OECD WORKSHOP ON AGRICULTURE AND WATER: SUSTAINABILITY, MARKETS AND POLICIES

14-18 November, 2005:

- **14-16 November – Adelaide Convention Centre, North Terrace, Adelaide, South Australia**
- **17-18 November – Barmera, South Australia**

SESSION N°2

Nutrient Trading – A Water Quality Solution?

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Abstract
The over-enrichment of rivers and estuaries by excessive levels of nutrients, such as nitrogen and phosphorus, is a persistent and growing water quality problem around the world. Even though there have been significant improvements in water quality, most of these improvements have resulted from regulating point sources- industrial and municipal wastewater treatment facilities; today the predominant source of nutrients is non-point sources, especially agricultural and urban runoff.

Innovative solutions are needed to provide incentives for non-point sources, whose nutrient discharges are difficult to regulate, to reduce their nutrient contributions. One such solution is nutrient trading. Trading involves setting a goal for the total amount of nutrients entering streams and rivers within a watershed and allowing sources, both point and non-point, to trade nutrient reduction credits in order to meet the local and regional water quality goals.

Nutrient trading is being explored and implemented as a viable mechanism to reduce nutrient pollution in a number of areas in the US and internationally. To facilitate the establishment of these markets, we have developed an on-line marketplace, *NutrientNet*, for point and non-point sources to estimate their nutrient loads and achievable reductions, provide a marketplace for trades to occur and a registry that allows trades to be tracked.

Keywords: nutrient trading, cost-effective, policy, performance-based instruments, water quality, agriculture.

Setting the Scene

Water quality is rapidly becoming one of the most pressing environmental concerns facing many parts of the world today. In the U.S. alone 39 percent of assessed U.S. rivers and streams, 45 percent of assessed lakes, reservoirs and ponds, and 51 percent of assessed estuaries were threatened or impaired for their designated uses in 2000 (USEPA, 2002).

Nutrient over-enrichment—one of the leading causes of water quality impairments in the U.S.—has led to the eutrophication of many of the nation’s rivers and streams, and to the formation of hypoxic zones in the Gulf of Mexico and the Chesapeake Bay. A majority of these nutrients come from non-point sources, principally agricultural sources. Approximately 82 percent of the nitrogen and 84 percent of the phosphorous in U.S. lakes, rivers and estuaries come from non-point sources (Carpenter et al., 1998). The nutrient pollution from non-point sources, such as agricultural or urban runoff, is typically diffuse in nature. Its precise origin cannot be identified, and because of this, non-point sources are frequently not regulated. The other source of nutrients is point sources, such as wastewater treatment facilities. Point source pollutants can be pinpointed to a specific source of origin, e.g., discharge from a pipe into a waterbody, and therefore are typically regulated.

This paper takes a closer look at policy instruments to improve water quality, comparing the traditional command-and-control approaches to the more innovative performance-based instruments. Given the apparent cost-effectiveness of performance-based instruments, it goes on to outline some of the challenges and issues with establishing successful nutrient trading programs, one type of performance-based instrument. Finally, the paper describes an on-line marketplace, *NutrientNet*, which we have developed to facilitate the implementation of these programs. The paper also recognizes some of the significant synergies between the efforts undertaken to reduce nutrient losses and a number of other environmental problems, such as climate change and soil erosion, highlighting the need to start addressing environmental problems more holistically.

Policy Approaches for Improving Water Quality

There are a number of policy instruments that can be used to address environmental problems—traditional policy instruments such as regulations, and taxes and subsides, and the more innovative performance-based instruments. All of these instruments can be applied directly or indirectly to water quality concerns.

Traditional policy instruments

Regulations

One popular policy instrument for addressing water quality problems (as well as many other environmental problems) is the use of regulations, also referred to as a command-and-control approach. Regulations are typically technology-based or performance-based standards aimed at point sources such as wastewater treatment and industrial facilities. Non-point source pollution—whose source is more difficult to identify than point-source discharges—cannot be as easily controlled through regulation.

Technology-based standards specify the type of equipment or processes that each facility needs to adopt to meet a water quality target, while a performance standard specifies a target and gives facilities greater flexibility in how they meet that target. This is often seen as regulatory limits placed on pollutant discharge into waterways (e.g., USEPA NPDES program[1]).

Even though this regulatory approach achieves initial success in improving water quality, it does place heavy financial burdens on facilities to continually upgrade their equipment, and regulators to keep abreast of new technological advances, and provides little opportunity or incentive for facilities to be innovative.

