Paper Title: A Water Quality Strategy for the Mississippi River Basin and the Gulf of Mexico

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A Water Quality Strategy for the Mississippi River Basin and the Gulf of Mexico

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Abstract

Nutrient pollution, now the leading cause of water quality impairment in the United States, has had significant impact on the nation's waterways. Excessive nutrient pollution has been linked to habitat loss, fish kills, blooms of toxic algae, and hypoxia (oxygen depleted water). The hypoxic 'dead zone' in the Gulf of Mexico is one of the most striking illustrations of what can happen when too many nutrients from inland watersheds reach coastal areas. Despite the efforts of municipal building programs, industrial wastewater requirements and agricultural programs designed to reduce sediment loads in waterways, water quality and nutrient pollution continues to be a problem.

We undertook a policy analysis to assess how the agricultural community could better reduce its contribution to the 'dead zone' and also evaluate the synergistic impacts of these policies on other environmental concerns like climate change. Using a sectoral model of U.S. agriculture, we compared policies including untargeted conservation subsidies, nutrient trading, Conservation Reserve Program extension, agricultural sales of carbon and greenhouse gas credits and fertilizer reduction. This economic and environmental analysis is watershed based, primarily focusing on nitrogen in the Mississippi River basin, allowing us to assess the distribution of nitrogen reduction in streams, environmental co-benefits and impact on agricultural cash flows within the Mississippi River basin from various options. The model

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incorporates natural resource accounts and alternative production practices, making it possible to get a more a complete picture of the costs and co-benefits of nutrient reduction. These elements also help to identify those policy options that minimize the costs to the farmers and maximize benefits to society.

Keywords: Hypoxia, Dead Zone, policy, trading, water quality, greenhouse gases, Mississippi River, Gulf of Mexico

Introduction

The pollution of rivers and estuaries by excessive levels of nutrients, such as nitrogen and phosphorus, is a persistent water quality problem in the U.S. and a growing problem worldwide. Most of this pollution comes from non-point sources, especially agriculture and urban runoff (Carpenter et al., 1998). Some of the most visible impacts of nutrient pollution have occurred in coastal waters and estuaries, where freshwater flows from land meet the ocean. Nutrient influxes in estuaries have increased up to tenfold since the beginning of this century, with the greatest increases occurring after 1950. Scientists have linked these increased nutrient loads with habitat loss, fish kills, blooms of toxic algae, and hypoxia (NOAA, 1998).

Hypoxia occurs when the amount of dissolved oxygen in water decreases to levels of 2 parts per million or lower[3]. Areas of hypoxia (or “dead zones”) are present in more than half of the estuaries of the U.S. The largest hypoxic zone off the U.S. coast -- which is also one of the largest in the world -- occurs near the outflows of the Mississippi and Atchafalaya Rivers in the

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[3] Normal levels of dissolved oxygen are about 5 parts per million.

northern Gulf of Mexico. This zone, which was 7,000 to 10,000 km^2 in the summers of 1985-1992, doubled to 20,000 km^2 in 1999 (Goolsby and Battaglin, 2000).

The principle factors leading to the development of hypoxic zones are: 1) the stratification of the saltwater/freshwater column and 2) the decomposition of organic matter from nutrient over-enrichment, particularly nitrates (CAST, 1999). During the summer months, the warmer weather and calmer seas cause stratification where the lighter freshwater floats on the seawater cutting off the flow of oxygen from the surface to the deeper saltwater layer. The nutrient rich water from the Mississippi River promotes algal growth, which when it dies or is consumed by other aquatic species produces large quantities of organic matter. As the organic matter decomposes it consumes the oxygen in the saltwater layer causing hypoxia. This condition is alleviated in the Fall when stormier weather conditions cause the layers to intermix allowing oxygen to move through the water column again.

As oxygen stress has increased in the Gulf the composition of organisms inhabiting bottom waters has shifted over time (Rabalais et al., 1999), resulting in fewer fish and a less diverse array of fish inhabit the area. Fishery managers point out that hypoxia could lead to significant losses for Louisiana, where Gulf fisheries generate more than $2.4 billion of economic activity from recreational and commercial fisheries per year (Holiday and O’Bannon, 1997). Despite the current lack of direct evidence of economic impacts in the Gulf of Mexico (Diaz and Solow, 1999) ecological and fisheries impacts of hypoxic zones worsen as they become bigger (Caddy, 1993; Diaz and Rosenberg, 1995) and can cause in economic impacts (Baden et al., 1990). The

Black Sea, for instance, is now permanently hypoxic below 100m, and of the 26 commercial fish species only 6 still support a fishery (Earles, 2000).

