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Point-Nonpoint Source Phosphorus Pollution Trading in the Minnesota River Basin: A Cost-Effectiveness Analysis

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Abstract

Two point-nonpoint source pollution trading programs in the Minnesota River Basin were reviewed to examine their cost-effectiveness in controlling nonpoint pollution. Other social benefits resulting from the programs were also examined. An agricultural field pollutant transport model, ADAPT, was used to examine the phosphorus load reduction effectiveness of an important agricultural BMP, spring cover cropping for sugar beets, used extensively in one of the two programs. Results indicated that without considering transaction costs, point-nonpoint source pollution trading in the Minnesota River Basin was able to achieve pollution control cost savings, although at various degrees. The most cost-effective nonpoint source pollution control measures were those involving pollution reduction structures with long lifetime. Initial analysis showed that sugar beet spring cover cropping may be only marginally cost-effective in phosphorus pollution reduction. ADAPT simulations demonstrated that high residue conservation tillage was more cost-effective than spring cover cropping, especially under average climatic conditions. An important finding from this study is that point-nonpoint source trading programs, besides introducing cost savings to pollution control, brought some other social benefits to the trading area. Issues identified in this study include the difficulty in the finding nonpoint source trading partners and potentially significant transaction costs.

Introduction

As early as the 1960s, economists and political scientists started to study and propose innovative environmental policy instruments as alternatives to traditional "command-and-control" pollution management approaches. These alternatives, represented by effluent fees and marketable emission permits, have been shown to be Pareto-optimal in that they enable the society to attain a set of predetermined environmental standards at the least cost (Baumol and Oates, 1988). For the last two decades, these alternatives, commonly called incentive-based approaches to environmental regulation, have received increasing acceptance by policy makers and have found application in many areas of pollution control in the United States. The most prominent example is the successful implementation of the SO_2 program (Title IV of the 1990 Clean Air Act Amendments), in which a system of tradable SO_2 emission allowances is used to reduce the costs of achieving an overall control of the emission level (Environment Defense, 2000). As the SO_2 program has illustrated, incentive-based regulatory instruments can provide a level of flexibility in pollution control that has the potential to reduce compliance costs by encouraging efficient resource allocation and innovation in environmental technology (Randall and Taylor, 2002). Trading programs, as an important category of incentive-based environmental regulations, allow pollution dischargers to choose between investing in in-plant abatement measures and purchasing pollution reductions (in the form of "allowance" or "credit") from other dischargers. The net result is the equalization of the marginal abatement cost of a particular pollutant across all pollution emission sources. Because of the cost-minimization behavior of individual dischargers, trading will eventually lead to the adoption of the most cost-effective pollution control measures and hence an overall reduction of compliance costs.

As water quality problems become increasingly linked to nonpoint sources and the marginal costs of further pollution reduction rise rapidly for point sources, watershed-based effluent trading between point and nonpoint sources offers an important alternative. It can potentially reduce the discharge of nutrients into the nation's water bodies in a much more cost-effective way than the traditional command-and-control approach. A study by Bacon (1992) estimated that the cost of point source reduction could be 65 times higher than nonpoint source reduction. The EPA (US EPA, 1992) also estimated that substituting tertiary water treatment with reducing nonpoint pollution from agriculture would provide a net saving of $15 billion in capital costs. Using a modeling approach, Faeth (2000) calculated the costs of removing one pound of phosphorus (P) under different management scenarios in three agriculture-intensive river basins including the Minnesota River Basin. The scenarios included a point source performance requirement only and point source performance requirement with options of trading with nonpoint sources. For the Minnesota River Basin, his modeling indicated that the nontrading scenario resulted in a cost of $19.60 per pound of P removed while the cost for the trading scenario was only $6.50.

Since the early 1980s, a number of trading experiments have been tried in water quality management. Early examples include effluent biological oxygen demand (BOD) trading among point sources on the Fox River in Wisconsin and P trading between point and nonpoint sources in the Dillon Reservoir watershed of Colorado. More recent examples include point and nonpoint sources nutrient (N and P) trading in the Tar-Pamlico River Basin in North Carolina and P trading among nonpoint sources in the City of Williamsburg, Virginia (Stephenson, 1998). A pilot program of P trading between point and nonpoint sources was completed in the Kalamazoo

River Basin in Michigan in 1998 (Kieser, 2000).

These programs have not created many trades among different sources, mostly because discharge reductions and cost savings were achieved by the adoption of performance standards (a prerequisite for trading programs) that allow the point sources to choose their abatement technology. As a result, point sources have been able to delay purchasing allowances or credits (Randall and Taylor, 2002). Nevertheless, the potential to substantially reduce abatement costs while still meeting water quality goals has drawn not only economists but also policy makers to give trading, particularly point-nonpoint source trading, serious considerations.

