Increased Regulatory Pressures on U.S. Fertilizer Use; a Heightened Role for 4R Nutrient Stewardship

by

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ABSTRACT

Fertilizer nutrients make possible 40 to 60% of the crop production, which nourishes the human family. Energy and commodity prices, and societal consumption all influence the production of commercial crops and the amount of fertilizer utilized. Yield per unit of nutrient input has improved for several principal crops, which reflects improvement in one key measure of nutrient use efficiency. Yet, public concerns about eutrophication of surface water resources, groundwater nitrate contamination, and nitrous oxide emissions and other unintended impacts are increasing. Greater implementation of 4R Nutrient Stewardship by industry can help meet current and future challenges.

FORWARD

We have attempted to include hyperlinks to the on-line posting of science, regulatory, and news reports mentioned within this paper, to make it easier for readers to find the resources. Each hyperlink was verified as functional on September 30, 2013. However, U.S. federal government offices, programs, and services were shutdown on October 1 because the U.S. Congress failed to perform its duty in developing and approving a new federal budget. As a consequence, some federal government websites were rendered temporarily inoperative. We regret any lasting effects of this dereliction of duty by elected U.S. Congress persons, and apologize for any frustrations readers may confront in tracking down some of the cited information.

Readers are invited to associate the text that follows with the companion slides, which were assembled for the Australia-New Zealand Fertilizer Conference 2013.

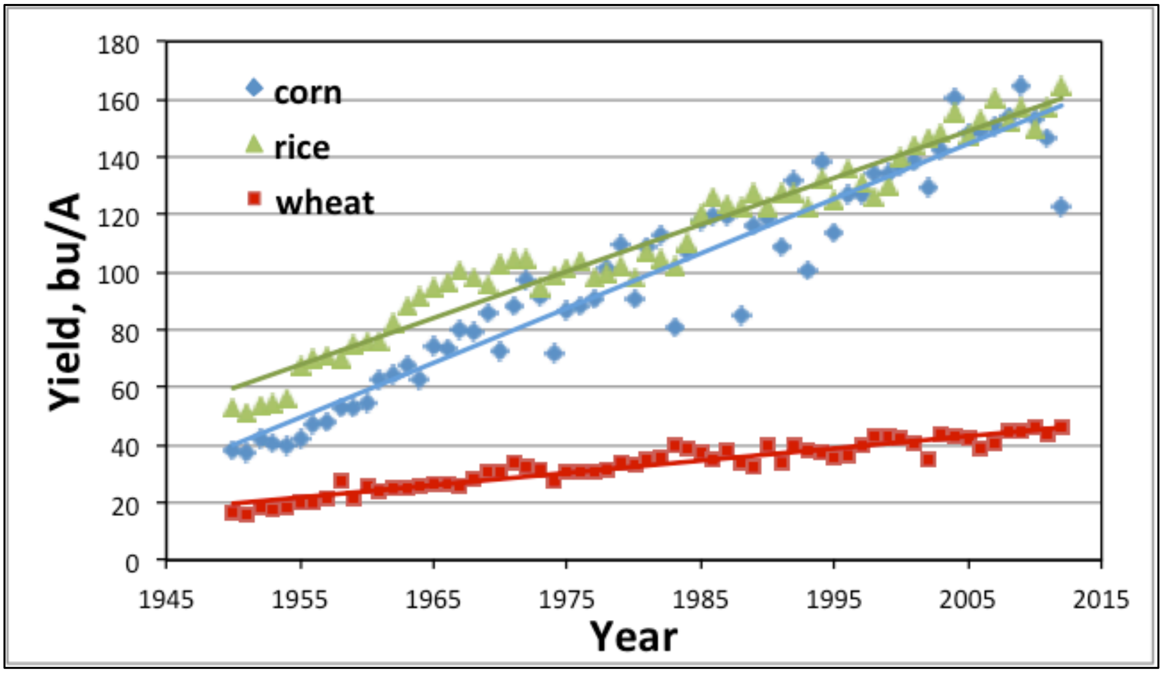
INTRODUCTION

Fertilizer nitrogen (N) consumption in the U.S. has trended slightly upward since the 1980s, in part due to the expanded corn acreage, while phosphorus (P) consumption has remained flat and trended downward in recent years. The world's human family depends heavily on the food, feed, fiber, and biofuel production made possible by proper fertilizer use; as much as 40 to 60% of the production in temperate regions has been attributed to the use of fertilizer N and other essential fertilizer nutrients, and more in the tropics (Erisman, 2008; Stewart and Roberts, 2012.)

Many in the U.S. fear the potential of increased fertilizer N and P use. They have heightened awareness and concerns about potential consequences related to: 1) increased ammonia emissions and fine particulate formation ($PM_{2.5}$); 2) nitrous oxide (N_2O; a potent greenhouse gas, or GHG) emissions associated with climate change, global warming, and stratospheric ozone depletion; 3) accelerated eutrophication in surface waters (lakes, streams, rivers, estuaries), hypoxia (dissolved $O_2 < 2$ mg/L), harmful algal blooms, and potential release of health-damaging toxins; and 4) groundwater nitrate contamination. All too often, commercial agriculture is blamed as the major cause of these environmental issues. Indeed, agriculture is faced with many challenges to improve crop nutrient recovery, fertilizer use efficiency and effectiveness (Cassman et al., 2004; Fixen and West, 2002; Galloway and Cowling, 2002; Ladha, et al. 2005; Snyder and Bruulsema, 2007; Snyder et al., 2009).

Major cereal crop yield trends in the U.S. have continued upward; particularly corn and wheat (**Figure 1**). Data from the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS) indicate that production efficiencies have increased for corn and wheat. Grain yield per unit of nitrogen applied (partial factor productivity, or PFP_N) is trending upward, in association with improved genetics and cropping system management. In 2010, those PFP_N values were approximately 50 kg of corn/kg of N, and 70 kg of corn/kg of N (Fixen et al., 2012. In Review).

