying land, soil, and spatial characteristics. The user then manually inputs land and agronomic management characteristics, current and future BMPs, and other details. MDNTT combines these data and processes them through the NTT (Nutrient Tracking Tool) model, the APEX (Agricultural Policy and Environmental Extender) model, and the Chesapeake Bay Model, in order to calculate scientific estimates on edge of farm loadings, edge of segment delivery, current load at edge of segment, and the TMDL baseline. The user then sees a report of estimates of current and future N (nitrogen) and P (phosphorus) loads (in lbs/acre and total lbs), the N and P baselines, and the N and P offsets generated (if the field is below baseline). The user can run different scenarios (i.e., different future BMPs) to examine the different levels of offsets generated.

Data

Original data collection involved three steps. First, researchers used a recently collected, unique data set on the agronomic, soil, and other characteristics of 196 farm fields from the Eastern Shore of Maryland. Second, data on these fields were entered in the MDNTT interface as a farmer might, with a set of nonessential assumptions (such as planting date) made for consistency across all fields. This allowed researchers to identify the subset of 77 fields that were below the baseline without requiring any BMPs. This subset of 77 below-baseline fields became the sample. The third step was to run scenarios for each field where one of seven BMPs was assumed. The status quo plus seven BMPs on each field results in 616 observations. These three steps detailed below.

Sample of Eastern Shore Fields: Agronomic Data

The original data set contained information on physical characteristics and management practices required to calculate Maryland's old and proposed revised phosphorus site index (Coale et al., 2002). Statewide, information was collected for 364 individual fields. These fields were selected by contacting nutrient management planners in each University of Maryland Extension county office and agricultural consultant companies that had an existing relationship with the authors. The nutrient management planners were asked to recommend farmers who were willing to grant access to the researchers to collect soil samples and review and copy information from their nutrient management plans. The planners were also asked to try and limit their selection to farmers who had fields where the soil phosphorus concentrations were above 150 on the fertility index value (FIV) scale. This is the legal threshold for soil P concentration above which a farmer would have to run a P site index in order to be allowed to apply P to the field. However, this last criterion was not always met as the requirement for access took precedence. The goal was to construct a data set containing approximately 200 fields on the Maryland's eastern shore. In addition, the original goal was to bias the selection towards fields located on the lower Eastern Shore (Wicomico, Somerset, and Worchester Counties), because this is where Maryland's poultry industry is most concentrated and as a result incidence of soil P concentrations above 150 FIV are known to occur most frequently.

Of the original 364 fields, 196 fields were located on the Eastern Shore with 96 of those located in the lower three counties. The average soil test P concentration for the 196 fields in the current data set was 264 FIV. The true mean of the entire population is unknown, but one may assume that this data set has some bias that results in a higher mean soil P concentration than the population. In addition, we can assume that the data set, due to the requirement of access to fields and nutrient management records, was biased toward farmers who are following current nutrient management regulations. As a result, these farmers may be more likely to participate in a trading program. Due to the sample selection criteria, the data set may be biased to farmers who are more likely to have more BMPs in place. In general, these known sources of bias should not affect production management practices, as methods for growing the primary cereal grain crops present on the Eastern Shore of Maryland are relatively standard. While the data set may be biased towards farmers who have historically used manure as a nutrient source and therefore have above average soil P concentrations, other management practices should not be influenced by the selection bias. Finally, selection of fields for the initial data set was not geographically weighted and multiple fields may have been sampled for one operator. Therefore, management may be more consistent across our data set than in the natural population.

Collecting Data on Sample Fields in MDNTT

The sample of 196 fields was entered manually into MDNTT, but incomplete data in MDNTT (mainly soil map) prevented seven fields from completing the process.[1] The data entry process required entry of basic agronomic factors such as commercial N and P application rates, manure application rates, and tillage type. Some data required by the MDNTT interface were either unknown to the researchers or tangential to the analysis, and so consistent assumptions were made across all fields so as to introduce no systematic biases. These assumptions are described in table 1. In the initial data entry, no BMPs were included. Some farms used no-till, but this is not treated as a BMP in this analysis or in MDNTT—just an agronomic option.

Following entry, MDNTT calculates an estimated load of N (*N-CURNT*) and P (*P-CURNT*) per acre. The baseline load is also displayed; for instance, for many fields in the region the baseline load for N is 11.1 lbs/acre. If a field has a current load of N and P below the N and P baseline, then the researchers labeled the field below-baseline. Fields below one baseline, but not the other, were excluded from the sample.

Table 2 displays sample data. Of the 189 fields in the sample, 77 or 40.7% were below baseline. The 77 fields constituted 36.8% of sampled acreage. These below-baseline fields constitute the sample examined in this analysis. Table 2 also shows the sample distribution across counties. In general, the fields tend to be similarly sized, with the average below-baseline field at 16.1 acres and above-baseline field at 19.1 acres. The greatest distinction is seen in Cecil, Kent, and Talbot counties, where very few fields qualified as below-baseline. These counties are three of four northern-most counties on the Eastern Shore. In sum, the sample of below-baseline fields will be more reflective of the lower Eastern Shore.

Table 3 shows the representativeness of the overall sample (below-baseline and above-baseline) to the farm acreage on the Eastern Shore. The data show that the sample captures between 0.1% and 0.7% of acreage in given counties. Queen Anne's is the least represented, while

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[1] Load and baseline calculations were made under the MDNTT modeling assumptions valid from March 31, 2011 to present. It is anticipated that these assumptions will change in summer 2012.

Caroline is the most. The table also helps clarify the distinction between field and farm. Most farms consist of multiple fields, but the data collected for the sample are at the field level. The sampled fields on average are 7.2% the size of the average farm. In Somerset, the sampled field average acreage is only 3.2% of the average farm acreage in the county. At the other extreme, sampled Caroline fields are 14.9% of the average farm acreage. This does not necessarily reflect a substantive bias because MDNTT makes calculations at the field level initially. However, a farmer enrolling multiple fields would average their nutrient loads over all fields when determining whether baseline is met and when calculating offsets.