Major obstacles in the adoption and spread of pollution trading between point and nonpoint sources include the scientific uncertainty of substituting nonpoint source pollution load reductions for point source load reductions and the difficulties in quantifying and monitoring nonpoint source pollution reductions. However, using case studies from several water pollution trading programs, Stephenson et al. (1998) argued that accounting for nonpoint source discharging with certainty was not an "insurmountable" technical obstacle to trading. They further indicated in their discussion that a properly designed trading program could stimulate the development of technical innovations in nonpoint source monitoring and measurement. Taff and Senjem (1996) proposed a four-fold path to regulators for designing point-nonpoint source trading to combat these uncertainties and difficulties. Their scheme calls for the regulators to (1) limit targeted pollutants to those whose water quality impact is conservative and chronic; (2) restrict eligibility to remedial practices whose effectiveness can be predicted with acceptable degrees of certainty; (3) associate trading with already existing regulatory mechanisms; and (4) help the market identify low-cost providers of pollution-reduction services.

In the Minnesota River Basin of southwest Minnesota, two point sources, the Rahr Malting Company (Rahr) in Shakopee and the Southern Minnesota Beet Sugar Cooperative (SMBSC) in Renville have traded with nonpoint sources for pollution (mostly P) reduction credits under the provisions of the National Pollutant Discharge Elimination System (NPDES) permits. These two point-nonpoint source trading programs were carefully designed for accountability and have been carried out under the close supervision of the Minnesota Pollution Control Agency (MPCA). A thorough study of these programs reveal how many of the issues mentioned above have affected the design and implementation of the programs, how these issues were dealt with, and what can be learned from the experience. In addition, such a study would yield valuable information on the cost-effectiveness of such trading programs.

The objectives of this paper is to: (1) analyze the cost-effectiveness of P pollution reduction measures used in the two trading programs; (2) examine the technical aspects of the programs by using the Agricultural Drainage And Pesticide Transport (ADAPT) model to compare the pollution reduction cost-effectiveness of two agricultural best management practices (BMPs)–cover cropping and conservation tillage; and (3) provide suggestions based on lessons learned from the two programs for improvement in future point-nonpoint source trading programs.

Information Sources

Ten in-person interviews were conducted with individuals directly involved in the two programs. Interviewees included (1) MPCA staff members administering the programs; (2) employees with the management and technical services of the two point sources of pollution; (3)

private technical consultants contracted by the point sources to conduct nonpoint source pollution control design, construction, and credit trading evaluation; (4) a staff member of a local environmental organization, who was instrumental in identifying potential nonpoint source trading partners for Rahr; and (5) a landowner participating in a trade with Rahr. These interviews served multiple purposes in the study. First, they provided crucial information regarding the origin and background of the trading programs. Second, they provided information about the specific settings of the two programs. Third, they made available some necessary information for the ADAPT model simulations. Fourth, they offered the perspectives of those actual trading on the overall successes and failures of the point-nonpoint source trading programs.

Most of the information from which P pollution reduction costs were derived was obtained by reviewing documents on the two trading programs. These documents can be broadly classified into two categories: reports submitted by the point sources and communication letters between the MPCA and the point sources. Reports included program progress reports, balance statements of the abatement trust fund, and technical reports on nonpoint source pollution control measures and the quantification of tradable P reduction credits. Communication letters were mostly concerned with the request and authorization of P reduction credits. They also occasionally dealt with specific issues arising from individual trades.

Background

In the Minnesota River Basin, two point-nonpoint source pollution trading programs administered by the MPCA have been operating since 1997. The design of these two programs closely followed the guidelines proposed in US EPA's Draft Framework (US EPA, 1996). Details of the design also drew on the four-fold design path proposed by Taff and Senjem (1996). A policy evaluation study by the MPCA in 1997 (Senjem, 1997) on pollution trading also recommended efficiency, equivalence, additionality, and accountability to be the four criteria for any point and nonpoint source trading to be considered desirable.