Figure 1 – Corn, wheat, and rice yield trends in the U.S. (data source; USDA National Agricultural Statistics Service)



In spite of these production efficiency improvements, there have been wide-spread concerns and a proliferation of misperceptions about the management of N on U.S. corn fields. To address these fears and to expose the facts, Snyder (2012) assembled information from the USDA NASS and Economic Research Service (ERS) in the summer of 2012, to show that since 2000, farmers in seven leading corn production states have been adhering closely to what their Land Grant University research-based recommendations suggest as the economic optimum N rates for corn that is rotated annually with soybean. A month after Snyder's report was published, the USDA ERS (Ribaudo et al., 2012) published a report that looked at all U.S. corn production, and showed strong agreement with Snyder's assertions and conclusions: more farmers have been managing N near the optimum rate recommended by their agricultural universities since 2001. Yet, there is still opportunity for improvement according to Ribaudo et al. (2012), because 66% of the corn production acres are not meeting optimum source, rate, time, and place of application criteria that help to minimize environmental N losses.

Data assembled by the Organization for Economic Cooperation and Development (OECD) showed that the gross N balance on agricultural land (fertilizer + manure + legume fixation + deposition – removal by crop harvest) for 2002-2004 in the U.S. was 37 kg of N/ha and ranked much below several European union countries and Japan, whose balances were >90 kg N/ha. The N balance for Australia ranked even lower at 17 kg of N/ha (OECD, 2008; Cavigelli et al., 2012). Using methods similar to those by the OECD, IPNI (2011) showed that the N balance was 31.2, 33.6, 32.4, 32.8, and 35.3 lbs N/A for the lower 48 U.S. continental states, in the Agricultural Census years 1987, 1992, 1997, 2002, and 2007, respectively.

Professional agronomists, experienced fertilizer dealers, and leading farmers recognize that many other factors affect field crop and pasture N and P use efficiency and effectiveness, other than the nutrient source, rate, time, and place of application. Soil physical, chemical, and biological characteristics, a balanced supply of all nutrients, favorable soil pH, tillage system, and plant health all come into play. The ultimate influence of these factors is usually dominated by environmental moisture and temperature conditions (i.e. weather) that are beyond the farmer's direct control; and which may be increasingly less predictable, with more extreme fluctuations. (Karl and Meehl, 2012; http://www.climatescience.gov/Library/sap/sap3-3/final-report/sap3-3-final-ExecutiveSummary.pdf)

WATER QUALITY STANDARDS AND NUMERIC NUTRIENT CRITERIA

Water quality nutrient (N and P) impacts have been monitored by several state and federal agencies, and according to the most recent U.S. Environmental Protection agency (USEPA or EPA) reports, nutrient contamination is contributing to:

- >100,00 miles (160,900 km) of impaired streams and rivers,
- 2.5 million acres (>1 million ha) of impaired lakes, reservoirs, and ponds,
- 800 square miles (>2,000 km2) of impaired bays and estuaries, and
- 166 coastal hypoxia areas or so-called "deadzones".

According to the EPA, nutrient pollution is widespread: 27% of monitored streams and rivers have been classified as having high N levels, and 40% have high P levels. This has resulted in damages to the stream biotic conditions, with 55% of streams rated in "poor" condition and 23% rated as "fair" condition. There is some slightly good news in the latest EPA reports (http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm), in that 9% more streams have been rated in "good" N condition, but 19% fewer streams have "good" P conditions compared to the previous wadeable stream quality assessments in 2004 (EPA, 2013a).

The EPA has developed summaries of the progress by states, which are charged with developing water quality standards and numeric nutrient criteria. Summary maps of the current status of those water quality standards within each state may be found at: http://cfpub.epa.gov/wqsits/nnc-development/ . More recently, Evans-White et al. (2013) reported that six (6) states have developed total N standards, while eleven (11) states have developed P standards for streams and rivers. Only two (2) states, however, - Wisconsin and Florida – have statewide numeric criteria that document the process of standard development, and which are supported by peer-reviewed science papers. Clearly, much work remains to develop good, science-based numeric nutrient criteria for U.S. waters; criteria that are not just based on frequency distributions and statistical rankings, but which also link nutrients to measured biological integrity or indices.

In early September 2013, rule changes to the U.S. Clean Water Act (CWA) were proposed that would affect the authority of the federal government (i.e. EPA) to set water quality standards (https://www.federalregister.gov/articles/2013/09/04/2013-21140/water-quality-standards-regulatory-clarifications). The proposed changes supposedly would:

- attempt to ensure that courts will not find EPA has made a determination that a federal water quality standard is necessary unless EPA actually intends to make such a determination
- define highest attainable use
- in situations where a CWA 101(a) designated use (e.g., fishable, swimmable) is found to be unattainable, the State must specify the next highest attainable use that will apply instead
- clarify that a Use Attainability Analysis (UAA) is needed to remove a 101(a)(2) use or to designate a use for a water body for the first time that is not a 101(a)(2) use
- clarify that no UAA is needed to modify non-101(a)(2) uses (such as an agricultural designated use)

However, fertilizer and other agricultural industries are concerned that these proposed changes could open the door to more citizen lawsuits and federal judicial interventions. Such judicial interventions could risk large political influences and thwart science-based water quality metrics development, and stir skepticism.

In response to growing public interests and pressures, the USEPA and the U.S. Geological Survey (USGS) have worked more closely with states in recent years to develop large databases that include state and federal data on N and P pollution and water quality conditions (EPA and USGS Water Quality Monitoring Links and Tools, 2013). Such monitoring data and tools will inform and empower more of the public, and many environmental watch groups, to more easily access and track current water quality nutrient conditions and trends for many surface water resources. With the greater probability that nutrient-related water quality impairments will be more readily and frequently observed, there will be an increased burden among all agricultural stakeholders in their respective watersheds to document and demonstrate appropriate, and resource protective, nutrient management practice (BMP) implementation.

There will be increasing ramifications of surface water quality standards – set by states, or forcibly established by the USEPA - for the agricultural community. Pressures will undoubtedly elevate and continue on the fertilizer industry –

producers, wholesalers, and retailers - and especially on those who consume agricultural fertilizers.