BMP Scenarios and the Final Data Set

The BMPs are described briefly in table 4, and verbatim descriptions from MDNTT are listed in the appendix. *DECISIONAG* involves systematic nutrient application with technology. Conservation plans can be instituted on low till (*CONSPLAN-L*) or high till (*CONSPLAN-H*) cropland. Water control structures (*WATERCTRL*) involve physical gates on ditches. Riparian buffers can use woody (*FORESTBUFF*) and nonwoody (*GRASSBUFF*) plants, and these are similar to federal Conservation Reserve Program (CRP) plantings. The conversion of cropland to forest offers another option (*CONVERSION*) for farmers to affect their nutrient loadings. All practices have N efficiencies from the Chesapeake Bay Model, meaning they are assumed to deliver a certain percentage reduction in loadings. *DECISIONAG* and *WATERCTRL* have no P efficiency, while the others do.

Table 4 provides descriptive statistics for the entire sample of below-baseline farms. For this research, there were eight scenarios per field: one status quo with no BMP and seven scenarios with one BMP at a time. Each observation thus reflects one possible realization of offset production in MDNTT, where all 77 fields are repeatedly measured eight times. The dataset resembles a panel, where the land/agronomic characteristics do not vary by field and thus the nonvarying field characteristics resemble fixed effects in the regression reported below.

In MDNTT, the researchers selected a BMP as a future practice—one at a time for each field—and the lbs of N and P reduced (reported to the nearest tenth) for the whole field was recorded.[2] MDNTT rounds the reduced load rounded to the nearest integer to determine offsets. The researchers divided the N and P reductions by field acreage to generate the dependent variables (*N-CREDIT* and *P-CREDIT*), which therefore are N and P reductions per acre from a given BMP. These dependent variables always equaled zero when the status quo was selected.

This paper focuses on additionality issues and not on the heterogeneity in offset production, but the bivariate relationship between a given BMP and *N-CREDIT* or *P-CREDIT* shows this heterogeneity. Heterogeneity reflects the incentives for BMP adoption induced by creation of the offset market (in effect, one important factor creating the derived demand for BMPs from farmers). This topic is addressed in on-going work, but in sum the data show that the buffers and conversion BMPs produce the greatest variance in N and P offsets. Offset variance is also found with water control structures for N, and conservation planning on high till for P.

The results in the next sections address the analysis of data using two regression models that explain *N-CREDIT* and *P-CREDIT* using BMP indicators, current load controls, and land/agronomic controls. Ordinary least squares estimates the models.[3] The BMP indicators test the hypotheses whether the MDNTT, on average, awards offsets to sampled fields for their BMPs. The (positive) point-estimates of statistically significant coefficients also offer evidence on how productive, on average, each BMP is in terms of offset production. The regression model can also be

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[2] One result discovered during scenario modeling is that these BMPs are not additive, i.e., a field with BMP A and B will generate fewer offsets typically than the offsets from BMP A alone plus the offsets from BMP B alone.

[3] Preliminary regressions using fixed and random effects produced similar statistical patterns, but do not allow for inclusion of the full set of non-varying land/agronomic controls. Because these controls are deemed of interest to policymakers, an OLS model is reported.

interpreted as "reverse engineering" the chain of scientific models that is used to predict load reductions. Each model introduces assumptions and uncertainty making it too complex to unpack exactly how one BMP will affect N and P loadings on average. The regression simply evaluates the results of MDNTT and, in controlling for key drivers of load reduction, estimates average BMP marginal effects.

Results and Discussion of the Institutional Analysis of Additionality

The results reported in this section suggest that nutrient trading programs, depending on their institutional design, have the potential to degrade water quality below the level established by the TMDL. The results are based on rules from Maryland's trading program as of spring 2012 and on sample data from Eastern Shore fields. Evidence shows what specific conditions create the opportunity for nonadditional contributions and empirically estimate how substantively and statistically significant nonadditionality will be for seven BMPs by "reverse engineering" MDNTT with regression models. This section first presents the institutional results and then the next section explains the results of the empirical model.

The institutions associated with MDNTT were assessed to determine whether a given BMP would produce a load reduction that always was additional.[4] Although in theory a practice either does (nonadditional) or does not (additional) currently exist, the assessment identified at least three possible conditions where some or all currently existing BMPs could be used to generate nonadditional offsets.

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[4] It is important to remember that program rules are currently in flux, and the following assessment reflects program design as of spring 2012. Also important is that there are various "safety factors" in place in MDNTT to adjust for uncertainty, but which equally could be see to adjust for nonadditional loadings. According to Branosky, Jones, and Selman (2011), Maryland has a 10% retirement rate for offsets from agricultural and an uncertainty ratio of at least 10%. These adjustments could potentially be great enough to offset nonadditional loadings, but future work will have to tackle this researchable question.

First, a distinction between structural and annual practices is important in determining eligibility of a BMP to generate offsets—and thereby have a direct impact on additionality. An annual BMP is one where decisions can be made year-to-year, such as planting a cover crop. A structural BMP is more durable and likely involves a physical manifestation, and as such imposes fixed costs. Both structural and annual practices can be used to meet baseline (a condition not relevant for this sample of below-baseline fields). However, rules in MDNTT suggest that only annual practices can be used to generate offsets and only if the practices received no cost share assistance. A rough rationale for this rule is that good stewards might currently maintain BMPs—and issuing credits for these would clearly be nonadditional—but structural BMPs are more difficult to destroy simply to re-implement during the next year for offset credit. In contrast, annual BMPs are comparatively easy to alter for a year, and so there is a greater potential for the perverse incentive of destroying a practice for one year simply to enroll later for offsets. Although no definitive list exists, *DECISIONAG* is likely to be an annual, non-cost-share BMP. Conservation planning may either be an annual practice—and thus potentially eligible for offsets—or treated as another prerequisite for meeting baseline—and therefore ineligible for selling offsets.[5]

As noted in Branosky, Jones, and Selman (2011, table 7, footnote a), a second consideration involves the expiration of cost-shared structural BMPs. For any buffer funded under a program, such as CRP, the contract expiration year creates an unclear conception of additionality. On one hand, the practice existed in the expiration year and prior to that in the year when the TMDL was set; thus Bay water quality reflected the buffer's ecosystem services. This implies if the buffer generated offsets, they would be nonadditional. On the other hand, there is no guarantee without a CRP contract that the practice would continue after the expiration year. As such, the landowner could quite possibly destroy and re-plant the buffer to generate offsets. According to this logic, a

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[5] It is unclear exactly what minimum set of practices constitutes conservation planning and whether it will be approved for offset generation or not. That said, the researchers were able to select it as a future practice and generate offsets in MDNTT.

trading program that recognized the practice as worthy of offset in the expiration year would be "additional" in the sense that the ecosystem services would otherwise be destroyed. Nevertheless, the latter story reflects a loading increase in the sense that the land provided no load before the expiration year and produced a load (through offsets at a point source) in the expiration year. Rules in the MDNTT are presently in flux with respect to these two competing views, but all trading programs will face similar dilemmas with expiring cost-shared structural practices. In sum, it is possible that cost-shared structural practices will be credited with nonadditional offsets in the expiration year and thus, over the fifteen years or so, all existing structural practices could potentially deliver nonadditional offsets.