Based on the EPA principles, the four-fold path, and the four evaluation criteria, the MPCA negotiated with the Rahr Malting Company (Rahr) and the Southern Minnesota Beet Sugar Cooperative (SMBSC) to implement point and nonpoint source trading in the Minnesota River Basin under the provisions of the NPDES. The pollutants being traded were essentially nutrients (P and nitrogen). Trading credit evaluation procedures were detailed in the permit for each of these eligible remedial practices. A trust fund was set up by the permittee, devoted to the trading program to achieve the required nutrient load reduction. The permittee was obligated to make up any shortfalls. A trust fund board composed of at least one local watershed manager, one government representative, and one local water resources organization representative was responsible for managing the trust fund. Both trading programs employed a trading ratio greater than 2:1–two units of nonpoint source P reduction traded for one unit of point source P reduction. This was done to assure equivalence and additionality of load reduction and account for uncertainties in converting nonpoint source loads into point source loads. In terms of accountability, every potential trade had to be verified by the MPCA and annual reduction goals were outlined in the permit for the permittee to achieve. The permittee was responsible for the construction, installation, operation and maintenance of remedial practices, and the MPCA had the right to revoke previously approved tradable credits based on inspection results. Annual reports on the operation and effectiveness of the remedial practices were required, and the format of the reports was specified in the permit. The permittee, however, had the option to meet its total load reduction requirement in several stages with specific and progressive stage targets.

The Rahr Malting Company Case

In early 1997, the first-ever nutrient emission trading program in Minnesota was inaugurated under an NPDES permit (MPCA, 1997) issued to the Rahr Malting Company in Shakopee. It was a five-year program (January 1997 to January 2002), the usual term duration for NPDES permits. The primary reasons behind the creation of the program were (1) the Total Maximum Daily Load (TMDL) established by the US EPA and the MPCA in 1988 for BOD (biochemical oxygen demand) at the Minnesota River below river mile 25 (near Shakopee, Minnesota), and (2) the Rahr's intention to build its own wastewater treatment plant (WWTP). According to the TMDL rules, no more point source was allowed to discharge into that reach of the river. Therefore, in order to build the WWTP, Rahr agreed to offset all the projected $CBOD_5$ (5 day carbonaceous biochemical oxygen demand) load to the river with $CBOD_5$ credits it would buy from nonpoint sources implementing pollution reduction measures. Rahr also agreed to provide a $250,000 trust fund to guarantee financially the realization of actual trades.

The program is unique in that $CBOD_5$, the result of nutrient pollution, not the nutrients (P and N) themselves, was the traded pollutant. Based on the scientific evidence presented by Van Nieuwenhuyse and Jones (1996), the MPCA and the permittee agreed upon conversion ratios of 1:8 for P and 1:4 (1:1 upstream of the TMDL zone) for N, respectively, to account for credits generated by the reduction of nutrient loadings into the river. In other words, for every unit of P discharge reduction, 8 units of $CBOD_5$ would be credited towards the total $CBOD_5$ offset requirement. Another unique feature of the program was that if needed, 60 pounds out of the required accumulative total load reduction of 150 pounds $CBOD_5$ per day was provided to the permittee to satisfy any shortfall at the end of the program. Thus, the minimum nonpoint source $CBOD_5$ reduction that Rahr must achieve was only 90 pounds per day. This was done because of the pioneering nature of the program and more importantly, because the effluent limits of the permit were the most restrictive for the Minnesota River on total P and the $CBOD_5$ levels imposed on the WWTP. On the technical side, a 2:1 trading ratio was used to account for the uncertainties. Thus for a two unit reduction of $CBOD_5$ at a nonpoint source, a one unit credit is counted towards the point source load reduction. This trading ratio was not explicitly mentioned in the permit provisions, but was implied in the credit calculation procedures outlined in the appendix of the permit.

During the five years of implementation, four trades took place between Rahr and four nonpoint sources. Pollution control measures employed included two river flood scoured area set-asides coupled with vegetation restoration (one on the Cottonwood River and the other on the Minnesota River, both near New Ulm), one stream bank erosion control and stabilization (Rush River, Le Sueur near Henderson), and one livestock exclusion plus stream bank erosion control (Eight Mile Creek, New Ulm). These four trades, up to February 2001, generated a total $CBOD_5$ reduction credits of 214.2 pounds or a $CBOD_5$ loading reduction of 781,830 pounds for the duration of the permit (Table 1), according to the calculations verified by the MPCA. The total cost (from the trust fund) for the permitee to carry out the trades, including land purchases, materials, engineering consulting, maintenance, and other miscellaneous costs was $250,044.

Overall, from Rahr's perspective, this trading program was executed well on budget and it generated more credits than it was required (150 pounds of $CBOD_5$). Furthermore, there was substantial savings that Rahr received from building its own WWTP and participating in the trading program. Prior to its own WWTP, Rahr made an annual payment of $1,260,240 to the Metropolitan Council's Blue Lake treatment plant. For its own WWTP, an estimated $5,000,000 investment was made. Using a typical business return rate of 9% for Rahr's funds (source: interview with Rahr Malting Company management personnel), it can be calculated that Rahr's WWTP resulted a net saving of about $315,000 during the five permit years. With $250,000 spent on the trading program, Rahr still saved about $65,000 from its own WWTP and the trading program.

