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Reducing Nitrate-N Losses to Achieve Water Quality Goals

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Abstract

Nutrient losses from agricultural systems in the Mississippi River basin have contributed to the hypoxic zone in the Gulf of Mexico. In 2008, in response to this challenge, the U.S. EPA's Hypoxia Task Force released an action plan for a national strategy to reduce, mitigate, and control hypoxia in the northern Gulf of Mexico and improve water quality in the Mississippi River basin (www.epa.gov/ms-htf). The action plan indicated that significant (i.e., 45%) reductions in riverine nitrogen and phosphorus loads are needed to achieve the goal of reducing the size of the hypoxic zone, and improve water quality in the basin. One of the main items in the 2008 action plan was the call for state-level nutrient reduction strategies. As a result, the twelve states bordering the Mississippi and Ohio Rivers have developed and begun implementing comprehensive nutrient reduction strategies (www.epa.gov/ms-htf/hypoxia-taskforce-nutrient-reduction-strategies). Iowa was one of the first states to conduct a scientific assessment of the potential nutrient reduction of different agricultural management practices and the level of implementation that might be needed to reach the goal of 45% reduction (www.nutrientstrategy.iastate.edu).

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While Iowa's nutrient reduction strategy is just one of the state strategies, it provides useful information about the range of applicable conservation practices and the high level of implementation that would be needed to reach the nutrient reduction goals across the entire Mississippi River basin. The Iowa nutrient reduction strategy evaluates both nitrogen (N)

A wetland specifically designed to remove nitrate-N. *Photo courtesy of Iowa Conservation Reserve Enhancement Program.*
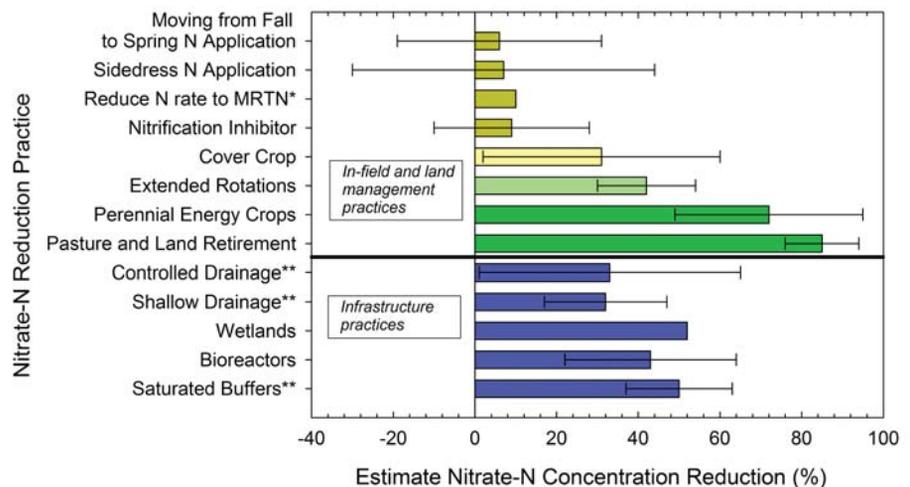
*MRTN - Maximum Return to Nitrogen Application Rate from Corn Nitrogen Rate Calculator (http://cnrc.agron.iastate.edu/)
** Load reduction
Error bars show standard deviation of practice performance

Nitrate-N reduction practices and their potential effects on nitrate-N concentrations. Horizontal bars are standard deviations.

Aerial view of a woodchip denitrification bioreactor. *Photo courtesy of Laura Christianson.*

and phosphorus. In this article, we focus on nitrate-N loss as an example of the larger strategy.

Nitrate-N reduction

As part of the Iowa nutrient reduction strategy, practices ranging from in-field N management to edge-of-field N treatment to land use changes were reviewed to assess each practice's potential for nitrate-N loss reduction and its impact on corn yield. The studies included in the review were limited to those conducted in Iowa or, in some cases, surrounding states to align with Iowa climate conditions. A summary of the expected nitrate-N loss reductions for each of these practices is shown in the graph on the previous page. Additional information on all the practices is available from Iowa State University Extension and Outreach (https://store.extension.iastate.edu/Product/Reducing-Nutrient-Loss-Science-Shows-What-Works). The nitrate-N reductions vary widely among practices and even for a given practice, as shown by the large standard deviations in the graph. This variation is largely due to the year-to-year variability in the weather.