Third, high monitoring costs could result in any BMP delivering nonadditional offsets. Among the below-baseline fields, good stewards who adopted BMPs prior to the trading program are penalized for their provision of ecosystem services by strict rules on the additionality of offsets because the BMP does not help them meet the baseline (they already are below baseline) and they cannot sell offsets for the BMP. These fields thus have a moral case (equity) and pecuniary incentive (revenue from offsets for the BMP) to omit these practices when using MDNTT to calculate current loads. These practices can be misrepresented as future practices, which would then produce offsets. The agency will have to decide the level of resources to devote to monitoring. Some BMPs may be relatively easy to monitor (such as *WATERCTRL*), while others require more effort (precise acreage calculations to determine *CONVERSION*), and still others are not measurable for practice purposes (whether a farmer did *DECISIONAG* in the past).

The three foregoing stories suggest that any BMP is potentially nonadditional. The regression model will estimate coefficients for each BMP indicator variable. The practical connection of these coefficient estimates to additionality is unintuitive and warrants explanation. As an example, consider a hypothetical field in MDNTT with no BMPs that has *N-CURNT* = 8 lbs/acre, which is below the baseline of 11.1 lbs/acre. If the researchers indicate *FORESTBUFF* is a current practice, then *N-CREDIT* = 0 even though the current load could drop from 8 to 6 lbs/acre. This is the MDNTT first level of protection against nonadditional offsets. However, if the researcher enters the same BMP as a future practice, then *N-CREDIT* = 2. The researchers have coded the data to reflect the later case—i.e., where *N-CREDIT* and *P-CREDIT*>0 because the BMP was entered as a future practice. That said, the example shows that there are two possible interpretations of the regression. The first interpretation is that:

> *BMP coefficients provide a straightforward measurement of how productive, on average, BMPs could be in generating offsets and holding all else (initial load and land/agronomic factors) constant on below-baseline fields sampled from the Eastern Shore.*

Thus, these coefficients measure the costs of nonadditionality protection rules borne by early adopters—i.e., the inequity to good stewards of improving management before the trading regime was created. These costs, in turn, are the opportunity costs of a nonadditional trading program, and a separate subsidy (side payment) to early adopters as predicted from this regression could make them indifferent.

A second interpretation is that:

> *BMP coefficients provide a measurement of the per-acre nonadditional load increases for each field with an existing BMP for which offsets are approved (as if they were future practices).*

According to this interpretation, the model shows how much cost (in terms of nonadditional offsets) to Bay quality for each BMP the regulator chooses to approve being moved from current to future.

This cost informs several debates, particularly if combined with other research on the current extent of BMPs in the area. Estimates of nonadditional loadings help inform the appropriate safety factors for offsets that are traded (such as the 2:1 trading ratio). Regulators also can use this information to gauge whether monitoring is warranted. For instance, if a BMP is relatively costly to monitor but the nonadditional load is low, then monitoring may be inefficient.

The relative impact (per acre nonadditional load times acres of existing BMP) can help regulators decide whether the nonadditional costs are so low as to be ignored, high enough to warrant strict protections against nonadditionality, or so extreme and pervasive as to raise questions about whether trading can improve water quality at all.

Results and Discussion: Empirical Analysis of Nonadditional Offsets

Descriptive and Sample Statistics

Perhaps the most important policy result comes from the sample statistics (table 2): 40.7% of sampled fields and 36.8% of sampled acreage are below-baseline. This means that perhaps 367,115 acres on the Eastern Shore alone could be classified as below-baseline (from tables 2 and 3: 36.8% of 997,594 acres). This is a relatively large percentage, especially given that the sample selection was biased toward high-P fields. Economists have long recognized that any cap can be selected and then achieved cost effectively with trading (if transaction costs are low). However, only one cap is efficient in that it balances marginal damages with marginal abatement costs. The researchers are unaware of any efforts in the Bay states to find this efficient level, so the selection of the cap (in this case, a baseline) seems likely driven to manage participation, avoid a thin offset supply, avoid too great an offset supply, select a "reasonable" offset price, and/or take a first guess before trial and error leads to a better cap.

Inadequate economic information exists to assess this percentage of below-baseline fields, but the evidence points to two preliminary conclusions. First, participation levels should be high. The large percentage below-baseline suggests there will be many farmers ready to participate because, as Ghosh, Ribaudo, and Shortle (2011) argue, the M-baseline allows below-baseline farms to sell offsets for their first additional units of abatement without bearing extra abatement costs to meet the baseline. The converse of this argument is that above-baseline farms will have less extra abatement cost to bear given that the baseline seems relatively "loose" or high. Second, nonadditionality for existing BMPs is likely to be a real threat. The large percentage of below-baseline farms will have some BMPs in place, though the researchers coded the data with a status quo without BMPs. The farmers will have an incentive to gain offsets for existing BMPs because they can be supplied with zero cost. The greater the percentage below baseline, the greater the threat will be for nonadditional BMPs.

The descriptive statistics also offer valuable insights because they likely reflect the first systematic data collection of a large set of possible offset suppliers in MDNTT, and possibly other water trading programs, using real land/agronomic characteristics. How "clean" on average are below-baseline farms? From table 4, the status quo loadings for N (*N-CURNT*) are 5.5 lbs/acre on average, and range from 1.6 to 11.0. Some fields therefore approach the N baselines, ranging from approximately 9 to 12, but on average these fields are significantly below baseline. For P, the average status quo load is 0.8 lbs/acre, ranging from 0.3 to 2.2. One implication of the current loadings is that the higher the load (closer to the baseline), the greater the set of possible offsets to sell. This source of heterogeneity will be important in identifying the farms most likely to participate. All else equal, a below-baseline field with *N-CURNT* = 9 will have greater incentive to implement BMPs than a similar field at *N-CURNT* = 4. This effect will be tested in the regression by estimating a coefficient on *N-CURNT* and *P-CURNT*.