In the U.S., between 1974 and 1994, local governments and the federal construction grants program spent approximately $213 billion for the construction or upgrades of municipal wastewater treatment facilities to control point-source pollution. During the next 20 years, it was anticipated that an additional $330 billion would likely be required to construct new plants and replace aging facilities to meet the water

[1] The National Pollution Discharge Elimination System (NPDES) program of the U.S. Environmental Protection Agency (USEPA) sets specific pollutant discharge limits for all point sources discharging into U.S. waters. The program was developed in 1974 and has been expanded to include dischargers such as large concentrated animal feeding operations (CAFOs), municipal wastewater treatment facilities, and commercial and industrial facilities.

quality levels and treatment demands of a growing U.S. population using this policy approach (Association of Metropolitan Sewage Agencies and the Water Environment Federation, 1999).

Taxes and subsidies

Another set of policy instruments used to address pollution includes taxes and subsidies. Taxes place a penalty on polluters, providing the 'stick' in the carrot and stick analogy, while subsidies are the 'carrot', providing incentives (usually financial) for polluters to reduce their discharges. These instruments are often used to provide incentives for non-point sources of pollution. In the U.S., taxes are rarely used in the agricultural sector to change behaviour while in some OECD countries taxes have been more widely used; especially where pollution sources can be tied to inputs, such as fertilizers and pesticides, in the production process. Fertilizer taxes have been introduced in Finland, Norway, and Sweden with this tax revenue frequently earmarked for various environmental uses. Sweden, for instance, uses its fertilizer and pesticide tax to finance environmental research and improvements (O'Riordan, 1997).

Subsidies are common instruments used to provide incentives to implement agricultural best management practices (BMPs) aimed at providing environmental benefits. In the U.S., some examples include the Conservation Reserve Program—which pays farmers to take agricultural land out of production—and subsidies to increase the use of conservation tillage practices on cropland; both are aimed at reducing soil loss from agricultural land. Subsidies target a prescribed set of practices, rather than allowing farmers to choose the most effective way for them to address the specific problem at hand.

Performance-based policy instruments

Performance-based policy instruments target an environmental outcome rather than the sources of pollution and are frequently market-based, i.e., kilograms of nutrient pollution reduced is the commodity of interest, not the implementation of a BMP that results in a reduction in nutrient losses. Two performance-based mechanisms that can be applied to improve water quality are nutrient trading and reverse auctions.

Nutrient trading

Nutrient trading is an example of a performance-based instrument that is gaining popularity as a mechanism to cost-effectively meet water quality goals. Nutrient trading is premised on the fact that compliance costs differ between individual industrial and wastewater treatment facilities depending upon their size, scale, age, and overall efficiency. This means that the cost of meeting a water quality standard (or regulation) may be less for one facility than for another. Trading between point sources provides an opportunity for those facilities whose costs are lower to make additional reductions beyond their obligation, and sell these additional reductions to facilities whose costs are higher.

Similarly, trading can also occur between point sources and non-point sources. Point sources with high compliance costs can purchase nutrient reduction credits from non-point sources, whose nutrient reduction costs are much lower. There are many instances where point source facilities are controlled by regulatory discharge permits (e.g., USEPA NPDES program), while non-point sources are often not controlled by regulatory limits. Trading gives both point sources and non-point sources the flexibility of achieving an environmental target using the most cost-effective option available to them. There are a number of nutrient trading programs currently in operation in North America. The Long Island Sound trading program administered by the Connecticut Department of Environmental Protection, for example, addresses the problem of low oxygen levels in Long Island Sound by trading nitrogen credits between point sources, which are the main cause of excessive nitrogen levels in the Sound. The South Nation watershed in Ontario, Canada also has a trading program in operation that targets phosphorus discharged from both point and non-point sources.

Reverse auctions
Reverse auctions are another example of performance-based policy instruments. They are competitive bidding systems where sellers compete to supply buyers with a specified good or service, enabling buyers to locate the most competitive sellers. The key difference between reverse auctions and conventional auctions is that in reverse auctions sellers bid to sell goods and services at lower prices than their competitors, whereas in a conventional auction buyers compete with each other to purchase goods and services from sellers. Thus, in a reverse auction sellers bid prices down while in a conventional auction buyers bid prices up. Reverse auctions are used in a variety of markets and are particularly suited to markets with multiple sellers and only a single buyer. The reverse auction concept has been used in the Conestoga watershed in Pennsylvania, U.S. to purchase phosphorus reductions from farmers. In this instance, an environmental organization with funding from the U.S. Department of Agriculture (USDA) acted as the buyer for these reductions.

How Do Performance-Based Mechanisms Compare?

The World Resources Institute has undertaken two analyses to compare a variety of policy instruments for improving water quality—one addresses the hypoxic zone in the Gulf of Mexico and the other looking at phosphorus reductions in three watersheds in the Upper Midwest of the U.S.

