NUTRIENT REDUCTION STRATEGIES

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ABSTRACT

The Hypoxia Task Force (HTF) 2008 Action Plan set a goal or reducing the nitrogen and phosphorus load reaching the Gulf by 45% in order to reduce the size of the hypoxic zone to 5,000 km^2. Each of the 12 states along the main stem of the Mississippi and Ohio rivers were to develop a state specific strategy by 2013 to achieve the goal by 2015. These plans have been developed and work is underway to implement the strategies, but the time line was not realistic. In February 2015, the HTF announced it would retain the 5,000 km^2 goal, but extended the time of attainment to 2035[i]. The HTF also announced a partnership with Land Grant Universities (LGU) in which they will assist their state agency tasked with developing and implementing the non-point source portion of the strategy. The starting place for many of the non-point source strategies is a science assessment of in-field and edge-of-field practices proven reduce the loss of N and P to surface water. This research-based approach also indicted the scope and scale of implementation necessary to achieve the 45% reduction goal. Convincing farmers to adopt practices that they do not currently use, are not costless to implement and may not provide a return on the private investment makes the task that much more challenging. Measuring and documenting progress to regulators and citizen stakeholders further complicates implementation. This paper provides a brief background on the HTF, the status of select state's strategies and examples of progress from Iowa.

INTRODUCTION

The loading of nutrients from upstream contributed to the hypoxic zone in the Gulf of Mexico, an area of low oxygen unable to sustain normal aquatic life. The first Action Item of the 2008 Action Plan calls for HTF states to develop by 2013 "comprehensive nitrogen and phosphorus reduction strategies encompassing watersheds with significant contributions of nitrogen and phosphorus to the surface waters of the MARB, and ultimately to the Gulf of Mexico."[ii] Comprehensive implies that both point-sources and non-point sources had to be addressed in the strategy. Point sources such as regulated municipal water treatment facilities, factories and CAFOs are places where water leaves through a single point such as a pipe. Non-point sources are largely not regulated by federal or state law and have dispersed discharge such as farms, lawns and golf courses where the movement of water and nutrients is greatly impacted by rainfall.

Alexander et al estimated that largest contributors to nutrient loading to the Gulf comes from the center of the Corn Belt (Figure 1). Iowa, Illinois and Indiana are the largest source of N. Illinois and Missouri contribute the most P. Furthermore, it is estimated that agriculture is the largest source of nutrients in the states considered, contributing 80% of N and 70% of P (Figure 2). Within agriculture corn and soybeans are the largest sources, accounting for half of total N

and a quarter of total P. While livestock facilities and manure application are often regulated even for smaller operations, fertilizer application and tillage to cropland and pastures is generally are not regulated.

Figure 1: Nutrient delivery to the Gulf of Mexico, State shares of the total nutrient flux

