GROUNDWATER QUALITY AND NITROGEN USE EFFICIENCY IN NEBRASKA'S CENTRAL PLATTE RIVER VALLEY

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Abstract

In response to increasing levels of nitrate-N in groundwater in the Central Platte River Valley of Nebraska, intensive education and then regulatory efforts were implemented starting in the 1980s, to encourage adoption of nitrogen fertilizer and irrigation management practices which can reduce nitrate leaching to groundwater. Since 1988, there have been steady declines in average NO_3-N concentrations in groundwater in the Central Platte River Valley, resulting from adoption of recommended practices – in particular conversion from furrow to center-pivot irrigation. However, fertilizer nitrogen use efficiency has remained fairly static over the past 25 years. Trends suggest that further improvement in nitrogen use efficiency may require development and adoption of next-generation nutrient management tools, such as increased use of fertigation, controlled release formulations, or crop canopy sensors for in-season fertilization.

Introduction

Elevated nitrate-N levels in groundwater have been a concern in Nebraska since the early 1960s, with the first reported NO_3-N concentrations of greater than 10 mg L^{-1} in Merrick County in 1961 (Nebraska Water Quality Survey 1965; Meals et al., 2012). Merrick County is in the eastern portion of the Central Platte River Valley, and is characterized by relatively shallow, coarse-textured soils, shallow aquifers, and extensive irrigation development. Exner and Spalding (1976) found elevated nitrate levels in groundwater through much of the Central Platte Valley in 1974, with approximately 20% of the area exceeding 10 mg NO_3-N L^{-1}. Nitrate movement into groundwater in the Central Platte Valley can be attributed primarily to overuse of both nitrogen (N) fertilizer and irrigation water (Spalding and Exner, 1993). By the late 1980s, it was not unusual to find irrigation wells with 30-40 mg NO_3-N L^{-1} in the Central Platte Valley, especially in Merrick County.

Approach

In 1988, the first Groundwater Management Area (GWMA) was established in Nebraska, in the area covered by the Central Platte Natural Resources District (CPNRD) (CPNRD, 2014). The CPNRD covers all or parts of 11 counties in the central part of the state. Regulations associated with the CPNRD-GWMA vary by region, or phase, within the district, according to the severity of nitrate contamination. Regulations discourage or ban fall nitrogen application, especially to sandy soils. The use of nitrification inhibitors is encouraged or required, depending on the region of the GWMA. Producers in Phase 2 and 3 areas are required to report annually to the CPNRD on the rate and timing of nitrogen fertilizer, as well as irrigation water amounts. Producers in Phase 2 and 3 areas are also required to be certified by the CPNRD in fertilizer and irrigation water management every four years, either through attendance at certifying workshops or conferences, or by taking an exam. Regulations in the CPNRD-GWMA also include the potential for imposition of Phase 4 areas, in which the CPNRD would set expected yield and thus the fertilizer N rate. However, no Phase 4 areas have been designated to date.

Beginning in 1979 with the Hall County Water Quality Special Project, and continuing to date, the CPNRD and the University of Nebraska-Lincoln (UNL) have collaborated on educational efforts to encourage adoption of nitrogen and irrigation best management practices. A central component of these efforts have been demonstration/on-farm research efforts with area producers. Practices demonstrated include use of the UNL N recommendation algorithm for corn, scheduling irrigation based on stored soil water and crop water use, appropriate use of irrigation technologies such as flow meters and soil moisture sensors, and the use of nitrification inhibitors. Over the past 30 years hundreds of demonstrations have been conducted in collaboration with area growers - typically field-length, randomized and replicated treatments implemented by the producer.

One of the benefits of the CPNRD-GWMA has been the development of a large database of producer practices over time. This resource allows tracking of change in producer practices as a result of educational and regulatory efforts in the GWMA. Figure 1 illustrates the trend in expected and actual yields over the past 25 years. On average expected and actual yields have increased between 1.1 and 1.6 bu acre^{-1} yr^{-1}, as yield potential has increased with improved hybrids and production practices. While we would like to see greater congruence between expected and actual yield, producers are more realistic today when setting expected yield than they were 30 years ago (Schepers et al., 1986; 1991).