Regression Results

The regression models (tables 5 and 6) explain the N and P offsets from various BMPs, controlling for land/agronomic characteristics and the current loadings. This will show the relative potential of BMPs to deliver nonadditional offsets and will help measure the likely extent of the identified incentive problem in MDNTT. Model fit offers evidence of strong explanatory power: R^2 was 0.65 for N and was 0.60 for P. When interpreting coefficients, several constraints of the model should be noted. First, for each BMP the coefficient reflects both the total change in offsets/acre and in lbs/acre of load reduction on average. Second, the model is only valid for having one BMP at a time (or no BMPs), but it is not built to assess two or more BMPs simultaneously implemented. Third, the BMP coefficients reflect on average the marginal and total change from adopting a single BMP—statistically, this is because the current load and land/agronomic controls, when evaluated at their means, sum to zero (within several thousandths of error).

The N model (table 5) shows that six BMPs deliver N offsets but *CONSPLAN-L* does not. Statistical significance was at the 1% level for five of these BMPs and at the 5% level for *DECISIONAG*. As each BMP has a built-in N efficiency in MDNTT, perhaps the only surprising result is that *CONSPLAN-L* does not deliver offsets on average.[6] Given the efficiencies, the results confirm expectations that the four structural BMPs deliver the largest point estimates of offsets. Forest and grass buffers produce N offsets of 2.1 and 1.5 lbs/acre from the practice alone and then a secondary effect from the buffer length (if it varies from the average). *BUFFER-FT* had a statistically significant impact of 0.005/ft.

Many fields would likely find that structural practices produce the most offsets of any BMP. Some forest buffers may produce well over 2 lbs/acre, but all *WATERCTRL*, *CONVERSION*, *FORESTBUFF*, and *GRASSBUFF* produced offsets on average at a high rate of more than 1.2 lbs/acre. This has implications for the incentives for farmers to participate in the trading market. Although the MDNTT tool is too new to have a good price signal, informal predictions the researchers have heard from policy experts focused on the range of \$4 - \$20/lbs offset.

At these offset prices, a structural practice at 1.5 lbs/acre would expect an incentive of \$6 - \$30/acre. First, note that these incentives are per field acre and not per acre of practice; therefore,

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[6] As the appendix shows, each BMP has an "efficiency" adapted from the Chesapeake Bay Model. MDNTT uses this average export coefficient, in part, to determine the productivity of BMPs. The regression "reverse engineers" these assumptions and their interaction with other assumptions, spatial location of actual farms, and land/agronomic characteristics of actual farms.

one cannot compare them to CRP incentives, which would be often well over $70/acre enrolled.[7] Second, the capitalized measures provide a better understanding of the "permanent" incentive for installing a durable structural practice. If one assumes a 6% discount rate, then the capitalized range is $100 - $500/acre. These incentives are far below incentives for more substantive conservation, such as conservation easements (which in this area would be thousands of dollars per acre). However, this does not imply that farmers would not seek to participate in the offset market. The opportunity cost of these BMPs is also far below that of easements. Also, these practices are likely quite easy for a farmer to "stack." The simplest form of stacking, to the farmer, would be enrolling both N and P offsets—an outcome that MDNTT is programmed to deliver automatically. A future sediment-trading platform in MDNTT would also be automatically stackable. Beyond this, however, stacking applies to any farmer that enrolls in, say, an easement program, which conveys an intention to farm in the long term, and then also sell offsets. The opportunity cost of a structural BMP should be substantially lower on conserved land, but the offset-revenue incentives received by farmers are not lowered to reflect this lower opportunity cost.

The interpretation of N regression results on structural BMPs suggests that annual BMPs have very low offset productivity, but that does not necessarily imply low incentives. *DECISIONAG* and *CONSPLAN-H* produce on average offsets at only 0.2 and 0.4 lbs/acre. At the above price range, these would only provide yearly offset revenue of $0.80 to $8.00/acre. For some farmers, this type of incentive will be insufficient to even "fill out the paperwork" required to participate, i.e., the transaction costs of using MDNTT. However, there are several reasons why this result could signal significant participation and incentive problems.

The capitalized values are estimated to be about $13 to $133 per acre. For large farms, these sources of revenue may warrant participation. The revenue estimates are relatively low, but

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[7] In this data set, the assumed buffer area (in acres) was calculated as (45 ft x buffer length in ft/acre)/43,560 ft^2. The sample average buffer length was 73.691 ft, which implies the average buffer area was: 0.076 acres of buffer per acre of field.

there are reasons why the costs may be very low—thereby implying that profit of participation is high. Consider first that when one adopts *DECISIONAG* or *CONSPLAN-H*, there may be low to moderate fixed costs, but the yearly marginal costs are very low as the knowledge capital does not likely depreciate and an physical capital has already been substituted for in the production process (like a GPS system to direct the application of nutrients). Second, a similar argument about stacking made above holds for these annual practices; the transaction costs of participating in the offset market with one additional BMP is likely the same in total as participating with multiple practices. So, the marginal participation costs are either spread over several practices or are zero for those already participating. Third, these BMPs may be assessed in MDNTT to be annual practices, which are not cost-shared. This means that these practices will be awarded offsets even if they currently exist. Nonadditional offsets have an implementation cost of zero. Fourth, given the relatively low capitalized costs, the incentive of the regulator is low to monitor against misrepresentation. Thus, even if rules prevent these existing practices from gaining offsets, the monitoring costs are so high relative to the benefits of monitoring that it is likely that misrepresentation would be "optimal" for both regulator and farmer. In sum, the evidence suggests that incentives are in place for some annual BMPs, though existing, to be awarded offsets. These instances would result in nonadditional loadings.

The P model (table 6) shows that statistic evidence exists that five BMPs deliver P offsets, but no evidence was found for *DECISIONAG* and *WATERCTRL*. The *DECISIONAG* and *WATERCTRL*[8] result is not surprising, as these two BMPs have no P efficiencies. The statistical evidence on the other five BMPs was strong, except for *CONSPLAN-L*, which had very weak statistical evidence and very low substantive significance. As a result, for practical purposes, *CONSPLAN-L* on average has no productivity for P offsets. Coupled with the result on N, it seems that there is no incentive from MDNTT for farmers to adopt *CONSPLAN-L*.