The annual phosphorus flux reaching the Gulf of Mexico is approximately 136,000 metric tons and has not increased significantly over the years. Of the annual phosphorus flux approximately 31 percent comes from commercial fertilizers, 18 percent is from animal manure and 10 percent is from point sources. Another 41 percent comes from sources that have not been quantified but phosphorus attached to soil particles is believed to be a major component (Goolsby et al., 1999).

The total annual nitrogen flux from the Mississippi River is approximately 1.5 million metric tons, with nitrates accounting for around 1 million metric tons. This is three times higher than the nitrate flux 30 years ago. Nonpoint sources are thought to contribute as much as 90 percent of the nitrogen flowing into the Gulf of Mexico, with 56 percent entering the Mississippi River above the Ohio River. Commercial fertilizer and mineralized soil nitrogen comprises about 50 percent of the total flux, while atmospheric deposition, soil erosion and groundwater discharge contributes 24 percent, animal manure 15 percent and point sources 11 percent. Of these sources, only commercial fertilizer and legumes have increased significantly since the 1950's (Smith, Schwarz and Alexander, 1997; Goolsby et al., 1999). As agriculture is the primary source of nitrogen, participation by the agricultural sector in finding a solution is essential in order to achieve the necessary nitrogen loading reductions. Any policy options aimed at reducing the nitrogen flux from the Mississippi River basin will have some economic impact, either positive or negative, on the farming community.

Federal Taskforce

The hypoxic zone in the Gulf of Mexico became a high priority problem with the establishment of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force in 1997. The role of the Taskforce was to study the causes and effects of excess nutrient runoff in the Mississippi River basin and to coordinate and implement nutrient reduction activities to alleviate hypoxia in the Gulf of Mexico. An initial scientific study of the problem resulted in a series of reports from which an Action Plan was developed. This Action Plan was released in January 2001 (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2001)

The central coastal goal of the Action Plan was that "by the year 2015, subject to the availability of additional resources, reduce the 5-year running average areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers through implementation of specific, practical, and cost-effective voluntary actions by all States, Tribes, and all categories of sources and removals within the Mississippi/Atchafalaya River Basin to reduce the annual discharge of nitrogen into the Gulf" (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2001, p. 9)

Model simulations from the scientific reports commissioned by the Task Force suggest that nutrient (nitrate) load reductions of between 20-30% would be sufficient to increase the bottom water dissolved oxygen concentrations by 15-50% (Brezonik et al., 1999) and meet the coastal goal. Some of the options to reduce nutrient runoff to surface waters include improving the efficiency of farming practices, restoring wetlands, establishing riparian buffers and tighter controls of point sources such as wastewater treatment plants. Many of the nutrient mitigation options available to reach this target reduction level will also provide local water quality benefits by reducing phosphorus losses.

An economic analysis of the agricultural nutrient loading and hypoxia was commissioned for the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Doering et al., 1999). This analysis explored a variety of options and their cost-effectiveness, in part by using a version of the USMP model that World Resources Institute (WRI) developed with the USDA Economic Research Service (USDA/ERS) for the last farm bill. This model version, while the best available at the time, had a number of deficiencies that limited its utility to address the hypoxia issue. First, the model was not configured by watersheds, making it difficult to draw conclusions about the economic and environmental impacts in the five major sub-basins of the Mississippi River, and to assess the nutrient loadings and loading reductions in the basin. Second, current industrial and municipal point source information was not explicitly included in the model. In assessing the feasibility of nutrient trading or tighter regulatory controls, using up to date point source nutrient discharges is important. Finally, only conventional agricultural production practices were analyzed for the Task Force analysis, which limits the flexibility of farmers to react to technological and economic changes. The intent of this study was to extend the modeling system to allow it to better address issues relating to the hypoxic zone in the Gulf of Mexico.

Modeling Approach

To evaluate water quality strategies for the Mississippi River basin and the Gulf of Mexico we used the U.S. Regional Agricultural Sector Model (USMP), a model developed and maintained by the USDA/ERS. This is the same model used for the economic analysis commissioned by the Task Force.