Analysis of nitrogen water quality impairments

A 2003 study by WRI (Greenhalgh and Sauer, 2003) assessed a variety of agricultural policy options to mitigate the hypoxic—oxygen depleted—zone in the Gulf of Mexico and found that nutrient trading was the most cost-effective solution. The hypoxic zone results from excessive amounts of nitrogen entering the Gulf of Mexico from the Mississippi River (Goolsby et al., 1999). By the summer of 2002 the hypoxic zone, which has been consistently monitored since 1985, reached a height of 22,000 km2 or 8,500 square miles in size (Rabalais et al., 1999; Dunne, 2002; LUMCON, 2002), A majority of the nitrogen in the Mississippi River Basin comes from agricultural non-point sources,[2] prompting us to explore several agricultural policy options as a mitigation strategy.

This study compared policy options that directly affected nitrogen losses in the Mississippi River Basin, as well as a number of options that focused on other environmental problems such as soil loss, phosphorus runoff and climate change. By comparing a wide range of policies and their impacts, we were able to look more broadly at the environmental benefits of the various options.

[2] 50% of nitrogen reaching the Gulf of Mexico comes from fertilizer and soil organic nitrogen; 24% from atmospheric deposition, groundwater discharge and soil erosion; 15% from animal wastes; and 11% from municipal and industrial facilities (Goolsby et al., 1999).

The policy options assessed included:

- Taxing nitrogen fertilizer applications,
- Subsidizing a change to conservation tillage practices,
- Extending Conservation Reserve Program (CRP) acreage,
- Trading greenhouse gas (GHG) reductions at both $5/t carbon and $14/t carbon,
- Trading nitrogen reductions to meet either a 3 or 8 mg/l/day N discharge limit[3] for wastewater treatment facilities,
- Trading phosphorus reductions to meet either 1 or <1 mg/l/day P discharge limit[4] for wastewater treatment facilities, and
- Trading nitrogen reductions (to meet 3mg/l/day N discharge limit for wastewater treatment facilities) with an additional payment for the associated GHG reductions achieved with any implemented BMP.

These policies were evaluated using an agro-environmental model of U.S. agriculture, the U.S. Regional Agricultural Sector Model (USMP). This model was developed and is maintained by the U.S. Department of Agriculture/Economic Research Service (USDA/ERS). WRI has worked with USDA/ERS to improve the spatial delineation of USMP, increase the diversity of cropping rotations included in the model, and simulate the environmental impacts of various cropping production practices and the Conservation Reserve Program.

Only a short synopsis of the results of this study is outlined in this paper. A more detailed explanation of the findings and recommendations of this study and description of the model used can be found in Greenhalgh and Sauer (2003).

Taking a broader look at the environmental impacts of the various policy options, nutrient trading performed better than the other options assessed (Figures 1a through 1f). Nutrient trading provided the largest decreases in nitrogen reaching the Gulf of Mexico and the greatest improvements in farm income. In addition, nutrient trading demonstrated improvements in local water quality as well as reductions in GHG emissions and soil losses. Other policy options performed well for some environmental parameters but not for others. For instance, conservation tillage subsidies gave the largest reductions in soil loss and reasonable reductions in nitrogen delivered to the Gulf of Mexico, but resulted in decreases in farm income. This decrease comes from an increase in farm acreage which led to increased crop production, and a subsequent decline in crop prices.

The other important aspect of assessing different policy options is how cost-effective they are at meeting the goal of interest, in this case reducing the amount of nitrogen reaching the Gulf of Mexico from the Mississippi River Basin. In other words, which policy gives the 'biggest bang for your buck.' The lowest-cost mechanisms in our study were the performance-based options, such as nutrient and GHG trading (Figure 2). However, the most cost-effective solutions were the options based on nutrient trading, which achieved large reductions in the amount of nitrogen delivered to the Gulf of Mexico at low prices.

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[3] These discharge limits are based on the limits the Chesapeake Bay are discussing to deal with their nitrogen pollution problem.

[4] The 1 mg/l/day discharge limit represents a transition point in technology and capital expenditure for phosphorus removal.

Our conclusion at the end of this study was that nutrient trading was indeed a worthwhile policy solution for helping meet water quality targets, and for providing other environmental benefits.

Analysis of phosphorous water quality impairments

Similarly, in an analysis of policy options to improve phosphorous impaired waters in Wisconsin, Michigan and Minnesota, performance-based mechanisms were the most cost-effective (Faeth, 2000).

This study tested four policy options:

- A point source performance standard where point sources had to meet more stringent regulatory requirements
- Conventional agricultural subsidies for mulch tillage, no-till and nutrient management
- A point source performance requirement coupled with trading which allowed point sources to trade with other point and non-point sources to meet the new regulatory requirement.
- A trading program coupled with performance-based conservation subsidies where point sources and non-point sources shared the nutrient reduction obligations, and non-point sources were allowed to meet their obligation using their least-cost option rather than the adoption of a particular BMP.

