Resources & Environment

Reducing Nitrogen Flow To the Gulf of Mexico: Strategies for Agriculture

A zone of hypoxic, or oxygen-deficient, water in the northern Gulf of Mexico stretches from the Mississippi Delta westward along the Louisiana coastline to Texas. At peak periods, the hypoxic zone covers an area of about 7,000 square miles, nearly as large as New Jersey. Located in the midst of one of the most important commercial and recreational fisheries in the U.S., the hypoxic zone poses a threat to the aquatic environment that supports these fisheries.

Hypoxia is a deficiency in breathable oxygen sufficient to cause damage to living animal tissue. The hypoxic zone in the Gulf of Mexico is the result of nutrient-laden water flowing into the Gulf from the Mississippi River. The nutrients support unchecked growth of microscopic plants and animals that use up dissolved oxygen in coastal waters, depriving other forms of aquatic life of adequate oxygen to survive. Although the size of the hypoxic zone varies during the year and some Gulf creatures are capable of fleeing the "dead zone," the potential for damage to the coastal fishing industry—particularly the fish, shrimp, and crab harvests—remains substantial.

While the interaction of several features of the Gulf have led to formation of the hypoxic zone, the primary cause of hypoxia in these waters is high loads of nitrogen in the discharge from the Mississippi River. Therefore, any effort to control hypoxia in the Gulf must concentrate on reducing excess nitrogen releases (soil nutrients that can be washed away if unused by plants) into the environment of the Mississippi River basin.

The multiple sources of nitrogen within the basin include atmospheric deposition (rainfall), septic systems, municipal and industrial activities, and farm operations (commercial fertilizer and animal manure use, legume production, and mineralization of soil nitrogen). Data from the U.S. Geological Survey indicate that agriculture contributes an estimated 65 percent of nitrogen loadings to the Gulf from the Mississippi River.

While uncertainty remains about the reduction in excess nitrogen releases needed to stabilize the hypoxic zone, the best scientific judgement is that it will take a 20-percent reduction in nitrogen from agricultural sources within the Mississippi River basin to achieve this goal. Further, the Mississippi River basin is so extensive (part or all of 31 states) that nitrogen reduction policies directed at agricultural producers in the basin will affect the entire farm sector.

In 1998, the White House Committee on Environment and Natural Resources initiated a study to assess the costs and benefits of reducing nitrogen emissions into the Gulf of Mexico. USDA's Economic Research Service (ERS) contributed to the study by analyzing the economic and environmental effects of three strategies for reducing excess nitrogen releases into the Mississippi River basin: reducing nitrogen use, restoring wetlands, and combining wetland restoration with reduction in nitrogen use. The results indicate expected impacts on commodity prices, net cash returns to crop and livestock producers, exports of major commodities, and nontargeted environmental emissions, as well as social costs.

Strategies to Cut Ag Nitrogen In the Mississippi River Basin

Improved nutrient management practices that require less nitrogen fertilizer can help reduce excess nitrogen runoff into the Mississippi River basin. Farmers can *reduce nitrogen fertilizer use* by cutting application rates (lowering production costs and possibly yield), by utilizing nitrogen fertilizer more efficiently, or by switching to crop rotations that include legumes to fix airborne nitrogen in the soil. Nutrient efficiency (the proportion of available nitrogen utilized by plants) increases when fertilizer applications are timed to match crop needs and/or when fertilizer application rates are based on soil test estimates of available nitrogen.

There is some evidence that many farmers apply more nitrogen than needed to

The White House report on hypoxia in the Gulf of Mexico was released on October 20 and is available at www.nos.noaa.gov/welcome.html.