USMP is designed for general purpose economic, environmental and policy analysis of the U.S. agricultural sector. This model is linked to a number of national databases – the regularly-updated USDA production practices surveys, the USDA multi-year baseline and geographic information systems databases such as the National Resources Inventory. USMP estimates how policy changes, demand or technology will affect the regional supply of crops and livestock, commodity prices, use of production inputs, net farm returns, government expenditures, participation in farm programs and environmental indicators.

WRI has collaborated in the past with USDA/ERS to improve the spatial delineation of USMP, increase the diversity of cropping rotations and to simulate the environmental impacts of each production practice and the Conservation Reserve Program. The model includes 10 major crops (corn, sorghum, oats, barley, wheat, rice, cotton, soybeans, hay and silage), a number of livestock enterprises (dairy, swine, poultry and beef cattle) and a variety of different processed and retail products. There are 45 production regions in the model that are derived from the intersection of the USDA farm production and land resource regions.

A majority of the environmental impacts are derived using the Erosion/Productivity Impact Calculator (EPIC) (Williams, Jones and Dyke, 1984; Sharpley and Williams, 1990). EPIC is a crop biophysical simulation model used to estimate the impact of management practices on crop yields, soil quality and a variety of environmental parameters like nutrient, pesticide and soil losses at the farm field level. It uses information on soils, weather, and management practices including specific fertilizer rates, to produce information on crop yields, erosion and chemical losses to the environment. Additional environmental effects that the USMP model produces include some greenhouse gas emissions, soil carbon flux, energy use including that embodied in inputs and related off-site soil damage. Nitrous oxide emissions from fertilizer use were derived using the same method as the USEPA Greenhouse Gas Inventory (USEPA, 1999) and calibrating to their estimate.

Modifications to the USMP Model

Alexander, Smith and Schwarz (2000) showed that the delivery of nitrogen from inland point and nonpoint sources is not a simple function of the distance from these sources to the coast. They demonstrated that the amount of nitrogen delivered from interior watersheds depends on the size of the channels through which nitrogen moves, with the rate of nitrogen loss in waterways decreasing as channel size increased. This means, in the case of the Mississippi River, that a larger portion of the nitrogen entering the system in the Upper Midwest and traveling through wider streams may reach the Gulf of Mexico than nitrogen travelling through smaller streams close to the Gulf.

Significant sources of nitrogen and phosphorus come from municipal wastewater treatment plants and industrial facilities within the basin. A study initiated by EPA to determine the total nutrient discharge level from these point sources using 1996 National Pollutant Discharge Elimination System (NPDES) information showed there were about 11,500 permitted facilities in the basin. The discharge rate varied from campgrounds at approximately 0.01 metric tons of nitrogen per year to the Chicago municipal wastewater treatment plant that discharges approximately 10,000 metric tons of nitrogen per year. The estimated total discharge level from point sources in the Mississippi River basin was 286,400 metric tons of nitrogen per year and 59,000 metric tons of phosphorus per year (Goolsby et al., 1999).

Watershed delineation, nitrogen attenuation coefficients and updated point source discharges are some of the modifications to the USMP version used by the Task Force economic analysis. The spatial delineation of watersheds within the Mississippi River basin is based on USGS 8, 4 and 2 digit hydrological units. This enables the economic and environmental parameters to be explicitly determined for the Mississippi River basin. To account for the loss of nitrogen as it moves through the basin, the attentuation coefficients derived using the SPARROW model (Alexander, Smith and Schwarz, 2000) were included into the model. This information combined with the watershed delineation provides more accurate information of the amount of nitrogen reaching the Gulf of Mexico from the Mississippi River sub-basin. In addition, 1996 point source discharges determined by the EPA commissioned study were included into the model (USEPA, 2000).

Water Quality Strategies for the Mississippi River Basin

Any successful water quality strategy for the Mississippi River basin must involve participation from the agricultural sector.

The question is what is the most effective way of involving agriculture to achieve the reductions in nitrogen flux to the Gulf of Mexico with the least impact on the agricultural community. There are a number of additional environmental co-benefits that can also be gained from strategies aimed at addressing the hypoxic zone in the Gulf of Mexico. Faeth and Greenhalgh (2000) showed that strategies aimed at reducing greenhouse gas emissions had significant water quality benefits. Considering these co-benefits as part of the solution set provides a more comprehensive assessment of overall environmental improvements when determining the appropriate strategies to adopt.

