# Targeting wetland restoration to cost-effectively reduce nitrogen loadings in the Gulf of Mexico

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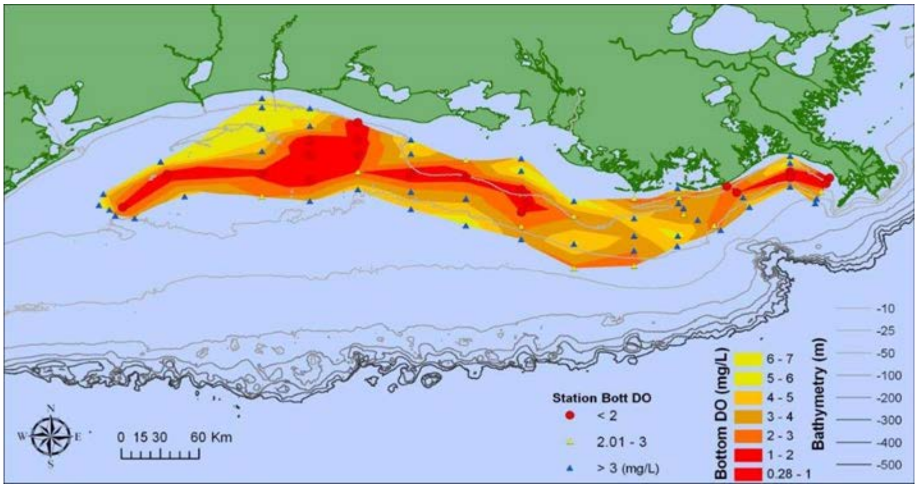
## Introduction

Agriculture contributes ~60% of the reactive nitrogen (N) reaching the Gulf of Mexico. High N inflows generate high algae densities. As algae die and decompose, oxygen concentrations fall to levels unsuitable to most aquatic life creating a ‘dead zone’.



## Objective

This analysis evaluates the cost-effectively of restoring wetlands to reduce N loadings in the Gulf of Mexico.

## Methodology

1. GIS data are used to identify where wetlands might be restored.
2. An N-removal model is used to generate spatial estimates of N removal rates.
3. A cost function is estimated and used to generate county-level estimates of the cost of restoring and preserving wetlands.
4. Cost estimates are laid on estimated N removal rates to generate spatial estimates of cost-effectiveness ($/lb).
5. The cost-effectiveness estimates are sorted and aggregated to derive the total N removed relative to costs ($/lb).
6. The cost-effectiveness of wetlands is compared to cost-effectiveness estimates of on-field practices.

Wetlands can be created in many areas but not all will be effective at removing N. In general, effective wetlands have:

1. Shallow, impermeable subsoils that block downward water movement. Waters then move horizontally and can be intercepted by wetlands.

2. Hydric soils that maintain healthy, productive wetland ecosystems.

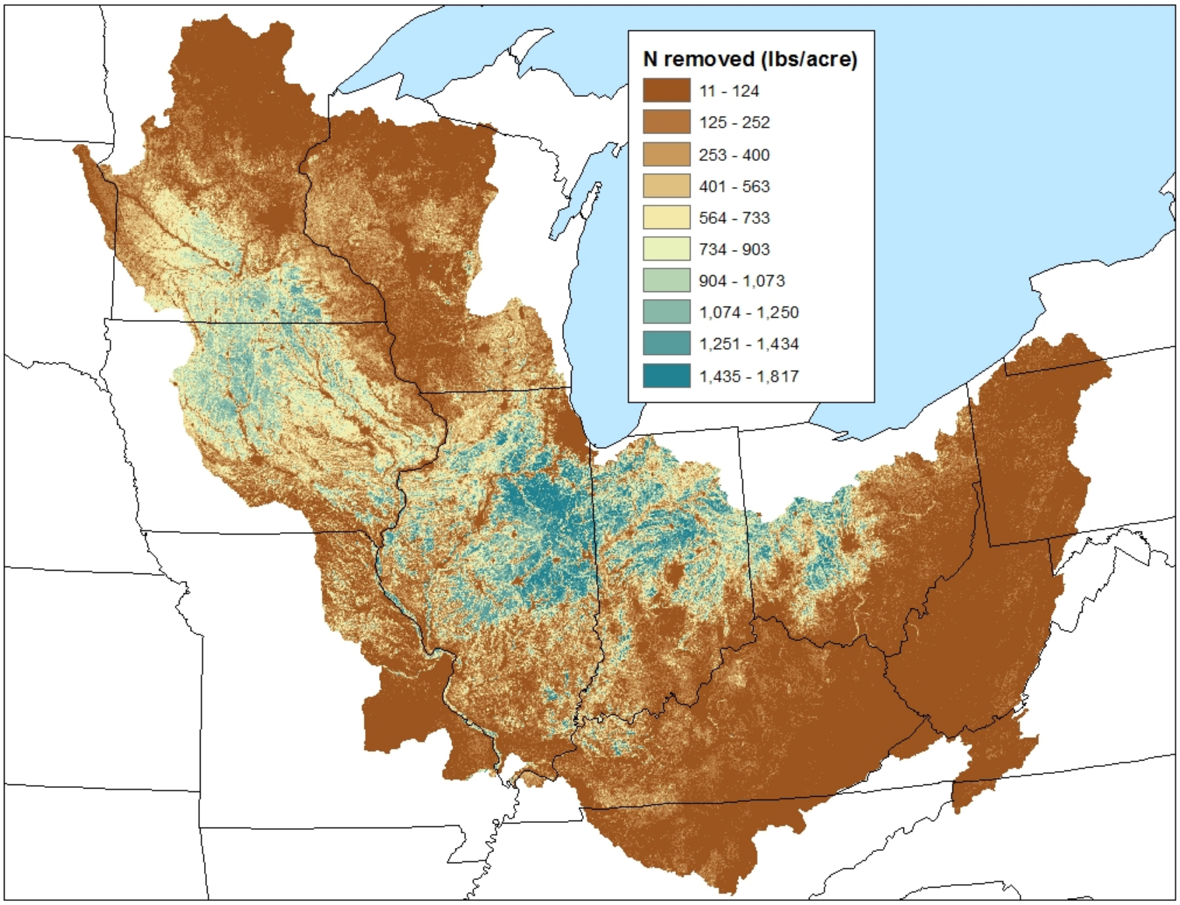
Our study area has conditions to support denitrification.

