Nitrogen, groundwater quality, and a changing climate: intersecting challenges for Wisconsin Agriculture

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Wisconsin’s agriculture is diverse! $104.8B to our economy
11.8% of our state’s jobs

US Rankings
#1 dairy farms
#1 cheese
#1 cranberries
#3 potatoes

Source: UW-Stevens Point Center for Land Use Education, 2010
Nitrogen fertilizer recommendations for common crops:

Farmers rely heavily on nitrogen fertilizer
Recommendations unfortunately do not eliminate nitrate leaching losses

* Legumes have symbiotic relationship with N fixing bacteria


Nutrient application guidelines for field, vegetable and fruit crops in Wisconsin, A2809. 2012. University of Wisconsin-Madison

Miscanthus and switchgrass recommendations: Anderson et al., 2013; McIsaac et al., 2010; Vogel et al., 2002; Arundale et al, 2014
Corn only takes up ~40-60% of fertilizer applied

No nitrogen uptake from soil

Nitrate leaching potential is high

Graph of root depth: http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html
Picture of corn roots: http://www.soilandhealth.org/01aglibrary/010137veg.roots/010137ch2.html
Nitrate leaching from Midwest Crops and other Land Use*

*Source: Shrestha et al., to be submitted to JSWC - Meta-analysis of > 1300 measurements in Midwest US Agroecosystems
Corn yield and nitrate leaching for varying fertilizer applied*

*Source: Shrestha et al., to be submitted to JSWC - Meta-analysis of > 1300 measurements in Midwest US Agroecosystems
Private Well Nitrate Concentrations

Nitrate-N Concentration (mg/L)*

- Blue: Less than 2
- Green: 2 - 5
- Orange: 5 - 10
- Red: 10 - 20
- Dark Red: Greater than 20

*Maximum displayed where overlapping values occur.

Disclaimer: This map represents well water data in the Center for Watershed Science and Education database, WI DNR Groundwater Retrieval Network. It does not represent all known private wells.
Land management and groundwater nitrate connection

Maps produced using WISCLAND Data Coverage. 2002. WiDNR/EDM

~20% of samples exceed the 10 mg/L nitrate-nitrogen standard when more than 75% of the area is cultivated (DATCP, 2017)
Safe, clean drinking water eludes many Wisconsinites

Lax enforcement, outdated rules and numerous substances — natural and manmade — threaten drinking water for hundreds of thousands of state residents.

By Ron Seely  November 8, 2015

Report: Wisconsin Among 12 Worst States for Drinking Water Safety

Healthiest Communities

What’s in the Water?

EPA investigates possible groundwater contamination in central Wisconsin as worries grow
Mississippi River/Gulf of Mexico Hypoxia Task Force long term goal: 45% reduction in N and P loads
Short term goal: 20% reduction by 2025
Our weather & climate is changing

Data and slides courtesy of Dan Vimont (UW-Madison), Nelson Institute Center for Climatic Research, and the Wisconsin Initiative on Climate Change Impacts (WICCI) Climate Working Group

https://wicci.wisc.edu/wisconsin-climate-trends-and-projections/

Night has warmed more than day; **most significant in winter**
Seasonal Precipitation Trends (1950-2018)

Significant increases during winter, spring, and summer in many agricultural regions of southern and central WI
Top 10 wettest years in Madison all-time:

#2 – 2018 (50.64")
#5 – 2019 (46.39")
#6 – 2016 (45.56")
#7 – 2013 (45.38")
#8 – 2007 (44.41")
#9 – 2008 (44.06")
#10 – 1993 (43.34")

23% increase since 1970!

2021: 22.82", 13th driest ever since 1869
Climate change is making it harder to provide clean drinking water in farm country

Updated November 23, 2021 · 8:58 AM ET
Heard on Weekend Edition Saturday
Climate change presents more challenges to protecting soils and water resources

1. **Fertilizer and manure management** – harder to keep nutrients in place and out of surface/groundwater

2. **Soil management** – more flooding, more erosion (phosphorus issues compounded)

   Increased rainfall and heavier rainfall events – more drainage and runoff

   Warmer temperatures during winter promote more freeze/thaw cycles

   Warmer temperatures during winter increase likelihood of rain vs. snow falling

   → **More drainage and loss of Nitrogen stored in the soil profile**
Annual precipitation impacts on nitrate leaching in continuous corn and corn-soybean rotations*