Nitrogen Reduction Strategies in the Mississippi River Basin Lead to Higher Prices and Lower Exports

		Price effect of strategy				Export effect of strategy			
	Unit	Base price	Cut nitrogen use	Restore wetland	Mixed approach	Base quantity	Cut nitrogen use	Restore wetland	Mixed approach
		$/unit	*-----------Percent change-----------*			*Million*	*-----------Percent change-----------*		
Crops									
Corn	*Bu.*	2.80	21.9	13.07	9.22	2,624.9	-12.5	-7.4	-5.3
Sorghum	*Bu.*	2.50	27.2	11.41	10.56	285.0	-31.8	-13.3	-12.4
Barley	*Bu.*	2.60	8.35	4.74	3.29	70.0	-11.9	-6.6	-2.1
Oats	*Bu.*	1.70	14.22	21.28	7.53	3.0	-9.2	-13.8	-4.9
Wheat	*Bu.*	4.30	9.23	3.29	3.5	1,375.0	-17.3	-6.2	-6.6
Rice	*Cwt*	10.31	2.47	6.4	2.8	64.0	-5.3	-13.8	-6.1
Soybeans	*Bu.*	6.45	-1.01	10.29	1.97	910.0	0.8	-8.0	-1.5
Cotton	*Bale*	331.20	5.15	4.75	4	6.7	-6.8	-6.3	-5.3
Silage	*Ton*	21.69	3.05	2.24	1.54				
Hay	*Ton*	60.48	0.25	2.33	0.71				
Livestock									
Hogs	*Cwt*	42.07	8.07	6.68	3.88				
Nonfed cattle	Cwt	53.22	1.41	0.92	0.6				
Fed cattle	*Cwt*	69.42	3.54	2.73	1.67				
Meat, dairy, poultry									
Milk	*Cwt*	14.10	1.63	1.25	0.77				
Butter	*Lbs.*	1.06	3.83	2.93	1.8	*	-2.3	-1.8	-1.1
American cheese	*Lbs.*	1.32	1.61	1.23	0.76	*	-1	-0.7	-0.5
Broilers	*Lbs.*	0.35	3.77	4.38	2.26	6,292.4	-2.3	0	0
Eggs	*Doz.*	0.69	4.1	3.4	1.97	290.0	-2.5	0	0
Fed beef	*Cwt*	308.04	1.79	1.38	0.85	17.5	-1.1	0	0
Nonfed beef	*Cwt*	235.49	0.77	0.5	0.32				
Veal	*Cwt*	512.38	0.12	0.09	0.06	0.1	-0.1	0	0
Pork	*Cwt*	207.98	2.34	1.94	1.12	11.2	-1.4	0	0
Processed products									
Soybean meal	*Cwt*	10.50	-2.07	8.16	1.46	128.0	2.3	-9.1	-1.6
Soybean oil	*Cwt*	24.00	1.4	9.49	2	23.5	-1.7	-11.9	-2.5

Cut nitrogen use = Reduce nitrogen fertilizer use by 40 percent. Restore wetland = Convert 18 million acres of farmland to wetland. Mixed approach = Reduce nitrogen fertilizer use 20 percent and convert 5 million acres of farmland to wetland.
* = Less than 0.1.
Based on estimates from the ERS U.S. regional agricultural model.

Economic Research Service, USDA

achieve optimal yields. In those cases, reducing nitrogen application rates should have little impact on yields, leading to a "win-win" solution where excess nitrogen releases are cut and farmers' incomes are increased because of lower input costs. However, overapplication of fertilizer may be a result of annual variation in growing conditions—in a year of good weather, plants utilize more nitrogen and little or no excess exists. While a constant year-to-year application rate represents an appropriate economic response to this uncertainty, it can lead to application of nitrogen in amounts that exceed what plants actually need during a specific growing season. This suggests that unless uncertainty created by fluctuating weather conditions can be reduced, cutting nitrogen application rates would impose significant costs on many producers and the agricultural sector overall.

Another strategy for cutting nitrogen runoff is to *create vegetative buffer strips and wetlands* that filter nitrogen from agricultural runoff by means of plant uptake (absorption) or by emitting it to the atmosphere (nitrogen constitutes 80 percent of earth's air, by volume) through the chemical action of nitrogen and water (denitrification). Restoring wetlands also eliminates nitrogen from the fertilizer that generally would have been applied to the former cropland.