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[8] There is no efficiency for *WATERCTRL* on P in the Bay Model, but there is a real scientific debate about whether this BMP actually does deliver load reductions.

CONSPLAN-H, *GRASSBUFF*, *FORESTBUFF*, and *CONVERSION* deliver between 0.1 and 0.2 lbs/acre of P offsets. The researchers have seen no evidence nor heard any speculation about the likely price of P offsets. For purposes of interpretation, assume a guess that P offsets sell for $100. Then, farmers would expect these four BMPs to deliver $10-$20/acre per year, or $167 to $333 in perpetuity. As with the analysis of N offsets, the same issues with low cost participation apply—i.e., although the individual payment may be low, the costs are often low and/or stacking possibilities lower the costs. In sum, many farmers may find that the opportunity to sell P offsets incentivizes participation, but this participation may come in the form of nonadditional offsets.

Joint Participation Incentives, Stacking, and Nonadditionality

The foregoing analysis makes clear that participation incentives are greater than implied by a single offset market. If one assumes N and P offsets sell for $13 and $100/acre, respectively, then the regression results can be used to estimate the average capitalized incentives per acre for each BMP. This is the simplest interpretation of stacking, from the perspective of the farmer. The greatest incentives are for structural BMPs: *FORESTBUFF* ($728), *CONVERSION* ($581), *GRASSBUFF* ($468), and *WATERCTRL* ($348). The incentives for annual practices are lower: *CONSPLAN-H* ($287), *CONSPLAN-L* ($63), and *DECISIONAG* ($44).

These incentives would be perceived to be substantial by some farmers, who would likely be encouraged to participate in the program. For instance, if one owned 500 acres (with the average characteristics), then the *FORESTBUFF* incentive is estimated to be $364,000. Although there is a substantial opportunity cost to permanent buffers, this is a large payment that may encourage some farmers to participate and this payment level may be competitive with substitute programs like CRP. Also, it would be much more likely that a farmer with land already in conservation easements would participate because the opportunity cost on un-eased land would be comparatively high. Specifically, a permanent forest buffer on a 500-acre farm would, in practice, be equivalent to a conservation easement on the farm. Conservation easements in this region typically sell for a much higher price per acre, but if a farmer already had an easement, then the opportunity cost is far lower.

Previous empirical work on Delaware farmers found that those who participate in one public program (conservation management, conservation easement, or commodity program) are significantly more likely to participate in multiple programs (Duke 2004). The intuition is that a farmer committing to agriculture for the long term will take advantage of all available programs that fit the farmer's needs. Nutrient trading should be similar. The farmers already involved in existing programs will generally participate in nutrient trading because the opportunity costs of foregone development options are lower, the costs of entering the policy process are lower, and the possibility for stacking or even "double dipping" is greater.

Nonadditional offsets offer a new form of "double dipping." If a farmer currently has an annual BMP in place, the farmer can gain an estimated $44 to $287/acre simply by filling out paper work. A farmer with an expiring buffer contract can get an estimated payment of $468 to $728/acre by seeking offsets instead of re-enrolling. Any farmer who misrepresents an existing practice may get payments, including, for instance, land-use conversion and water control structures at estimated rates of $581 and $348/acre. In terms of equity, such early adopters would be compensated for their provision of ecosystem services. But in terms of Bay quality, these nonadditional offsets would pose a threat to water quality—potentially lowering it below the TMDL target. Policymakers will note that these incentives also are equivalent to the estimated equity subsidy necessary to make early adopters indifferent to nonparticipating in the trading market with nonadditional offsets.

Possible Extent of Nonadditionality

The regression model results also allow a first cut at estimating the extent of the nonadditionality issue for each BMP and relative to assumptions on existing BMP adoption among below baseline farms. Table 3 shows there are 997,594 agricultural acres on the Eastern Shore, and the sample, if random, suggests that 367,115 acres are below baseline. For this application, assume that 50% of the below-baseline acres have a single BMP in place currently and that the MDNTT rules allow the owners to sell nonadditional offsets by moving this one BMP from current to future in the MDNTT interface. Table 7 shows the impact of this scenario on Bay loadings if the BMP moved from current to future is one of the seven studied in this paper. Table 7 shows the impact of N and P in lbs/year, and then compares to the existing loads of N and P attributed to Eastern Shore agriculture.

The results of this policy simulation suggest that allowing nonadditional offsets from decision agriculture will have relatively little impact on Bay quality. N loads would increase by about 0.5%, and P loadings are unaffected. This BMP was probably the most difficult to monitor, so the regulator can simply balance the benefit of offering the decision agriculture option to those farms that currently do not have decision agriculture (i.e., farms where it would be additional) with the estimate 40,566 lbs/year of nonadditional N. Of course, this all is accurate only if the application assumptions are true.

Similar arguments apply to the conservation planning. Crediting offsets for planning on high till would increase N and P loadings by 1.1%, but on low till only 0.4% and 0.1%. This difference is due to the low assumed efficiency of conservation planning on low till. As with decision agriculture, the regulator could attempt a rough but simple balancing of monitoring costs with the benefits of offering these BMPs as an offset option to nonadopters.

The results on the structural BMPs pose a more significant policy challenge. The potential nonadditional N and P loadings are each substantive (except water control structure, which is assumed not to affect P). Each impact is estimated to increase loadings by 3.0 to 8.3%. At minimum, the benefits to the regulator of crediting these structural practices as nonadditional would include: (1) equity to early adopters; (2) lowering monitoring costs; (3) encouraging participation; (4) increasing the supply of offsets available to point sources; (5) incentivizing interdependent BMP adoption[9]; and (6) avoiding perverse incentives where farmers destroy a structural practice or abandon a practice, just to enroll in future years. At minimum, the costs of crediting nonadditional structural BMPs are: (1) significant N and P load increases to the Bay, relative to the TMDL baseline; and (2) expanding the supply with these low- or zero-cost offsets has a price effect, which lowers offset price and thereby the incentive to adopt BMPs delivering additionality.

Conclusion

The purpose of this paper is to explore the potential for nonadditional loadings in the Bay as a result of institutions in the new Maryland Nutrient Trading program. To assess the potential, the MDNTT rules were examined and three possible circumstances were identified under which a farmer's existing BMP could be credited with an offset: (1) non-cost-shared annual practices; (2) expiring cost-shared structural practices; and (3) misrepresentation. The role of monitoring costs was also discussed with respect to each circumstance. The institutional analysis concluded that, though rules are still in flux, as of spring 2012 it was possible that any existing BMP could potentially be credited on a below-baseline field.