<table>
<thead>
<tr>
<th>Annual precipitation range (inches)</th>
<th>Annual N leaching (kg N ha(^{-1}))</th>
<th>Sample size</th>
<th>Annual Fertilizer N (kg N ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 29.5 in</td>
<td>24.0 ± 1.4 a</td>
<td>317</td>
<td>103</td>
</tr>
<tr>
<td>29.5 - 36.6 in</td>
<td>29.9 ± 1.3 b</td>
<td>349</td>
<td>100</td>
</tr>
<tr>
<td>&gt; 36.6 in</td>
<td>34.7 ± 1.2 c</td>
<td>327</td>
<td>107</td>
</tr>
</tbody>
</table>

Increasing precipitation = increased nitrate leaching

*Meta-analysis of > 1300 measurements in Midwest US Agroecosystems**
Farming Adaptations to Increasing Rainfall

• They are adding more N fertilizer to make up for the increased risk of leaching losses

“Yeah I think we’ve gone to more extremes…when you get these heavy rains it’s harmful. We lose our nitrogen that we all spend money to put out there, it’s not cheap” – Iowa Farmer

“If it keeps raining and it’s warm, we’re going to lose nitrogen, big time lose nitrogen, and that’s when you’ve got to come back in and put some more [nitrogen] on or you’re going to lose the crop, and there’s ‘why did you lose the crop?’ when with another 10 to 15 gallon of [liquid nitrogen fertilizer] you can fix it” – Indiana Farmer.

“We usually put [a little extra nitrogen on] just to make sure if we have a really wet year, like we had last year and how this year is turning out, that we still have some nitrogen left over [to ensure sufficient yields]” – Iowa Farmer.

“I never want to be short on nitrogen, let’s put it that way. You don’t want nitrogen to be your limiting factor” – Iowa Farmer.

How are farmers adapting to changing weather? More tile-drainage.

18.8M ha, 83.8% of US tile drained land area is in 6 Midwest states

Source: Valayamkunnath et al. 2020, Mapping of 30-meter resolution tile-drained croplands using a geospatial modeling approach, *Scientific Data*
What can farmers do to help meet water quality goals?
Simple adjustments to N management do not allow us to get to 40-50% reduction goals.

Need large-scale transformation of our landscape (and management of agricultural systems) to achieve desired load reductions.
Recent modeling study of Yahara Watershed illustrated water quality goals met with increased perennials and reduction in fertilizer amounts*

Agricultural Landscape Transformation Needed to Meet Water Quality Goals in the Yahara River Watershed of Southern Wisconsin

Tracy A. Campbell,1,2* Eric G. Booth,1,2 Claudio Gratton,3,4 Randall D. Jackson,3,4,5 and Christopher J. Kucharik1,4,5,6

*Tracy Campbell et al., 2021, *Ecosystems*

• Yahara watershed modeling results for increasing perennials planted and reducing nutrient applications to row crops – have to do both and in large quantities!!!

• Together these can reduce erosion, P yield, and nitrate leaching

• Achieve water quality goals (50% reduction)
We need to develop policies that protect ecosystems and promote multifunctional landscapes. Simple adjustments to nutrient management practices will not fix largescale water quality issues in a reasonable amount of time.

Need to pay farmers for ecosystem services other than carbon sequestration; e.g. those that adopt practices that significantly improve water quality.
Create future policies that eliminate unintended and negative consequences for ecosystems in a changing climate.

Adapting food-energy-water systems to withstand shocks and stressors.
Thank you!

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Funding Sources

National Science Foundation
Innovations at the Nexus of Food-Energy-Water Systems - INFEWS

Wisconsin Department of Natural Resources

Wisconsin Department of Agriculture, Trade and Consumer Protection

US Department of Agriculture

Wisconsin Potato and Vegetable Growers Association
Extra Slides
1. Reconfigure the livestock industry
2. Regulation: must play a parallel role with voluntary adoption of conservation practices
3. Policies should be tailored to respond to changing climate and production systems.

“New and existing funding should not be allocated to water quality measures without adequate monitoring and other mechanisms to assess effectiveness.”