The effectiveness of wetlands as a filter for excess nitrogen loadings has been well documented. A wetland demonstration project in Iowa showed that wetlands retained from 40 to 95 percent of nitrogen contained in water flowing into them.

Because wetlands can treat runoff from large areas, restoring wetlands may be less disruptive to the agricultural sector than reducing nitrogen fertilizer use. Restoring wetlands has the added benefit of providing wildlife habitat and providing flood control. Although buffer strips accomplish much the same purpose as wetlands in filtering nitrogen from runoff and may be suitable in some situations, they are generally less effective than wetlands and were not included in the ERS study.

An alternative to relying strictly on reducing fertilizer use or filtering would be a *mixed approach*—reducing fertilizer use and restoring wetlands. This mixed approach could be less costly than either of the other approaches used separately because it allows greater flexibility in

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reducing excess nitrogen releases. Small reductions in nitrogen use may impose relatively small costs on agriculture producers, as they are able to alter rotations to compensate for chemical fertilizers. As required reductions in use increase, however, costs to agriculture producers become proportionately greater as opportunities for substituting crop rotations for chemical fertilizer are exhausted. The same is likely to be true of wetlands restoration: producer costs accelerate as cropland conversion to wetland rises. By exploiting the low-cost opportunities available under each approach first, it may be possible to reduce the overall cost of achieving the targeted reduction in agricultural nitrogen loadings.

Three Strategies: The Assumptions

ERS used a regional agricultural model to assess the effects of the three strategies for achieving a 20-percent reduction in excess nitrogen releases in the Mississippi River basin. The model predicts how producers will alter production practices (land use, fertilizer application rates, crop rotations, and tillage practices) in response to restrictions or changes in economic incentives. It then estimates how these changes in production practices affect supply and demand for crops and livestock, commodity prices, farm income, and nutrient losses to the environment from soil erosion and nitrogen releases.

ERS found that reducing nitrogen releases from cropland by 20 percent in the Mississippi River basin using improved nutrient management would require a 40-percent *reduction in nitrogen fertilizer use*. The targeted reduction in fertilizer use would be achieved by reducing fertilizer application rates, substituting crop rotations containing legumes for monoculture (continuous same crop), and reducing planted acres. The largest reductions in nitrogen applied per acre would be concentrated in the Corn Belt, where highly productive and nitrogen-intensive crops (those requiring high amounts of nitrogen to achieve a high yield) predominate. The effectiveness of reducing nitrogen releases by targeting nitrogen fertilizer would be impeded by the sizable amount of acreage devoted to legumes. Even though legumes do not generally use nitrogen fertilizer, they fix nitrogen from the air, and some of the nitrogen not taken up by the succeeding crop in the rotation can be lost through the leaching action of surface water.

Using *additional wetlands* to accomplish the targeted reduction in nitrogen loadings would require restoration of 18 million acres of wetlands, a net reduction of 15 million planted cropland acres (3.5 percent of total U.S. cropland) in the Mississippi River watershed. Cropland suitable for wetland restoration was identified and allocated among subregions based on contribution to total excess nitrogen releases in the Mississippi River basin. It was then assumed that the government purchased easements for the identified land from farmers and compensated them for the cost of restoring the acreage to wetland function.