The second part of the analysis used real land/agronomic data from a survey of Eastern Shore fields to run BMP scenarios in the MDNTT interface. One result was that 36.8% of acres are estimated to be below-baseline. This is a significant and perhaps surprising fraction of acres, suggesting that Maryland performance-based baseline may be "looser" than many might think.

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[9] If a farmer has one BMP in place and can gain offsets, they are more likely to adopt another BMP because the participation costs are (in effect) fixed. In addition, this allows "stacking-type" incentives for farmers.

Regression models were used to isolate the marginal impact on average of seven BMPs, individually adopted, using a sample of 77 below-baseline fields. The results suggested that six BMPs generate N offsets, while four BMPs generate substantively significant P offsets. The discussion argued that though annual BMPs (like decision agriculture and conservation planning) generate low numbers of offsets, the costs for farmers to submit these may also be very low. Coupled with loose rules about additionality for annual practices and the difficulty in monitoring them, the analysis suggests that annual practices pose viable avenues for nonadditional loadings.

The regression analysis of structural practices suggests that they tend to generate substantive offsets (and, equally, have substantive impacts on Bay quality). Although these practices are easier than annual practices to monitor, they also may be exempted by MDNTT rules to prevent perverse incentives to destroy them. When one examines possible offset prices and recognizes the possible lower costs of "stacking-type" behavior by farmers, the analysis suggests that reasonably high revenue can be generated from participating in the offset market with any one structural BMP. If this BMP currently exists and the adoption costs are therefore zero, the profit in the offset market is substantial—certainly enough to warrant participation and maybe enough to compete with substitute programs such as CRP. In sum, this evidence suggests that farmers will have significant incentives to bring nonadditional offsets from structural BMPs to the trading market. The analysis concluded with an estimation of the possible impact on the Bay if 50% of below baseline fields have a BMP currently in place. The analysis shows that for some structural BMPs, the impact of one BMP can be at a level that is 3.0 - 8.3% of the current N and P load for agricultural in the Eastern Shore.

Works Cited

Branosky, E., C. Jones, M. Selman. 2011. “Comparison Tables of State Nutrient Trading Programs in the Chesapeake Bay Watershed.” *WRI Fact Sheet*. Washington DC: World Resources Institute.

Catma, S., A. Collins. 2011. “Phosphorus Imbalances in the Chesapeake Bay Watershed: Can Forestland and Manure Processing Facilities Be the Answers?” *Agriculture and Resource Economics Review* 40(1): 116-132.

Coale, F. J. , J. T. Sims, A. B. Leytem. 2002. “Accelerated Deployment of an Agricultural Nutrient Management Tool: the Maryland Phosphorus Site Index. *J. Environ. Qual*. 31:1471-1476.

Duke, J.M. 2004. “Participation in Agricultural Land Preservation Programs: Parcel Quality and a Complex Policy Environment.” *Agricultural and Resource Economics Review* 33(1):34-49

Ghosh, G., M. Ribaudo, and J. Shortle. 2011. “Baseline Requirements Can Hinder Trades in Water Quality Trading Programs: Evidence from the Conestoga Watershed.” *Journal of Enviornmental Management* 92: 2076-2084.

Hanson, J.C., K.E. McConnell. 2008. “Simulated Trading for Maryland’s Nitrogen Loadings in the Chesapeake Bay.” *Agriculture and Resource Economics Review* 37(2): 211-226.

Shortle, J.S., R.D. Horan. 2001. “The Economics of Nonpoint Pollution Control.” *Journal of Economic Surveys* 15(3): 255-289.

Stephenson, K., L. Shabman. 2010. “Plan for Nutrient Trading to Pay for Agricultural BMPs an Illusion.” *Chesapeake Bay Journal*.

Van Houtven, G., R. Loomis, J. Baker, R. Beach, S. Casey. 2012. “Nutrient Credit Trading for the Chesapeake Bay: An Economic Study.” Annapolis, Maryland: Chesapeake Bay Commission.

Wainger, L.A., G. Van Houtven, R. Loomis, J. Messer, M. Deerhake. Forthcoming. “Tradeoffs Among Ecosystem Services, Performance Certainty, and Cost Efficiency in the Implementation of the Chesapeake Bay TMDL.”

Walker, S., M. Selman, S. Payne, A. Saleh. 2012. “Maryland Nutrient Trading Tool: Estimating Creditable On-farm Nutrient Reductions.” *21st Century Watershed Technology Workshops: Improving Water Quality and the Environment, CD-ROM Proceedings*. American Society of Agricultural and Biological Engineers.

Table 1: Assumptions Used to Augment and Reconcile Agronomic Survey Data in NN

Agronomic Factor	Assumption(s) Made
Planting Method	If no-till is used, assumed no-till drill as the planting method
Soil P Test Values	If a value was missing, assumed value to be 150 FIV All units measured in FIV All values tested at UMD Lab for Ag and Environmental Science
Planting Date	Corn (grain, sweet, and silage): 5/1 Soybeans: 5/1 or 7/1
Harvest Date	All harvested on 9/15
Commercial Fertilizer Application Date	Corn 4/15 Soybeans 5/1
Commercial Fertilizer Incorporation Depth	2 inches
Manure Type	If poultry manure used, assumed to be broiler chickens
Manure Application Date	3/15, 2/15, or 5/1
Manure Consistency	If poultry, assumed solid If milk cow, assumed liquid
Manure Nitrogen Concentration	Poultry: 73 lbs/ton Milk Cows: 5.95 lbs/ton
Manure Phosphorus Type	Measured in P2O5
Poultry Manure	Assumed phytase and poultry litter treatment
Manure Incorporation Depth	4 inches
Manure Moisture Content	Broiler Chickens: 27.48% Milk Cows: 94.02%
If Land Use Conversion BMP	Assumed 25% of field converted to forest