FERTILIZER USE REGULATION

At present, there is no national over-arching fertilizer use regulation in the U.S. Of course, fertilizer producers, wholesalers, fertilizer dealers and agricultural retailers have federal, state, and local government regulatory compliance requirements. Every state has its own fertilizer regulatory authority, which oversees consumer protection, product labeling, proper fertilizer handling and application, for the protection of human health and the environment. Each state fertilizer control agency is a member participant in the Association of American Plant Food Control Officials (AAPFCO: http://www.aapfco.org/).

Those reading this paper, who may be interested in more details about production storage, blending, and transportation rules and regulations, should contact The Fertilizer Institute (TFI) in Washington, DC (http://www.tfi.org/). Industry members within and outside the U.S. may be aware of the 17 April 2013 explosion tragedy at the West, Texas fertilizer retail facility in the U.S., and the implications for the secure and safe handling of ammonium nitrate; and potential regulatory ramifications for other fertilizers. The role and actions of different state and federal agencies, including the U.S. Department of Homeland Security and the USDA, on ammonium nitrate handling rules are being re-examined. The Responsible Ag initiative by TFI has been launched, which includes a third-party inspection, " to help ensure that all fertilizer retailers fully understand and comply with existing regulations".

Example - Nutrient Management Guidance within USDA NRCS Conservation Plans

Farmers who voluntarily participate with the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) in soil and water conservation programs, must also have farm conservation plans. Those conservation plans must adhere to what is known as the "590 Nutrient Management Conservation Practice Standard", which may be modified as necessary in each state, to satisfy local laws and regulations. Policy statements associated with that 590 Standard, which date to 2001, state that commercial fertilizers and animal wastes are to be stored, applied, and disposed of properly so that groundwater standards are not violated (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/npm/). A media article (http://farmprogress.com/story-iowa-nrcs-updating-nutrient-management-standards-9-93922) publicized the spring 2013 NRCS 590 standard changes in the state of Iowa, which may be representative of changes in many other states. Those revisions include the following statements or guidance:

- Incorporation of the 4R's nutrient decisions: apply the Right nutrient source at the Right amount at the Right time in the Right place.
- fall-applied manure with high ammonium content, monammonium phosphate (MAP) and diammonium phosphate (DAP) fertilizers, and anhydrous ammonia should be applied when soils are 50 degrees F at the 4-inch (10 cm) depth and trending colder
- Rescue nitrogen application is allowed when nitrogen is lost due to weather conditions.
- Tile inlets are added to sensitive areas to be protected when applying nutrients.
- Manure testing must be done by certified labs.

In most states, the USDA NRCS 590 standard includes some language about nutrient rates and management and general statements about adherence to the local Land Grant University recommendations. In Iowa again, for example, the 590 standard states: "To determine nitrogen rates for corn in a continuous corn or corn-soybean rotation, use ISU's Corn Nitrogen Rate Calculator or use PM-1714 "Nitrogen Fertilizer Recommendations for Corn in Iowa." (*That on-line economic optimum N rate (EONR) calculator may be found at: http://extension.agron.iastate.edu/soilfertility/nrate.aspx . The supporting reference may be found at: http://www.extension.iastate.edu/Publications/PM2015.pdf*) It should be made clear that this university-supported N rate calculator is only a starting place for N rate determinations, since it is rather general. The calculator tool relies on corn and fertilizer N price ratios and it estimates the maximum return to N found in research studies, based on the average of N responses accumulated from a population of N rate trial sites. The calculator tool does not fully consider site-specific factors, N source, N application time, or place of N application; nor farmer management skills and capabilities, and any local surface or groundwater issues, which should also be weighed in farm, field, and sub-field specific N management recommendations.

Example – Indiana new state regulations in 2013

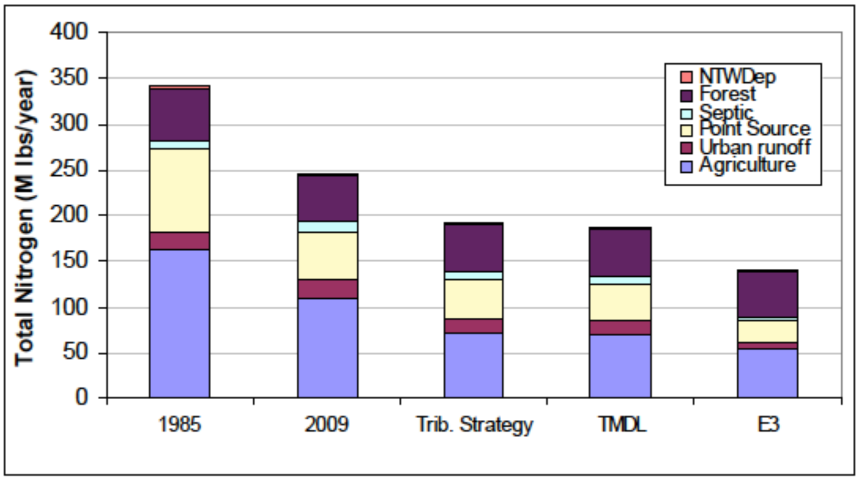
Indiana, in the northcentral U.S., has just implemented specific farm fertilizer use regulations. The new 2013 Indiana regulation pertains to any person that uses or distributes fertilizer material for the purposes of producing an agricultural crop. However, the article of the regulation does not apply to any person who uses or distributes less than ten (10) cubic yards (7.6 m^3) or four thousand (4,000) gallons (~15,000 liters) of fertilizer material in a calendar year. Assuming a N application rate of 150 lbs of N/A (134 kg of N/ha) and use of a 30% N solution, this regulation would affect anyone who farms more than about 90 acres (~36 ha). The farm fertilizer regulation article is in addition to rules passed by the water pollution control board regulating confined animal feeding operations. The regulation has specific restrictions on applications near water resources or drainage inlets. Anyone affected by the farm fertilizer regulation is required to keep detailed records for at least two (2) years (http://www.isco.purdue.edu/fertilizer/fert_pdf/fert_use_rules_and_faq.pdf).