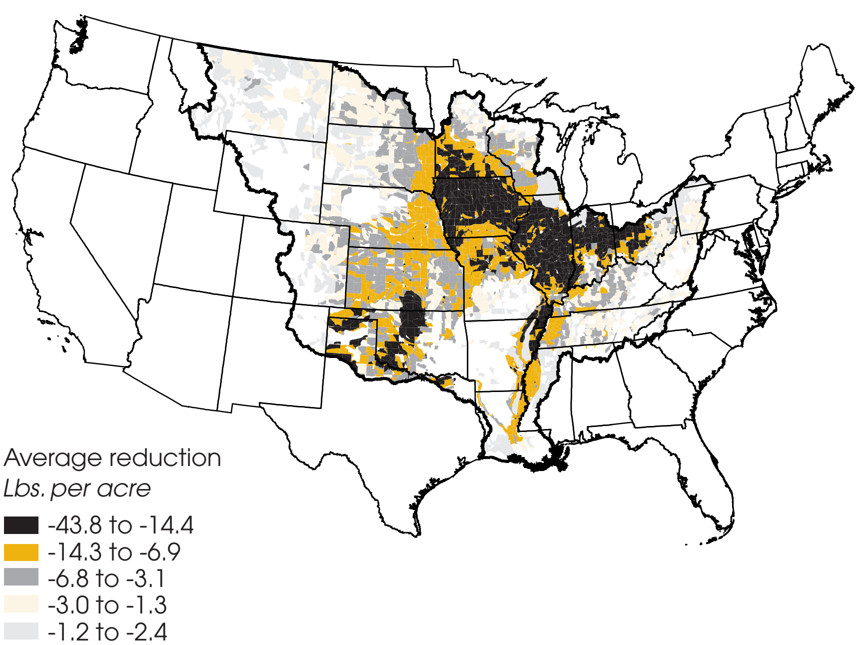
The result showed a concentration of restored wetlands in the Corn Belt and along the Mississippi River. Approximately 25 percent of the achievable reduction in nitrogen loadings in the basin from the wetlands strategy can be attributed to reduction in planted acres, and the remaining 75 percent to the filtering action of wetlands.

Using the *mixed strategy* to achieve a 20-percent reduction in excess nitrogen releases in the basin, the model estimated results based on restoring 5 million acres to wetlands and cutting nitrogen use by 20 percent. Reductions in nitrogen use and planted acres would account for nearly 60 percent of the reduction in nitrogen loadings, with the remaining 40 percent due to wetland filtering.

Comparison of Strategies' Effects

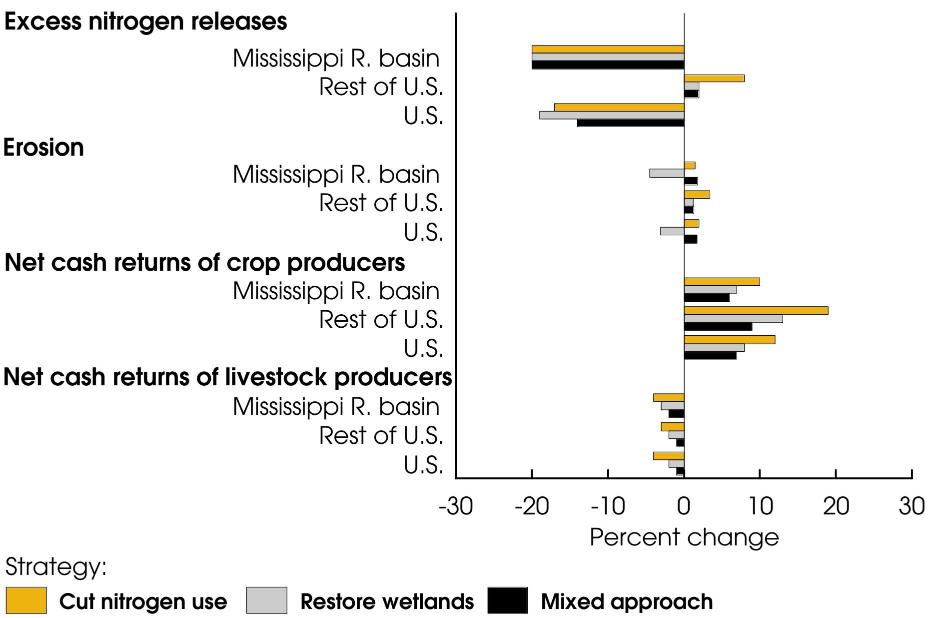
Production and prices. Results indicate that reducing fertilizer use limits the supply of nitrogen-intensive crops— primarily corn and sorghum—and raises prices of these commodities by more than 20 percent. Price increases for other crops are more moderate, ranging from 10 percent for wheat to 2 percent for rice. The price of soybeans declines slightly because soybean production expands as rotations that include soybeans become