Table 2: Sample Data by County

	Below-baseline fields			Above-baseline fields			Total		
County	# Fields (% of total)	Acreage Total (% of total)	Acreage Average	# Fields (% of total)	Acreage Total (% of total)	Acreage Average	# Fields	Acreage	Acreage Average
Caroline	13(50%)	417(47%)	32.1	13(50%)	468.4(53%)	36	26	885.4	34.1
Cecil	3(21%)	127.5(48%)	42.5	11(79%)	140.8(52%)	12.8	14	268.3	19.2
Dorchester	5(33%)	157(51%)	31.4	10(67%)	153(49%)	15.3	15	310	20.7
Kent	0(0%)	0(0%)	0	10(100%)	366.3(100%)	36.6	10	366.3	36.6
Queen Anne's	4(33%)	25.6(14%)	6.4	6(60%)	139.9(85%)	23.3	10	165.5	16.6
Somerset	29(48%)	171.8(46%)	5.9	30(51%)	179.1(51%)	6	59	350.9	5.9
Talbot	2(9%)	54(9%)	27	21(91%)	558.8(91%)	26.6	23	612.8	26.6
Wicomico	9(53%)	148(63%)	16.4	8(47%)	88(37%)	11	17	236	13.9
Worcester	12(63%)	140.7(56%)	11.7	3(20%)	42.3(23%)	14.1	15	183	12.2
Total	77 (40.7%)	1241.6 (36.8%)	16.1	112 (59.3%)	2136.6 (63.2%)	19.1	189	3378.2	17.9

Source notes: Although 196 fields from the Eastern Shore of Maryland were in the sample seven lacked sufficient data to make them compatible with MDNTT. Those seven were excluded from the sample.

Table 3: Sample vs. Population Data

	Sample			Population		
County	# Fields	Field Acreage Total (% of Farm Population)	Field Acreage Average (% of Farm Population)	# Farms	Farm Acreage Total	Farm Acreage Average
Caroline	26	885.4(0.7%)	34.1(14.9%)	574	131,277	229
Cecil	14	268.3(0.3%)	19.2(13.2%)	583	85,026	146
Dorchester	15	310(0.2%)	20.7(6.6%)	424	133,188	314
Kent	10	366.3(0.3%)	36.6(10.8%)	377	128,220	340
Queen Anne's	10	165.5(0.1%)	16.6(5.9%)	521	146,927	282
Somerset	59	350.9(0.6%)	5.9(3.2%)	329	60,255	183
Talbot	23	612.8(0.6%)	26.6(7.5%)	305	109,002	357
Wicomico	17	236(0.3%)	13.9(7.6%)	508	92,852	183
Worcester	15	183(0.2%)	12.2(4.2%)	384	110,847	289
Total	189	3,378.2(0.3%)	17.9(7.2%)	4,005	997,594	249

Notes: Population is Eastern Shore farm acreage. Farms consist of many fields, so the best measure of sample coverage is acreage. Source: Population data come from USDA, 2007 Census of Agriculture - County Data. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Maryland/st24_2_001_001.pdf. Accessed it on 6/6/12.

Table 4: Descriptive Statistics for Agricultural Fields in Sample

	Description	Mean	Std. Dev.	Min	Max
	Dependent Variables				
N-CREDIT	Change in lbs per acre of nitrogen from BMP (=0 for status quo)	0.911	1.165	0	7.426
P-CREDIT	Change in lbs per acre of phosphorus from BMP (=0 for status quo)	0.080	0.111	0	0.806
	BMP Indicators (Efficiency)				
DECISIONAG	Information-based agricultural management, precision agriculture (TN=4%); applied to entire field	0.125	0.331	0	1
CONSPLAN-H	Agronomic, management, and engineered practices, on high-till land (TN=3, 5, or 8%, TP=5, 10, or 15%); applied to entire field	0.125	0.331	0	1
CONSPLAN-L	As above, on low-till land	0.125	0.331	0	1
WATERCTRL	Using boarded gated systems on land with surface drainage (TN=33%); applied to entire field	0.125	0.331	0	1
GRASSBUFF	Grass and non-woody vegetation along rivers, streams, tidal areas, and down-slopes (TN=13-46%, TP=30-45%); applied to buffer ft	0.125	0.331	0	1
FORESTBUFF	Wooded areas along rivers, streams, shorelines, field edges, and down-slopes (TN=19-65%, TP=30-45%); applied to buffer ft	0.125	0.331	0	1
CONVERSION	Cropland converted to forest; applied to 25% of acreage	0.125	0.331	0	1
	Current Load Controls				
N-CURNT	Estimated load of N lbs per acre	5.502	3.169	1.6	11.0
P-CURNT	Estimated load of P lbs per acre	0.842	0.278	0.3	2.2
	Land Characteristics and Agronomic Measures				
N-CONSTANT	Measures status quo load, agronomic reference category for N model	1			
P-CONSTANT	Measures status quo load, agronomic reference category for P model	1			
ACRES	Acres of field	16.125	20.996	1.24	112
BUFFER-FT	Estimation of length of buffer (in ft per acre)	73.691	45.754	4.51	239.52
SWEETCORN	Indicator: Field produces sweet corn	0.104	0.305	0	1
GRAINCORN	Indicator: Field produces corn for grain	0.377	0.485	0	1
SOYBEANS	Reference level for production				
SOILTEST	Soil P-Test Value	188.870	95.005	0	533.21
N-APPLIED	Total N applied per acre via manure, litter, or inorganic fertilizer	71.686	80.713	0	219
P-APPLIED	Total P applied per acre via manure, litter, or inorganic fertilizer (measured in P2O5)	67.860	87.210	0	264

N=616

Data collected by authors using scenarios in Maryland's nutrient trading interface, MDNTT. See appendix for details on BMPs from interface.