In all three watersheds, tightening the point source regulatory requirements was the most expensive option, and a trading program coupled with performance-based conservation subsidies was the least-cost option (Table 1).

Table 1. Cost of phosphorus control under different policy options

U.S. $/pound P removed / Case Study Watersheds	Point Source Performance Standard	Conventional agricultural Subsidies	Point Source Performance Standard with Trading	Trading Program with performance-Based Conservation Subsidies	Least-Cost Solution
Minnesota River, Minnesota	19.57	16.29	6.84	4.45	4.36
Saginaw Bay, Michigan	23.89	5.76	4.04	2.90	1.75
Rock River, Wisconsin	10.38	9.53	5.95	3.82	3.22

Source: Faeth, 2000.

Giving point sources the flexibility to meet their performance requirements by either upgrading their facilities or by trading with other point sources or non-point sources considerably lowers the cost of meeting regulatory requirements. Figure 3 illustrates the costs associated with achieving different levels of phosphorous reductions for the Michigan case study.

Challenges to Implementing Nutrient Trading

Based on the comparative assessment of various policy options for improving water quality, nutrient trading emerged as the most cost-effective solution. However, while the concept of water quality trading has found favour with many in the environmental, agricultural and policymaking communities, the application of water quality trading has achieved only limited success in the few watersheds where it has been applied. Water quality trading faces some unique challenges given that it includes both regulated and unregulated sources, must address nutrient fate and transport, and must be able to quantify reductions from non-point sources that are not directly measurable. Outlined below are some of the challenges and issues that face organisations or government agencies in implementing nutrient trading programs.

Establishing the rules

There are a number of issues that need to be considered when establishing the rules of a trading program. Some of these issues are briefly discussed below.

Market design

The design of the market for trading programs is important for establishing who can trade, how the trading mechanism would work, and the rules that would sanction a trade. Trading programs can be designed in a number of different ways including:

- Traditional market structures where individual regulated sources (e.g., point sources) can purchase credits from non-regulated (e.g., many non-point sources) or other regulated sources to meet their compliance obligations. The Dillon Reservoir and Cherry Creek trading programs in Colorado, U.S. are examples of these markets.
- A market where an aggregate cap is established for regulated sources and trading with sources outside of the cap is allowed for compliance purposes. The Tar-Pamlico and Long Island Sound trading programs in the U.S. are characterized as being this type of market structure.
- Using a bank to aggregate credits from non-regulated sources. Reductions from non-regulated sources are often small compared to the reductions needed by the regulated sources. A bank can serve three roles—to bundle credits into larger trading lots, potentially reduce the liability for these small sources (see liability discussion below), and to help stimulate markets that are not yet fully functioning. This structure is being discussed widely in the U.S. as a way to more successfully incorporate non-point agricultural sources into these trading markets. The South Nation trading program in Ontario, Canada is structured similar to a bank model. Regulated dischargers purchase phosphorous reduction credits from South Nation Conservation (SNC), a community-based watershed organization. In turn, the SNC uses this money to pay farmers to reduce phosphorus through implementation of BMPs.

Ensuring fungibility

Because non-point source nutrient reductions are difficult to measure and quantify, there is real concern in any nutrient trading program about the fungibility of credits: how does a trading program quantify non-point source reductions and ensure that a credit from a non-point source is equal to that of a point source?

Most of these fungibility concerns are addressed through the use of discount factors. For instance,

1) The uncertainties involved with non-point source reductions can be addressed through the establishment of sound and consistent estimation tools. Using the same method to calculate all non-point source reductions will ensure that they are all comparable (see NutrientNet discussion below). Uncertainties within the estimation method itself can then be addressed through the application of trading ratios. Trading ratios are discount factors related to the uncertainty associated with the actual measurement of reductions, e.g., the uncertainty associated with the effectiveness of an agricultural BMP in achieving nutrient reductions. Applying a 2:1 trading ratio means that a point source whose nutrient discharge is known with certainty has to purchase two units of nutrient reduction from a non-point source whose actual achieved reduction is more uncertain for every unit of reduction they require.
2) Another factor with credit fungibility is the variability in nutrient fate and transport depending on the location of the source within the basin. Nutrient trading programs can be designed to address the variability in nutrient delivery by using location-specific attenuation factors or spatial delivery ratios. For non-point sources this means estimating the delivery of nutrients from the source to the stream as well as the attenuation of the nutrient from where it enters the stream to the point of interest within the watershed. Spatial delivery ratios are frequently determined from existing bio-physical models. For instance, the Revised Soil Loss Equation (RUSLE) (Renard et al., 1991) estimates nutrient loss to the edge of a farm field for sediment-bound phosphorus. Other models, e.g., SEDMOD (Fraser et al., 1996), can then be used to assess how much of the sediment-bound phosphorus reaches the nearest water body. Similarly, nitrogen models such as the Chesapeake Bay Model (Cerco et al., 2002) provide estimates for both the attenuation of nitrogen within river segments and from various river segments to different points of interest within a watershed.
3) Some nutrient trading programs allow trading between pollutants. An equivalence ratio, which refers to how much of one pollutant should be reduced compared to another, can be used in these situations. For example, in Minnesota a trading permit requires eight units of phosphorus to be reduced for every unit of BOD discharged.