Reduction in Ag Nitrogen Use Needed to Lower Nitrogen Flowing into Gulf



Meeting the 20-percent nitrogen reduction target in the Mississippi River basin requires an overall 40-percent decrease in nitrogen fertilizer use on cropland.
Based on estimates from the ERS U.S. regional agricultural model.
Economic Research Service, USDA

Strategies to Reduce Ag Nitrogen Flowing into the Gulf of Mexico Would Affect:



Cut nitrogen use = Reduce nitrogen fertilizer use by 40 percent. Restore wetlands = Convert 18 million acres of farmland to wetland. Mixed approach = Reduce nitrogen fertilizer use by 20 percent plus convert 5 million acres of farmland to wetland.
Based on estimates from the ERS U.S. regional agricultural model.

Economic Research Service, USDA

more profitable relative to other rotations (the exceptions are some parts of the Delta and Southeast). Livestock and fresh meat product prices increase moderately in response to increased grain prices.

Wetland restoration also causes crop prices to increase substantially, but by considerably less than if nitrogen use is restricted. Research results show that prices of corn and sorghum increase by 13 percent and 11 percent because of a drop in total planted acres, but the price of soybeans also increases (by 10 percent) because of decreased production. Soybean production is concentrated in areas where conversion of cropland into wetland is most likely to take place, causing total soybean acreage to fall.

Effects of the wetland restoration strategy on livestock prices are similar to those of the fertilizer reduction strategy. Even though corn and sorghum prices increase significantly less using the wetlands strategy, prices of other important feeds, such as soybeans and hay, increase significantly more, and livestock prices rise.

The mixed strategy that combines wetland restoration with nitrogen reduction has a more moderate effect on commodity prices. The price of corn increases less—up 9 percent v. 13-20 percent under the other two strategies. At the same time, prices of soybeans and hay increase only slightly, and substantially less than under the wetlands strategy. Since corn and soybeans represent the dominant cost of livestock feed, overall feed prices increase significantly less under the mixed strategy, resulting in a more modest increase in livestock product prices.

Because increases in commodity prices from declining domestic production affect the agricultural sector's competitiveness in world markets, the fertilizer reduction strategy, which increases prices the most, causes the greatest declines in agricultural exports.

Net cash returns. Net cash returns to crop producers increase under all three strategies, while net returns to livestock producers decline because of increases in feed costs. The fertilizer reduction strategy has the largest impact on net returns to the farm sector. Net returns to crop producers increase 17 percent and net returns to livestock producers decline 5 percent, nearly double the estimated change in net cash returns under the wetland restoration and mixed strategies.

Within and outside the Mississippi River basin, net returns for cropping enterprises increase by similar amounts. For livestock producers, however, the declines in net returns within the basin are nearly double the drop in the rest of the U.S. This reflects the predominance of high-feed-cost operations (grain-fed livestock) within the Mississippi watershed relative to lower cost grass-fed operations in the rest of the U.S.

Net returns to crop producers increase because gains from increases in commod-

Reducing Fertilizer Use Is Most Cost-Effective of Three Nitrogen Reduction Strategies for Mississippi River Basin

Strategy	Net private costs	+	Wetland restoration cost	–	Erosion benefits	–	Wetlands benefits	=	Total social cost
					$ million				
Cut nitrogen use	1,961				45				1,916
Restore wetland	17,502		352		51		9,904		7,899
Mixed approach	4,754		119		26		2,751		2,096

Cut nitrogen use = Reduce nitrogen fertilizer use by 40 percent. Restore wetlands = Convert 18 million acres of farmland to wetland. Mixed approach = Reduce nitrogen fertilizer by 20 percent plus convert 5 million acres of farmland to wetland. Private costs represent amount necessary to assure that all affected parties are as well off after policy implementation as before—e.g., compensation to farmers whose costs rise because of fertilizer restrictions or whose income potential drops when cropland is converted to wetland.
Based on estimates from the ERS U.S. regional agricultural model.

