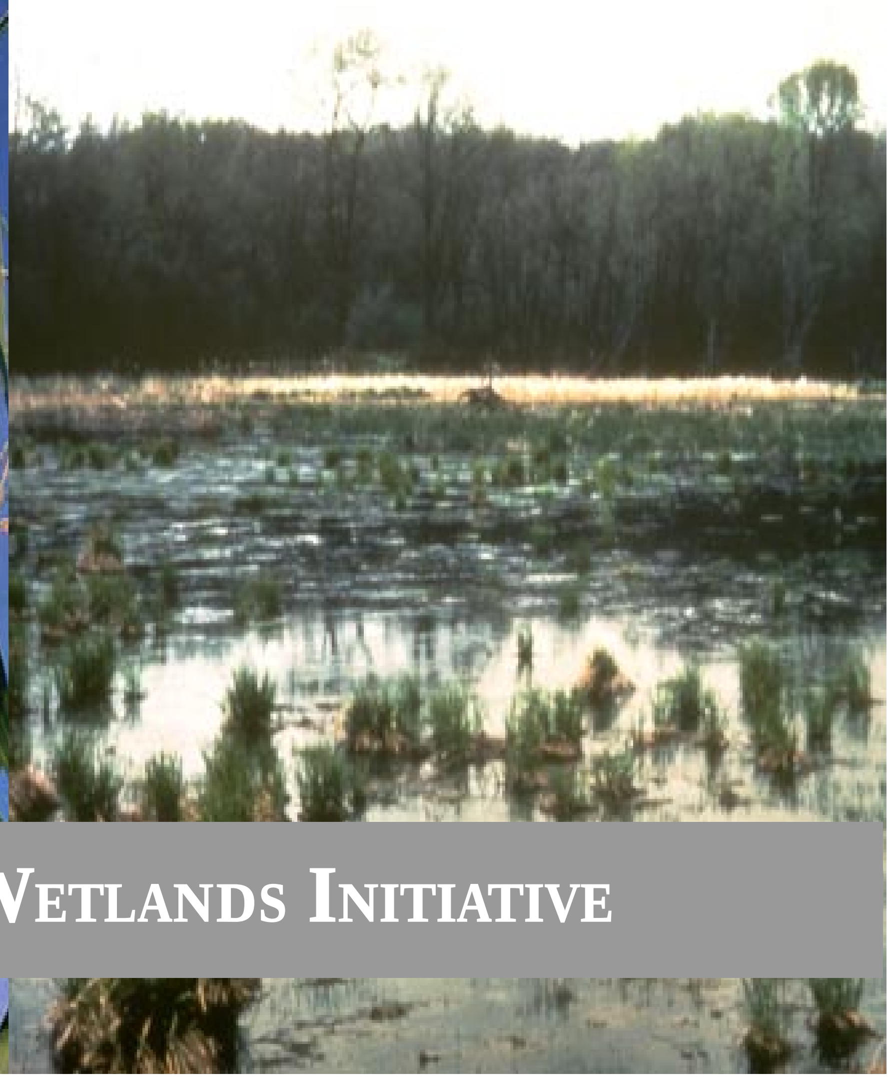
NITROGEN FARMING:

USING WETLANDS TO REMOVE NITROGEN FROM OUR NATION'S WATERS

MAY 2002



THE WETLANDS INITIATIVE

The Wetlands Initiative

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The Wetlands Initiative is a non-profit corporation dedicated to restoring the wetland resources of the Midwest to reduce flood damages, improve water quality, and increase wildlife habitat and biodiversity. Our mission is to promote restoration in ways that provide environmental and economic benefits to society and the landowner. Through research, education, public policy analysis, and large-scale demonstration projects, TWI aims to restore one million acres by the year 2010. While this number may seem large, it represents only 2 percent of the wetlands lost in the Midwest.

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INTRODUCTION

Today there is too much nitrogen in our surface waters, degrading the water quality and destroying the wildlife habitat in our rivers. In the Mississippi River basin, excess nitrogen also contributes to the hypoxic zone in the Louisiana shelf of the northern Gulf of Mexico. Nitrogen farming would use restored and created wetlands in a managed process to remove this nutrient and to create a market for exchange of nutrient-removal credits.

Nearly 60 percent of the nitrogen in our rivers enters from run-off or groundwater from agricultural activities, including commercial fertilizer, manure, and leachate from soybeans. By removing nitrate-nitrogen (the prevalent form of aqueous nitrogen), we can begin to reverse the adverse impact that human settlement has inflicted on our water supply for the past 200 years. As land use has changed during this time, the amount of nutrients such as nitrogen in our nation's streams, rivers, and oceans has increased dramatically.

Developing an economically viable means to remove nitrate-nitrogen is a critical and timely need. The U.S. Environmental Protection Agency, for the first time, has set nutrient criteria for nitrogen concentrations in our rivers and streams. Wetland-based "nitrogen farming" could prove to be an important vehicle that states use to meet nutirent standards. The concept also potentially could be used to remove other nutrients, such as phosphorous.

Specifically, nitrogen farming would involve flooding land with nutrient-rich water to achieve denitrification. (During denitrification, a biochemical reaction takes place that dispels nitrate-nitrogen to the atmosphere as inert nitrogen gas.) When the tons of removed nitrate-nitrogen (NO_3-N) are measured, this amount is recorded as the landowner's "harvest" and tallied as "credits" to be sold to industries, municipalities and farmers who discharge excessive amounts (as defined by federal and state regulations) of nitrate-nitrogen. The price for these credits would be set by the exchange between buyers and sellers.

Nitrogen farming has the added benefit that it asks those who traditionally have contributed to the excess nitrogen load (e.g., corn and soybean farmers) to begin to treat that load on site. This reduces the need for costly wastewater treatment facilities, while providing income for farmers. In addition, restoring wetlands provides other benefits: increased biodiversity, wildlife habitat, flood storage, and both passive and active recreational opportunities.

To consider how to create and implement a wetland-based, nitrogen removal system, the McKnight Foundation sponsored four workshops through The Wetlands Initiative (TWI) in the spring of 2001. The subjects covered at the workshops were: 1) the required science and policy structure; 2) the needed economic framework; 3) the interests and roles of the agricultural community; and 4) the perceived effects on wildlife and related human benefits.

This report details the discussion, questions, and concerns raised at each workshop while considering how this concept could be applied in the five-state region of the Upper Mississippi River basin. The Illinois River basin is used as a reference watershed for this concept.