Establishing baselines

Baselines are important for ensuring the integrity of nutrient trading programs. Similar to the concept of ‘additionality’ in the GHG trading world, baselines are established to prohibit unregulated sources from selling reductions from management practices that are already required or have already been implemented. To avoid the difficulties associated with operationalising the concept of additionality in the GHG world, baselines should be set by the trading program. In many instances, non-point source baselines are a minimum set of baseline practices, e.g., a nutrient management plan, which must be in place before the non-point source can generate reductions to sell. Establishing a required set of baseline practices for non-point sources ensures that “bad actors” are not rewarded for their ability to generate low-cost reductions by implementing basic good steward practices that should have been implemented in the first place. Baselines for point sources are typically straightforward as they usually have permitted nutrient discharge limits that can form the baseline.

Who holds compliance liability

Liability issues—who holds liability and how liability is determined—often pose significant challenges to the implementation of nutrient trading programs. Liability for credit malfeasance could potentially rest with either the buyer or the seller of credits. What frequently occurs with buyer liability is that it fails to foster market development. If a buyer cannot be assured that the purchased credits are viable reductions, it is difficult for the buyer to effectively manage the cost of their exposure, making them more unlikely to participate in a trading program. Therefore, seller liability is often an important element to achieving well-functioning environmental commodity markets. Small sources wishing to sell reductions, however, may find this a deterrent to participating in nutrient trading markets.

One approach to addressing liability issues is using a bank to aggregate non-point source credits. Credit buyers purchase credits from the bank, who in turn guarantee the creditworthiness of the credit. The bank is responsible for ensuring that non-point sources comply with their contracts and providing the agreed-upon reductions. The bank may also keep a ‘credit reserve’ to mitigate any risk of non-point sources failing to implement a BMP or when a BMP fails to function properly.

Stakeholder engagement

One of the often overlooked components of nutrient trading programs is stakeholder engagement during the establishment phase. As there is still some skepticism surrounding nutrient trading programs, this raises the importance of including stakeholders in the formation and rule discussions of these programs. Early stakeholder engagement will help create trust between potential buyers and sellers, and the administrators of the trading program; and help promote an active trading program.

Providing the infrastructure

A successful water quality trading program needs to provide the appropriate infrastructure. Some basic infrastructure elements for water quality trading programs include:

1) An administrative agency (or agencies) to manage the program, certify reductions and trades, and monitor compliance. A water quality trading program which involves unregulated agricultural non-point sources may face several logistical and administrative hurdles that can be mitigated by working closely with the agricultural community and agricultural agencies to ensure program support.
2) A trading registry to track the nutrient reductions and trades, and facilitate compliance monitoring. A registry is simply a database that stores information on the entities which generate and use credits.
3) A forum where buyers and sellers can meet. Many point and non-point source trades have involved a single point source locating non-point sources such as farmers one by one and negotiating individual contracts with each farmer to provide a specified number of nutrient reductions. For example, the Southern Minnesota Beet Sugar Cooperative contracted with over 100 farmers to purchase phosphorous reductions to allow them to expand their capacity and still meet their phosphorous discharge limit. This process can be significantly streamlined through the establishment of a central marketplace that allows buyers to easily identify sellers and vice-versa.

Evaluating success

Monitoring is an important component of any nutrient trading program and is used to assess the success of the program. Regulated sources typically have some form of monitoring already in place as monitoring is required to prove regulatory compliance. However, unregulated sources, commonly non-point sources, do not have any monitoring requirements. As a proxy for the direct monitoring of non-point source nutrient losses, the BMPs implemented to reduce nutrient losses can be monitored to ensure they are installed and properly functioning. Similarly, water quality at the watershed level should also be monitored to determine whether the watershed's water quality goal is being attained. As there is typically a lag time between program implementation and any improvement in water quality, this should be a long-term commitment. In many trading programs, watershed monitoring is often only cursory and ensuring BMP implementation is frequently left to the buyers of the associated nutrient reductions.

***NutrientNet*: Providing a Trading Infrastructure and Facilitating Implementation**

Recognizing that nutrient trading had the potential to play a significant role in meeting U.S. water quality goals, WRI and partners from the Michigan Department of Environmental Quality started to think about how to efficiently implement these markets. Furthermore, we recognized that nutrient trading faced a number of obstacles that made its widespread implementation complicated, including high transaction costs, initially thin markets, and no actual marketplace for trades to occur.