Economic Research Service, USDA

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ity prices outweigh losses from reduced production, reflecting the price impact of a production decline in an area as large as the Mississippi River basin. Since the demand for agricultural commodities is generally unresponsive to changes in prices, the percentage increase in price resulting from a production decline is greater than the percentage reduction in production itself.

However, gains and losses are not distributed evenly across the basin. All three strategies will cause cropping to cease on some acreage within the basin and alter production practices on others, but overall, production of crops high in potential excess nitrogen releases shift out of the basin, increasing excess nitrogen releases in the rest of the U.S. For example, if the price of corn rises high enough because of cutbacks within the Mississippi River basin, farmers farther east in the Middle Atlantic states may find it profitable to plant additional acreage to corn. Some farmers in the basin may experience severe declines in net returns, while others may reap substantial benefits.

Environmental indicators. Wetland restoration outperforms both the nitrogen reduction and mixed strategies with respect to impact on soil erosion from water, damage from erosion, and excess nitrogen releases from farmland. The reduction in planted acreage resulting from wetland restoration leads to a 5-percent decrease in water erosion within the Mississippi River basin but a slight increase in erosion in the rest of the country. It also leads to small increases in nitrogen loadings outside the Mississippi River basin as farmers adjust acreage and enterprise mix to market conditions resulting from changes within the basin.

Restricting nitrogen fertilizer use, on the other hand, leads to significant increases in erosion both within and outside the basin. Erosion increases because some farmers within the basin switch to rotations with soybeans—a commodity with production practices that are generally more erosive than crops in current rotations. In addition, the fertilizer reduction strategy leads to an 8-percent increase in excess nitrogen releases outside the Mississippi River basin as farmers there increase production of nitrogen-intensive commodities in response to higher prices

The mixed strategy also leads to increased water erosion within the basin, but since the mixed strategy has less impact on commodity prices, it has less effect than the others on erosion and nitrogen loadings in the rest of the country.

Social cost. Net social cost of the three strategies—the total impact on society as a whole—is the combination of:

- the change in producer and consumer welfare resulting from changes in production costs and commodity prices (net private costs);
- plus costs of restoring wetlands;
- minus net environmental benefits from establishment of additional wetlands and changes in wind and water erosion.

A policy of restrictions to cut nitrogen fertilizer use by 40 percent represents the most cost-effective strategy (least cost to achieve targeted reduction) for meeting the targeted 20-percent reduction in nitrogen loadings. The mixed strategy, however, is nearly as cost-effective as the nitrogen reduction strategy. The mixed strategy also has some desirable features that are not captured by a simple cost-effectiveness measure, including a smaller impact on prices that results in smaller adjustments throughout the nation.

Wetland restoration is the least cost-effective approach for reducing excess nitrogen releases, even though nearly half the costs associated with restoring wetlands are offset by benefits from increasing wildlife habitat. The main reason for the relatively low cost-effectiveness of wetland restoration is the high cost of taking productive farmland out of production—i.e., decreasing the overall efficiency of agricultural production—and the substantial costs of restoring wetland functions.

Although agriculture is just one of a number of sources contributing to high nitrogen loadings in the rivers and streams of the Mississippi River watershed and the resultant hypoxic zone in the Gulf of Mexico, evidence indicates that an estimated 65 percent of water-borne nitrogen carried down the Mississippi River into the Gulf derives from agricultural production. Changing agricultural production practices—especially reducing fertilizer use—and converting farmland to wetland can play a significant role in reducing excess nitrogen in waters flowing into the waters of the Gulf. AO

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12 *Oil Crops Outlook (4 p.m.)***
15 *Feed Outlook (9 a.m.)***
15 *Wheat Outlook (9 a.m.)***
17 *Vegetables and Specialties**
18 *Rice Yearbook**
19 *Agricultural Outlook**
22 *Cotton and Wool Yearbook**
U.S. Agricultural Trade Update (3 p.m.)
23 *Livestock, Dairy, and Poultry (4 p.m.)*
30 *Outlook for U.S. Agricultural Trade**

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