The first step in estimating Iowa's potential nitrate-N reduction was establishing the state's baseline nitrate-N load. This process required estimates of the existing land uses, literature-based estimates of nitrate-N concentrations in tile and subsurface water, and estimates of water yield to streams. The nitrate-N loads were calculated for each major land resource area in Iowa and totaled into a statewide load. To assess the impacts of the different nitrate-N reduction practices, the baseline nitrate-N concentrations were reduced to reflect the efficiency of each practice. These adjusted concentrations and the land area on which the practices were implemented were then used to compute a scenario load for nitrate-N, which was compared to the baseline load.
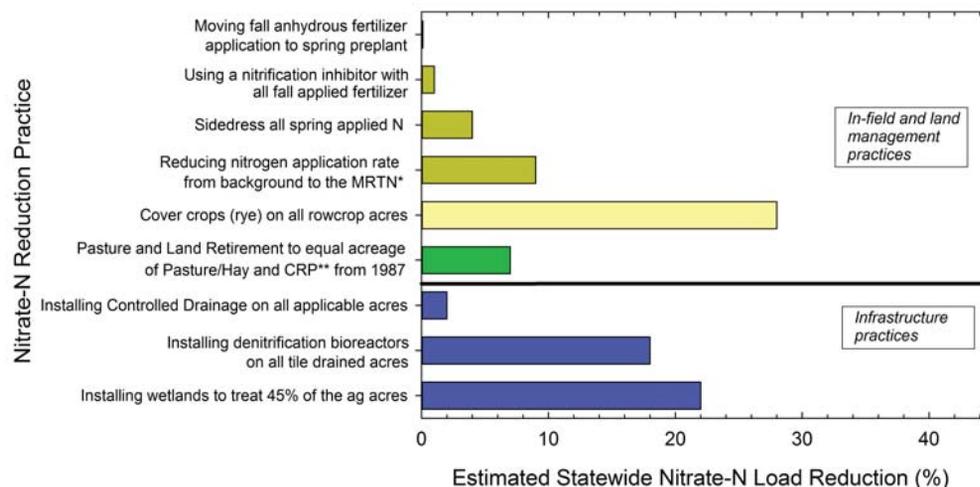
From this comparison, an estimate of the maximum practical nitrate-N load reduction for each practice was developed, a summary of which is shown in the graph on this page. A review of this graph clearly shows that no single practice can achieve the nutrient reduction goal. Instead, a combination of practices is needed. However, the computed load reductions for the individual practices are not additive. In

*MRTN - Maximum Return to Nitrogen Application Rate from Corn Nitrogen Rate Calculator (http://cnrc.agron.iastate.edu/)
**CRP - Conservation Reserve Program

Estimated statewide nitrate-N reductions in Iowa with maximum practical implementation of individual practices.
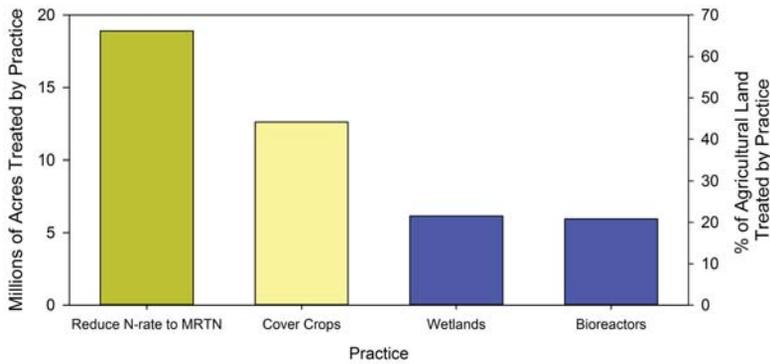
Area and percentage of agricultural land treated by each practice in an example scenario that achieved the nitrate-N reduction goal of 42%. Agricultural land includes corn/soybean, continuous corn, extended rotation, and pasture/hay. Reduced N-rate, cover crops, and bioreactors were applied only to row crop land, while wetlands were applied to all agricultural land (MRTN = maximum return to nitrogen application rate).

other words, due to the complex interactions of conservation practices, it's not appropriate to simply add up the reductions that can be achieved with different practices.

Scale of implementation

Several example scenarios for achieving the nitrate-N load reduction goal are outlined in Iowa State University's report on the Iowa nutrient reduction strategy (http://www.nutrientstrategy.iastate.edu). One scenario that is commonly discussed includes the assumptions that all corn acres use the maximum return to nitrogen (MRTN) application rate (133 lbs per acre at the time of development) and that 60% of corn-soybean and continuous corn acres have cover crops, 27% of all agricultural land is treated with wetlands, and 60% of tile-drained acres are treated with bioreactors. This scenario was estimated to have the potential to reduce nitrate-N loads by 125,000 tons per year, which is an overall nitrate-N load reduction of approximately 42% at an annual cost of approximately $755,518,000. An overall reduction of 42% was the estimated requirement for agricultural sources in Iowa.

The estimated area treated with each of these practices is shown in the graph on this page. For wetlands, it was assumed that each wetland (including 10 acres of wetland surface area with 35 acres of buffer) treats 1,000 acres of agricultural land, which results in approximately 7,600 wetlands for this scenario. For bioreactors, it was assumed that each bioreactor treats 50 acres of subsurface drained land, which totals approximately 120,000 bioreactors in Iowa alone.

From a review of the three graphs, it is obvious that achieving the desired nitrate-N load reductions will require a combination of practices that include the best in-field nitrogen management, cropping system, and edge-of-field practices. In addition, the scale of the required implementation is extremely large, and all producers and landowners must be involved to reach the goal. While the scale of implementation and the associated costs may seem daunting, it is important to recognize the benefits that could come from pursuing nutrient reduction, including the economic benefits of cleaner water and the employment opportunities in implementing the various strategies.

To reach these ambitious goals, the role of agricultural and biological engineers is critical. There is a need for engineers who can design and implement infrastructure practices, such as controlled drainage, shallow drainage, bioreactors, saturated buffers, and wetlands. In addition, there is a need for continued evaluation of the implementation and performance to verify that progress is being made in reducing downstream nutrient export.

A cover crop in a no-till field. *Photo courtesy of Emily Waring.*

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