Our solution was to develop an on-line marketplace, *NutrientNet* (www.nutrientnet.org), to overcome these obstacles. There are two prototype versions of *NutrientNet* currently available—one for phosphorus in the Kalamazoo watershed in Michigan and the other for nitrogen in the Potomac watershed in the Chesapeake Bay. In addition there are three other sites currently under development:

- A point-point source trading market for nitrogen in the Susquehanna watershed, Pennsylvania
- A reserve auction pilot program in the Conestoga watershed in Pennsylvania
- An updated Kalamazoo watershed market with improved BMP estimation algorithms for nutrient losses.

The *NutrientNet* site comprises two key components:

1) Standardized tools for estimating point and non-point source nutrient contributions to surface waters, exploring nutrient reduction options, and estimating the cost of achieving reductions.

NutrientNet currently incorporates on-line calculation tools that enable farmers and wastewater treatment facility managers to estimate nutrient loads from their operations and the cost of reducing nutrient loads through various mitigation options. The rules for converting reductions into tradable credits are also incorporated into the calculation tools. This includes the discount factors used to ensure fungibility, such as trading ratios, spatial delivery ratios, equivalence ratios and retirement ratios.

The *NutrientNet* estimation tool utilizes a Geographical Information System (GIS) interface that allows the users to identify the geographical location of their operation. The GIS interface retrieves the relevant information for each type of discharge from a geographic database to estimate phosphorus and nitrogen loads. The types of GIS information used include aerial photographs delineating roads, streams and landuses, distance to streams, topography and soil type.

In addition to the geographical data, *NutrientNet* requires specific information relevant to each operation to estimate nutrient loads. For point sources users provide information about their specific facility, such as current flow rates, nutrient concentration and regulatory nutrient discharge limits. Using the total annual permitted load as a baseline, *NutrientNet* calculates the total credits needed for compliance (for those who exceed their regulatory limit), or the total credits generated (for those who are under their regulatory limit). Generated credits are calculated by subtracting the actual load from the baseline limit and applying the appropriate attenuation factor or spatial delivery ratio.

For non-point sources, users provide information on their location, field area and physical characteristics (e.g., slope), phosphorus content in the soil (when calculating phosphorus reductions), current and previous crops, current tillage practices, and currently installed BMPs. With this information plus the underlying GIS information, *NutrientNet* estimates phosphorus or nitrogen loads based on a series of algorithms.[5] *NutrientNet* provides users with nutrient loads from their particular farm, the effectiveness of various mitigation options available to reduce nutrient losses, the cost of implementing these options on their farm, and number of credits available to sell (based on the rules of the nutrient trading program).

2) A marketplace where potential trading partners can meet and enact trades.

NutrientNet's market section provides a virtual marketplace for users to contact buyers or sellers and post their offers. Information about who is selling or buying credits is listed, as well as a means for potential traders to contact each other.

NutrientNet can also be modified to accommodate a reverse auction. For example, in the Conestoga watershed of Pennsylvania, *NutrientNet* was used to conduct a reverse auction for farmers in Lancaster County. Farmers used *NutrientNet*'s online estimation tool to estimate their phosphorous reductions associated with implementing certain BMPs. The farmer then bid a price he was willing to accept to implement a specific BMP. The market section of *NutrientNet* was modified to rank farmer's bids from most cost-effective to the least cost-effective in terms of dollars per unit of phosphorous reduced (instead of ranking bids based on total BMP implementation cost). A purchasing committee reviewed bids on-line, issuing contracts to the lowest bidders until the earmarked money was exhausted.

One unique advantage to an online estimation tool and marketplace is the ability for such a system to interface with a trading registry. A tool like *NutrientNet* can allow for the automated update of a registry with records of credit generation and credit purchases. Once a user has estimated their nutrient reductions, they may submit a notice to the registry electronically where it would be reviewed and approved by the

[5] Phosphorus losses are calculated using the Revised Universal Soil Loss Equation (RUSLE) to estimate losses to the edge of the field (Renard et al., 1991) and the Spatially Explicit Delivery Model (SEDMOD) to estimate how much is delivered to the stream (Fraser et al., 1996). Nitrogen losses (for the Chesapeake Bay) are calculated using the Nutrient Management Yardstick to estimate losses to the edge of the field (IATP, 1999) and the U.S.EPA Chesapeake Bay Program's Chesapeake Bay Model to estimate how much is delivered to the stream (Cerco et al., 2002).

administering agency. Likewise, once a trade is completed using *NutrientNet*, the parties to the trade could electronically submit a notice of the trade to the registry which in turn could be reviewed and approved by the administering agency.