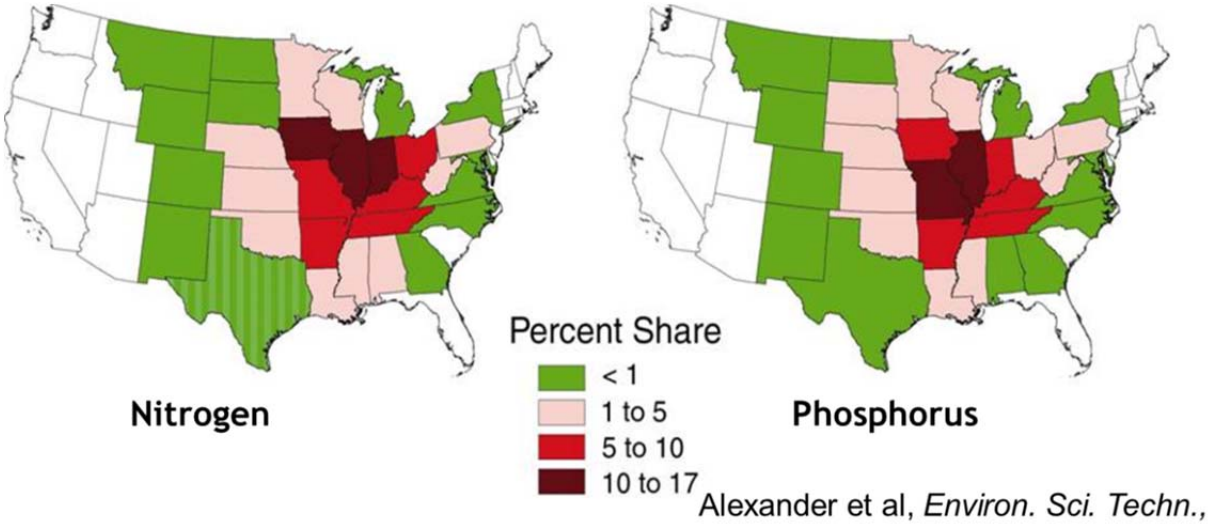
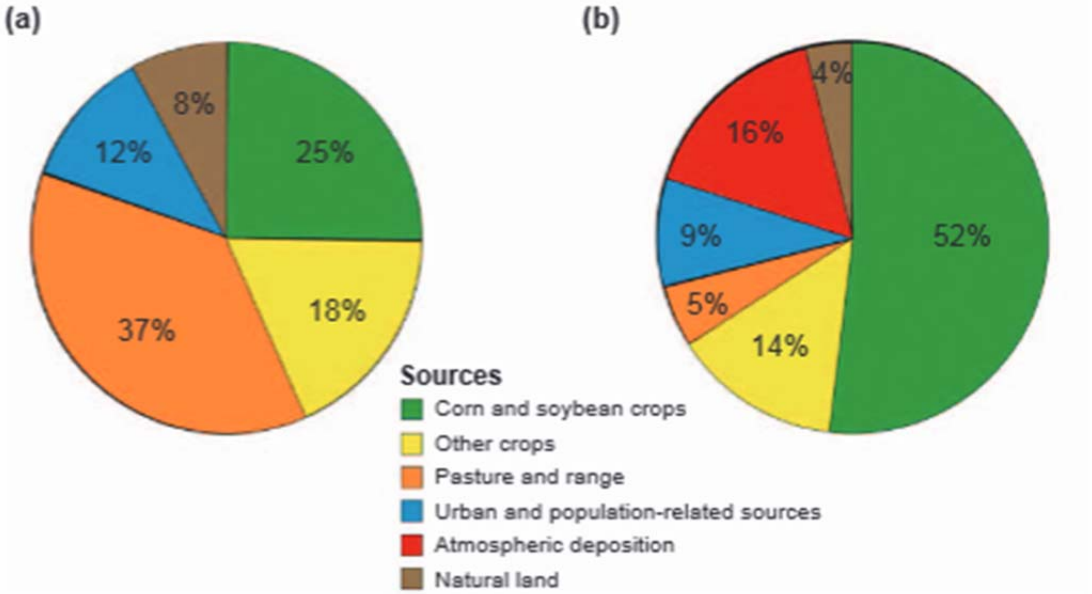


Figure 2

Primary sources of (a) phosphorus and (b) nitrogen delivered to the Gulf of Mexico. Image courtesy of Alexander et al. (2008), US Department of Interior and US Geological Survey.



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The HTF call for nutrient reduction strategies gives the states the flexibility to decide how they will reach the goals and leave it to the states if that includes regulations. The 2011 EPA directive known as the "Stoner Memo" identified eight criteria the strategies must address.[iii] EPA said in the memo. "States need room to innovate and respond to local water quality needs, so a one-size-fits-all solution to nitrogen and phosphorus pollution is neither desirable nor necessary." Also in 2011, EPA Administrator Jackson indicated the EPA might look at ways to quantify how voluntary conservation methods in the Mississippi River basin are helping reduce hypoxia in the Gulf of Mexico. Further, Jackson "ruled-out" the need to move directly to a regulatory approach when states are working to apply more conservation measures on the ground. This flexibility provides agriculture an opportunity to make changes best suited for local land and climate, but with it comes the responsibility to prove progress.

Each of the 12 states has submitted a strategy to EPA[iv] and they are various stages of review and implementation. Iowa, Illinois, Indiana and Minnesota conducted a science assessment as the foundation for their non-point source plan within their strategy. Other states similarly conducted analysis or modeling to determine how best to achieve the nutrient reduction goals. The strategies differ by state depending on their soils, climate, farming systems or assumptions of the causes of nutrient loading and effectiveness of practices. Some states rely on existing NRCS conservation practices and nutrient management. Other states tied the strategies closely to research linking the practice to water quality impacts that have an estimated numeric reduction in nutrient loss.