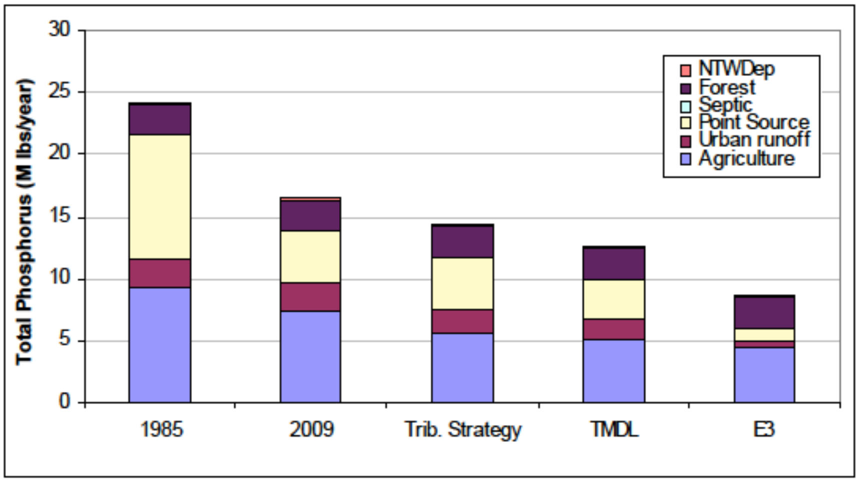
Example - Chesapeake Bay Watershed

Parts of six (6) states and the entire District of Columbia (Washington, DC) are within the Chesapeake Bay watershed (CBW) in the northeastern U.S. Since 1987, those states have been striving to reduce N and P loads to the Chesapeake Bay from all nutrient sources: industrial point sources and also urban, suburban, and farm non-point sources. States were required in 2012 to submit a draft strategy to significantly reduce their nutrient loads to the Chesapeake Bay, and they are required to establish “enforceable and accountable” measures for all agriculture by 2025. The state of Maryland has placed regulatory limits on fertilizer applications in the fall for small grains, and established “no-fertilizer-application” buffer zones next to streams. Consistent application method and timing restrictions also apply to all organic nutrient sources: animal manure, sludge, soil amendments, conditioners, and food processing waste. In Delaware and Maryland, all producers must have nutrient management plans with N and P application rates conforming to their state rules. Other states in the CBW also have nutrient management plan rules, but their coverage of all farms may not be as inclusive or complete.

Voluntary actions and regulations on the urban and farm communities have resulted in significant declines in total N and P loads to the Chesapeake Bay, which have been documented since 1985 (**Figure 2**), but water quality is still considered impaired and greater nutrient load reductions are being required (http://www.nap.edu/catalog/13131.html).

Figure 2 – Changes in total N and P loads to the Chesapeake Bay from different sources, associated with implementation of nutrient loss reduction strategies and Total Maximum Daily Load limits (NRC, 2011).



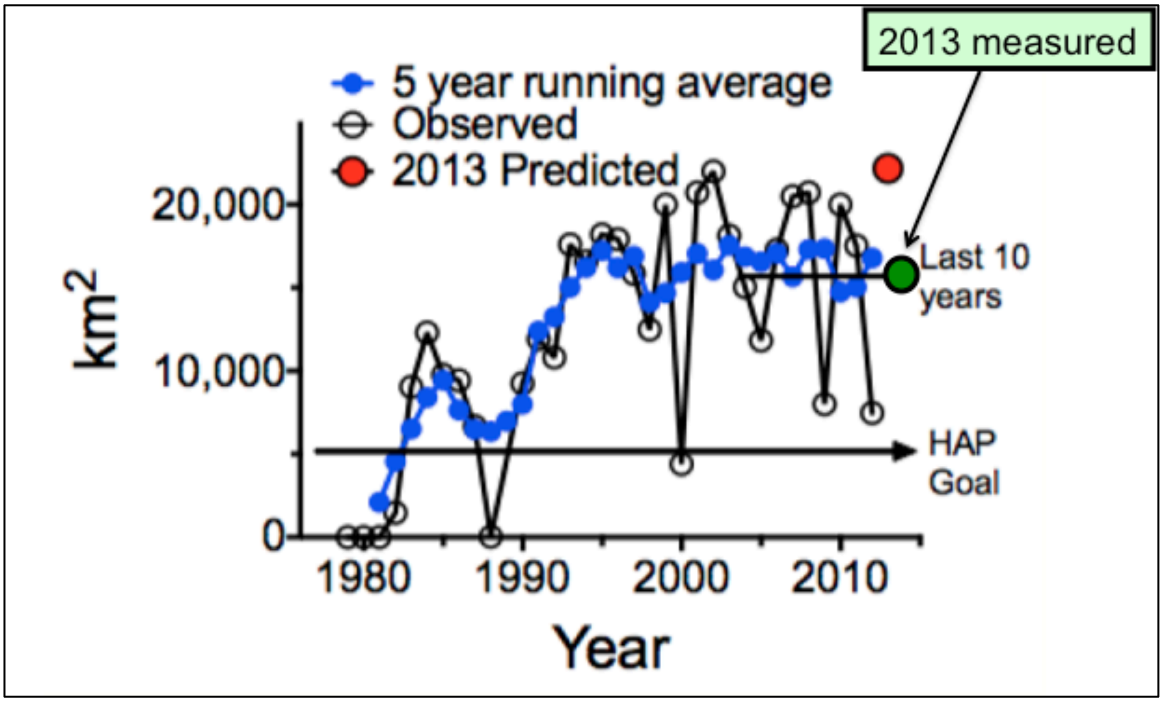


Example – Mississippi River Basin and Gulf of Mexico Watershed

The Mississippi River Basin, which covers 41% of the conterminous U.S., 31 states, two Canadian provinces, and 1,245,000 square miles (3,224,550 km^2). The river itself runs 2,350 miles (3,781 km), with roughly one-third (1/3) of its flow diverted through the Atchafalaya River Basin in the state of Louisiana, to help protect the city of New Orleans from potential flooding. About 60% of all U.S. grains are shipped along the river. About 60 to 65% of all fertilizer N and P_2O_5 consumed in the U.S. is utilized within the Mississippi River Basin; making it the most important watershed in the U.S. for the fertilizer industry, and probably also for the livestock and poultry industries.