Our Final Word

With the traditional policy instruments struggling to achieve environmental targets or becoming increasingly costly solutions to our water quality problems, performance-based instruments such as nutrient trading are becoming increasingly attractive instruments to use. Many studies have pointed to the use of performance-based mechanisms as cost-effective solutions to water quality problems (Faeth, 2000; Faeth and Greenhalgh, 2000; Greenhalgh and Sauer 2003). As an adjunct to regulatory policy, nutrient trading provides the flexibility for regulated sources to achieve their regulatory requirements more cost-effectively, while achieving overall water quality improvements.

In the U.S., these instruments are gaining popularity. Currently there are approximately 40 trading initiatives involving 17 states and one regional effort, and six statewide trading policies and programs in existence. There are a further 27 proposed trading initiatives under development (Breetz et al., 2004). The release of the USEPA Water Quality Trading Policy in January 2003 has also provided certainty to many regions and states that would like to use trading to achieve water quality targets that these reductions will be recognized, spurring even greater interest in nutrient markets.

The often overlooked beauty of these instruments is the synergistic benefits for other environmental problems. For instance, a nutrient trading policy for nitrogen aimed at reducing the size of the hypoxic zone in the Gulf of Mexico also leads to improvements in local water quality, reductions in GHG emissions and reductions in soil loss. Policies that address a diversity of environmental issues are becoming increasingly attractive in many areas that are facing a myriad of environmental concerns. This awareness, tied with the evolution of on-line nutrient trading markets like *NutrientNet* will help pave the way for a new era that focuses on performance-based instruments to meet environmental goals.

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Figure 1: Impact of various policy options on the environment and farm income.
Source: Greenhalgh and Sauer, 2003