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SCIENCE AND POLICY WORKSHOP MARCH 9, 2001

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AGRICULTURE WORKSHOP MARCH 26, 2001

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CONSERVATION NGOS WORKSHOP MARCH 27, 2001

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> "REDUCING NUTRIENT LOADS, PARTICULARLY NITROGEN, FROM THE MISSISSIPPI-ATCHAFALAYA RIVER BASIN, WILL CAUSE IMPROVEMENTS BOTH IN THE HYPOXIC CONDITIONS IN THE GULF AND IN WATER QUALITY AND LAND-USE CONDITIONS WITHIN THE BASIN."
>
> INTEGRATED ASSESSMENT REPORT OF HYPOXIA IN THE NORTHERN GULF OF MEXICO, MAY 2000

Reference Watershed

Because the Illinois River watershed is typical of Midwestern streams, it was used as a reference for the discussion at the workshops. Approximately eighty-two percent (24,000 sq. mi.) of the watershed area is used for agriculture.[1] Nitrogen-based fertilizer used in the Mississippi River Basin has increased sixfold since the 1950s.[2] While other nitrogen sources—including soil mineralization, legumes and pasture, animal manure, atmospheric deposition, and municipal and industrial point sources—have remained fairly constant, fertilizer usage represents the largest percent increase.

Not coincidentally, nitrate-nitrogen concentrations in the Illinois River also have risen. By the late 1980s, the concentrations averaged more than 5 mg/L with peak concentrations in spring.[3] A century previously, at the end of the 19th century, concentrations of nitrate-nitrogen in the Illinois averaged less than 1.5 mg/L with peak concentrations occurring in fall.[4] Both the concentration and seasonal distribution of nitrate-nitrogen have changed.

The rise in nitrate-nitrogen concentrations in the river also is closely related to the massive loss of wetlands in the watershed. More than 90 percent of the wetlands in the Illinois River basin have been drained.[5] In their place, miles of clay, concrete, or plastic tile lines efficiently drain soil and near-surface groundwater. The tile networks connect to a labyrinth of outlet ditches—narrow canals that replace the shallow, plant-clogged swales that once dominated surface drainage in the region. The modern agricultural drainage system moves water from the field to the stream in a matter of hours. In the presettlement landscape, the same quantity of water required days to move through the soils, wetlands, sluggish swales and debris-clogged, meandering streams. Today the Illinois River yields 126,000 tons/year of nitrogen—12 percent of the load reaching the Gulf of Mexico.[6] The Illinois River watershed, however, accounts for only 2.3 percent of the Mississippi River basin's total area.

By removing nitrate-nitrogen in the Illinois River basin, we also will create an important impact on the Mississippi River Delta: Decreased nitrogen loads could lead to a reduction in hypoxia—the condition in which dissolved oxygen is below the level necessary to sustain most animal life—in the Gulf of Mexico's continental shelf.

Pilot Projects

Three types of pilot projects were considered, each with a different scale and different parameters. Each project, as conceived by The Wetlands Initiative (TWI), could potentially provide different kinds of scientific data for researchers.

Small Scale

The first would be a small-scale project using scattered wetland sites throughout a watershed. TWI's proposed Spring Creek project outside of Macomb is such a project. About 100 small wetlands (averaging 6 acres each) restored throughout this heavily tiled watershed could demonstrate the cumulative impact of many wetlands on an area's water quality. The restored wetlands would be situated, in large part, on private property along incised and highly eroded stream channels. They would denitrify surface water and trap sediments and associated chemicals. The entire flow of the creek would pass through one or more wetlands before reaching the City of Macomb's primary water supply, the Spring Lake Reservoir. The total cost of the project is estimated to be $1.3 million. Alternatively, if Macomb chose to treat this water in a conventional method (e.g., deionization), the cost would be and estimated $5 to $8 million.

MODERATE SCALE

The second pilot is a moderate scale (2,600 acres), single-farm project, called the Hennepin & Hopper Lakes Project. The site, on land currently in private conservation ownership as facilitated by TWI, lies behind levees along the Illinois River and formerly was managed as the Hennepin Drainage and Levee District. TWI currently is restoring the site to include wetlands, prairie, and a savanna, in addition to two lakes. The existing levee and other drainage structures, which represent a sizeable investment, can be effectively used in nitrogen farming and the associated research. The levee will exclude multiple flow paths to and from the river, enabling the staff to quantify the sources and sinks of water and material (e.g., nitrogen). The existing pump will permit easy manipulation of water depth (critical to denitrification and wildlife functions). Water can be withdrawn from the river and passed through the restored wetland complex at metered rates, allowing the study of soil development, propagation of microfauna and flora, and macroinvertebrate effects on substrate stability and denitrification. The estimated cost of the project is $9 million.

LARGE SCALE

The third pilot project would be on a larger scale: 13,000 leased acres on the floodplain of the Mississippi River, north of Quincy, Illinois. This project could test the feasibility of a conservation organization renting land for wetland restoration and returning it to row crop agricultural use five or ten years later if nitrogen farming doesn't prove cost effective. Despite its levees, this area suffered more than $10 million of damage in the 1993 Mississippi River floods. Parallel levees with little or no setback shunt a large tributary directly into the Mississippi, denying the tributary access to its original, sinuous course through the floodplain. Some structural modifications would be needed to reintroduce the tributary to the floodplain and to allow floodwaters from the Mississippi River to safely flow over the levees and reach the cordoned floodplain. Even in the absence of a major flood, a gated, sufficiently low spillway could be constructed to frequently test the effects of flooding on nitrogen farming and wildlife.

Given that the scale of this project would be five times that of Hennepin & Hopper Lakes and almost 20 times larger than Spring Creek, it would establish the end points of the economic curves, and therefore, little extrapolation would be required. Because of its scale, the environmental and cost factors are expected to be quite different than those for the other projects. By leasing the land for five years, the project cost would be reduced. (To date, no attempt has been made to lease the land, although the idea has been briefly discussed with the farm manager.) At the end of the experiment, the land could be returned to the production of corn and soybeans. However, if nitrogen farming proved successful, the land could be purchased or the corporate owner could continue to operate the district as a for-profit nitrogen farm. The estimated cost of the project would be $15 million.

SCIENCE AND POLICY

Nitrate-nitrogen concentrations in the lower Illinois River have increased nearly three-fold over the past 100 years.[10] Not coincidentally, the hypoxic zone that develops each spring and summer on the Louisiana-Texas shelf of the Gulf of Mexico has been growing, too, more than doubling since it was first mapped in the 1985.[11] In 1999, the zone was the size of the state of New Jersey. Nutrients—including nitrate-nitrogen—in the water of the Gulf fuel the production of algae, which, when they die, fall to the bottom, forming organic deposits. Bacteria feed on this organic matter and, in the process, remove oxygen from the water. The result is a zone of low dissolved oxygen where shellfish, fish, and other animals cannot live. Such a zone is known as a hypoxic zone or “dead zone.”