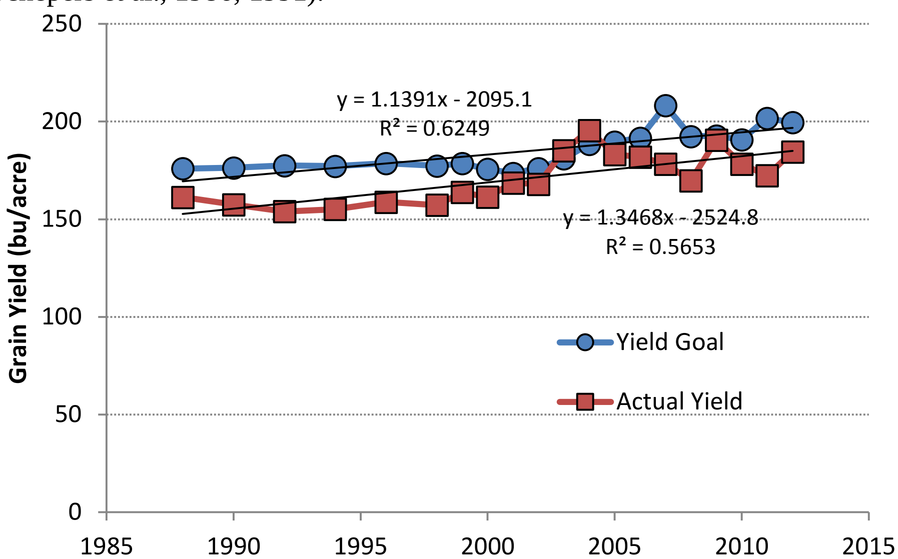

Figure 1. Trends in expected and actual corn grain yield, CPNRD-GWMA, 1988-2012.

Recommended fertilizer N rates have gradually increased over the past 25 years (Figure 2), as have actual applied rates. Based on current trends, grower N rates are closer to the desired goal in 2012 than they were in 1988. The environmental impact from 24 years of combined education and regulatory efforts is shown in Figure 3. On average, groundwater NO_3-N concentrations in these Phase 2 and 3 areas has declined by 0.15 mg NO_3-N L^{-1} yr^{-1}, from a peak of around 19 mg L^{-1} to around 15 mg L^{-1} in 2012. These trends indicate that grower adoption of recommended practices is having a positive impact on groundwater quality.

In a study conducted over a Phase 3 area of the CPNRD-GWMA as part of the National Institute of Food and Agriculture (NIFA) Conservation Effects Assessment Project (CEAP), Exner et al. (2010) found that in this area conversion of irrigated land from furrow to sprinkler irrigation had the greatest effect on improving groundwater quality – accounting for ~ 50% of the decline in groundwater NO_3-N concentration from 1988 to 2003. During this period, approximately 15% of fields on the Platte River terrace converted from furrow to center-pivot irrigation. They also found increased crop removal of N – associated with increased yield while fertilizer N rates remained static – to be responsible for ~20% of the decline.

The GPNRD-GWMA database allows calculation of one measurement of nitrogen use efficiency (NUE) – Partial Factor Productivity, or lb of grain produced per lb of fertilizer N (PFP_N). Figure 4 illustrates that in this GWMA there has been little change in PFP_N over the past 24 years, increasing from around 60 in 1988 to around 65 lb grain/lb fertilizer N in 2012. This is in contrast to the average trend statewide for Nebraska (Figure 5) – around 49 lb grain/lb fertilizer N in 1988, and around 65 lb grain/lb fertilizer N in 2012. These trends suggest that the level of N

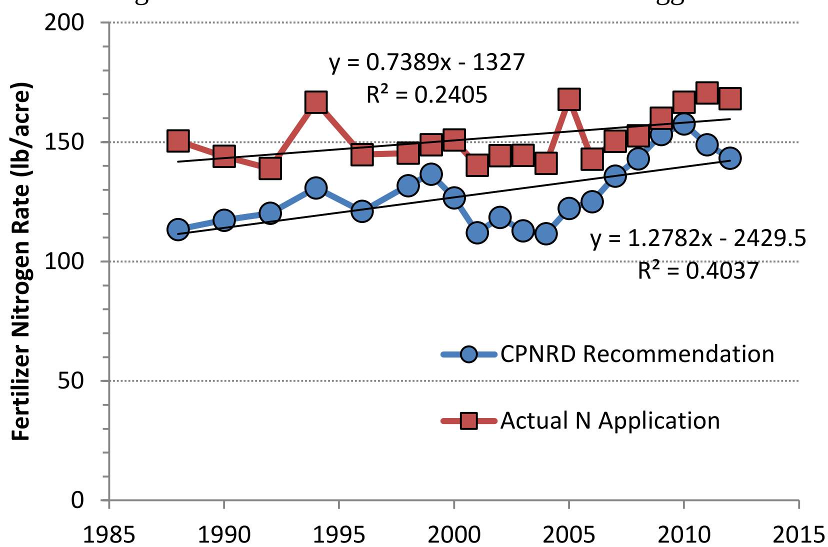

Figure 2. Trends in recommended and actual fertilizer N rate, CPNRD-GWMA, 1988-2012.