Ecological concerns about the impacts of N and P loads reaching the Gulf of Mexico have been a focus point since 1985. An EPA Science Advisory Board report in 2007 (http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_1_31_msba sin_sab_report_2007.pdf) and a federal and state agency Action Plan were developed in 2008 (http://water.epa.gov/type/watersheds/named/msbasin/actionplan.cfm) to help protect local, state, and Gulf of Mexico waters, while aimed at achieving a shrinking of the annual summer size of the bottom-water hypoxic (< 2 mg/L dissolved O_2) zone in the Gulf to below 5,000 km^2 (<2,000 mi^2) by 2015. In addition, a goal of 45% reductions in loads of both N and P reaching the Gulf of Mexico by 2015 was suggested. No new fertilizer use regulations were included in that 2008 Action Plan, or individual state water quality plans. The annual summer mapping of the areal extent of the hypoxic zone has failed to show a significant decline in the zone's size since 1985, or since the implementation of the 2008 Action Plan (**Figure 3**). With severe drought in much of the Mississippi River Basin in 2012, followed by record wetness in the spring of 2013, there were fears that the N and P loads to the Gulf of Mexico might cause the size of the hypoxic zone to reach a new record. However, the size of the hypoxic zone was less than predicted and near the average over the last 10 years.

Figure 3 – Annual summer hypoxic area in the Gulf of Mexico compared to the Hypoxia Action Plan goal, and the predicted size in 2013 (Data source: N. Rabalais, Louisiana Universities Marine Consortium).



The federal and state agency Task Force released its 2013 reassessment on September 26 (http://water.epa.gov/type/watersheds/named/msbasin/upload/hypoxia_reassess ment_508.pdf), with the following statement by the U.S. EPA Acting Administrator for Water and Task Force Co-Chair, Nancy Stoner: "*Achieving significant water quality improvements in water bodies as large as the Mississippi River and Gulf of Mexico takes time, and the increasing impacts of climate change such as more frequent extreme weather events pose additional challenges. The progress we've made across the board during the past five years provides an excellent foundation and we will work to accelerate our progress over the next five years.*" One of the key conclusions in that 2013 reassessment was that the Task Force should work to "*accelerate implementation of nutrient reduction activities and identify ways to measure progress at a variety of scales.*" Lack of a reduction in the size of the Gulf hypoxic zone is in general agreement with the USGS-reported data showing that nitrate-N loads have remained static, total N loads have declined, while total P and orthophosphate P loads have increased just slightly since the early 1980s (http://toxics.usgs.gov/hypoxia/mississippi/flux_ests/delivery/index.html). More people are beginning to recognize that it will take a long time to see downstream effects of local changes in soil, crop, and nutrient management because of the lag effect often observed between implemented changes and water quality responses in large basins and watersheds (Meals et al., 2010).

A dozen or more environmental groups sued the U.S. EPA and called for strict numeric nutrient standards up and down the Mississippi River, in an effort to "regulate farmland runoff and other pollution". A ruling by a federal judge in New Orleans, Louisiana on 20 September 2013 gave EPA six months to decide whether to set Clean Water Act standards for N and P not just in the Mississippi River Basin, but in all U.S. waterways, or explain why they're not needed. (http://online.wsj.com/article/AP2487f967679546a68c80936888476f7b.html).

Minnesota, in the Upper Mississippi River Basin

Recently heightened water quality monitoring, numeric nutrient criteria or standard development, and policy actions among states have been driven in no small part by the fear that the U.S. EPA will step in and trump state water quality standards, and force states to implement onerous Total Maximum Daily Loads (TMDLs; the maximum nutrient loads possible to a water body without causing it to fail to meet its designated use). In the Upper Mississippi River Basin, one of the states recognized as a national agricultural and water quality leader is the state of Minnesota. In June 2013, the Minnesota Pollution Control Agency (MPCA) released its report looking at the sources and pathways of N loads to surface waters in their state, and identified reductions in those loads to obtain desirable water quality conditions (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nitrogen-study-looks-at-sources-pathways.html) . In connection with that report, that agency has proposed a nutrient-reduction (i.e. loss reduction) strategy with a target of 20% less N and 35% less P reaching waterways by 2025. In response to the MCPA report, the

Minnesota Department of Agriculture revised its fertilizer N management plan in August 2013, in collaboration with the University of Minnesota (http://www.mda.state.mn.us/en/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/draftplan.aspx). Those N plan revisions (initially developed in 1990, revised in 2007-2008) will cover 10 basins or watersheds across the state, covering at least four distinct soil and cropping regions, to achieve reductions in N loss. In an average year, 37% of the N load to Minnesota's surface waters comes from subsurface drainage (i.e. tile drains), and contributes 67% of the N load in the heavily-tiled Minnesota River Basin. These revised management and N pollution prevention plans call for: 1) better in-field nutrient management with more optimal fertilizer rates, applied closer to the time of crop use, nitrification inhibitors, and variable fertilizer rates, 2) tile drainage water management with shallower depth of tile drainage, control structures that let farmers adjust water levels, constructed and restored wetlands for treatment purposes, woodchip trench bioreactors, and saturated buffers, and 3) more vegetation/landscape diversification to include cover crops, perennials planted in riparian areas or marginal cropland, extended rotations with perennials, and energy crops in addition to corn. Presently, the Minnesota Nitrogen Fertilizer Management Plan strategies are " *based on voluntary BMPs, intended to engage local communities in protecting groundwater from nitrate contamination*".

Another key factor driving the implementation of fertilizer N management to achieve water quality protection and mitigation is the detection of elevated nitrate-N (i.e. (above the safe drinking water limit of 10 mg/L nitrate-N) in 8 to 62% of the sampled wells among different regions in Minnesota. Most of the wells above the safe limit were shallow, and in known sensitive areas (i.e. permeable soils), but there was great variability and the reasons for adjacent wells to have strikingly different nitrate-N levels are not known.

