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Biophysical and Social Barriers Restrict Water Quality Improvements in the Mississippi River Basin

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The Gulf of Mexico hypoxic zone that was measured in July of 2013 was 15 120 km^2, the result of riverine losses of nitrate and total P from the Mississippi River Basin (MRB). Despite twelve years of an action plan calling for reducing the zone to a five-year running average of 5000 km^2 by 2015, little progress has been made (ref 1, Figure 1). To meet the hypoxic zone target, the 2007 plan called for 45% reductions in total N and total P.[2] There is no evidence that nutrient loading to the Gulf has decreased during this period. Here we discuss the biophysical and social barriers that have limited measurable progress. We suggest that the most viable approach to developing the suite of practices needed to reduce nutrient losses from agricultural fields is a partnership of researchers working closely with farmers to develop realistic practices on real-world farms (where the constraints that influence management are present), to document the effectiveness, and to communicate the environmental and socioeconomic results regionally. To widely implement the resulting nutrient reduction practices will require substantial new funding if we are to continue using our current agronomic production systems in the MRB.

Much of the nitrate that leads to the hypoxic zone formation is lost from millions of acres of fields across the upper Midwest, where drainage has been accelerated by a variety of practices.[3] Many flat agricultural fields are artificially drained with perforated plastic tubing or older clay drainage pipe (tiles) to allow timely field work and enhance crop growth. During recent decades more extensive patterned systems have been installed. There are now tens of millions of acres of tile drained fields, with large losses of nitrate even with the recommended best management practices (BMPs) being followed. Corn acres have also increased during the past decade on this tile-drained landscape, driven by the increase in price due in large part to increased demand for corn for ethanol production.

Changing weather patterns have led to warmer winter temperatures and more frequent intense precipitation during the winter and spring in the upper Midwest, before crop growth makes use of applied nutrients. The combination of expanded and patterned tile drainage, increased fertilizer use due to more corn production, and more frequent high intensity precipitation events all contribute to greater losses of nutrients, and therefore a large hypoxic zone. This occurs even though nutrient balances (inputs minus outputs) have generally improved across the upper Midwest.[3,4]

The USDA Natural Resources Conservation Service (NRCS) promotes and provides technical information on a wide array of techniques that can be used to reduce nutrient losses, including fertilizer rate, timing and placement; cover crops, nitrification inhibiters, water table management, tile bioreactors, constructed wetlands, buffer strips, and conversion of row crops to CRP or perennial crops. However, on tile-drained fields few are used mainly because these practices impose substantial costs and/or risks on the producer, without increasing crop production. For example, end-of-pipe practices such as tile bioreactors or constructed wetlands have substantial construction costs, require land to be taken out of production, and provide no production benefit to the producer. Conversion to CRP or perennial crops can substantially reduce nutrient losses, but are rarely found on fields that have highly productive soils,

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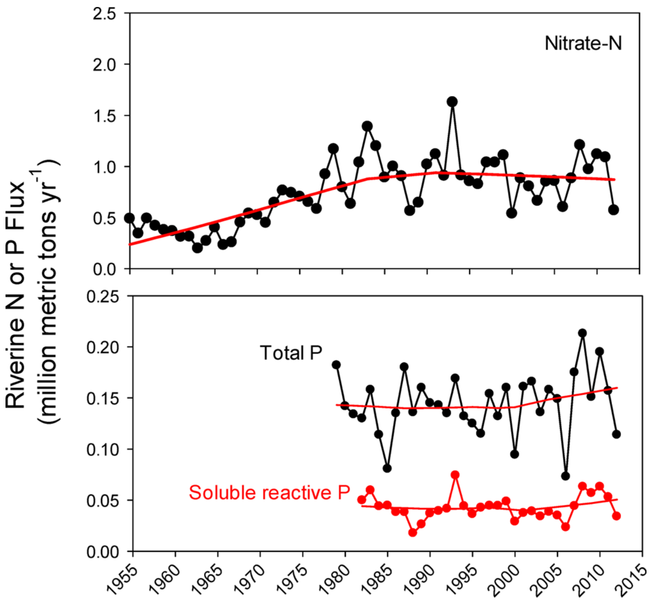

Figure 1. Mississippi River basin annual nitrate-N, soluble reactive P, and total P riverine flux with LOWESS fitted line in red. Adapted from http://toxics.usgs.gov/hypoxia/mississippi/flux_ests/.

are tile drained, and have a large monetary return from corn production. There are landscape level limitations for placement of many of these nutrient reduction techniques. Woodchip bioreactors, for example, fit best into existing filter strips located along ditches and streams. However, at current commodity prices, many conservation areas such as filter strips are returning to row crop production. Finally, most experience with conservation comes from NRCS work to reduce soil erosion, primarily by conservation tillage or no-till. Producers can easily see and recognize that large losses of soil from their fields leads to decreased productivity. However, farmers cannot see the loss of nutrients from tile lines or through surface runoff, so these losses are not readily apparent nor acted on.

Additional and critically important constraints are in the socio-economic realm and relate to factors influencing adoption of farm conservation practices. Producers view themselves as stewards who care for the land, but need to make a living from it. Not only can they not see the loss of nutrients, they are disconnected physically from the downstream effects. Information can influence awareness and concern for water quality, but trust in sources of information and farmers' practical capacity to directly respond are often compromised. Conservation goals are only one of several farm planning considerations, which include production goals, market constraints and opportunities, multigenerational family issues, technical capacity, and weather and climate variations and threats. Stewardship objectives may be strong, but they can be trumped or complicated by other economic, social and environmental drivers. Additionally, there is a growing sense among farmers that policy makers are too far removed from the realities of farming. This leads to an ever-widening trust-gap that is a major barrier to effective collaboration and policy development for water quality improvement in the MRB and beyond.

Policy makers need to further understand that just targeting a small percentage of fields managed by a few "bad" actors will not solve the MRB problem, or that over application of nutrients is the major issue. In areas with steep slopes and concentrated livestock generating manure, a small portion of the landscape coupled with poor production techniques can lead to large losses. Although targeting these few operators and locations with conservation can lead to large reductions, this is not true across the tile-drained MRB. The complexity of reducing nutrients across extensive acres of tile drained corn and soybean fields will take new programs and substantial funding if we are to make large-scale reductions called for in the hypoxia action plan.

Iowa's recently released nutrient reduction strategy[5] demonstrates the billions of dollars needed, and the difficulty that lies ahead in making substantial reductions in riverine nutrient transport. We agree with this view, and believe the best path forward is to have farmers actively participating with researchers to develop realistic suites of practices that could find widespread regional acceptance. We call for more real-world, on-farm longitudinal studies of nutrient loss reduction practices appropriate to overall farm management and landscape context. However, there still will be a need for considerable funding for cost sharing practice development and implementation. Involvement of farmers is critical to making progress, given the considerable biophysical and social constraints to reducing nutrient losses under which they now operate.

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Notes

The authors declare no competing financial interest.

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