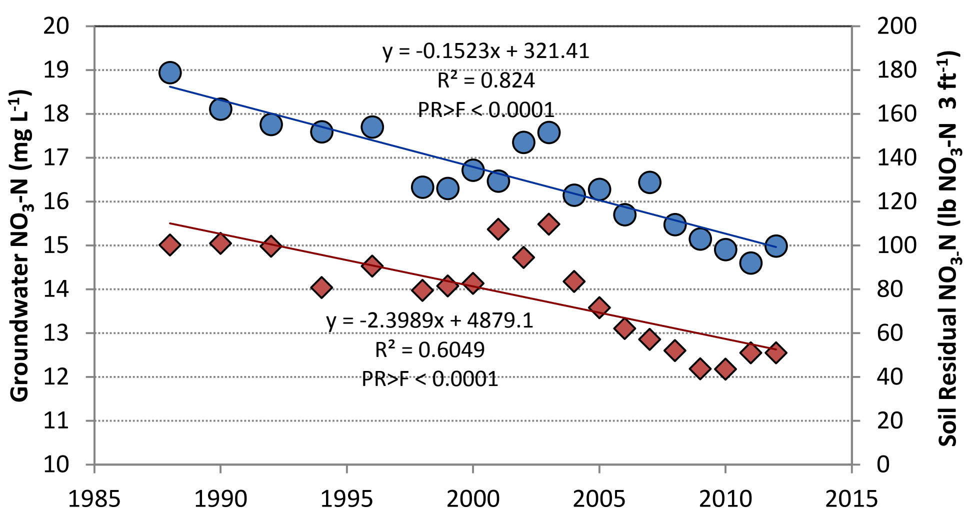

Figure 3. Groundwater and soil residual nitrate-N trends, CPNRD-GWMA, 1988-2012.

management in the CPNRD-GWMA was above the state average in 1988, but about the same as the rest of the state in 2012. The lack of substantial improvement in NUE in the CPNRD-GWMA over the past 24 years is of concern. When credit for other sources of N is accounted for, where measureable available inorganic N is the sum of fertilizer N, soil residual nitrate, and irrigation water nitrate credit, the trend is more positive. However, these trends suggest that current practices may be reaching their maximum efficiency, and that further gains in NUE will require more aggressive or refined practices.

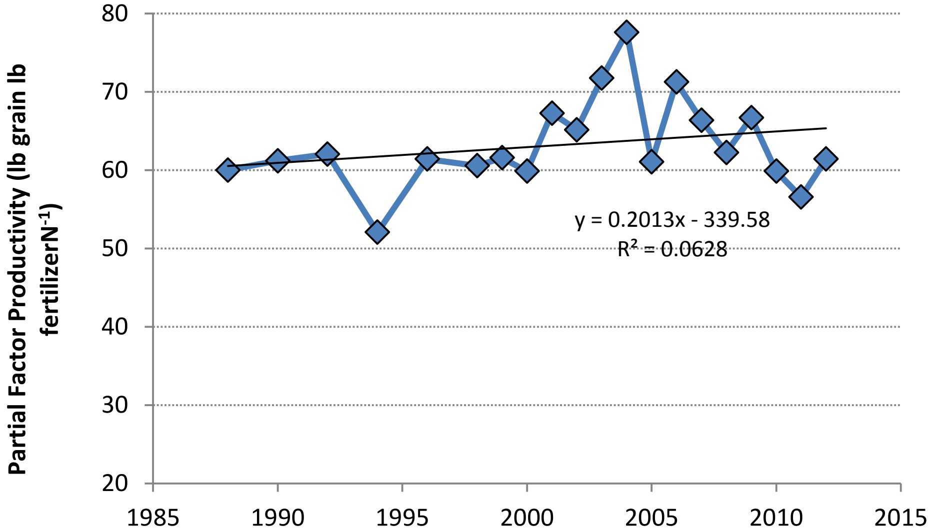

Figure 4. Partial factor productivity for nitrogen, CPNRD-GWMA, 1988-2012.