A breakdown of the credits generated by each trade and associated costs (Table 1) shows that the river flood scoured area set-asides coupled with vegetation restoration on the Cottonwood and the Minnesota Rivers were the most cost-effective trades. Using the $P:CBOD_5$ ratio of 1:8, the per pound P reduction cost for the two river sites was $4.44 during the five years of the NPDES permit duration. The Rush River bank stabilization was a close second at $4.49. Although the Eight Mile Creek trade cost the most, it was still an acceptable $5.28/lb. We can contrast this number to the price that most municipal WWTPs with a designed flow comparable with Rahr's permitted discharge rate of 1.5 million gallons per day would have to pay to meet a 1 mg/L total P effluent limit. This limit has been considered necessary for significant water quality improvement in most waterways in Minnesota if only point sources were to bear the burden of all the necessary P load reductions (Senjem, 1997; Faeth, 2000). According to Senjem (1997), to achieve this 1 mg/L P limit, depending on the influent P concentration these municipal WWTPs would have to spend $4-18 per pound of P removed on capital and operation, based on a 20 year investment life time and an 8% annual interest rate. Compared to these values, nonpoint source control activities such as those carried out in the Rahr trading programs resulted in substantial savings in most cases.

From a societal point of view, as long as the P load control structures are in place and function as designed, they will continue to contribute to maintaining a lower P level in the Minnesota River. If we assume a structure life time of 10 years and a 8% discount rate (Senjem, 1997), costs per pound of $CBOD_5$ reduction would be only $0.24. With the 1:8 P to $CBOD_5$ conversion ratio, costs per pound of P reduction rise to $1.91 (Table 1). Compared with municipal WWTPs costs, nonpoint source control measures clearly show a cost-effectiveness advantage when long-term social cost-effectiveness is considered.

The Southern Minnesota Beet Sugar Cooperative Case

The second point-nonpoint source trading program in the Minnesota River Basin was conducted under an NPDES permit issued to the Southern Minnesota Beet Sugar Cooperative (SMBSC; Renville, MN) in 1999 for its planned WWTP (MPCA, 1999). Similar to the Rahr case, SMBSC intended to build a new WWTP as part of its development strategy to meet the challenges of decreases in sugar price on the world market. The new WWTP would enable SMBSC to modernize its sugar beet slicing process and expand its production scale. However, the new plant would have to discharge its effluent (1.75 million gallons per day) into a nearby stream (West Fork Beaver Creek), which eventually flows to the Minnesota River. Previously, SMBSC stored its wastewater in ponds during its production season (October to May) and spray-irrigated the water to its 500 acres of alfalfa/grass land off-season. The permit required SMBSC to trade with nonpoint sources to eventually offset all its projected 4,982 lb P/yr (2,260 kg P/yr) discharged from the new WWTP within the permit duration of five years, because (1) spray-irrigation is considered to result in zero P load to the river and (2) MPCA has adopted a strategy of no overall net increase in P loading to the Minnesota River. With a trading ratio of 2.6:1, this trading requirement means a total of 12,954 credits (12,954 lb P yr or 5,876 kg P/yr) would have to be purchased from nonpoint sources to meet the requirement. The permit, however, provided a grace period of three years (1999-2001) because of the partial operation of a newly-opened WWTP and the time needed for establishing trades. During the grace period, the permit specified credit requirements were lower than the eventual number but increased at a 2,600 credits/yr rate. The trust fund set for this program was $300,000.

For the first three years, SMBSC was able to meet the stepwise requirements by mainly contracting with its cooperative member sugar beet farmers to adopt spring cover cropping as an erosion control BMP. Typical practices for sugar beet spring cover cropping involves planting wheat or oats when or just before the sugar beets are planted (late April to early May). The cover crop emerges from the ground earlier than the beets and provides the field with some vegetative cover at a time where the potential for soil erosion from rain events is particularly high. Three to four weeks after beet emergence, the first application of post-emergence herbicide is applied to kill the cover crop. The remainder of the cover crop is killed two weeks later. To SMBSC, sugar beet spring cover cropping was the easiest and most economic way to obtain P credits because the cooperative had a large base of sugar beet growers (about 600) who were willing to help the cooperative meet its environmental obligations. During the period of 2000-2001, each year, SMBSC contracted on average with about 100 farmers for 17,920 acres of farmland for sugar beet spring cover cropping (Table 2). SMBSC compensated the growers at a rate of $2/acre. These acres of spring cover cropping generated an average 5,765 credits per year (i.e., 5,765 lbs of P load reduction per year) computed from the credit calculation procedures specified in the permit. Therefore, the annual cost of P load reduction was $6.22/lb to SMBSC (Table 2). However, it actually cost growers about $6/acre to implement the cover crop. As a result, the actual cost of reducing P load by planting sugar beet spring cover crop was $18.65/lb. This is as high as most municipal WWTPs with a design flow around 1-2 million gallons per day would have to pay to meet a 1 mg/L total P effluent limit ($4-18/lb, see the last section on the Rahr case [Senjem, 1997]).

