Center For Agricultural & Natural Resource Policy

RESEARCH BRIEF

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Simulated Trading for Maryland's Nitrogen Loadings in the Chesapeake Bay: A Policy Overlook

Jim Hanson and Ted McConnell looked at whether decreasing nutrients into the Bay could cost less if trading is permitted. Rather than having the sewage treatment plants install new technology (high cost), these sewage plants could pay farmers to plant more cover crops (low cost) to meet the nitrogen loading goals.

PHOTO: VIR VIKRAM SINGH

An excess of nitrogen and phosphorus in water bodies causes eutrophication – i.e. the rapid growth of algal blooms, and the depletion of dissolved oxygen- causing water quality to diminish.

Nutrients, primarily nitrogen and phosphorus, are a leading cause of water quality impairment in lakes, estuaries, rivers, and streams. Though one may at first be inclined to think that an abundance of nutrients can only benefit a given environment, this is not so. In actuality, an excess of nutrients causes eutrophication. Eutrophication is characterized by an influx of biodegradable organic material, the rapid growth of algal blooms, and the depletion of dissolved oxygen. Depletion of dissolved oxygen is a severe threat in waterways because an adequate level of dissolved oxygen is a necessary to sustain life in a healthy aquatic ecosystem. Most aquatic species "breathe" oxygen dissolved in the water column, and while some aquatic life can adapt to low oxygen levels post-eutrophication, most can not. This, in turn, results in a variety of problems, including clogged pipelines, fish kills, and reduced recreational opportunities.

The sources of nutrients can be classified into two different groups:

AT A GLANCE

- An excess of nitrogen and phosphorus in water bodies causes eutrophication. Eutrophication is characterized by an influx of biodegradable organic material, the rapid growth of algal blooms, and the depletion of dissolved oxygen. These then result in clogged pipes, dead fish, and fewer recreational opportunities.
- Point sources of nitrogen and phosphorus are facilities that discharge wastewater containing these nutrients directly into the waterway. Non-point sources discharge nutrients indirectly by rainwater runoff; agriculture can be a cause of non-point nutrient pollution from chemical fertilizers and animal manure.

Glance continued on page 2

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Glance continued from page 1

- In 2002 alone, an estimated 56.7 million pounds of nitrogen flowed into the Chesapeake Bay from all Maryland sources, including agriculture, urban non-point, and sewage treatment plants.
- Maryland's 2005 "Flush Tax" added an additional $7.50 per quarter onto everyone's water bill to fund: 1) upgrading sewage treatment plants to enhanced nutrient reduction (ENR), 2) farmers' incentives to plant winter cover crops; and 3) improvement in septic systems within the critical areas
- Cover crops reduce soil erosion decreasing the rate and quantity of water that drains off agricultural fields. They also retain and recycle soil nitrogen in the soil.
- Nutrient trading between point and non-point sources would employ market mechanisms to address nutrient reduction. In theory, those who can reduce emissions at the lowest cost will do so, and those with higher costs will pay them to do so. Society then achieves pollution reduction at the lowest possible cost.
- Hanson and McConnell estimate that only 16 of the 64 publicly owned sewage treatment plants are upgraded if nutrient trading is permitted. This reduces nitrogen emissions by almost 3 million pounds.

Glance continued on page 3

PHOTO: QIZHONG GUO

The dense algal growth on the stones suggests that the sewage plant's discharge (effluent) is richer in nutrients than society would like. Is it more costly to clean up the sewage plant's discharge or to plant cover crops to decrease nutrients in the streams?

point and non-point sources. Point sources are facilities that discharge wastewater containing nutrients directly into the waterway, whereas non-point sources are facilities that discharge nutrients indirectly by rainwater runoff. Essentially, rain lifts and carries nutrients from the land and the subsequent runoff either travels directly overland to a waterway or sinks down into the groundwater until it eventually reaches a waterway. As nutrients are naturally present in human waste and chemical fertilizers, the greatest point source contributors are sewage treatment plants, industries, and factories. For non-point sources, the greatest contributors are agricultural producers using farm fertilizers and animal manure. Other non-point contributors include lawn fertilizers, septic tanks, discharge from boat toilets, etc.