In addition to increasing the hypoxic zone in the Gulf, high nitrogen levels cause other adverse conditions in the immediate subwatersheds where the runoff occurs. These conditions[12] include:

1) nuisance algae;

2) taste and odor problems in drinking water due to algae;

3) decreased water clarity caused by algae density, reducing quality habitat for fish and other aquatic organisms;

4) toxins affecting human and animal health produced by some algae;

5) high total and dissolved organic carbon levels associated with algal production that promote the formation of harmful byproducts (trihalomethanes, haloacetic acids) in the chlorination and disinfection process of drinking water treatment;

6) blue baby syndrome (methemoglobinemia);

7) increased risks of bladder cancer even when nitrates in drinking water are at levels less than 10 mg/L.[13]

The EPA has established and promulgated a criterion for total nitrogen in rivers and streams of 2.18 mg/L in the Corn Belt and Northern Great Plains Ecoregion (which primarily includes parts of Minnesota, Iowa, Illinois, and Indiana, and eastern Nebraska and North and South Dakota). It is now up to the states to enact the laws that will enforce that criterion. Of this concentration, approximately 1.6 mg/L is NO_3^-.

Relative to the typical concentrations found in the Midwest, the criterion is extremely low compared to ambient levels. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) currently releases approximately 7 to 8 mg/L. Many tributaries of the Illinois River run as high or higher. The mean NO_3^- concentration in the Mackinaw River was over 12 mg/L for October 1997 through September 1998. To meet the EPA’s criterion, an enormous quantity of nitrogen will need to be removed from the Illinois River.

Based on estimates of the MWRDGC, the capital cost of building the structures and purchasing the equipment needed to denitrify using conventional treatment technology will be $500 million. Operating the facilities will cost $50 million per year—enough to pay $125/acre/year to rent 400,000 acres of wetlands. This would be a sufficient wetland area to reduce the nitrate-nitrogen load in the Illinois River to well below the EPA’s criterion.[14]

While the MWRDGC represents the largest single point source of nitrate-nitrogen, it accounts for only one-third of the total nitrogen load. From this perspective, nitrogen farms might rent for $375/acre/year, that is, three times the $125/acre/year figure computed above. This would be a very handsome rental rate, considering farmland in Illinois currently rents for $125 to $150/acre. Rather than putting money into concrete and steel solutions—which do nothing to build functioning ecosystems—the money should be used to pay farmers to treat his or her own nitrogen load and that of others. The restored wetlands would remove nitrate-nitrogen from the water while providing wildlife habitat, flood storage, cleaner water, and recreational opportunities.

The ability of wetlands to remove nitrate-nitrogen from the water has been well established. Based on research conducted at the Des Plaines River Wetlands Demonstration Project, William Crumpton reports that wetlands, properly operated under warm weather conditions, can remove over 80 percent of the influent nitrate-nitrogen load in six days.[15] In addition to denitrification, nitrogen is

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removed by plants, which utilize nitrate-nitrogen and ammonium for growth. Nitrogen farming also could change the timing of nitrogen loads by stripping nitrogen from water during the spring growth period and releasing a portion during fall senescence. Similarly farming could involve water—and, hence, nitrogen—storage in impounded areas during peak flow times, followed by release and treatment during subsequent months.

Crumpton concluded that less than 700,000 acres placed in appropriately-sited wetlands in the Mississippi River basin would be enough to reduce its nitrate-nitrogen load by 20 percent. Accordingly, on the Illinois River, less than 400,000 acres would be required to reduce, to acceptable levels, the nitrate-nitrogen concentration therein.[16]

Because there is little doubt that wetlands can effectively remove nitrate-nitrogen, the critical topics were reduced to the factors that affect wetland performance: location, seasonality, wetland characteristics, and connectivity.

LOCATION

The location of nitrogen farms is extremely important. If they are sited on uplands, the tile lines that deliver the nitrogen-rich agricultural runoff won't reach the wetlands; if they are too far downstream, the nitrogen becomes diluted, reducing the possibility that it can be removed efficiently. The ideal location is where the wetlands can capture the largest volume of tile and surface water at the lowest land and restoration/operation costs. Greater nitrate-nitrogen removal efficiencies will occur if the treatment wetlands are sited in watersheds with high levels of nitrate-nitrogen inputs, such as from fertilizer and manure applications and soybean production.

Bottomlands are ideal locations for nitrogen farms because most were formerly wetlands and gravity flow will minimize energy costs. Other locations, however, will work as well. At the headwaters, both in-channel and riparian wetlands would offer more easily controlled topography and hydrology, keeping facility development costs low. On the other hand, land cost will be more expensive in upland areas, where better drainage is available. Regardless of the landscape position, headwaters or bottomlands, multiple benefits will accrue. Denitrification, floodwater detention, and sediment trapping will occur where nitrogen farms are established.

SEASONALITY

Most of the problems associated with nitrate-nitrogen contamination have a seasonal characteristic. For example, the principal cause of hypoxia in the Gulf is the luxuriant growth of algae fueled by excess nitrate-nitrogen, but other conditions such as stratification of the water column, and increased light and temperature must be present as well. These conditions typically occur in June and July. If nitrogen is the limiting nutrient, as most scientists have concluded, the amount reaching the Gulf must be reduced prior to this period. Reducing nitrogen input in August and September will have little or no affect on hypoxia.

For nitrogen farms to help reduce Gulf hypoxia, they will need to be able to remove nitrate-nitrogen from water that enters the Gulf during March through June. Because it takes approximately two to four weeks for nitrogen to travel from streams in Illinois to the Gulf of Mexico, the nitrate-nitrogen load in Illinois streams will need to be reduced in March, April, and May. Because the influx of nitrate-nitrogen into the Illinois River is very seasonal, peaking in the spring, the maximum detention and storage time will be needed in the spring also. For example, more than 50 percent of the annual nitrate-nitrogen load carried by the Illinois River occurs in just 10 percent of the year (during the spring).

In addition to helping reduce the hypoxia problem, denitrification can improve local water quality conditions. If backwater lakes and river reaches were to be restored throughout the Mississippi basin, an overabundance of nitrate-nitrogen would be undesirable in these local water bodies. Consequently, it would be beneficial to these water bodies to have denitrification occur throughout much of the year.

WETLAND CHARACTERISTICS

What are the ideal wetland parameters (e.g., loading rate, water depth, plant density, and retention time) for optimal nitrogen removal? The efficiency of wetlands as nitrate-nitrogen sinks is largely determined by hydraulic loading rate, nitrogen loading rate, vegetation dynamics, and temperature. Hydraulic loading rates and nitrate-nitrogen loading rates are the principal factors over which a farmer can exert control (in addition to indirectly influencing vegetation dynamics). Nitrate-nitrogen loads are usually highest during spring snowmelt and rainfall events, but the hydrograph is usually much less easily managed during such events, making it difficult to divert the water into the treatment wetlands when the water most needs to be diverted. The nitrogen farm wetlands, therefore, will need inlet control structures that can work effectively during flood events; and can continue to function even in the face of natural channel alterations (e.g., natural levee formation, meandering, etc.), which occur during higher flows. Nitrate-nitrogen loads are not negligible during low flows, however. Particularly in areas drained by artificial ditches and “tile” systems, streams are chronically polluted by nitrate-nitrogen that has leached into the water table and from there drained away into the streams. Truly effective reduction in nitrate-nitrogen loading will require means for diverting base flows into the treatment wetlands, not just flood flows.