It is important to note that farming and conservation practices of the past have led us to the non-point source nutrient loading of today. To reduce the amount of N and P reaching the Gulf will require either greater adoption of existing practices, new practices or both. In particular, many of our conservation practices have focused on soil erosion. Because much of the P transport is attached to soil particles, these practices have been effective in reducing new P from reaching streams. However, soil conservation practices have little effect or possibly contribute to N and dissolved P loss that moves with water through the soil profile.

One difference across the strategies is how much impact nutrient management can have in reducing the loss of N and P to surface water. Specifically, how much does the rate, time, placement and form of nutrients relate to the loss of nutrients? The starting point for the question of course is, how good of a job are farmers doing on nutrient management currently? Are there other factors such as soil organic matter or rainfall that contribute to nutrient loss that must also be addressed?

Another common challenge for the states is to show meaningful progress. Ultimately, society and regulators expect to see a reduction in nutrient concentration and load in surface water and the Gulf. These measures are highly dependent on weather and can vary widely from season to season and year to year. As a result most if not all states are tracking some type of practice or process adoption model as a precursor to sustained improvement in water quality. Accurately capturing practice implementation and the pathway and inputs necessary to achieve implementation is also a challenge.

MATERIALS AND METHODS

In Iowa the Nutrient Reduction Strategy (NRS) Policy Team with input from agencies and scientists allocated the load reduction goal between point sources and non-point sources. The allocation is based on both contributions to nutrients and on the technical and economic

feasibility to reduce N and P from reaching surface water. It was determined that in Iowa non-point sources contribute 93% of the N and 79% of the P. However, because of water treatment facilities technologies considered, non-point sources are expected to remove 91% of N and only 64% of P. Thus the 45% load reduction goal is divided as 4% and 16% to point sources for N and P, respectively. The non-point source goal is 41% N and 29% P.

Iowa and Mississippi were the first of the 12 states to develop and submit to EPA a NRS. In both states the Land Grant University was involved in helping develop the non-point source portion of the strategy. Iowa State University, College of Agriculture and Life Sciences led the Science Assessment that is the basis of the non-point source section of the Iowa NRS. The team included scientists from ISU, USDA-ARS and NRCS, Iowa Department of Agriculture and Land Stewardship, and Iowa Department of Natural Resources with input from researchers in other states.

The Iowa Science Team conducted an assessment in the following steps[v]:

- Establish baseline conditions: Available information was used to estimate existing conditions relative to nutrient application, timing of nutrient application, existing soil test phosphorus conditions, land use, crop rotations, extent of current tillage practices, estimated extent of land benefitting from tile drainage, and estimated extent of existing conservation practices. These conditions were aggregated by Major Land Resource Area (MLRA).
- Review scientific literature to assess potential performance of practices: A comprehensive list of practices potentially reducing nitrate-N or phosphorus export was assembled and refined based on practices expected to have the greatest potential impact and for which there was research data on the impact to water quality. An extensive review of scientific literature was conducted to assess the potential impact on nitrate-N and phosphorus reductions. Studies included were limited to those conducted in Iowa or surrounding states so climatic conditions would be similar to Iowa conditions. Initial documents on baseline conditions and practice performance were subjected to outside blind peer review.
- Estimate potential load reductions of implementing nutrient reduction practices (scenarios): The potential for nitrate-N and phosphorus load reduction with implementation of individual practices or a combination of practices was assessed using the baseline data and information on practice performance. Scenarios of practice combinations where the water quality goals could potentially be achieved were identified. It is important to note these scenarios represent EXAMPLES of practice combinations and are not the recommendations of the science team.
- Estimate cost of implementation and cost per pound of nitrogen and phosphorus reduction: Economic costs of combination scenarios were computed considering the cost for implementing the practice and any potential impact on crop yield, specifically corn grain yield. An equal annualized cost (EAC) was computed so those practices with annualized costs and those with large initial capital costs could be appropriately compared.

The outcome of this process is a list of practices for Iowa with an estimated load reduction if implemented. The practice list[vi] is a living document in which new practices can be added by the Science Team using the same research based criteria that established in the initial list. A practice or product must have research showing its impact on water quality, specifically nitrate-N and phosphorus and the research must be done in Iowa or surrounding states with similar soils and

climate.

EPA accepted Iowa's NRS and encouraged other states to use a similar process of developing recommended practices based on research appropriate for their soils and climate. Several states followed suit. In particular, Illinois, Indiana and Minnesota developed their own practice list with estimated load reductions for specific practices. Ohio identified NRCS practices that help farmers achieve the NRS goals. Missouri included the Iowa practice table, SR0435 in its official report, but also identified a list of Best Management Practices targeted to the specific challenges in the state[vii]. Wisconsin also has identified management practices to address the sources of nutrient loss to surface waters.