A number of scenarios aimed at improving water quality or reducing greenhouse gas emissions were tested to determine their impact on the nutrient load at the mouth of the Mississippi River and agricultural cash flows. These include:

Nitrogen Fertilizer Tax: A significant portion of the nitrogen lost to water in the Mississippi River basin comes from fertilizer. In many instances, farmers apply ‘insurance’ fertilizer rates hoping that climatic conditions produce a ‘bumper’ crop. In years, were the growing conditions are less than ideal this additional fertilizer is not used. Frequently, the nitrogen is lost to the atmosphere, leaches into groundwater or moves with sub-surface drainage to surface waterways. Tax rates that resulted in a 70 and 500 percent increase in price were used in this analysis. The 70 percent tax rate corresponds to the increase in nitrogen fertilizer price observed between 2000 and 2001. The 500 percent tax was found in the Task Force analysis to achieve the reduction in fertilizer use that resulted in a 20 percent decrease in nitrogen losses. This loss value includes nitrogen losses in solution (via surface runoff), nitrogen losses with sediments, nitrogen leaching potential and nitrogen losses through denitrification.

Conservation Tillage Subsidies: Tillage subsidy payments have been used for many years to encourage farmers to convert from conventional and moldboard tillage practices to conservation tillage practices. In this analysis, a payment of $25/acre was given for changing to ridge tillage, mulch tillage or no-till practices. In most cases conservation tillage subsidies were paid on a 75 percent cost-share basis. Suggested subsidy payments to provide incentives for conservation tillage adoption varies from $10/acre in parts of the cornbelt and lake states to $25/acre for cotton acreage in the southern plains and appalachia regions (Dan Towery, CTIC, pers. com., June 12, 2000). A payment of $25/acre was chosen as this amount should provide sufficient incentive for farmers to change tillage practices in a majority of regions across the U.S. There was no restriction placed on the type of conservation tillage practices implemented, acreage limits on adoption or specific areas targeted.

Conservation Reserve Program (CRP): CRP was instituted in the 1986 farm bill to take marginal, highly erodible land out of production to reduce soil erosion and improve water quality. At the end of 2000, there was 31.4 million acres enrolled in this program. CRP land is not tilled and does not use fertilizer so any increase in CRP would decrease the amount of nitrogen, phosphorus, sediments and pesticides lost to waterways. Greenhouse gas emissions also decrease on CRP land as there is less nitrous oxide emissions from fertilizer applications, no carbon emissions related to tillage operations or the production of fertilizers and more carbon sequestered in the soil due to the lack of soil disturbance. This analysis allowed CRP acreage to increase to 40 million acres and included an across the board increase in rental rates of 20 percent.

Carbon Trading: Agricultural soils sequester carbon and tillage practices that cause little soil disturbance, like no-till, sequester larger amounts of carbon than conventional tillage practice. Different crop rotations also affect the rate of soil carbon sequestration. The trading of soil carbon credits generated by agriculture has the potential to reduce overall U.S. greenhouse gas emissions. In a previous study, Faeth and Greenhalgh (2000) showed that strategies to reduce greenhouse gas emissions also provided water quality co-benefits. Many agricultural practices that increase soil carbon sequestration also have significant water quality benefits. CRP land sequesters large amounts of carbon and has no nitrogen loss, both to water and as nitrous oxide to the atmosphere, associated with fertilizer applications. A carbon price of $23/t was used to simulate a carbon trading system. This price corresponds to the Administration's upper bound assessment of the carbon permit price if the Kyoto Protocol was implemented (AEA, 1998).