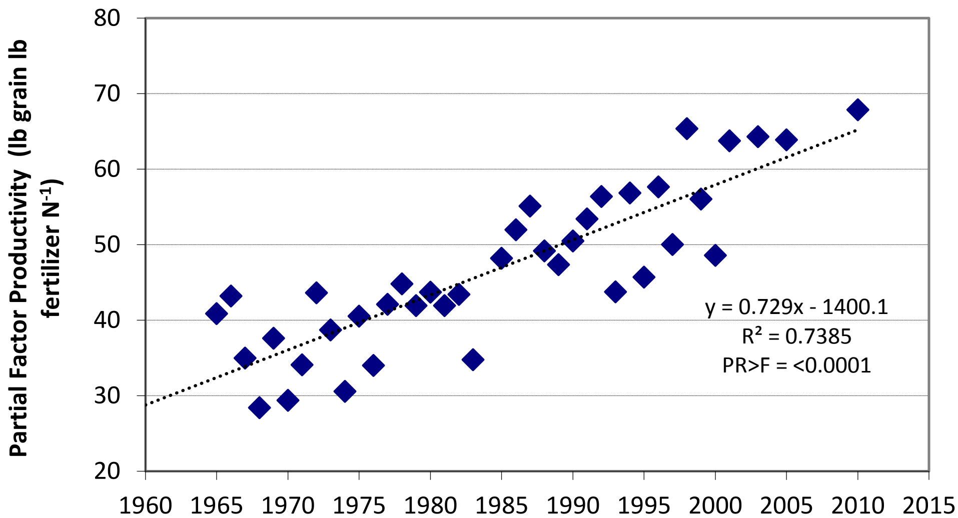

Figure 5. Partial factor productivity for nitrogen, state of Nebraska (includes rainfed and irrigated corn).

Summary

Groundwater nitrate contamination has been of concern in the Central Platte River Valley of Nebraska for over 50 years. Elevated nitrate in groundwater is due to the combination of extensive irrigation development, growing primarily corn, with initially inefficient irrigation and nitrogen fertilizer management, as well as shallow aquifers and frequent occurrence of sandy soils. Improved irrigation and nitrogen management practices implemented over the past 25 years have resulted in measured improved in groundwater quality, although NO_3-N levels are still high. Trends in PFP_N statewide and in the CPNRD-GWMA suggest that current N fertilizer management practices may be reaching their limit on improving N use efficiency. The development, refinement, and adoption of next-generation nutrient management techniques, such as increased use of fertigation, controlled release formulation, or use of crop canopy sensors for in-season N application, may be required for further significant gains in N use efficiency in these irrigated systems.

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MAKING EVERY SEED COUNT: WHO'S RESPONSIBLE FOR STAND LOSS[1]

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Seedling diseases of soybean and corn can cause significant losses through poor stand establishment and reduced plant vigor. Identifying the causal agent of seedling disease is not a simple process as the soil environment is complex and contains many thousands of microbe species but only a small portion of these actually cause disease. The primary causes of soybean seedling disease are *Pythium* spp., *Phytophthora sojae, Rhizoctonia solani* and *Fusarium* spp. In this study it was our objective to identify the predominant oomycete (*Pythium* and *Phytophthora*) species that cause soybean seedling disease. Only by understanding which pathogens cause disease are we are ultimately able to improve disease management.

A survey was conducted over two years across the north central region to identify oomycete species that contribute to seedling disease. The survey was conducted in collaboration with Extension specialists in each state. In each state approximately 6 fields with emergence issues were sampled by collecting 50 diseased soybean seedlings. The soybean seedlings were then taken back to the individual labs at each state, washed thoroughly and isolations were made using agar medium containing antibiotics to limit the growth non-oomycete species.

Overall, 82 different oomycete species were identified across the Midwest, including species of *Pythium, Phytophthora, Phytopythium* and *Aphanomyces*. *Pythium sylvaticum* was the most abundant species across both years. In 2011, a total of 52 *Pythium*, 2 *Phytopythium* and 3 *Phytophthora* spp. were recovered, with *Py. sylvaticum* (16%) and *Py. oopapillum* (12%) being the most frequent. In 2012, a total of 57 *Pythium* spp., 7 *Phytophthora* spp., and 4 *Phytopythium* were found, with *Py. sylvaticum* (15%) and *Py. heterothallicum* (13%) species being most abundant.

Analyses of the oomycete species collected by location have demonstrated that similar geographies group together, i.e. the species identified in one state closely reflect the species collected in a neighboring state. This indicates that fungicide seed treatments may need to be tailored by region to have maximum efficacy. Further analysis to understand these geographic patterns using GIS and metadata are currently being conducted.

We have screened representative isolates of all 82 oomycete species for their pathogenicity to soybean seed and soybean seedlings. Using a combination of this pathogenicity data and the distribution data we will be able to identify the predominant pathogens by region.

By identifying the most significant pathogens that cause seedling and root rot disease we will be able to direct soybean breeding efforts by screening germplasm (cultivars) for resistance against the most appropriate pathogens. The same is true for seed treatments. Understanding which species are the primary pathogens enables us to work with companies in screening and developing chemical or biological seed treatments to minimize the impact of seedling disease. Using data generated from this study we are also in the process of developing improved diagnostic methods, which will assist in establishing more rapid, specific and accurate diagnoses, which will ultimately improve disease management.

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