From the perspective of the society, the above analysis suggests that trading with farmers practicing sugar beet spring cover cropping does not result in cost saving in P pollution control. Nevertheless, there are other benefits not related to pollution control that may lend some support to this control measure. For example, sugar beet growers are willing to adopt spring cover crop because it also protects emerging sugar beet plants from wind damage. Although no quantitative research has been done on exactly what the agronomic and economic benefits of spring cover cropping are to the sugar beet production, anecdotal evidence suggests these benefits. In general, acceptance of cover cropping is increasing among sugar beet growers in the basin.

Economic Implications of the ADAPT Simulation Results

For the purpose of this study, a 120-acre field near Granite Falls, Minnesota (Hawk Creek-Yellow Medicine River Watershed) was chosen to compare the pollution reduction cost-effectiveness of two agricultural BMPs–sugar beet spring cover cropping and conservation tillage--in the SMBSC P trading program. This field was a participant of the program in 2000 with a spring cover crop of wheat for sugar beets. The field had a typical three year corn-sugar beet-soybean crop rotation system. To have a more complete picture of the erosion control performance of spring cover cropping, a six year two rotation system (corn-sugar beet-soybean–corn-sugar beet-soybean, 1996-2001) was simulated. Minnesota suffered a very damaging flood season in spring of 1997. A two rotation system that included 1997 would enable one to observe and compare the impact of extreme climatic events and also to test the sensitivity of the ADAPT model to climatic conditions.

Although ADAPT can directly simulate P losses from agricultural fields, model simulations showed that the sensitivity of the model's P algorithm was not high enough to take into account the effect of cover cropping, particularly when the soil P level is low and precipitation conditions are normal or below average. Therefore, a method developed by Fang (2002) was used to translate the ADAPT output of soil losses to P losses in evaluating the cost-effectiveness for both cover cropping and conservation tillage in reducing P losses. Four ADAPT simulations were run for the selected sugar beet field in Granite Falls, Minnesota, representing the combinations of two tillage practice systems (high residue [conservation tillage] and low residue [conventional tillage]) and the choice of spring cover cropping (with or without).

Using the $6 per acre cost for growing sugar beet spring cover crop (Table 2) and the 0.054 lb per acre P reduction calculated with ADAPT soil loss simulation results and the method developed by Fang (2002), the actual cost of P loss reduction by spring cover cropping would be $110.77 per pound P for the 1999-2001 rotation (Table 3). Compared to the $18.65 per pound P originally calculated (Table 2), this is a six-fold jump. On the other hand, during the first crop rotation (1996-1998) 0.559 lb per acre P reduction could be achieved (Table 3) due to the extreme wet climatic conditions in Upper Midwest in 1997. As a result, the actual cost of P loss reduction by spring cover cropping in that rotation (1996-1998) would be only $10.71 per pound P removed (Table 3), lower than the $18.65 mark.

ADAPT simulations also demonstrated that adopting high residue conservation tillage practices is more cost-effective than spring cover cropping in reducing P losses. Kurkalova and Kling (2001) reported that on average, an annual subsidy of $2.40 per acre for corn and $3.50 per acre for soybeans in 1992 would have allowed Iowa farmers to overcome a possible profit loss and aversion to the risks they perceived in adopting conservation tillage practices. Using a consumer price inflation rate of 2.4% (IMF, 2002), these costs can be translated into $2.90 per acre for corn and $4.23 per acre for soybean in 2000. If we assume that it costs the average of the two to introduce the high residue conservation tillage system to a farmer in the three year rotation of corn-sugar beet-soybean, the cost would be $3.57 per acre per year for three years, i.e., a subsidy of $10.71 per acre per rotation for the adoption of the high residue system for sugar beet farmers. For the field studied, a hypothetical switch from a low residue system to a high residue system in the second rotation (1999-2001) would produce 96.9 lb (or 0.807 lb/acre) P loss reduction (Table 3) using the calculation method developed by Fang (2002). Consequently, the load reduction cost-effectiveness would be $13.25 per pound P during the crop rotation years of 1999-2001, which had average climate conditions. The same conclusion can be reached by using a credit calculation method that is a hybrid of ADAPT soil loss simulation and the SMBSC trading program P credit calculation procedure specified in the NPDES permit (Table 3).