Nutrient Loadings in the Chesapeake Bay & the Flush Tax

In 2002 alone, an estimated 56.7 million pounds of nitrogen flowed into the Chesapeake Bay from all Maryland sources, including agriculture, urban non-point, and sewage treatment plants. Consequently, nutrient pollution has significantly reduced the size of seagrass beds and lowered concentrations of dissolved oxygen. Seagrass beds not only provide a rich

Nutrient pollution has significantly reduced the size of seagrass beds and lowered concentrations of dissolved oxygen. Seagrass beds not only provide a rich habitat for shellfish and fish nurseries, but also contribute to the prevention of further deterioration in water quality.

PHOTO: QIZHONG GUO

Maryland's 2005 "Flush Tax" added an additional $7.50 per quarter onto everyone's water bill in part to upgrade sewage treatment plants like this one to enhanced nutrient reduction (ENR) technology.

The Flush Tax is expected to reduce nitrogen emissions in the state by 7.5 million pounds, primarily from improvements in sewage treatment plants. However, the question remains, are investments in public sewage treatment plants the most cost effective method of reducing nutrients? Could Maryland reduce nutrient emissions by the same amount for less?

habitat for shellfish and fish nurseries, but also contribute to the prevention of further deterioration in water quality; seagrasses filter nutrients and anchor sediment, stabilizing the bottom and making the water cleaner and clearer. Although seagrasses once covered several hundred thousand acres in the Chesapeake Bay, they now cover only 10 to 20 percent of their historic acreage. In turn, excess nutrients have caused sharp declines in oysters, blue crabs, sturgeon, and flounder. Oyster populations are at one percent of their historic highs of the 1880s, and blue crab populations have fallen approximately 70 percent since the early 1990s.

In an effort to restore the Chesapeake Bay by reducing nutrient flow, Maryland Governor Robert Ehrlich signed the "Flush Tax" into law in May 2004 effective January 1, 2005. The Flush Tax adds an additional $7.50 per quarter onto each resident's water bill. (Homeowners with septic systems pay an annual fee of $30.) The fund has three purposes:

- to upgrade sewage treatment plants from biological nutrient reduction (BNR) to enhanced nutrient reduction (ENR), which further reduces nutrient emissions from sewage;
- to provide farmers incentives to plant winter cover crops; and
- to improve homeowner septic systems that are located in critical areas.

The Flush Tax will raise $72 million annually, $60 million of which will be from users of public sewage systems and $12 million from private users of septic systems. Funds raised from public sewage system users will go towards upgrading the sewage treatment plants, while of the funds raised from private septic system users, 60 percent will go to refitting failing septic systems in critical areas of the state, and the remaining 40 percent to funding agricultural cover crops. Cover crops reduce soil erosion decreasing the rate and quantity of water that drains off agricultural fields. Furthermore, cover crops retain and recycle soil nitrogen already present in soil. Overall, the Flush Tax is expected to reduce nitrogen emissions in the state by 7.5

Glance continued from page 2

Agriculture's 111,419 acres of cover crops achieves the remainder of nutrient reduction (814,661 pounds). For the same level of abatement, the cost was 29% less.

- Cover crop effectiveness in reducing nutrients is tied to planting date. Cover crops planted before October 1 have a 30 percent reduction effectiveness; those planted after have a 15 percent reduction effectiveness
- Increases and decreases in point source nutrient pollution are immediately transformed to corresponding changes in nitrogen levels in the Bay. However, with non-point source nutrient reductions, the impact can take anywhere from days to decades to impact the Bay. Surface water runoff affects Bay nutrient levels sooner. But nitrogen transported by groundwater can take up to 50 years to reach the Bay.
- If trading is on a statewide basis, the Eastern Shore and Western Shore watersheds will actually experience a relative increase in nutrient pollution compared to a no trading scenario.
- Cover crops work well to inexpensively reduce nitrogen pollution, but not so well in reducing phosphorus pollution. Upgrading sewage treatment plants to enhanced nutrient reduction however would decrease both nitrogen and phosphorus pollution.

million pounds, primarily from improvements in sewage treatment plants. However, the question remains, are investments in public sewage treatment plants the most cost effective method of reducing nutrients? Could Maryland reduce nutrient emissions by the same amount for less?