Restorationists and wetland managers will need to know more about how nitrogen loading and restoration potential interact. Nitrogen farm wetlands should be able to remove a great deal of nitrogen from the inflowing water via denitrification, but there might be a threshold for nitrogen loading that would be detrimental to the very ecosystems we want to restore. Excess inflows could cause eutrophication, algal blooms, and hypoxia in the lakes if denitrification cannot keep pace with nitrogen loading. Special consideration will need to be given to what loads a wetland can carry without affecting other functions.

CONNECTIVITY

Half of the floodplain of the Illinois River has been leveed. Previously, the broad expanses of backwater lakes and wetlands provided water storage and denitrification. If the nitrogen load of the Illinois River is to be appreciably decreased, some portion of these land surfaces will need to be reconnected to the river.

Reconnection, however, brings with it several problems that could diminish the denitrification value of the farm. The water of the Illinois River conveys suspended solids, which, if allowed into the nitrogen farms, could begin to reduce their productivity by limiting light penetration in the water and adding sedimentation to the substrate. At controlled rates, however, the sediment load contributed to any nitrogen farm would be quite small—only a few inches over decades. A larger sediment load enters the floodplain from the lateral tributaries. Care will need to be taken to minimize the sediment reaching the nitrogen farm.

MULTI- V. SINGLE-FUNCTION WETLANDS

One of the most intriguing questions about nitrogen farming is the relationship between productivity (e.g, nitrate-nitrogen removal) and biodiversity. Specifically, if nitrogen farms are designed for maximum nitrate-nitrogen removal will all other wetland functions be compromised? A worthy goal would be to create wetlands that are efficient at removing nitrate-nitrogen yet also manifest other desirable wetland functions (e.g., wildlife habitat and species diversity).

When managing for biodiversity, scientists know that at least three factors are critical for supporting more species: 1) large-size wetlands ; 2) varied topography creating diverse habitats; and 3) connection to a river. The benefits to having a wide variety of species in a wetland also are known: more production of predators for pests; protection for birds; better pollination when more insects are present; and more resilience of native species, making constant replanting unnecessary.

Often created or constructed wetlands support only a few species (e.g., cattails and reed canary grass) and provide only low quality wildlife habitat. Could nitrogen farms do better?

Two recommendations emerged from this discussion. First, to the extent possible, identify a series of specific goals for nitrogen farming, regardless of whether they seem entirely compatible with one another. These goals will delimit a range of hydraulic and nitrogen loading rate regimes for wetland systems. The question of whether these multiple goals could be met in a single wetland or in a series of wetlands also could be addressed.

Secondly, create performance forecast models of nitrate-nitrogen removal to evaluate the efficacy of nitrogen farming under the various hydraulic and nitrogen loading rate regimes suggested by the project goals. The understanding of nitrate-nitrogen loss in wetlands has progressed to a point that their performance can be accurately forecasted. Thus, forecast models could be used to compare nitrogen-farming performance under operating conditions that might optimize nitrate-nitrogen removal for a specific wildlife or biodiversity goal. It may well be possible to obtain reasonable nitrate-nitrogen removal performance without sacrificing habitat values.

REGULATORY ISSUES

State and federal regulations could be both a help and a hindrance to the practice of nitrogen farming. Regulations will help promote nitrogen farming when water quality criteria (constituent concentrations, levels, or narrative statements) are set low enough to require treatment of nutrient-rich streams or rivers and discharge limits are established to drive dischargers to action. The U.S. Environmental Protection Agency has issued nutrient criteria for streams in various regions of the country. For the Corn Belt and Northern Great Plains Ecoregion the criteria for total nitrogen is 2.18 mg/L. Of this concentration, about 1.6 mg/L would be NO_3^-. The Illinois River typically carries about 4 mg/L NO_3^-.[17] Given the NO_3^- criterion and load of the Illinois River, over 100,000 tons annually of NO_3^- will need to be removed. John Meagher, of the U.S. Environmental Protection Agency, concurred that using wetlands to remove nitrogen from waterways could be done at a lower net cost than other traditional treatment systems, making the program potentially attractive to the USEPA.

To be able to truly promote nitrogen farming, however, regulations will need to be flexible enough to not prohibit nitrogen-rich waters from traveling from nitrogen sources (e.g., fields of row crops) to nitrogen farms. Varying water quality standards could be created for *transporting* water bodies and *receiving* water bodies. This idea is not completely far-fetched. According to the USEPA, establishing an appropriate water quality standard for a stream or river requires more than simply setting the lowest, scientifically-possible criteria for nutrient components. A standard also considers the designated use of the reach, including economic, social and political considerations.[18] Thus, some reaches would need to have a designated use to transport nutrient-rich water to treatment wetlands.

Other regulatory issues also are crucial to the viability of nitrogen farming. For example, regulators will need to establish a system for measuring and monitoring nitrogen outputs from both traditional farms and wetland nitrogen farms. Mechanisms would need to be created to give a farmer credit if he reduces the nitrogen load in a waterway (via wetlands).

Finally, issues of wetland jurisdiction (established under Section 404 of the Clean Water Act) will need further discussion. To be able to capture the benefits of a free market, nitrogen farmers will need to be able to move in and out of "farming" nitrogen. That is, in years when corn prices are depressed, a farmer may decide to allow his land to return to wetlands. Perhaps five years later, as corn prices rise, that same farmer may decide to return his land to row crops. Regulatory mechanisms would need to be created that would allow such fluidity in land use. These mechanisms would exempt nitrogen farm wetlands from Section 404 jurisdiction. Without such mechanisms, farmers—afraid that their crop land, once placed in wetlands, will not be permitted to be returned to crops—may be unwilling to place their land in wetlands at all.

Such regulatory safeguards already exist for landowners who create habitat for endangered species. The federal Safe Harbor Program exists to encourage property owners to enhance their land for endangered species without penalizing them for changing the land use—even if endangered species begin to nest or breed on the land. A similar law could be created for farmers who choose to create wetlands for water quality enhancement.

PILOT PROJECTS AND CONCLUSIONS

At various scales, each of the pilot projects will address the following questions:

1) How much per pound will it cost to use wetland restoration to remove nitrogen?

2) What wetland parameters maximize denitrification?

3) How would wetland design be modified if we were interested in reducing nitrate-nitrogen *and* increasing biodiversity?

4) How do we quantify and certify nitrate-nitrogen reduction? The pilot project analyses should consider the relative cost and accuracy of different accounting and reporting methods.

Although we currently can predict nitrogen removal rates in general, we need to determine how much denitrification can occur across wetlands of varying types under specific environmental conditions. Demonstration sites—on several scales—will provide the scientific documentation necessary to complete wetland restoration throughout the Mississippi River basin and elsewhere—wherever nitrogen removal is needed to improve water quality. If progress is to be made in controlling water quality of both small and large rivers, testing new ideas, on a large-scale basis, is essential.

Economics

Two different economic approaches are possible for nitrogen farming: 1) create marketable permits for nitrate-nitrogen removal using a cap and trade system, or 2) offer government incentives to encourage landowners to establish a nitrogen farm. These two approaches might also be combined in some cases.