The Minnesota Department of Agriculture has stated:

> *"Best Management Practices (BMPs) for nitrogen fertilizer are tools to manage nitrogen efficiently, profitably and with a minimum practicable environmental loss. The BMPs are built on a four-part foundation that takes into account the nitrogen rate, application timing, source of nitrogen, and placement of the application. If one of the above is not followed, the effectiveness of the system will be compromised, and there will be agronomic and or environmental consequences. Minnesota has officially recognized state-wide and regional nitrogen fertilizer BMPs"*

Strategies are being developed for more frequent water quality monitoring and surveys of fertilizer BMP implementation are being devised to document changes and the evaluate effects of improved N management.

Example - Lake Erie Eutrophication

Lake Erie is the 4th largest of the five Great Lakes in North America and ranks among the top 10 globally. Nutrient loading, eutrophication, and harmful algal blooms have been a concern in Lake Erie since the 1960s, abated in the 1980s, but have increased since the 1990s. One factor that has complicated the cause and effect evaluations has been the arrival of invasive Zebra and quagga mussels in the mid- to late-1980s (http://www.epa.gov/med/grosseile_site/indicators/algae-blooms.html). Joint U.S. and Canada concerns about Lake Erie water quality and algal blooms have led to a bi-national agreement to help address the problem (Lake Erie LaMP, 2011). A study was initiated in 2008 by a team of government, university and private scientists who reported, among other findings, that:

> "The net effect of the combination of (1) increasing loads of dissolved reactive phosphorus that is 100% bioavailable, (2) decreasing loads of particulate phosphorus that remain approximately 30% bioavailable, and (3) an increasing frequency, and intensity of storm events, is such that the overall loading of bioavailable phosphorus during the 2000s is at the highest level observed in the 35-year monitoring record for the Maumee and Sandusky rivers."
>
> "Harmful algal bloom (HAB) species are likely present in most waters of thestate (i.e. Ohio) and are simply waiting for the appropriate conditions to reproduce"
>
> "Phosphorus should still be the primary target for nutrient loading reduction efforts as stated in the background of this summary. Reduction of both P and N loadings should be encouraged, when feasible."

That report concluded that excess P loading was the primary nutrient concern (LEMNST, 2011).

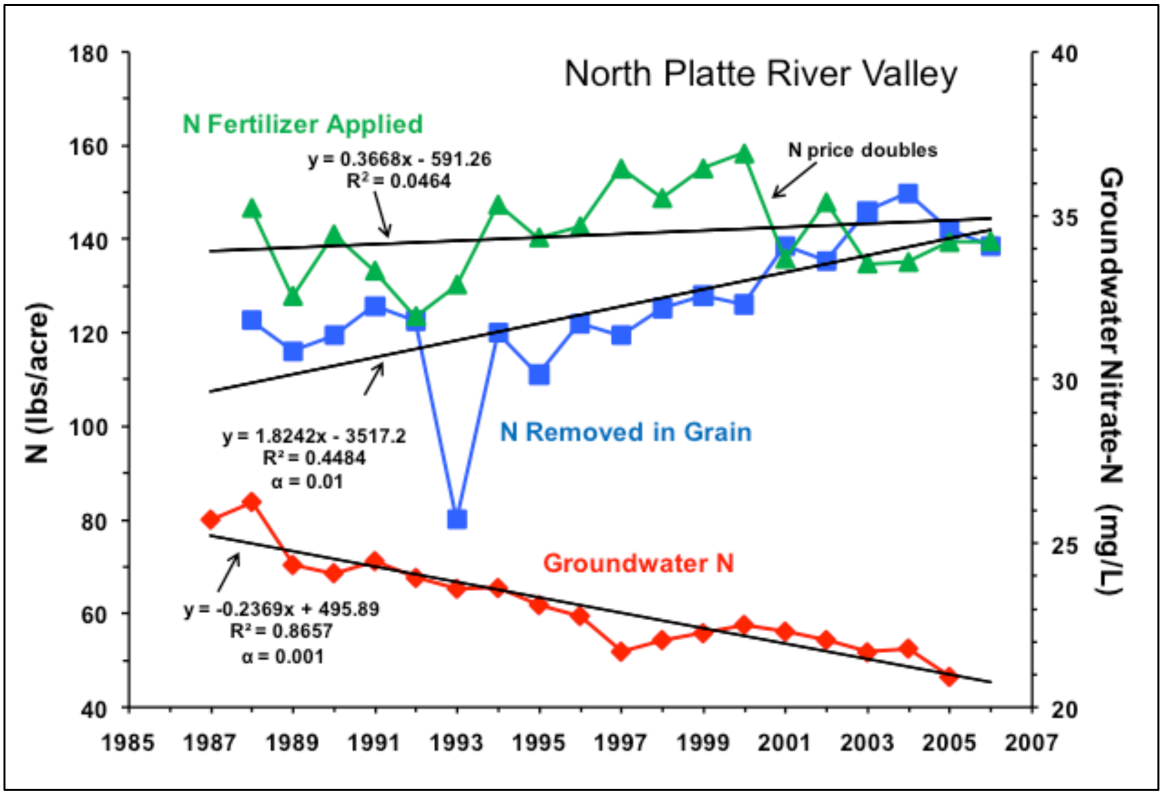
Dissolved P concentrations and loads in runoff waters can be significantly reduced where fertilizers and/or manures are soil-incorporated, rather than surface applied. For decades, farmers in Ohio and the Sandusky and Maumee River watersheds, that empty into Lake Erie in the northcentral U.S., have been steadily adopting no-till and reduced till practices to control soil erosion and runoff sediment loads to Lake Erie. Many farmers have also relied on surface applications of fertilizer P and/or manures to meet their crop P demands. Those P application and tillage practices need to be re-evaluated in light of the elevated dissolved P runoff concerns. In October 2011, the Ohio Department of Agriculture, the Ohio NRCS, and the Ohio EPA recommended P applications, based on 4R Nutrient Stewardship. Ohio officials are currently developing a new numeric water quality index as part of their plan to address the eutrophication challenges (http://insideepa.com/201306172437890/EPA-Daily-News/Daily-News/fearing-epa-ohio-pushes-novel-numeric-nutrient-water-quality-index.html)