In summary, under average climatic conditions (1999-2001) switching to a high residue conservation tillage system is more cost-effective, at least for the field studied here, than cover cropping in reducing P losses. This is true no matter what credit evaluation methods were used (Table 3). The costs for cover cropping, under average climatic conditions, shown in Table 3 exceed the cost of $4-18 per pound P removed for small to mid-sized municipal WWTP (Senjem, 1997). In contrast high residue conservation tillage system can yield comparable cost-effectiveness under average climatic conditions.

Cost-effectiveness of Nonpoint Source Pollution Control Measures

The analysis indicates that the most cost-effective nonpoint source pollution control methods were long-term structural measures coupled with bioengineering techniques, such as the three bank stabilization/flood scouring area set-aside and re-vegetation sites in the Rahr trading program (Table 1). The advantages of these measures lie not only in the higher pollution reduction they can achieve with low investment but also in the greater scientific certainty they can offer when pollution reduction is estimated. The reason for the latter is the long lifetime of the structures and the equally long time frame involved in the pollution reduction estimation process. For example, the credits calculation procedure for the Rush River bank stabilization project was based on seven aerial photographs taken from 1964 to 1999 of the project site on the river. The average bank recession rate was estimated over a of 36-year time period that included both high and low flow periods, and average flow years. The lifetime of the bank stabilization structure is expected to be the same as the trees planted. Even after catastrophic flood events, they still can continue to be self-sustaining when properly repaired and maintained. Since the lifetime of the structures approaches the time span used to estimate the bank recession, we have more certainty regarding the value of the credits estimated for the control measures.

ADAPT simulations of spring cover cropping for sugar beets illustrated the climate-dependency of the effectiveness of nonpoint source control measures. The more damaging the spring weather conditions were (1996-1998), the more effective spring cover cropping became. The simulations also showed that the high residue tillage system had a greater cost-effectiveness in average climatic condition years than cover cropping did. The cost-effectiveness of a high residue system in some cases can be comparable to point source P control measures (Table 3), making it a good candidate for generating credits in point-nonpoint source pollution trading. However, using the high residue conservation tillage system for trading credits may run into the so-called "baseline problem". Currently, many farmers, like the one who farms the field selected for this study, have already adopted conservation tillage practices. Allowing only those with a current low residue system to earn credits by switching to a high residue system would create an equity problem and discourage farmers who are at the forefront of practicing environment-friendly farming. If we reward farmers already practicing conservation with credits, these credits would not provide any net pollution reduction from current levels. This would create what many environmental groups regard as "paper credits", which is a violation of the "additionality" criterion for pollution trading (Senjem, 1997). The "baseline problem" arises when we cannot impose a uniform reference level of required control measures from which additional efforts will earn tradable credits.

Another issue identified here, as a result of ADAPT model simulations on cover cropping, is the importance of the method chosen for evaluating the effectiveness of pollution reduction measures. Including the method outlined in the permit, three evaluation procedures (MPCA, 1999; Table 3) were used for the same model farm field investigated in this study. Although in general the results pointed to the same conclusion regarding the P pollution reduction effectiveness of cover cropping, they were clearly different in magnitude (Table 2 and 3). This difference has far-reached consequences not only in cost-effectiveness analysis for trading programs, such as shown earlier in this report, but also in the debate on the actual environmental benefits of point-nonpoint source pollution trading. Research is currently being conducted by the authors on this subject.

Benefits of the Point-Nonpoint Source Pollution Trading Programs

From a societal point of view, the two trading programs may have produced social benefits other than cost savings in pollution reduction. First, the trading programs provided much needed funds for nonpoint sources to take pollution control measures. This is best illustrated by the Rush River and the Eight Mile Creek trades in the Rahr program. Before the program, the owners of the land at these two sites had been in desperate search of financial aid since 1988 to control river bank erosion because the erosion was so severe at times that it had threatened to cut the banks deep into the adjacent land and destroy nearby houses and barns. Until the program came along, the owners could not raise sufficient funds for effective bank stabilization work to solve the problem. Now, four years after the installation of bioengineered bank stabilization structures on the sites, there has been "no problem," as one of the owners commented.