Emissions Trading

Drs. Jim Hanson and Ted McConnell of the University of Maryland investigate nutrient trading for point and non-point sources as an alternative solution. Nutrient trading would employ market mechanisms in addressing pollution control. To administer an emissions trading program, the state places a cap on the amount a pollutant can be emitted. Firms are then issued tradable emission permits which represent the right to emit a certain amount. The total emissions amount of all permits is equivalent to the cap placed by the state. Firms that need to increase their emissions above their permit allowance can buy other permits from those who pollute less than their permit allowance and permit-selling firms must reduce their emissions to that allowed by their remaining permits. This scheme forces polluters to pay for their excess pollution and also rewards firms that reduce their emissions below their allowance. Thus, in theory, those who can easily reduce emissions most cheaply will do so, and society achieves pollution reduction at the lowest possible cost.

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A frequently cited success story, sulfur dioxide (SO_2) has a trading program under the framework of the Acid Rain Program of the 1990 Clean Air Act. Under the program, SO_2 emissions were reduced by 50 percent from 1980 levels by 2007. More importantly, the program reduced the cost of controlling acid rain by as much as 80 percent when compared to the cost of each source reducing their sulfur dioxide emissions to meet a specified cap. The success of this trading program has led to the use of emissions trading in water pollution policy.

Returning to the issue at hand - nutrient pollution control in the Chesapeake Bay – Maryland, as part of the Flush Tax legislation, has set nitrogen and phosphorus caps for each publicly owned (sewage) treatment work (POTW) based on their daily discharges. As mentioned earlier, placing a cap on pollutant emissions is an essential element of any trading system. A POTW that upgrades to enhanced nutrient reduction (ENR) from biological nutrient reduction (BNR) will initially be operating under its nitrogen and phosphorus caps. However, as populations grow, the POTW will inevitably increase its emissions of nitrogen and phosphorus until it eventually reaches its caps. At that point, it would trade with another POTW that is operating under its limits or purchase a permit to offset its emissions. The current limit for all nitrogen emissions from Maryland's 66 POTWs is 9.1 million pounds per year of nitrogen. In 2000, total nitrogen emissions were 16.6 pounds. The total capital cost of upgrading all POTWs to ENR in order to meet the nitrogen emissions cap is almost $741 million – far exceeding the revenues generated by the Flush Tax.

Administered Nutrient Trading among POTWs and Cover Crops

Alternatively, Hanson and McConnell investigate a nutrient trading system to reduce nutrient emissions most effectively using only the revenues generated by the Flush Tax. Their approach allows POTWs, point sources, to trade with farmers, non-point sources, for nutrient credits. This program uses a market system to determine who can reduce their nutrient emissions at the lowest cost. That is, the nitrogen source that can be reduced at the lowest cost is chosen first and so on.

Hanson and McConnell compute marginal nitrogen reduction curves for Maryland and individual regions within the state by using reductions from the cheapest source first, whether POTW or cover crop. They choose to exclude the two largest POTWs, Blue Plains (DC Metropolitan Area) and Black River (Baltimore City), from their reduction calculations as they account for almost 48 percent of all nitrogen emissions, and are too large to trade with the smaller POTWs. In addition, Hanson and McConnell assume these two plants have been upgraded from BNR to ENR. Therefore, any gains from trading will be seen with the remaining 64 POTWs. The total reduction target is set equal to the amount of reduction that would be achieved by the POTWs if they

Table 1

Efficient Allocation of Nitrogen Reduction between Point Source and Cover Crops When Traded on a Statewide Basis

	Flush Tax	Efficient Combination			Percent of Total
	Point Source	Point Source	Cover Crops	Total	
No. of Units	64 POTWs	16 POTWs	111,419 ac	—	—
Abatement (lbs)	3,763,387	2,948,726	814,661	3,763,387	100%
Capital Cost ($)	$263,742,760	$136,600,000	$49,951,337	$186,551,337	71%

Note: Cover crops are calculated at $30/acre and 30 percent reduction efficiency.

all upgraded to ENR. That is, if there were no trading system and all 64 POTWs were upgraded to ENR, nitrogen emissions would be reduced by 3.8 million pounds.