Each state is taking as somewhat different approach to non-point sources nutrient loss reduction, but in general they all involved using research, education and incentives to adopt selected practices. Ultimately, farmers will have to make changes on the land to reduce the nutrients leaving it. In Iowa, and perhaps generally, these practices can be divided into three broad categories: land use, in-field practices and edge-of-field practices. The effectiveness of each and the scale of adoption needed differs by state or region and highlights the importance of the flexibility that EPA allows as one size does not fit all.

Two common approaches that make sound agronomic sense have been advocated to reduce nutrient loss illustrate the need for local research. First, the 4R approach of the right rate, right time, right place and right form of fertilizer application. In Iowa, based on our best estimate of existing application rates shifting all farmers to the University recommended Maximum Return to Nitrogen (MRTN) rate would reduce N load to surface water by approximately 10 percentage points of the 45% goal. For the individual farmer the impact may be more or less depending on current application rates. Similarly, moving from fall to spring application is estimated to reduce N loss by 6% at the field level, but because it is estimated that only about a quarter of the acres going to corn receive fall applied N, the statewide reduction is about 1.5 percentage points of the 45% goal. There are still placement and form tools, but you see the challenge—farmers are not mis-applying badly enough that if they would just follow these guidelines the problem would be resolved.

A second approach is that if farmers would improve soil health, it would solve the problem water quality problem. Soil health has many components and is difficult to define and measure, but is generally associated with organic matter and living organisms in the soil. Iowa has relatively high organic matter soils. It is estimated that on average there is 10,000 pounds of native nitrogen in soil organic matter and approximately 1-4% is mineralized and released annually for crop uptake, but also for leaching below the root zone. Approximately 25-30 pounds of nitrate-N per acre is lost from a field of corn or soybeans each year. Will adding organic matter to the soil, increasing the pool of native N reduce the loss of N with water movement through the soil profile? Based on data from long-term no-till fields compared to conventional tillage, there was no difference in the amount of N lost even though no-till may be better for soil health.

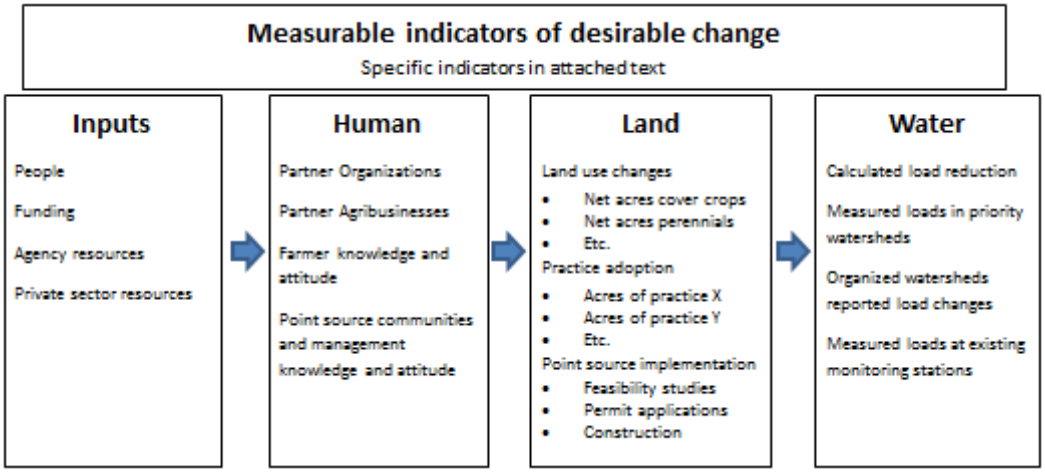
Once a strategy is developed and a plan created to implement it is the challenge on measuring progress. Regulators, naysayers and the general public locally and downstream are expecting improvements in water quality, but change takes time and monitored results in streams and rivers are impacted by weather and are highly variable.

Iowa's NRS called for the development of a Measurement Committee that would determine how progress toward the strategy goals would be documented and reported. The committee was formed and began working shortly after the final version of the Iowa NRS was announced in

May 2013. The committee adopted a logic model concept for to show progress (Figure 3). While the list variables tracked and reported will be refined and improved over time, the committee believed it was important to start the process.