Second, pollution trading provided the necessary solution through which the two NPDES permittees were able to (1) build their own WWTP to lower production cost (Rahr) or (2) expand production scale (SMBSC) during a time in which domestic and international competition has created hardship for the survival of an important local employer. Rahr's Shakopee facility is the largest producer of malt at a single site in the world, and SMBSC employs 190-300 workers in the local labor market with an annual payroll of over $6 million.

Third, before the operation of its new WWTP, SMBSC stored its production wastewater in ponds and spray-irrigated the retained waste water during spring. Pond-storing not only limited the production scale but also caused an odor problem that once was the major environmental nuisance in Renville County. Therefore, point-nonpoint source trading also contributed to environmental quality in the form of air pollution reduction.

Finally, involvement of farmers, environmental groups and local watershed officials in the trading programs brought the unregulated nonpoint sources to the spotlight. This likely had positive effects on the public awareness of both the nonpoint source pollution problems and the opportunity of using trading to introduce nonpoint source pollution controls. In addition, Rahr donated the Cottonwood and Minnesota River sites, which are basically restored wetlands, to the city of New Ulm and a local environmental organization (the Coalition for a Clean Minnesota River), respectively, to be used as park space and an environmental education site.

Other Lessons Learned

The major difficulty encountered in the two trading programs was of finding nonpoint source trading partners for the point sources. The ultimate reason for the difficulty is the absence of a true market for water pollution trading credits. The demand from the point sources for trading credits was created by the trading provisions in the NPDES permits, but there was no readily available supply of these credits from nonpoint sources. Under current law and regulations, most nonpoint sources have no legal obligations to take actions to reduce their pollution. As a result, the owners of the point sources in the two trading programs studied here had to find suitable project sites and then "talk the landowners into trading." This is particularly true in the SMBSC case, where a recent contract negotiation with the owner of a potential project site for cattle exclusion created considerable difficulties for SMBSC, and the MPCA. To reduce costs, SMBSC redesigned the structure for cattle stream crossing at the site (from a bridge to a box culvert). The landowner, however, was opposed to the change based on perceived losses of potential benefits. This resulted in a delay of the construction of key pollution control structures, higher transaction costs due to the extra time spent and legal disputes, and the deferral of SMBSC fulfilling the trading credits requirement. Program managers from Rahr considered themselves "fortunate" because they were able to find a well-connected and respected activist from a local environmental organization to help identify potential project sites and build initial contacts with landowners. Three out of the four trades (the Minnesota River, the Cottonwood River, and the Eight Mile Creek sites) were brought into the program in this manner.

Another reason for the difficulty in finding nonpoint source trading partners, according to some point source managers, surprisingly was competition from government land conservation and water quality protection programs such as the RIM (Reinvestment in Minnesota) and CRP (Conservation Reserve Program). These programs occasionally out-competed the point sources in purchasing land for control measures such as river flood scoured area set-asides. Although more research is needed to verify this claim, anecdotal evidence suggests that this was true in some individual cases.

The current regulatory reality combined with the fact that the water pollution trading market is still in its experimental stage, put the point sources in a vulnerable position of facing high transaction costs in realizing trades. This issue deserves further research because administrative costs for both the point sources and the MPCA can be significant at times. Besides the costs associated with finding trading partners, other transaction costs included the time spent on the permit negotiation, administrative expenditures, mandated communications between the permittee and government authorities, and MPCA staff time on credits verification, post-project site inspection, and routine program management. The cost-effectiveness analysis in this study did not include transaction costs because reports from the point sources on use of the trust funds do not account for these costs. Including transaction costs would inevitably lower the cost-effectiveness of the trades studied in this article.

Suggestions for Future Trading Programs

In the Minnesota River basin it appears practices involving long-lifetime structural controls are likely to be cost-effective measures in point-nonpoint source pollution trading. Therefore, when looking for trading partners, point sources should first consider longer-term practices on or near rivers or streams.

To deal with the problem of a low supply of credits, an independent organization might be established to act as a broker for pollution trading credits. The functions of the organization should include soliciting nonpoint source trading partners, managing trading trust funds provided by point sources, appraising credits, mediating trades, and educating the public. The government should encourage or even financially support such organizations especially at the early stages of development. In the long run, creating more trading programs and fostering the growth of the pollution trading credits market may be the ultimate solution to the problems of low supply and high transaction costs. A working and properly regulated market should generate market mechanisms seeking innovative solutions to many of the practical issues.