Greenhouse Gas Trading: U.S. agriculture is responsible for 11 percent of the total U.S. emissions of greenhouse gases. Even though carbon dioxide accounts for 80 percent of U.S. greenhouse gas emissions, agriculture's share of this is only 2 percent. By far the greatest emissions by agriculture are from nitrous oxide, primarily from fertilizers, and methane from animal waste handling. Not only does 74 percent of nitrous oxide come from agriculture, but nitrous oxide has a heating potential 310 times greater than carbon dioxide. Similarly, methane from agriculture contributes approximately 30 percent of the total U.S. emissions and is 80 times more powerful than carbon dioxide. Implementing a trading program that addresses all three major greenhouse gases provides greater opportunities for agriculture to reduce its overall emissions. By including nitrous oxide emissions into a trading program provides direct benefits to reducing the hypoxic zone in the Gulf of Mexico as a majority of these emissions come from nitrogen fertilizer. As with the carbon trading scenario, a carbon price of $23/t was used.

Nutrient Trading: This market-based mechanism is being explored by a number of state and federal agencies to reduce the cost of improving water quality. This concept derives from the fact that each industrial facility or municipal wastewater treatment plant faces different compliance costs depending upon size, scale, age and overall efficiency. Therefore, the cost of meeting water quality standards may be cheaper for one facility than another. This provides an opportunity for those facilities whose costs are lower to make additional reductions beyond their obligation, and sell these additional reductions to facilities whose costs are higher. As an adjunct to regulation, trading can lower the overall cost of compliance.

Trading can occur between two point source facilities like municipal wastewater treatment plants or between a point source and nonpoint source such as agriculture. Point source facilities are generally controlled by a discharge permit while nonpoint sources are usually not controlled by regulatory limits.

The inclusion of nonpoint sources, such as agriculture, into trading programs has raised the question of uncertainty in the amount of reduction actually achieved by these sources. For agricultural nonpoint sources to reduce their nutrient contribution to water bodies, some kind of best management practice (BMP) would be implemented. These practices may include changing tillage practices or crop rotations, reducing fertilizer rates, or creating filter strips and can frequently improve water quality at a lower cost than upgrading wastewater treatment facilities. Trading ratios or discount factors are used to account for the uncertainty surrounding nonpoint source nutrient reductions. For this analysis the trading ratio is set at 2:1, this means that for a nonpoint source to generate and sell a one-pound credit, that source would have to reduce its nutrient contribution by two pounds.

Findings

The preliminary findings from this analysis suggests that none of the scenarios alone produce sufficient nitrogen flux reductions (20-30 percent) to the Gulf of Mexico to reduce the size of the hypoxic zone in the Gulf of Mexico to under 5,000 square kilometers.

Nitrogen Fertilizer Tax: A tax on nitrogen fertilizer at the 70 percent level results in decreases in nitrogen application rates in the Mississippi River basin of around 7 percent which relates to an approximate 2 percent reduction in nitrogen loadings to the Gulf of Mexico. There are corresponding decreases in farm net cash returns and crop acreage under this scenario because of higher input costs. The associated environmental benefits include reductions in greenhouse gas emissions, erosion rates, pesticide losses and phosphorus runoff to waterways. Using a 500 percent tax on fertilizer prices resulted in a 35 percent reduction in nitrogen fertilizer application with about 12 percent less nitrogen reaching the Gulf of Mexico. The corresponding decreases in farm income and crop acreage and improvements in other environmental co-benefits are of higher magnitude than the 70 percent tax rate. This scenario produced the greatest reduction in greenhouse gas emissions because of the large decrease in nitrous oxide emissions from nitrogen fertilizer. The 500 percent tax on nitrogen fertilizers, however, would not be a feasible policy option for reducing the size of the 'dead zone' because of the substantial decrease in farm net cash returns.

Conservation Tillage Subsidy: Untargeted conservation tillage subsidies have few environmental benefits and lead to decreases in farm income. By providing incentives to change tillage practices more land goes into production which leads to increases in crop production and a reduction in crop prices. As a result there is a small decrease in nitrogen fertilizer use and a small increase in nitrogen flux at the mouth of the Mississippi River because of increased crop acreage. There are small decreases in greenhouse gas emissions and nitrogen reaching the waterways. There are increases, however, in pesticide losses to waterways. Erosion, as expected with increases in conservation tillage, does decrease.

Conservation Reserve Program: By increasing the rental rate for CRP acreage there is an increase in CRP acreage and a decrease in crop acres. The increase in overall net cash returns in the Mississippi River basin results from the increase in CRP payments. There are small reductions in nitrogen, phosphorus, pesticides and soil losses to waterways. Larger decreases in greenhouse gas emissions relate to larger amounts of carbon sequestered on the additional land in CRP. The reduction of nitrogen to the Gulf of Mexico is also small, around 1 percent.