Table 5: Explaining Nitrogen Credits (lbs/acre/year) Generated from BMPs in MDNTT

	Coefficient	Std. Err.
	BMP Indicators	
DECISIONAG	0.221**	0.112
CONSPLAN-H	0.445***	0.112
CONSPLAN-L	0.150	0.112
WATERCTRL	1.738***	0.112
GRASSBUFF	1.471***	0.112
FORESTBUFF	2.014***	0.112
CONVERSION	1.247***	0.112
	Current Load	
N-CURRENT	0.165***	0.010
	Land Characteristics and Agronomic Measures	
N-CONSTANT	-1.254***	0.127
BUFFER-FT	0.005***	0.001
SWEETCORN	-0.033	0.194
GRAINCORN	-0.082	0.120
SOILTEST	-0.00000	0.0003
N-APPLIED	0.0001	0.0008

N=616

Statistical significance: *** 1%, ** 5%

F(13, 602)	86.77***
R-squared	0.652
Adj R-squared	0.645

Table 6: Explaining Phosphorous Credits (lbs/acre/year) Generated from BMPs in MDNTT

	Coefficient	Std. Err.
	BMP Indicators	
DECISIONAG	0.00000	0.011
CONSPLAN-H	0.119***	0.011
CONSPLAN-L	0.020*	0.011
WATERCTRL	0.00000	0.011
GRASSBUFF	0.104***	0.011
FORESTBUFF	0.195***	0.011
CONVERSION	0.199***	0.011
	Current Load	
P-CURRENT	0.096***	0.011
	Land Characteristics and Agronomic Measures	
P-CONSTANT	-0.111***	0.014
BUFFER-FT	0.00035***	0.00006
SWEETCORN	-0.012	0.018
GRAINCORN	-0.011	0.010
SOILTEST	0.00003	0.00003
P-APPLIED	0.00005	0.00006

N=616

Statistical significance: *** 1%, ** 5%, * 10%

F(13, 602)	69.90***
R-squared	0.602
Adj R-squared	0.593

Table 7: Possible Estimated Extent of Nonadditional Offsets to Lower TMDL Bay Quality: Assuming 50% of Fields Have Existing BMP

BMP	Estimated nonadditional N (lbs/year)	As a percentage of yearly Eastern Shore N load	Estimated nonadditional P (lbs/year)	As a percentage of yearly Eastern Shore P load
DECISIONAG	40,566	0.5%	0	0.0%
CONSPLAN-H	81,683	1.1%	9,720	1.1%
CONSPLAN-L	27,534	0.4%	551	0.1%
WATERCTRL	319,023	4.1%	0	0.0%
GRASSBUFF	270,013	3.5%	28,081	3.2%
FORESTBUFF	369,685	4.8%	72,089	8.3%
CONVERSION	228,896	3.0%	45,550	5.2%

Notes: Assumes population of agricultural acres on Eastern Shore, Maryland, and assumes that sample is randomly drawn from this population. Uses calculation sample estimate of 367,115 acres are below-baseline (divides this number by 2), and then multiplies this by regression coefficients. Assumes that 50% of below-baseline acreage has BMP in place currently and that this BMP can be moved to "future" in MDNTT to generate offsets, which are sold to a point source to be emitted. The numbers cannot be added up across BMPs because this violates an assumption in the regression model. The Eastern Shore load for N is 7,711,200 lbs/year and for P is 872,351 lbs/year
Sources: The estimated loads were collected from three reports from the Maryland Deptartment of Natural Resources from 2007: (1) http://www.dnr.state.md.us/irc/docs/00015905.pdf; (2) http://www.dnr.state.md.us/irc/docs/00015910.pdf; and (3) http://www.dnr.state.md.us/irc/docs/00015909.pdf.

Appendix: BMP Descriptions

This appendix contains verbatim description of BMPs taken from within the Maryland Nutrient Trading Tool interface (http://nutrientnet.mdnutrienttrading.com/). MDNTT has a note on one practice that suggests these definitions come from the Chesapeake Bay Program, though no document is explicitly cited. Decision agriculture is defined as:

> "Decision Agriculture is a management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment. Applicable NRCS Practices:
> Precision Agriculture. Efficiencies: TN efficiency: 4%"

Conservation Plans are defined as:

> **"**Farm conservation plans are a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases the plan must meet technical standards. Applicable NRCS Practices: 560–Access Road, 311–Alley Cropping, 575–Animal Trails and Walkways, 327–Conservation Cover, 328–Conservation Crop Rotation, 332–Contour Buffer Strips, 330–Contour Farming, 342–Critical Area Planting, 362–Diversion, 386–Field Border, 393–Filter Strip, 410–Grade Stabilization Structure, 412–Grassed Waterway, 468–Lined Waterway or Outlet, 344–Residue Management, Seasonal, 555–Rock Barrier, 557–Row Arrangement, 350–Sediment Basin, 585–Stripcropping, 587–Structure for Water Control, 600–Terrace, 620–Underground Outlet, 638–Water and Sediment Control Basin, 380–Windbreak/Shelterbelt Establishment. Efficiencies: TN efficiency for conventional tillage: 8%, TP efficiency for conventional tillage: 15%, TN efficiency for conservation tillage or hay: 3%, TP efficiency for conservation tillage or hay: 5%, TN efficiency for pasture: 5%, TP efficiency for pasture: 10%"

Water control Structures are defined as:

> **"**Water Control Structures involve installing and managing boarded gate systems in agricultural land that contains surface drainage ditches. Applicable NRCS Practices: 587–Structure for Water Control. Efficiencies: TN efficiency: 33%"

Riparian and Conservation Forest Buffers are defined as:

> "Agricultural riparian forest buffers are linear wooded areas along rivers, stream and shorelines. Conservation buffers are linear wooded areas along field edges, down-slope of agricultural fields. Forest buffers help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35 feet minimum width required. Forest buffers treat nitrogen from an upland area four times the acreage of the buffer and treat phosphorus from an upland area two times the acreage of the buffer. New forest buffer area is treated as a land use conversion from cropland to forest. Applicable NRCS Practices: 391–Riparian Forest Buffer. Efficiencies: TN efficiency: 19-65%; varies geographically, TP efficiency: 30-45%; varies geographically."

Riparian and Conservation Grass Buffers are defined as:

> "Agricultural riparian grass buffers are linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment and other pollutant from runoff. Conservation grass buffers are located down-slope of an agricultural field but do not need to be on the edge of streams or rivers. The recommended buffer width for riparian grass buffers (agriculture) is 100 feet, with a 35 feet minimum width required. Grass buffers treat nitrogen from an upland area four times the acreage of the buffer and treat phosphorus from an upland area two times the acreage of the buffer. New buffer area is treated as a land use conversion from cropland to grass.
> Applicable NRCS Practices:390–Riparian Herbaceous Cover, 386–Field Border, 393–Filter Strip, 412–Grassed Waterway. Efficiencies: TN efficiency: 13-46%; varies geographically. TP efficiency: 30-45%; varies geographically."

Land Use Conversion Only BMP is defined as:

> "Enter information if you have a land use conversion BMP, converting to hay, grass, forest, or alternative crop (perennial). If the BMP is in a riparian area, enter it in the appropriate category, buffer, wetland, or streambank restoration, above rather than here."