N removal rates

Using a previously-estimated model, we generated N removal rates by square-kilometer gird points within our study area. Independent variables include:

1. The quantity of water reaching the wetland, which depends on precipitation and the size of the wetland watershed.
2. N concentrations of incoming waters.
3. Spring water temperatures, which affect biota activity when much of the N passes through.
4. Water holding time as more time allows more N to be removed.

N-removal rates are the average values generated through 26-year simulations and range from 11 to 1,817 lbs/ac/yr.



Cost estimates

The dependent variable, total wetland cost (TWC), is a function of the upfront payment to landowners that compensates them for retiring their lands and the effort need to restore and protect the wetlands.

- The primary data are 3,321 Wetland Reserve Program contract records. The records have three useful variables:

  1. TWC

  2. The size of the contract (Acres)

  3. A county identifier

Lacking necessary data, we constructed proxies.

First, the size of compensation payments depend on land's agricultural value, effects of urban proximity, and the value of land with a wetland. So we developed:

1. Agr_Value as a proxy for agricultural value by multiplying the contract size by the county-average dryland rental rate.
2. Rural_Acres as a proxy for the effects of urban proximity by multiplying the contract size by a dummy variable that equals 1 in rural counties and 0 otherwise

Second, the 'effort to restore wetlands' depends on the level and types activities needed. So we developed:

1. Acres—the size of the wetland contract—as a proxy for effort (larger wetlands require more effort).
2. PPW_Acres as a proxy for the difference in activities/actions needed to restore prairie pothole wetlands (PPW) relative to others, by multiplying contract acreage by a dummy variable that equals 1 when a contract lies in the PPW region and zero otherwise. We've assumed that restoring similar types of wetlands requires similar activities.

Finally, because effects may be non-linear, we included second-degree variables.