Currently, municipalities, industries and farmers can export nitrate-nitrogen directly to streams and rivers without economic or regulatory consequences. A market-based system for nitrogen "credits" would need an institutional structure where consequences exist, thus providing the incentive for landowners to use bottomlands as nitrogen farms and for other dischargers to pay nitrogen farmers to remove nitrate-nitrogen. To be effective, this institutional structure would require several components: 1) a regulatory "cap" on nitrogen releases; 2) a market structure to trade debits and credits for nitrate-nitrogen release and removal; and 3) a state agency to monitor removal and to certify the trading system.

The most obvious and immediate regulatory structure needed is the passage of state water quality standards and a determination of how these standards are to be met. In regulatory parlance, this is a Total Maximum Daily Load (TMDL) analysis. The TMDL would establish a "load cap"—the total amount of nitrate-nitrogen that could be discharged into the water. If the TMDL rule was established in such a way that an "allowance market" was created, then local or regional dischargers could sell and purchase their discharge rights, as explained below.

> These [allowance] markets give dischargers along the waterway the "right" to discharge a certain amount of pollution, with the total amount of permitted pollution equaling the waterway's load cap. Such allowance markets, which have been used successfully in air quality improvement efforts, lower the cost of achieving water quality standards. Moreover, they provide incentive for dischargers to reduce their discharge below their permitted levels; they could then sell a portion of their rightful allotment to other dischargers. In this way, allowance markets would accommodate economic growth while preserving watersheds' environmental health.[7]

Ideally, potential purchasers for these nitrogen credits would include row crop farmers and other nonpoint source polluters. According to the U.S. Geological Survey, only about 1 percent of the nitrogen inputs in the Mississippi Basin are from municipal and industrial point sources.[8] Approximately 58 percent of the nitrogen in the basin, however, comes from agricultural sources, including fertilizer, manure, and legumes (e.g., soybeans). Clearly the agriculture industry could be a large potential market for purchasing nitrate-nitrogen removal credits.

Credits generated would be self-recorded by the nitrogen farmer, similar to how a municipal wastewater treatment plant self-monitors its own effluent. A state agency would need to conduct spot checks for verification and to set baseline parameters. The twin issues of what credit calculation rules would be used and who would approve them still need to be addressed in detail. The strength and clarity of the measurement and monitoring strategies in the nitrogen-farming program will be key to its success.

There may be, however, perverse impacts from market-based permits. It may be hard to look into the future for nitrogen reduction permits, but experience tells us that markets —often when stimulated to act by a government regulation—can create unintended outcomes. For example, in the early 1990s an emissions trading market was created in response

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to the acid rain problems, which were principally caused by sulfur dioxide (SO_2) emissions. A robust trading market for sulfur dioxide emissions, however, did not emerge. Rather, permit prices dropped because power plants used fuel substitution to avoid emitting SO_2 altogether, rather than cleaning up existing polluters or building new, cleaner coal plants. Thus, one of the pitfalls of trading schemes is that point sources overestimate the costs of meeting regulations prior to their imposition. It is possible, therefore, that a nitrogen trading market could fail to materialize if the point sources are able to engineer cheaper solutions than they had previously advertised, thus short-circuiting the need for a discharge allowance market. Nitrogen farming pilot projects could demonstrate more clearly the actual costs to use wetlands to remove nitrate-nitrogen.

INCENTIVE-BASED PROGRAMS

Nitrogen farming also could be established using voluntary incentive programs. Both the federal and state governments currently fund several programs that pay landowners to convert their cropland to wetlands. The U.S. Department of Agriculture administers two such programs: the Wetland Reserve Program (WRP) and Conservation Reserve Enhancement Program (CREP). Federal funds also are available through buffer programs of the Natural Resources Conservation Service (NRCS) and Section 319 grants for nonpoint source control through the Environmental Protection Agency (EPA). The EPA also has made money available from a revolving fund that can issue low interest loans for water supply and wastewater treatment. These are some of the authorized mechanisms by which farmers or landowners might receive incentive payments.

The potential for nitrogen reduction could be one of the criteria for assessing the value of a proposal for funds. The basis for payment simply could be the acres of corn or soybean converted to wetlands. In this respect, the incentive payments would be little different than the CREP, lacking an incentive to maximize nitrate-nitrogen removal, or, for that matter, even monitor the load reduction. If incentive-based programs are used, some demonstration of nitrate-nitrogen removal will be necessary. For example, the baseline might be that a wetland has been created or restored, following along the lines of the Army Corps of Engineers' 1987 manual and, for that, the landowner receives a given amount of money. Then, the landowner is paid according to an agreed upon price for every ton of nitrate-nitrogen removed. Measurements of regular flow and associated concentrations—certified by a local laboratory and reviewed by the state—might determine the load reduction.

Federal programs could be expanded to specifically identify wetland nitrogen farming as a recognized conservation practice. Congress should be encouraged to fund pilot projects to test the practice and establish design, construction, and management guidelines. During this session of Congress, the Farm Bill is likely to be reauthorized and provision for nitrogen farming would greatly help the development of the concept.

ECONOMIC ANALYSES

Traditional benefit/cost analysis is very difficult where both costs and benefits have components that are not normally valued in the market (e.g., wildlife habitat, clean water, and flood storage). For an individual to decide whether to farm nitrogen, however, there will need to be solid evidence of the costs that the landowner will incur to compare with the incentive payments, tradable permit benefits, and other income that might be derived from nitrogen farming. Wetland-based nitrogen removal will be widely implemented only if it is less expensive than other denitrification technologies and generates more income than row crop farming or other farming activities on the converted land.

Economic evaluation of nitrogen farming also should be based on implementation cost effectiveness, that is, the expected private and social costs of an option for a large region. In cases where productive agricultural land is converted to wetlands, implementation cost includes the opportunity cost of conversion—namely the loss in net agricultural income—and changes in regional income and employment. Opportunity cost is higher when agricultural land is taken out of production than when it is not. Implementation cost also includes transaction cost. For nitrogen credit trading, transaction cost is the cost of establishing and maintaining the market. The more complex the nitrogen credit market, the higher the transaction cost.

The most cost-effective way to reduce nitrate-nitrogen loading is to minimize private plus social costs per unit of nitrate-nitrogen reduction. For any desired level of nitrate-nitrogen reduction, the least costly combination of areas/options should be chosen. This differs from using cost/benefit analysis to sell an incentive program to the public.

Economists with the Integrated Assessment of Hypoxia in the Northern Gulf of Mexico Task Force—lacking hard data on the *economic* damages caused by hypoxia—eventually gave up on benefit/cost analysis. Rather, they preferred to look instead at "cost-effective" ways that the public might want to accomplish a goal (e.g., cleaner drinking water). If the goal was important to the public and it could not reasonably be accomplished at a lower cost, then the approach was perceived as being "cost effective." The notion of cost effectiveness is based on the idea that if the public really wants to do something (regardless of the benefit/cost involved), then it should be aware of the costs of the different approaches for reaching that goal, and there will be some approaches that are more cost effective to do the job than others. This line of thinking, rather than traditional benefit/cost analysis, might be the most useful way to "sell" the public on the need for nitrogen farm subsidies.