The easiest way to understand the logic model is to start from the right-hand side—the goal you are trying to achieve. Ultimately, we want to see a 45% reduction in N and P in the water. However, there are multiple water indicators: individual watersheds, calculated load reduction, ambient water monitoring network or monitoring streams leaving the state. Iowa will use all of these to measure progress.

Figure 3. Iowa Nutrient Reduction Strategy Measures of Success Logic Model



Before we can expect to see a change in the water, we must see a change on the land. Moving one box to the left is where we measure the number of practices farmers have implemented and on how many acres and the number point sources (cities and factories) have upgraded treatment facilities. Public data such as Farm Service Agency acreage reports for land use and NRCS and IDALS report of cost shared edge-of-field practices are used. The Iowa Legislature also funded a pilot project for Iowa State University to work with the private sector to develop and implement a statistical sampling of farm fields to determine in-field practices. The private sector, ag retailers and Certified Crop Advisors, work directly with farmers and can access the data, ground truth the practices in the field and can protect the individual data from Freedom of Information requests.

In order to have a change on the land we have to have a change in human behavior, one more box to the left. City leaders must decide to invest in upgrades to water treatment facilities. Farmers have to understand the relationship between agriculture and nutrients in surface water and how their action may or may not have an impact. Ag retailers and CCAs will have to help incorporate nutrient loss to surface water as part of their recommendations to farmers. Farmer organizations will encourage farmers to adopt practices to reduce nutrient loss. Humans will behave differently and will make decisions that lead to the adoption of nutrient loss reduction practices.

However, it will take inputs to change human behavior, the box on the far left. Education, information and marketing are important tools to impact human behavior. Also, incentive such as cost share and tax credits also influence decision. Such inputs are investments by the public and private sector to bring about change.

Indicators in each "box" of the logic model can be measured and tracked over time to determine if Iowa is progressing toward its goal of a 45% reduction of N and P loads. While it will take many years to achieve sustained reductions in nutrient loads in surface water, if there are not measureable changes in the inputs, human and land indicators in the next few years why would society or regulators believe that the goal will ever be reached.

RESULTS AND DISCUSSION

The Iowa Science Assessment team developed two scenarios that achieve the goal as examples of the scope and scale of practice adoption needed (Table 1). These examples each achieve the 41% N and 29% P goal allocated to non-point sources. In Iowa it will take a high level of adoption of a whole suite of practices to achieve the goal.

Table 1. Example Practice Adoption Scenarios that Achieve Iowa Nutrient Reduction Strategy Non-Point Source Goal

Combined Scenario	N	P	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
	% Reduction from baseline				
MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor	42	30	3,218	756	36
MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs	42	50	1,222	1,214	58

The two scenarios each achieve the goal, but use different paths and have different costs. Notice these are "and" not "or"; it will take a high adoption of several practices under each scenario. The first scenario uses a combination of reduced N application, cover crops, wetlands and bioreactors. The second relies more heavily on cover crops and focuses the wetlands and bioreactors to only to the Des Moines Lobe. The Equal Annualized Cost is the annual cost for a 50 year horizon at a 4% discount rate. The first scenario has a higher upfront cost because it invests more in structures, but ultimately a lower EAC. The second has lower upfront cost but higher annual cost because it relies more on cover crops.

Achieving the level of practice adoption necessary to reach the goal is significant and work is well underway. The Iowa Legislature and Governor have approved additional resources for cost share of practices, research to improve existing and find new practices and to measure progress. Farmer organizations, conservation agencies and Extension have increased education and information activities to farmers about the NRS and practices to reduce the loss of nutrients. Farmer awareness and understanding of the NRS is being documented and is improving. Water monitoring is occurring through the ambient water monitoring network and at other select locations. All of these indicators are included in the annual report to the Governor.[viii]

SUMMARY

States involved in the Gulf Hypoxia Task Force Nutrient Reduction Strategy have a major task before them. EPA is allowing a flexible, and currently voluntary, approach to reduce the loss of N and P to surface water and ultimately the Gulf of Mexico. Agriculture in a significant contributor to the problem and will need to be a leader in the solution. Farming as we have to get to this point is not going to fix the problem going forward. Change will have to occur. While there are existing practices proven to reduce the loss of nutrients, they must be used on many more acres. Similarly, new practices and technologies must be discovered, proven and adopted if we are going to keep the nutrients in the fields and out of the streams.

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