Conclusions

Program review and cost-effectiveness analysis indicated that point-nonpoint source pollution trading in the Minnesota River Basin was able to achieve pollution control cost savings, although at various degrees. The most cost-effective nonpoint source pollution control measures were those involving river bank stabilization structures with long lifetime. Analysis showed that spring cover cropping for sugar beets may be only marginally cost-effective in P pollution reduction, and agricultural transport model simulations demonstrated that high residue conservation tillage was more cost-effective than spring cover cropping, especially under average climatic conditions.

Point-nonpoint source trading programs, besides introducing cost savings to pollution control, brought some other social benefits to the program areas. These social benefits included bringing in funding for nonpoint source pollution controls, providing a solution to the potential conflict between environmental protection and economic growth, delivering additional environmental benefits, and raising the public awareness of nonpoint source pollution. Issues identified in this study include difficulties in finding nonpoint source trading partners and potentially significant transaction costs. Suggestions for future programs include encouraging long-lifetime structural pollution controls and conservation tillage for generating trading credits and developing a trading credits broker organization.

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Table 1. Trade cost analysis of the Rahr trading program (1997-2002).

Costs to Rahr	Cottonwood & Minnesota R.[‡]	Eight Mile Creek	Rush River	Total	Average (per trade)
Credit generated (per day)[†]	100.7	14.8	98.7	214.2	53.6
$CBOD_5$ removed (lb in 5 years)	367,555	54,020	360,255	781,830	195,458
P removed (lb in 5 years)	45,944	6,753	45,032	97,729	24,432
Cost ($)[†]	102,000	17,810	101,122	250,044[§]	62,511
Cost per credit ($)	1,013	1,203	1,025	--	1,167
Cost per lb $CBOD_5$ removed ($/lb)	0.56	0.66	0.56	--	0.64
Cost per lb P removed ($/lb)	4.44	5.28	4.49	--	5.12
Social costs (10-year)[¶]					
Cost ($, annualized)	15,201	2,654	15,070	37,264[‡]	9,316
Cost per lb $CBOD_5$ removed ($/lb)	0.21	0.25	0.21	--	0.24
Cost per lb P removed ($/lb)	1.65	1.97	1.67	--	1.91

[†] Source: communication letters between Rahr Malting Company and the MPCA.

[‡] Two trades are combined here, the Cottonwood and the Minnesota River sites, both of which are located near New Ulm and are flood scoured area set-asides and vegetation restoration. Separate cost numbers were not sought after in this study.

[§] Also includes additional expenditures totaled at $29,112, resulting mostly from a failed trade and miscellaneous post-construction site maintenance.

[¶] Assuming a 10-year structure lifetime.

Table 2. Cost analysis of spring cover cropping for sugar beets for the 120-acre field in Granite Falls, Minnesota.

	2000	2001	Average
Acreage (acre) †	18,188	17651	17,920
Payment made by SMBSC ($/acre)	2.00	2.00	2.00
Total payment by SMBSC ($)	36,376	35,302	35,839
Credits generated (lb P) †	5,298	6,232	5,765
Credits per acre	0.29	0.35	0.32
Cost per lb P ($/lb)	6.87	5.66	6.22
Cost to growers ($/acre)	6.00†	6.00	6.00
Total cost to growers ($)	109,128	105,906	107,517
Actual cost per lb P ($/lb)	20.60	16.99	18.65

† Source: communication letters between Southern Minnesota Beet Sugar Cooperative (SMBSC) and the MPCA.
‡ Expert estimate, not inflation adjusted.

Table 3. Cost-effectiveness comparisons for P loss reduction measures for the 120-acre field in Granite Falls, Minnesota.

	Adopting Cover Cropping		Switching Residue System	
	I†	II†	I†	II†
First Rotation (1996-1998)				
Cost ($/acre)	6.00‡		9.96	
P loss reduction (lb/acre)	0.395	0.559	0.350	0.365
Cost-effectiveness ($/lb P)	15.19	10.71	28.46	26.92
Second Rotation (1999-2001)				
Cost ($/acre)	6.00		10.70	
P loss reduction (lb/acre)	0.055	0.054	0.705	0.807
Cost-effectiveness ($/lb P)	109.09	110.77	15.18	13.25
Average of the Two Rotations				
Cost ($/acre)	6.00		10.33	
P loss reduction (lb/acre)	0.225	0.307	0.528	0.587
Cost-effectiveness ($/lb P)	26.67	19.35	19.58	17.61

† I. calculation method 1: combination of ADAPT simulation and the SMBSC trading program P credit calculation procedure (MPCA, 1999); II. calculation method 2: developed by Fang (2002).

‡ Expert estimate, not inflation-adjusted.