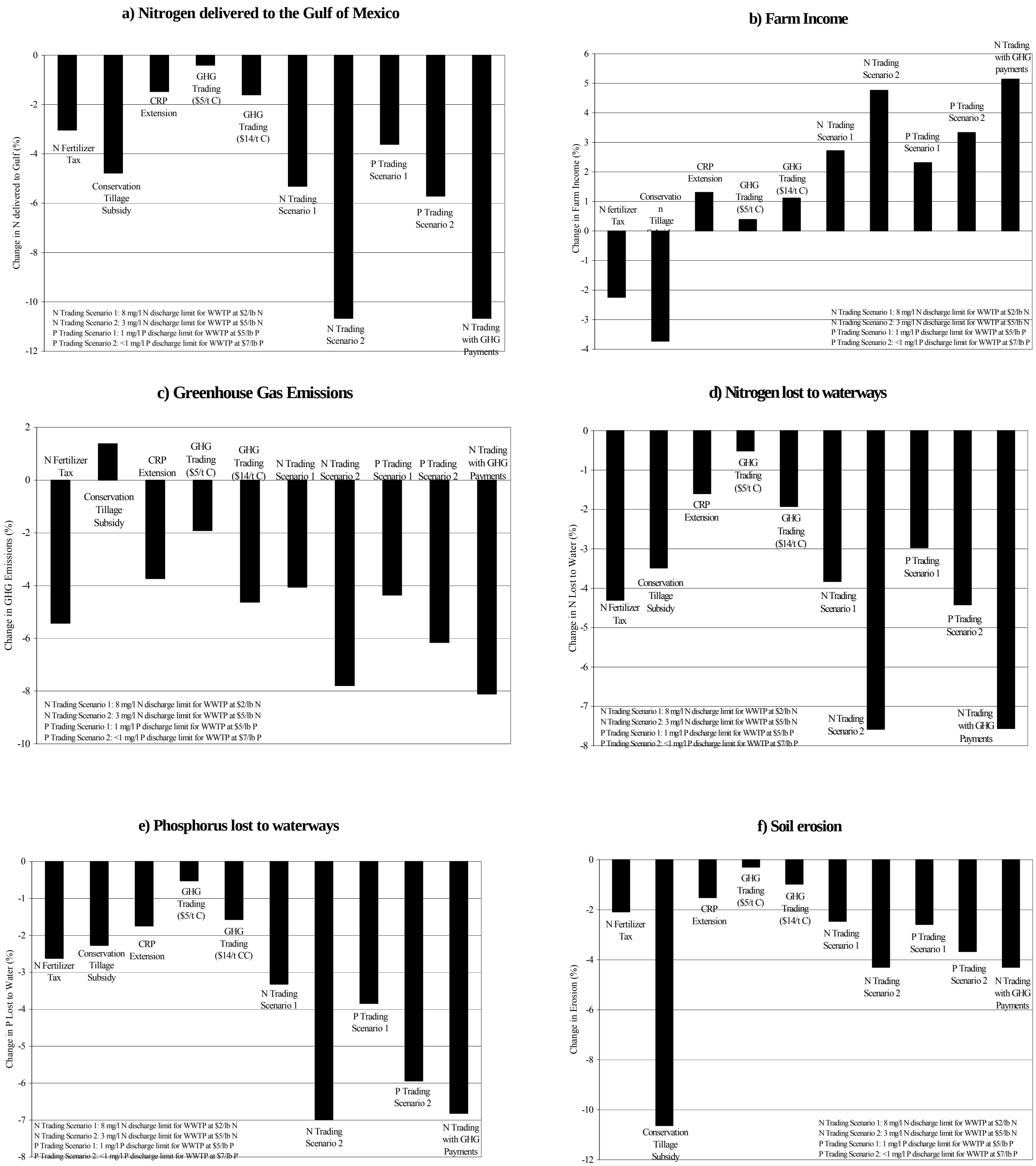
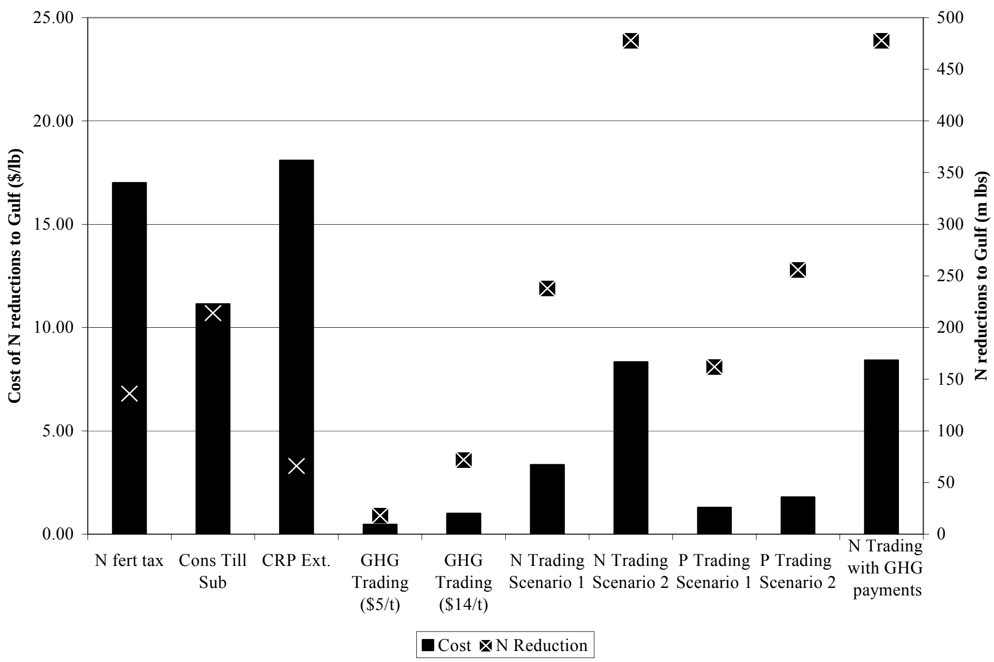
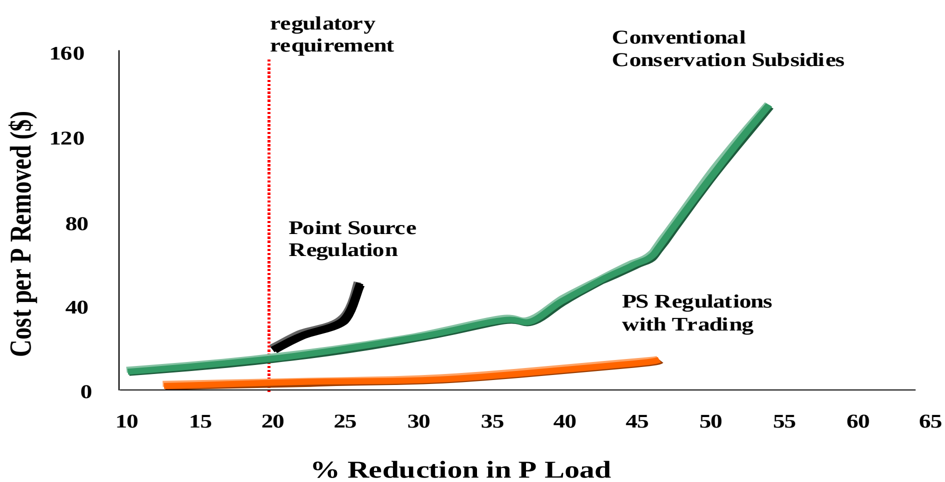


Figure 2: Cost-effectiveness of policy options tested at reducing the amount of nitrogen delivered to the Gulf of Mexico.



Source: Greenhalgh and Sauer, 2003

Figure 3. Cost-effective of nutrient trading: Michigan case study for phosphorus (in U.S. dollars)



Source: Faeth, 2000.