Examples of groundwater nitrate-N concerns

Nebraska

Nebraska is among the top-five states in corn production. Elevated groundwater nitrate (> 25 mg/L nitrate-N) has been an issue for decades in the sandy soil area of the North Platte River Valley in Nebraska. To address those concerns both educational programs by the University of Nebraska and regulatory programs were implemented beginning in 1988. Local soil and water conservation districts (Natural Resources Districts) were given authority to regulate N management for irrigated crop production (Exner et al. 2010).. Such local regulation coupled with intensive educational efforts contributed to the success in lowering groundwater nitrate concentrations from >25 mg/L 1987 to about 20 mg/L in 2007, while fertilizer consumption has slightly increased and corn yields have increased (**Figure 4**). These results help to underscore the need to prevent rather than correct groundwater nitrate-N contamination, and they illustrate the long time required to measure such groundwater quality impacts, and beneficial changes to landscape management.

Figure 4 – Changes in fertilizer N consumption, corn yields, and groundwater nitrate-N levels in the North Platte River Valley in Nebraska. (Source: R. Ferguson, University of Nebraska).



California

Elevated groundwater nitrate-N levels have been detected in certain geographic areas in California. Water Boards in several of those areas have developed Irrigated Lands Regulatory Programs that require farmers to develop N management plans, which have been approved by Certified Crop Advisers (CCAs) in nitrate-impacted areas are required to attend N management plan training conducted by the California Department of Agriculture.

In the Central Valley of California, 25,000 out of an estimated 35,000 landowners/operators, on a total of nearly 5 million acres (2 million ha) of land, are currently regulated by the Water Board and are part of water quality coalition groups (http://www.swrcb.ca.gov/rwqcb5/water_issues/irrigated_lands/). Water coalitions are conducting surface water monitoring and are preparing regional plans to address water quality problems. Growers are required to implement management practices to protect surface waters; especially where monitoring has identified problems. In some of these water coalitions, farmers report their nutrient removal to use ratios (i.e. nutrient harvest removal divided by nutrient input) and their irrigation water use on specific crops. The reported data are then aggregated within the coalition, and averages and statistical distributions are developed, against which farmers within the coalitions may be compared. Some water coalitions think these pilot efforts with growers are a pro-active way to protect the privacy of individual growers/land owners while still meeting Water Board regulations.

Local and municipal turf and horticultural fertilizer regulations

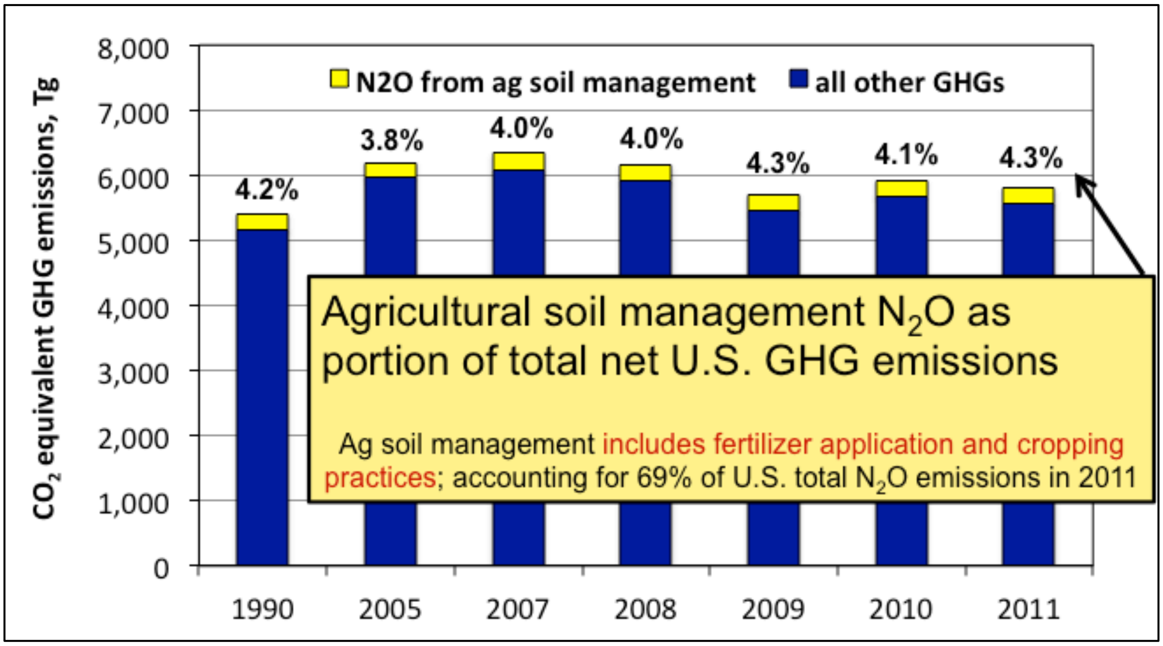
Many states have local or municipal ordinances or regulations that may limit the source, rate, and time of fertilizer application to turf and horticultural plants. Such regulations are not always based on sound science, and some may even ignore the wisdom and guidance of renowned agronomic and horticultural scientists; scientists who may have a wealth of data and many years of real field experience. An attempt to avoid the complexities of multiple turf fertilizer ordinances was made in the state of Florida, when the Florida Department of Agriculture and Consumer Services adopted an urban fertilizer rule in 2007 (Trenholm, 2013). However, efforts to establish primacy of state regulations over local ordinances in Florida have not met with political success. Consequently, the trials and challenges of fertilizer industry and other sector interests have grown monumentally as they try to properly and legally label product containers, and apply fertilizers for turf and some horticultural settings in Florida.