Under statewide trading of nitrogen permits, only 16 of the 64 POTWs are upgraded and this reduces nitrogen emissions by almost 3 million pounds. The remainder of the reduction (814,661 pounds) is achieved by planting 111,419 acres of cover crops. In terms of percentages, 78 percent of nitrogen is abated from point sources and 22 percent is abated by cover crops. More importantly, instead of spending $263 million on 64 POTWs, only $136,000,000 is spent on 16 POTWs. The cost of planting cover crops is less than $50 million, and therefore, the total cost comes to $187 million. This figure is 71 percent of the allocated amount from the Flush Tax legislation, saving over $77 million.

Hanson and McConnell also limit trading to within each of the four different watersheds of the state: Eastern Shore, Potomac, Western Shore, and Patuxent. The goal remains the same – 3.8 million pounds of nitrogen reduction - but unlike trading within the entire state, POTWs can only buy permits from farmers within their respective watershed. The differences among watersheds are dramatic and illustrate the geographic and demographic diversity of Maryland.

The POTWs of the Eastern Shore and Potomac watersheds have lower average abatement per POTW.

PHOTO: RONALD DAVID MYERS

Farmers who plant rye as a cover crop receive a higher payment. Abruzzi is a giant or tetraploid cultivar of rye, capable of growing two feet taller than a standard cereal rye variety.

They also have more acreage available for planting cover crops, thus, there is a greater potential for nitrogen reduction from the use of cover crops than from upgrading POTWs from BNR to ENR. In fact, it is feasible to plant almost one million acres of cover crops in these two watersheds. Hanson and McConnell find that under an administered nutrient trading scheme for the Eastern Shore watershed only one of 19 POTWs is upgraded, and 76 percent of its abatement goal is met by planting cover crops. For the Potomac watershed, six of 23 POTWs are upgraded and 25 percent of its abatement

Table 2

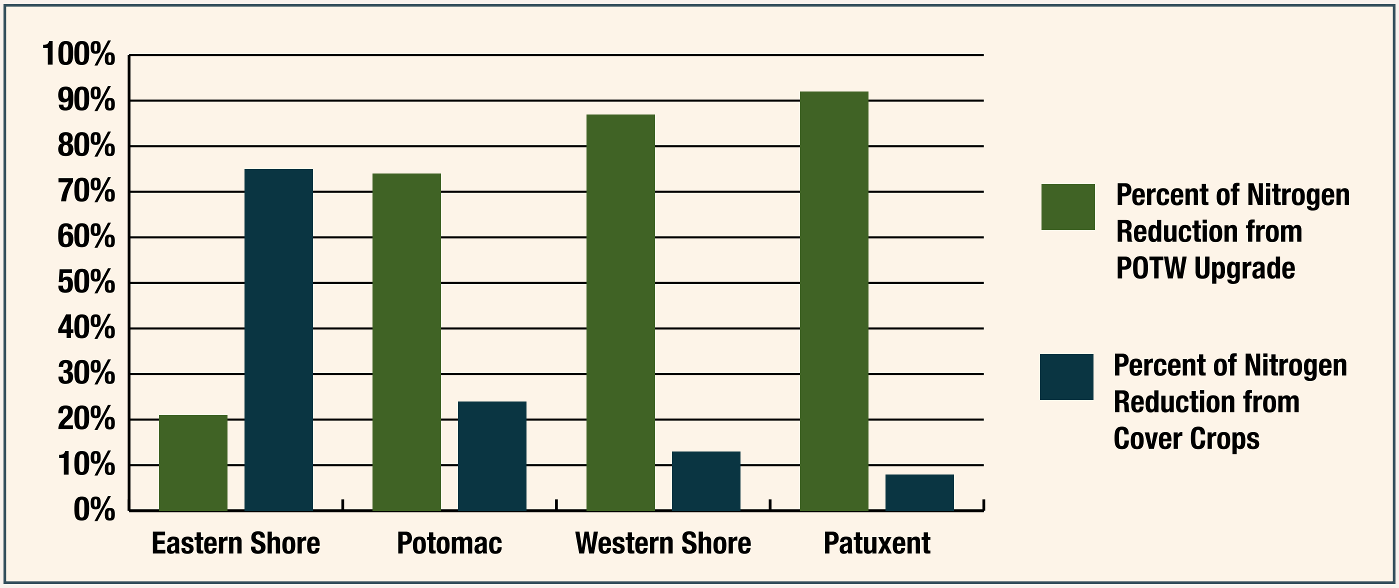
Efficient Allocation of Nitrogen Reduction between Point Source and Cover Crops When Traded on a Watershed Basis