SELECTING PRIORITY SITES

The supply curve for nitrogen reduction using wetlands essentially arrays the potential areas for establishing a market for nitrogen credits and purchasing parcels from willing sellers from lowest to highest incremental cost per ton of nitrogen reduction. For this reason, the supply curve for wetland conversion can be used to determine priority sites. To minimize the overall cost of nitrogen reduction, supply curves for all options (more efficient use of nitrogen, conversion of agricultural land to uses that require less nitrogen, and wetland conversion) would need to be generated for all of the regions in the upper Mississippi River Basin. This is a daunting task. Another approach is to select the most cost-effective combination of sites and options within a particular region, such as the Illinois River.

One of the difficulties with the supply curve approach described above is that it does not consider the other social and environmental values provided by wetlands. Multiple attribute decision making (MADM) is a procedure that allows a decision-maker, or for that matter any user, to evaluate and rank alternatives for reducing nitrogen with wetlands based on the monetary and non-monetary attributes of alternatives and the decision-maker's preferences for attributes. Application of the MADM method requires selecting and measuring the multiple attributes of alternatives; determining the relationships, if any, among attributes; identifying relevant constraints on the selection of alternatives, such as time and budget; and determining preferences for (relative importance of) attributes. Possible attributes of wetland alternatives include: minimizing cost per ton of nitrogen reduction, improving aesthetic qualities of the landscape, reducing flood damages, enhancing fish and wildlife habitat, and increasing recreational opportunities. A MADM approach can be used to evaluate and rank the pilot sites and other sites. Economist Tony Prato, professor at University of Missouri – Columbia, has applied this procedure to other landscape management issues.

PILOT PROJECTS

From the point of view of economics, specific pilot projects can answer six important questions:

1) What are the capital and operating costs?

2) What are the opportunity costs?

3) Are there economies of scale?

4) What is the likely income from nitrogen farming and related activities such as flood and sediment control or hunting and fishing?

5) What are market area and market size?

6) What are the costs of monitoring and certifying nitrate-nitrogen removal?

7) What are the regional (i.e., county or state) economic effects?

The three proposed pilot projects (see "Pilot Projects," page 5) offer a wide range of scale and opportunity to address these questions.

The cost of nitrogen farming will vary relative to the location: The more expensive the land and the more difficult to acquire the necessary flow, the more expensive nitrogen farming will be. Where pumping is necessary, not only will the capital cost be greater, but the operating cost will be higher. Inexpensive land and gravity flow into and out of the nitrogen farm would be more desirable. The higher the concentration of nitrate-nitrogen, the easier it will be to remove a sizable load, maximizing the income from nitrogen farming. (The cost of nitrogen credits, however, will likely discourage the excessive release of nitrate-nitrogen just to increase concentration.) The opportunity cost—or the lost income from other activities not undertaken on the land—also needs to be carefully evaluated.

In a market-trading scenario, the price per ton of nitrate-nitrogen removed would be based on others' willingness to pay. For example, a farmer should be willing to buy nitrogen credits up to the value of the increased yield gained from adding nitrogen to his crops. He also would consider the opportunity cost incurred if he had to take his own land out of production to establish wetlands for nitrate-nitrogen removal on his own property. Municipalities and industries that would consider purchasing nitrogen credits from farmers would weigh the costs of nitrogen reduction via both nitrogen farming and alternative methods, such as treatment system upgrades. If the cost of nitrogen credits proved lower, then a market would be created for nitrogen farming.

Similarly, given an operating nitrogen farm, the removal rates for sediments, phosphorus, and other agricultural chemicals and their residuals could be determined and an allowance discharge market created for those constituents as well. The prices for these removed constituents could be established based on technologies that are well established in the wastewater treatment field. The cost of sediment control, however, might be best established by determining the cost of dredging a ton of sediment from a navigational canal or river.

Hunting and fishing income can be readily established from such uses in nearby preserves or commercial hunting operations. Also, given the pilot projects, hunting and fishing can be offered for sale.

If advertising is necessary, the expense for this activity can be included in the overall evaluation of costs for nitrogen farming.

Potentially, nitrogen farming also could generate income by providing mitigation required through Farm Bill Swampbuster and/or Section 404 or 401 needs. These wetland areas, obviously, would not be permitted to stop nitrogen farming after a few years.

The market area for a nitrogen farm needs to be carefully evaluated. Ideally, the nitrogen farm should be positioned near a source of nitrogen loading. For Spring Creek, the market area is largely downstream, near the city of Macomb and its waste discharge locations. Furthermore, the city of Macomb has need for nitrogen reduction from the upper part of the watershed for protection of its potable water supply. The Hennepin & Hopper Lakes project is upstream of Peoria and its wastewater treatment plant, but downstream of Chicago. The concentration of nitrate-nitrogen in the Illinois River at the location of the Hennepin project runs at about 6 mg/L. Although a large-scale project, the Lima-Hunt Project on the Mississippi would remove lower concentrations of nitrate-nitrogen than projects on the Illinois. While scale is important, location and proximity to high concentrations of nitrate-nitrogen may be even more important in terms of a profitable nitrogen farm.

Finally, the economic effects of nitrogen farming on the regional economy need to be determined. Unlike more traditional forms of farming, few chemicals would need to be purchased for a nitrogen farm. Some weed control will be necessary, but in large part, the aquatic vegetation that volunteers in a wetland is adequate for the production of nitrogen credits. Some labor will be necessary, but little equipment or fuel. Where pumping is required, the local utility will earn income, but this income may not find its way into the county or villages in the surrounding area. Nevertheless, each of the pilot projects is situated in counties and communities that are, in large part, dependent on farm activity to support their economies. The impact of nitrogen farming can be readily assessed through these demonstration projects.

CONCLUSION

One of the chief goals of nitrogen farming is to create a legitimate way for a landowner to profit from wetland restoration. It is inefficient and impractical for government agencies to simply buy land to restore or create the needed wetlands. For example, despite a decade-old state and federal mandate in Florida to put 10 percent of the Everglades Agricultural Area into wetlands, today only half of the 40,000 acres are built. It is estimated that phosphorus removal from those wetlands now occurs at a cost of $84 to $425/lb/year.[9] This inefficiency is caused by the extreme difficulty of removal at low concentrations, aggravated by the government's need to condemn land to acquire it and the lack of profitable alternatives to traditional farming for landowners.

It is clear that alternative mechanisms and financial structures are needed if wetlands are to be used for removing nitrate-nitrogen or other contaminants from our nation's rivers and oceans. Rigorous economic analyses should demonstrate that nitrogen farming is a viable alternative for improving the health of our nation's waterways.