**The coefficient of AcresSq was not significant and dropped from the model.**

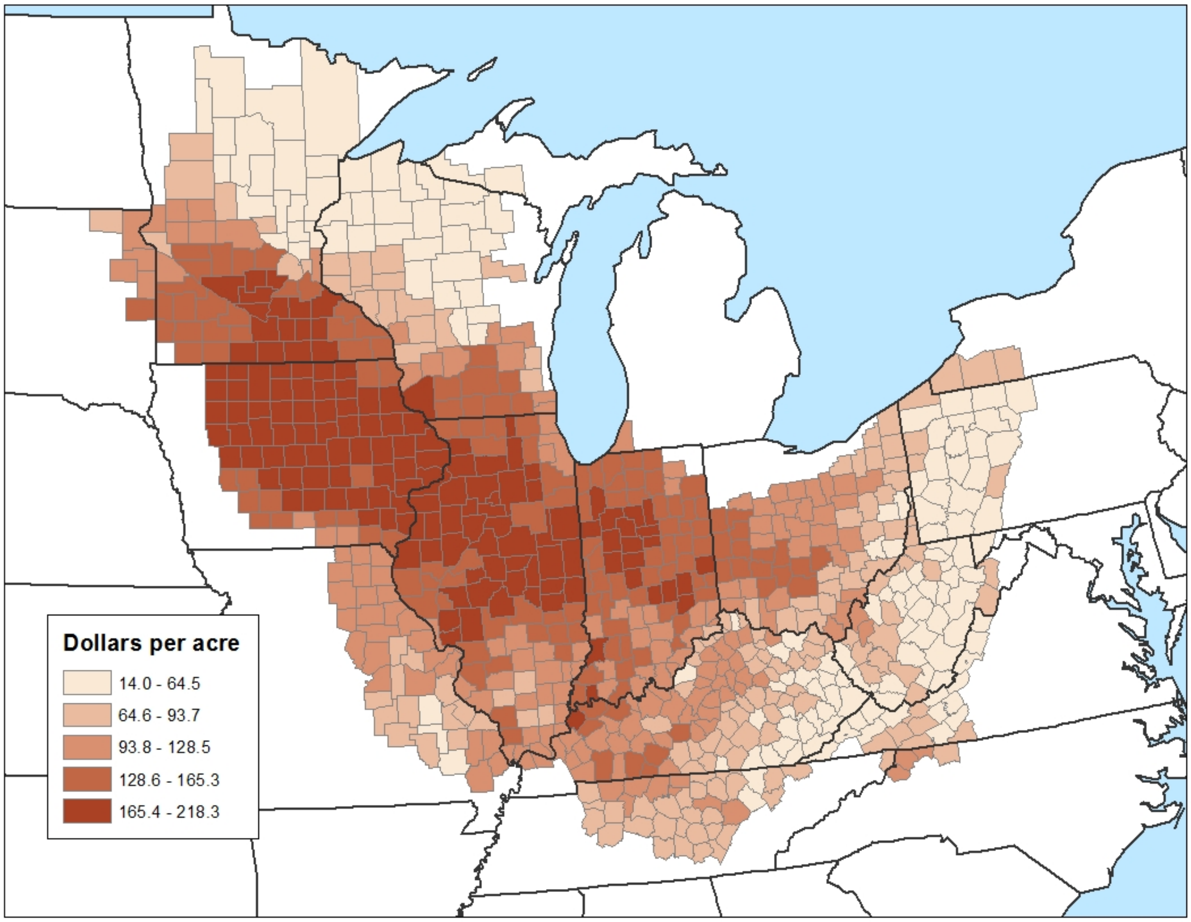
| Variable | Estimated coefficient | t-value |
|---|---|---|
| Intercept | 1040 | 0.46 |
| Agr_Value | 20.6 | 30.4 |
| Agr _ValueSq | -8.7E-05 | -7.14 |
| Acres | 335 | 7.17 |
| PPW_Acres | -350 | -8.92 |
| PPW _AcresSq | 0.776 | 7.11 |
| Rural_Acres | -164 | -6.45 |

Adj R-square = 0.78

On the positive side: the adjusted R-square suggests that the model is likely to provide reasonable cost estimates.

On the negative side: variables are likely to be correlated with each other and with excluded variables so that coefficients are likely to be bias.

The model-generated wetland cost estimates range from $14 to $219/ac/yr.



Cost-effectiveness estimates

Cost-effectiveness estimates are generated at grid points by laying costs on N removal rate estimates. But wetlands cannot be restored everywhere. So we apply some reasonable assumptions.

1. Not knowing where wetlands once existed, we assumed that hydric soils are an indicator of prior-existing wetlands. SSURGO data indicate that ~13% of the study-area has hydric soils. Thus we assume that the probability that a parcel of land was once a wetland equals 0.13.
2. We assumed that it is not practical to restore 25% of the converted wetlands because the land is in high-valued uses (roads, urban development, etc.).
3. We assumed that 50% of eligible landowners would not participate.

Based on these assumptions, the probable restorable acreage at grid points is 5.4 (=0.13*0.75*0.5*247). This is mathematically equivalent to assuming 5.4 acres are restored at each grid point.

The N-removal cost function (total quantity removed based on cost-effectiveness) is derived by 1) sorting GIS estimates by cost-effectiveness and 2) summing the quantity of N-removed across grid point based on cost.

**Results**

Among other things, the table indicates that 842,000 wetland acres will remove 424,000 tons of N at less than $0.15/lb

| Removal cost/price ($/lb) | Total N removed (1,000 tons) | Wetland acres restored (1,000) | Total cost (million $) | Average total cost ($/lb) |
|---|---|---|---|---|
| **0.15** | 424 | 842 | 82.9 | 0.098 |
| **0.50** | 722 | 2,330 | 225 | 0.16 |
| **1.00** | 774 | 3,390 | 297 | 0.19 |
| **3.00** | 793 | 3,990 | 347 | 0.22 |

**Conclusions**

The estimates of cost-effectiveness and quantities of N removed suggest that restoring wetlands is an effective N-conservation policy tool.

Cost is competitive: Petrolia and Gowda (2006) estimated on-field N conservation costs to be $0.78/lb for a 20% reduction in N losses—which is higher than average-cost estimate of $0.22/lb reported here.

Also note that, at a removal cost/price of $0.78/lb, about 3 million wetland acres would be restored reducing N loadings by 759,000 tons/yr.