Watersheds	Flush Tax	Efficient Combination			Percent of Total
	Point Source	Point Source	Cover Crops	Total	
Eastern Shore					
No. of Units	64 POTWs	16 POTWs	111,419 ac	—	—
Abatement (lbs)	3,763,387	2,948,726	814,661	3,763,387	100%
Capital Cost ($)	$263,742,760	$136,600,000	$49,951,337	$186,551,337	71%
Potomac					
No. of Units	23 POTWS	6 POTWs	43,597 ac	—	—
Abatement (lbs)	1,248,726	936,273	312,453	1,248,726	100%
Capital Cost ($)	$68,033,645	$24,000,000	$19,545,634	$43,545,634	64%
Western Shore					
No. of Units	15 POTWs	5 POTWs	28,449 ac	—	—
Abatement (lbs)	1,472,377	1,274,426	197,951	1,472,377	100%
Capital Cost ($)	$104,999,020	$78,000,000	$12,754,283	$90,754,283	86%
Patuxent					
No. of Units	7 POTWs	4 POTWs	7,740 ac	—	—
Abatement (lbs)	719,476	659,853	59,623	719,476	100%
Capital Cost ($)	$39,599,020	$29,600,000	$3,470,291	$33,070,291	84%
Sum of Watersheds					
No. of Units	64 POTWs	16 POTWs	113,201 ac	—	—
Abatement (lbs)	3,763,387	2,948,726	814,661	3,763,387	100%
Capital Cost ($)	$263,742,760	$136,600,000	$50,751,097	$187,351,097	71%

Note: Cover crops are calculated at $30/acre and 30 percent reduction efficiency.

Figure 1:

Percent Comparison of Efficient Nitrogen Reduction between Point Source and Cover Crops When Traded on a Watershed Basis



goal is met by planting cover crops. The cost savings for these two watersheds are significant and impressive. One hundred percent of the abatement goals for the Eastern Shore and Potomac watersheds can be met at only 39 percent and 64 percent of the costs, respectively.

The POTWs of the Western Shore and Patuxent drain into more urban watersheds. In these watersheds, there is a greater potential for nitrogen reduction from upgrading POTWs from BNR to ENR than from planting cover crops. Unlike the Eastern Shore and Potomac watershed, in the Western Shore and Patuxent watersheds it is only possible to plant 200,000 acres of cover crops. Therefore, under an administered nutrient trading scheme, five of 15 POTWs are upgraded in the Western Shore watershed to meet 87 percent of its abatement goal and four of seven POTWs are upgraded in the Patuxent watershed to meet 92 percent of its goal. As these watersheds are more urban, the cost savings are not as large as those in the Eastern Shore and Potomac watersheds. Nonetheless, 100 percent of the abatement goals for the Western Shore and Patuxent watersheds can be met at 86 percent and 84 percent of costs, respectively.