In many states, laws have been enacted to require turf fertilizers with low or no P content. Within a few years after such regulations were adopted, the tonnage of P-containing turf fertilizers dropped more than 70% in several states. Voluntary or regulatory actions in the Chesapeake Bay, in Minnesota, and in Florida are examples where turf and lawn P consumption tonnage declines have been documented. Examples of other state fertilizer P bans during the last 10 years in 11 states may be found at: http://www.cga.ct.gov/2012/rpt/2012-R-0076.htm .

NITROUS OXIDE - A POTENT GREENHOUSE GAS AND OZONE DEPLETER

The U.S. and agriculture share prominence as the world's largest carbon dioxide equivalent (CO_2-e) greenhouse gas (GHG) emitters. The U.S. ranks fist in total GHG emissions, while Australia ranks first in emissions per capita (WRI, 2010). Globally, agriculture is estimated to emit 14 to 16% of the world's total GHG emissions. Annual inventories of GHG emissions in the U.S. show that since 1990, national total GHG emissions have not increased (EPA, 2013b). National nitrous oxide emissions also have not increased, and represent <4.5 % of the U.S. total CO_2-e GHG emissions. Agricultural soil management (which includes fertilizer use) contributes an estimated 69% of those nitrous oxide emissions in the U.S. (**Figure 5**). Nitrous oxide has been ranked among the leading catalysts of stratospheric ozone depletion (Ravishankara et al., 2009), which may allow more harmful ultraviolet (UV) radiation exposure and may elevate risks of skin cancers.

Figure 5 - Annual national CO_2-e GHG emissions in the U.S., and the portion attributed to soil management-related nitrous oxide emissions. (Source: EPA, 2013b).



There is no national U.S. limit on GHG emissions currently within agriculture or other sectors. California is the only state at present to enact a carbon cap and trade program (http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm), which is administered by the California Air Resources Board. Pressures on U.S. energy and industry sectors to reduce CO_2 emissions are fueling interests in GHG trading and offset protocols. Since nitrous oxide has a radiative forcing power (global warming potential) that is almost 300 times greater than an equivalent of CO_2, it should not be surprising that those leading CO_2-emitting industries and interests are focusing their sights on agriculture as an economic GHG offsetting entity. For example, the Electric Power Research Institute has partnered with Michigan State University in developing methodology for quantifying emission reductions associated with reduced fertilizer N applications on agricultural crops (http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025834). The EPRI-Michigan State methodology has been approved and registered with the American Carbon Registry (http://americancarbonregistry.org/carbon-accounting/methodology-for-n2o-emission-reductions-through-fertilizer-rate-reduction). Regrettably, that methodology effort has not fully considered other equally important options of altering the source, time, and place of N application in reducing nitrous oxide emissions. The nitrous oxide seasonal and annual emission reduction potential can be quite large (>50%) with changed fertilizer N source, time, and place of application in some environments (Halvorson and Del Grosso, 2012; Maharjan and Venterea, 2013). Snyder and Fixen (2012) called attention to the opportunities for reduced nitrous oxide emissions through the use of enhanced efficiency fertilizers, in addition to other science-based 4R practices; including adequate supply and balance of other essential nutrients along with N.

4R NUTRIENT STEWARDSHIP NEEDED TO ADDRESS THE CHALLENGES

In 2012, the International Plant Nutrition Institute developed and released a new educational resource, entitled the 4R Plant Nutrition Manual, and also released supplemental resources (IPNI, 2012). The purpose of the 4R Nutrient Stewardship educational resources is to help enable greater nutrient use efficiency and effectiveness (i.e. more crop yield per unit of nutrient input); and to enhance the education and plant nutrition management skills of Certified Crop Advisers (CCAs), professional agrologists, fertilizer dealers, Extension workers, and other agricultural field practitioners. The 4R Nutrient Stewardship knowledge, tools, and their implementation should assist in meeting sustainability criteria. While it might be argued that 4R Nutrient Stewardship principles are not novel or brand new, what is different is the way in which nutrient management challenges and economic, social, and environmental goals are approached and addressed through greater local stakeholder involvement. Because there is no single BMP that will satisfy both production and environmental goals, it is imperative that the agricultural community, and especially all sectors of the fertilizer industry, endorse and support the global outreach and adoption of 4R Nutrient Stewardship principles and practices. In the U.S., the American Society of Agronomy (ASA, 2009) and the American Society for Horticultural Science (ASHS, 2011) have embraced 4R Nutrient Stewardship and assisted in its dissemination, by publishing papers in their magazines and journals on use of the right nutrient source, at the right rate, right time, and in the right place. The USDA Natural Resources Conservation Service has integrated 4R Nutrient Stewardship into its national 590 standards for nutrient management, and more agricultural retailers and conservation groups are aligning on the principles. The expansion of intensified, broad-based, 4R nutrient management on existing croplands is entirely consistent with the concept of ecological intensification, which was advanced in 1999 by Dr. Ken Cassman at the University of Nebraska (Cassman, 1999).

SUMMARY

In the absence of robust research results and science-based recommendations, which are underpinned by 4R Nutrient Stewardship, the focus on nutrient input rate reduction as the principal or only means to reduce environmental nutrient impacts may only increase. If U.S. and global agriculture fail to implement greater crop, soil and nutrient management changes aimed at increasing field and farm retention of applied nutrients, there will be an increasing likelihood that local, state, and national policies and/or regulations will be enacted that could place crop production potential in jeopardy and negatively impact fertilizer markets. More efforts are needed to show that while input rate reduction can help address unintended losses of nutrients from fields and farms, it is not the only way forward in striving to satisfy the burgeoning food, feed, fiber, and biofuel demands of the human family. Increasingly, the agronomic and environmental beneficial effects of all 4Rs of nutrient stewardship should be documented. Crop production on existing lands must be intensified through more efficient and effective nutrient stewardship (i.e. 4R Nutrient Stewardship), which couples with other sustainable agricultural practices while minimizing encroachment into natural areas. Such actions are advocated to better achieve U.S. and global economic, social, and environmental sustainability goals.

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