Carbon Trading: The trading of carbon credits results in a similar reduction in the nitrogen load reaching the Gulf of Mexico as the 70 percent tax on nitrogen fertilizer. Reductions in phosphorus and pesticide runoff is greater than the 70 percent nitrogen tax, conservation tillage subsidies and CRP expansion, while soil losses are greater than those achieved with the expanded CRP but less than all the other scenarios tested. As expected greenhouse gas emissions are reduced more than all other scenarios except for greenhouse gas trading. Increases in net farm returns is also greater than the 70 percent nitrogen fertilizer tax, conservation tillage subsidies and CRP expansion.

Greenhouse Gas Trading: The reductions in nitrogen reaching the Gulf of Mexico, phosphorus, pesticide and soil losses and the increase in net cash returns are greater than all scenarios except for nutrient trading. As expected the impact on greenhouse gas reductions is the best of the scenarios tested. This scenario has the greatest increase in CRP enrollment due to the ability of CRP land to sequester carbon and the lower nitrous oxide emissions resulting from no nitrogen fertilizer applications.

Nutrient Trading: Implementing nutrient trading produces the largest reduction in nitrogen flux at the mouth of the Mississippi River, close to 8 percent. There is a similar reduction in nitrogen fertilizer use in the basin. Reductions in phosphorus, pesticides and soil losses to waterways are higher than the other scenarios, while the decrease in greenhouse gas emissions are greater than all other scenarios except carbon and greenhouse gas trading. Net cash returns for farmers also increases more than in the other scenarios. This increase relates to the reduction in crop production from land moving into CRP, the corresponding increases in crop prices that result from decreased supply, and the direct payments received for reducing nitrogen lost to waterways. There is greater enrollment in CRP as this land does not use nitrogen fertilizer making reductions in nitrogen losses to waterways easier to achieve.

Summary

Of the scenarios tested, no one scenario produced nutrient loadings sufficient to met the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force coastal goal. To meet this goal, nitrogen (nitrate) loading reductions of 20-30% to the Gulf of Mexico are needed. By taking into account the attenuation of nitrogen as it moves down the basin, the impacts of improved nutrient management through more efficient nitrogen fertilizer use and changes in cropping and tillage practices, depending on where they are located in the basin, are diluted. For instance, nitrogen reductions in the Arkansas-White-Red region have higher attenuation rates than the Upper Mississippi Region (Alexander, Smith and Schwarz, 2000), so targeting those sub-basins with higher nitrogen delivery rates will produce that greatest reduction in the amount of nitrogen reaching the Gulf of Mexico.

The nutrient trading program for nitrogen produces greater reductions in nitrogen fertilizer use in the Upper and Lower Mississippi sub-basin than the other scenarios. These sub-basins have high nitrogen delivery rates leading to greater reduction in nitrogen losses to waterways and the nitrogen flux at the mouth of the Mississippi River. In addition, substantial improvements in local water quality from reduced phosphorus, pesticide and soil loss occur in most sub-basins. Similarly, greenhouse gas emissions reductions range from 3 to 25 percent in all Mississippi River sub-basins, highlighting the synergies between water quality improvement and climate change mitigation strategies.

The greenhouse gas and carbon trading scenarios do not produce the same level of improvements in water quality that are seen with nutrient trading but the improvements are still greater than the other scenarios. Climate change improvement, though, is more substantial overall. Most sub-basins except for the Tennessee and Lower Mississippi sub-basins have greater reductions in greenhouse gas emissions under these trading programs than with nutrient trading.

Net cash returns to the agricultural sector tend to decline when a nitrogen fertilizer tax is applied or untargeted conservation tillage subsidies are implemented. The other scenarios induce higher net cash returns with nutrient trading exhibiting the largest increase.

It appears that trading strategies produce greater all round benefits for the environment and for farm returns than traditional policy approaches. Trading not only exploits the synergistic co-benefits between water quality and climate change but also provides a voluntary incentive mechanism for the agricultural community to be part of the solution to the ‘dead zone’ in the Gulf of Mexico. However, further explorations of combinations of strategies and adding Wetland Reserve Program acreage is necessary to ascertain if better policy solutions can be found to more effectively meet the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force coastal goal.

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