Whether trading is allowed across the state or restricted within the four watersheds, the costs savings are the same – both meet the abatement goal at 71 percent of the cost of requiring all POTWs to upgrade from BNR to ENR.

Further Considerations

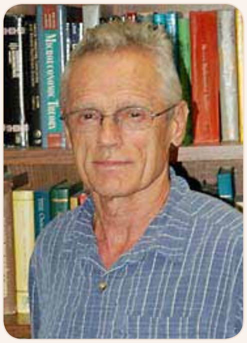
An administered nutrient trading program such as the one considered here demonstrates the potential savings available from capitalizing on the differences in nitrogen reduction costs. However, several issues must be fully considered in the implementation of an administered trading scheme.

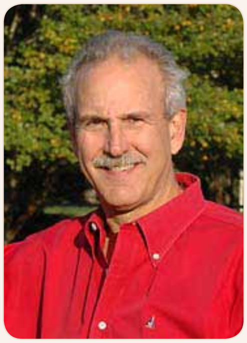
First, in the figures presented above, Hanson and McConnell assumed that the cost of subsidies to farmers to plant cover crops was $30 per acre and that the cover crops effectively reduced nitrogen runoff by 30 percent. However, cover crop effectiveness is often tied to planting date. Cover crops planted before October 1 have a 30 percent reduction effectiveness and those planted after have a 15 percent reduction effectiveness. Therefore, the relative attractiveness of cover crops versus upgrades of POTWs largely depends on when cover crops are planted. If cover crops are planted after October 1, the most efficient outcome is 32 of 64 POTWs are upgraded and 89,763 acres of cover crops are planted, with savings of 17 percent.

Second, the cost of nitrogen emission reduction from cover crops has been computed on the assumption that cover crop plantings result in reductions in loadings as rapidly as POTWs. Yet one of the biggest differences between point and non-point source emissions is the lag between changes in nutrient emission reductions and changes in nutrient loadings to the Bay. Whereas increases and decreases in point source emissions are immediately transformed to corresponding changes in nitrogen levels in the Bay, non-point source nutrient reductions can take anywhere from days to decades to impact the Bay. When nitrogen is part of surface water runoff, the lag time can be quite short. But if nitrogen is transported by groundwater, it may take up to 50 years to reach the Bay.

Third, while total cost savings for the state of Maryland are the same whether trading statewide or within a watershed, trading in a larger region enhances the potential for "hot spots", i.e. smaller areas may experience an increase in nitrogen pollution. In fact, if trading on a statewide basis, the Eastern Shore and Western Shore watersheds will actually experience a relative increase in nitrogen pollution compared to what would have occurred with the Flush Tax. The problem can be remedied, however, by trading on a watershed basis. But this could lead to inequities among tributaries, and if trading occurred within tributaries to alleviate these inequalities, then individual cities or counties could complain about their POTW not being upgraded.

Fourth, and lastly, when the goal is to maximize nitrogen reduction given the funding from the Flush Tax, phosphorus reductions suffer. Phosphorus loadings must not be overlooked as they also contribute to the eutrophication of the Bay. Therefore, one of the advantages


Dr. Ted McConnell


Dr. Jim Hanson

of upgrading from BNR to ENR is that systems can be designed to reduce emissions of several nutrients at once. Cover crops, however, work well to inexpensively reduce nitrogen pollution, but not so well in reducing phosphorus pollution. If all POTWs were upgraded, as legislated under the Flush Tax, phosphorus reductions would be abated by 658,593 pounds. Whereas under the statewide administered trading scheme considered here, the amount of phosphorus reduced would be only 533,200 pounds.

Conclusion

Hanson and McConnell present compelling evidence that under an administered trading system, where the state selects the least cost abatement source first and so on, Bay water quality can be improved at a lesser cost than the legislation currently administered under the Flush Tax. Therefore, this scheme has the potential to restore the Chesapeake Bay to the same level as proposed by the Flush Tax while reducing the tax imposed on Maryland residents. ■

For more information about this research, contact Jim Hanson at ***(301)405-8122*** *or Ted McConnell at* ***(301)405-1282.***

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