AGRICULTURAL ISSUES

It can be said that nitrogen farming is a system designed to sustain an unsustainable system, that is, the nation's corn-soybean agricultural system. Nitrogen farming unwittingly encourages the continuation of this current agricultural system by allowing farmers to continue to distribute nitrogen-rich fertilizer over thousands of miles of our landscape. Our nation props up this agricultural system with various forms of governmental aid for row crop farmers. Therefore, an appropriate first question about nitrogen farming might be the social and political question: How can we reduce the need for nitrogen inputs altogether?

While the question may be crucial to the nation's debate about farm policy, for the purposes of discussion on wetland-based nitrogen farming, we assume that the practice of heavy application of nitrogen fertilizer will continue, and, therefore, the need to remove the excess nitrogen from our nation's waterways will remain. Many in the agricultural industry believe that a move toward a new agriculture economy—one based on something other than soybeans and corn—is unlikely. As long as the infrastructure, climate, and demand continue to support these crops, farmers will continue to plant them. [Note: Some voices would debate whether the demand for corn and soybeans in our current global economy will continue at a brisk pace. While American farmers formerly had strong opportunities for exporting oversupply, currently, international demand is being met to a much greater extent by our global competitors. This reduced demand could lead to reduced acreage of corn and soybeans grown in the United States in the future.]

Once these crops are planted, however, it is much cheaper for a farmer to pay for a plentiful supply of nitrogen-based fertilizer than to pay for a low-yield crop harvested without the fertilizer. Nitrogen fertilizer, in a word, becomes a farmer's insurance policy. Depending on the climate, tillage conditions, and available technology at the time of application, approximately one-third of all nitrogen applied to agricultural fields ends up in the outlet ditch and receiving stream.

INCENTIVE PAYMENTS V. FREE MARKET?

Farmers would be most likely to engage in nitrogen farming if they perceive it to be a voluntary, incentive-based practice. Government incentive payments currently make up a large percentage of a farmer's income and are likely to continue to do so. Annual direct payments to farmers reached a record $32 billion in 2000.[19] Current Congressional debate over the next Farm Bill, scheduled for passage in 2002, includes discussion on how to tie more of those payments to conservation practices. Such discussions would need to cover the concept of wetland restoration and management as a means for nitrogen removal.

On the other hand, farmers could harvest nitrogen and generate certified nitrogen credits, which could be sold in a free market to municipalities, industries, farmers or any other individual or institutions needing to reduce the nitrogen load of their receiving stream. Garnering nitrogen credits would become an alternative "crop" for the farmer. When corn or soybean prices are depressed, the farmer could operate wetlands and produce nitrogen credits with a very low opportunity cost. Conversely, when corn or soybean prices rise, some farmers may opt out of nitrogen farming to return to row cropping, however, others may enter the nitrogen farming business as the open market drives up prices of nitrate credits. The landowner could earn additional revenue from phosphorous, carbon, or sediment sequestration; flood storage, which could be marketed to downstream municipalities; wetland mitigation banking; and hunting and fishing rights.

Drainage and levee districts could provide efficient management, optimal landscape positions, and political acceptability of nitrogen farming. Rather than an individual farmer working alone, the interested landowners in a watershed could participate together in nitrogen farming. Such an organizational structure could monitor and control the flow of nitrogen from the contributing lands, transferring payments from the high yielding, corn and soybean lands to the less productive bottomlands where nitrogen farming is better suited. Nitrogen farming districts could more easily make management decisions as to when and where to pump drainage water and how best to use the existing infrastructure (e.g., pumps, ditches and levees).

"It is much cheaper for a farmer to pay for a plentiful supply of nitrogen-based fertilizer than to pay for a low-yield crop harvested without the fertilizer. Nitrogen fertilizer, in a word, becomes a farmer's insurance policy."

Potential Pitfalls

Workshop participants identified three components of nitrogen farming that could make the practice appear unattractive to traditional row crop farmers. The first would be if the market for nitrogen credits included themselves as potential customers. Workshop participants stated clearly that farmers do not want to add to their disproportionately high production costs. Any system that required farmers to buy credits of nitrogen reduction—perhaps purchasing such credits from a neighbor who would convert cropland to wetlands—would not be well received. Industry representatives emphasized the difficulty of convincing the agricultural community that farmers should pay for nitrogen reduction (even by purchasing nitrogen credits) themselves. Currently there are no national criteria or state laws controlling agricultural runoff and the associated contaminants. Consequently, the agriculture industry continues to expect point source polluters (e.g., municipalities and industries) to pay for any new nutrient controls enacted by the states.

The second potential pitfall would be if farmers perceived nitrogen farming as a program that somehow penalized farmers who already have placed some of their acreage in wetlands, perhaps through the USDA's Wetlands Reserve Program. Presumably those wetlands already are removing some of the nitrogen load reaching area streams and rivers. Therefore, a nitrogen farming program cannot just give out new incentives to farmers who build wetlands after a certain date, but also must find a way to reward farmers who already have done so. Similarly, strong programs will need to be in place to prevent further wetland loss or enterprising farmers who could rip out existing wetlands, farm them for a few years, and then sign up to be a nitrogen farm. "Slippage" and gaming in these kinds of programs can be a problem that needs to be guarded against.

One last consideration that would make nitrogen farming unattractive to farmers would be a permitting-type scheme that monitored how much and when they could discharge nitrogen from their fields. Politically and technically, such a scheme could be difficult to implement.

Pilot Projects

The need for pilot projects was never more evident than during the discussions of agricultural issues. The new, proposed farm activity is without precedent. The activities associated with wetland restoration through wetland management and operation are unfamiliar to most farmers. The capital and operating costs of these activities, on a significant scale, are largely unknown. Even to a greater extent, revenue streams of nitrogen farming and the collateral activities are unknown. The risks and liabilities are undefined. Pilot projects could provide the basis for the answers to these issues. Perhaps, more importantly, pilot projects could give farmers a place to observe, firsthand, a nitrogen farm. The pilots could act as research facilities and classrooms.

Conclusion

Farmers are more likely to embrace nitrogen farming if it is offered as an "income stabilization" program for farm income. Incentive payments offered for nitrate-nitrogen removal would be viewed as yet another optional income stream. Before farmers can decide if they want to participate in nitrogen farming, they will need more detailed economic information on the startup and operational costs involved.

If nitrogen farming is to be initiated as another farm subsidy, Congress would need to institutionalize payments rather than pay farmers through *emergency* funds. In recent years Congress has authorized \$5–\$10 billion annually in emergency payments to farmers. If these same funds were budgeted—and spent on conservation-friendly practices such as nitrogen farming—the money could be more effectively spent. States also could fund these payments through their Department of Agriculture soil cost-share programs.

CONSERVATION CONCERNS

The workshop on concerns among conservation organizations raised several issues that any system of nitrogen farming will need to address. Many of these issues were addressed by the Science and Policy workshop participants, as well. Concerns highlighted by the conservation organizations are discussed below.

BIODIVERSITY

Workshop participants expressed concern over creating an incentive for the restoration of one wetland value in the absence of incentives for the development of other values. Optimization of wetland design or management to promote denitrification may not support desirable biodiversity, particularly because such optimization often is achieved by eliminating micro-topographic variation and promoting colonization by a few plant species. Low plant and animal diversity, dominance of a few and often nonnative plant species, and lower micro-topographic variation—the latter a crucial habitat feature in natural wetlands that promotes biodiversity—reflect the artificial character of “created” or “treatment” wetlands.

Indeed, both by design and by accident, artificial and restored wetlands could become points of establishment of non-native species, which could spread to infest entire watersheds. (Note: This point is under some debate by scientists.) If not carefully controlled, therefore, nitrogen farming could interfere with watershed restoration by preventing restoration of bottomland wetlands to natural conditions and also could promote further degradation of aquatic life by encouraging the spread of non-native wetland species.

Nitrogen farming also could impact stream biodiversity. Natural floodplain wetlands are often critical habitat for animal (particularly fish) species that use the floodplains to breed, feed, or find refuge from strong currents during floods. Floods also are crucial mechanisms for moving plant matter (including coarse woody debris) into the stream or river channel. Optimal management of bottomlands for denitrification potentially could involve preventing flooding except through control structures. This, in turn, would prevent the free exchange of plant and animal life between such bottomland areas and the stream or river.

While this situation would be no worse than if the bottomland were protected by levees to allow farming, it may not be any better for restoring the connectivity between river and floodplain. Decisions on siting and managing nitrogen farms, therefore, would need to be made with careful consideration to ensuring adequate stream-floodplain connectivity.

Another key feature of healthy stream and river ecosystems is up-downstream connectivity, that is, the ability of aquatic species to move freely up and down stream as needed. Yet, where a nitrogen farm straddles a stream and weirs are used to control and measure inflow and outflow, fish passage, for example, may be affected. In small streams, this effect would probably be no different than that of a beaver dam, a formerly natural feature of many headwater streams in the Mississippi basin. In larger streams, the effects might be more significant.

The challenge of maintaining up-downstream connectivity also arises when considering the siting of nitrogen farming facilities in relation to the sources of the nitrogen they are seeking to remove. In particular, nitrogen farms cannot always be located immediately adjacent to the source of excessive nitrogen loadings. A potential result is that some streams and rivers will have to serve, in effect, as conduits to move polluted water downstream to reach an area suitable for nitrogen farming. Reaches that serve to convey nitrogen loads downstream will be less likely to sustain healthy aquatic ecosystems. The greater the density and wider the distribution of nitrogen farms, and the less they rely on natural stream hydrographs to transport the polluted water to treatment areas, the less will be the impact on up-downstream connectivity and ecosystems. However, river valley morphology and the human geography of the region may require that streams sometimes be used as conduits of nitrogen-enriched water, and the in-stream effects of this water must be recognized and addressed.

CONSIDER THE WHOLE ECOSYSTEM

Nitrogen pollution of our nation's streams in agricultural watersheds occurs in the context of a wide range of other impacts to stream ecosystem integrity. From a conservation perspective, addressing nitrogen pollution without addressing these other problems will reduce the conservation effectiveness of such actions.

Specifically, nitrogen loading from agricultural areas in the Mississippi basin typically comes as part of a package of alterations to watersheds, involving the complete rearrangement of stream food webs. Headwater stream food webs in the Mississippi basin naturally depend primarily on inputs of particulate and dissolved plant matter to fuel life. Agriculture typically eliminates most of this natural plant matter input, greatly reduces shading along the streams, and adds massive amounts of largely inorganic ("mineral") nutrients. These changes convert the food web to one based largely on the production of biomass by algae, changing vast arrays of microbes and plankton and the larger fauna that feed on them. Reducing nitrogen loads without addressing the losses of natural plant matter inputs to streams would prevent the restoration of native food webs. A macrophyte-rich wetland used for nitrogen farming, however, would begin to address this concern for the food web by adding plant matter to the stream system.

Traditional agricultural activities also create significant changes to watershed hydrology and sediment transport. Reducing nitrogen loads without addressing these additional and often severe impacts on streams will prevent the restoration of native food webs. If properly designed and sited, on the other hand, nitrogen farms could function additionally as storm pulse storage areas, sediment traps, and exporters of dissolved and particulate plant matter. This would help to address the wider range of agricultural impacts on stream ecosystems. It is crucial, therefore, to determine whether the use of nitrogen farming wetlands for these additional functions may reduce their effectiveness for nitrogen removal.

PILOT PROJECTS

Pilot projects would be useful in better understanding the effects of nitrogen farming on the wetland ecosystems and the entire watershed. Results from the three pilot projects currently under consideration by TWI (see "Pilot Projects," page 5) would produce information vital to addressing many of the conservation organizations' concerns about

"Participants expressed concern over creating an incentive for the restoration of one wetland value in the absence of incentives for the development of other values."

dependent physical and wildlife resources. Funding these or any other pilot projects will require some considerable effort.

While there was strong interest in the free market approach to nitrogen farming (based on a cap and trade structure), participants believed that greater political will could be engendered if nitrogen farming were promoted through government incentive payments. Nitrogen farming should be included as a recognized conservation measure in the Conservation Security Act or the next federal Farm Bill. State revolving funds for sewage treatment or for drinking water improvement also potentially could be applied to this practice. Politically, it is more realistic to modify an existing incentive payment program to include nitrogen farming, than it is to create a completely new program.

Regional funding may be available for these projects. The Spring Creek project could be part of an Upper Mississippi River Basin initiative. District offices of the U.S. Army Corps of Engineers may be looking for restoration projects that meet their criteria. Taking a watershed approach may be able to open up avenues for other funding options. Specific areas that might be potential sites for nitrogen farming pilot projects include: the Minnesota River Basin (Minnesota); the Mark Twain Natural Wildlife Refuge (Illinois); Raccoon River (Iowa); and Lake Mendota (Wisconsin). It was widely agreed that placing projects in several states would be important for gaining a broader base of political support.

Conclusions

Can nitrogen farming become an accepted and desirable means for improving water quality by promoting wetland restoration? From a conservation perspective, the answer is based not just on meeting a stream water quality standard, but on actual measures of stream ecosystem integrity. Therefore, restored wetlands will be deemed a success when they not only serve as agents of denitrification, but when they also provide a rich food web, sediment and flood control, and wildlife habitat. Workshop participants also noted that nitrogen farming will have an impact not only on stream ecosystems, but on their adjacent and closely-integrated bottomland ecosystems. Restored wetlands will be judged as a success when they also support restoration of the natural interactions between streams and riparian ecosystems.

Overall, any barriers to carrying out a program of nitrogen farming are not insurmountable, assuming development of some institutional structure that would provide its economic foundations. However, there clearly are challenges for making such a program effective not only for optimizing "treatment" of a watershed's waters for the single purpose of nitrogen removal, but also for promoting—or at least not interfering with—larger ecological improvements.

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