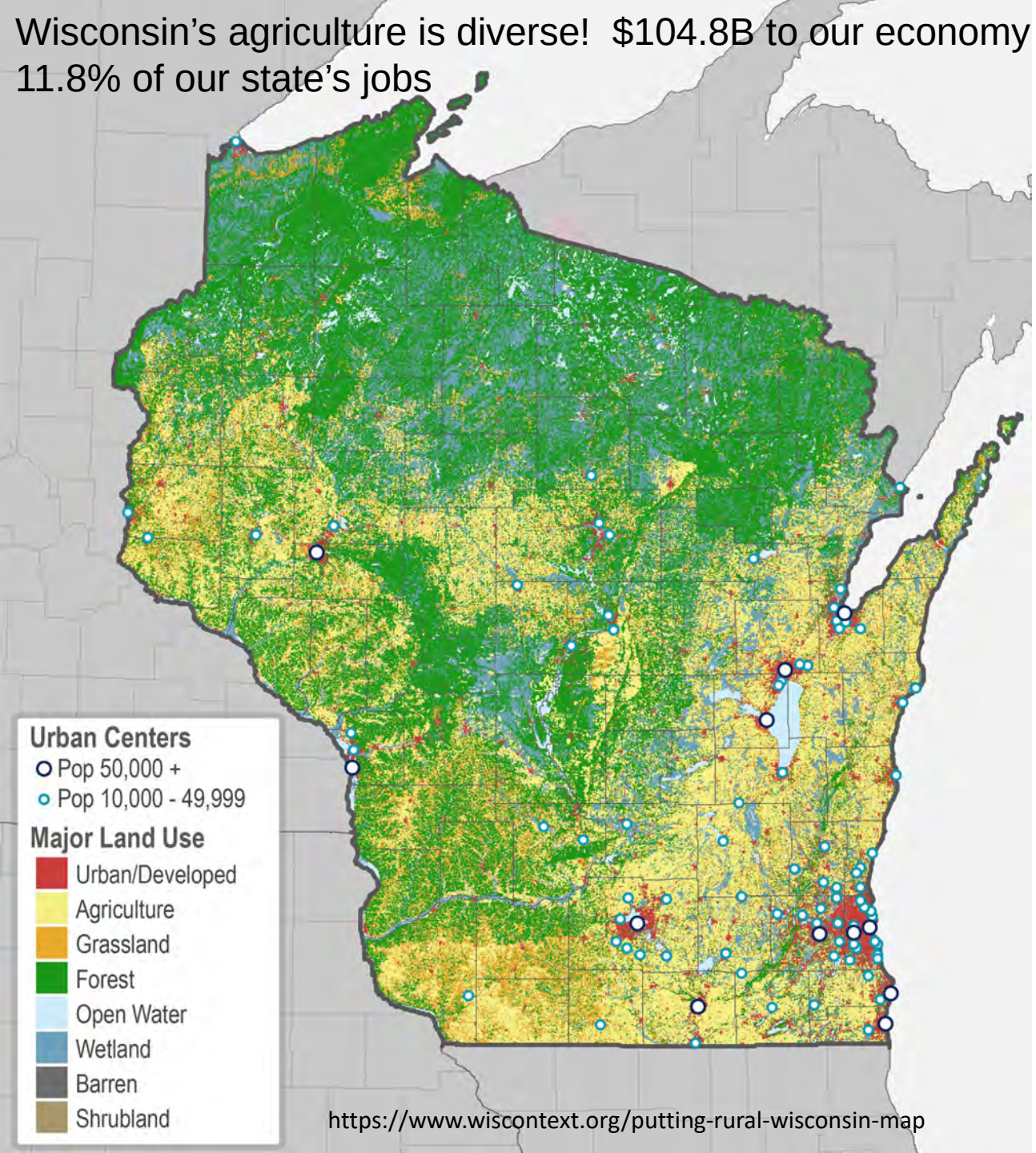
Nitrogen, groundwater quality, and a changing climate: intersecting challenges for Wisconsin Agriculture

Dr. Christopher J. Kucharik
University of Wisconsin-Madison

Professor and Chair, Department of Agronomy
Professor, Nelson Institute Center for Sustainability and the Global Environment (SAGE)

http://fewscapes.wisc.edu
http://www.kucharik-lab.com
Twitter: @Chris_Kucharik
Email: kucharik@wisc.edu

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

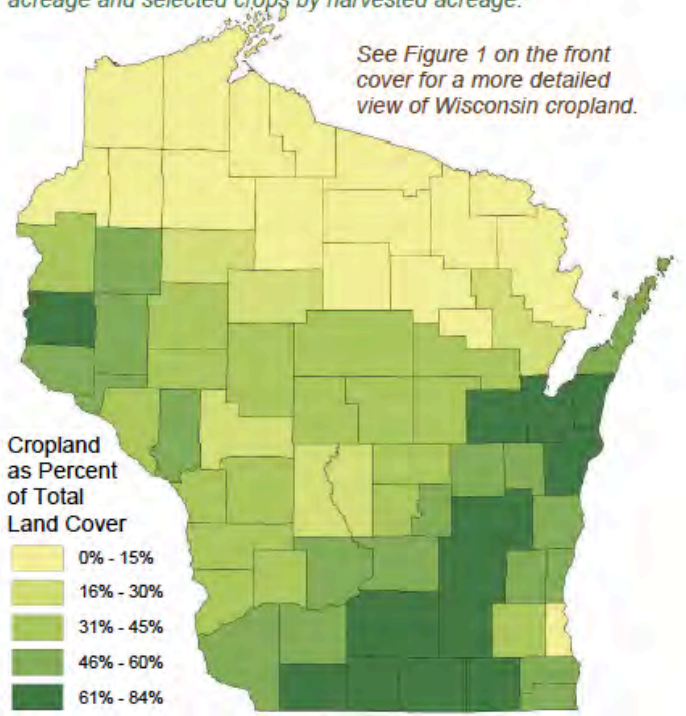


https://www.wiscontext.org/putting-rural-wisconsin-map

Wisconsin Cropland

This map shows the percent of total land cover in each county classified as cropland.[1] The table below shows farmland use by acreage and selected crops by harvested acreage.[5]

See Figure 1 on the front cover for a more detailed view of Wisconsin cropland.



	Acres
Cropland	*10,116,279*
Selected Field Crops	
Corn for Grain	*3,250,847*
Soybeans for Beans	*1,363,124*
Corn for Silage	*732,626*
Wheat for Grain	*280,464*
Oats for Grain	*166,794*
Other Crops	
Vegetables	*291,223*
Orchards and Berries	*30,215*
Hay and Forage	*2,797,497*
Woodland	
Permanent Pasture and Rangeland	*1,065,814*
Farm Buildings, Roads, etc.	*1,088,497*
All Land in Farms	*15,190,804*

<u>US Rankings</u>

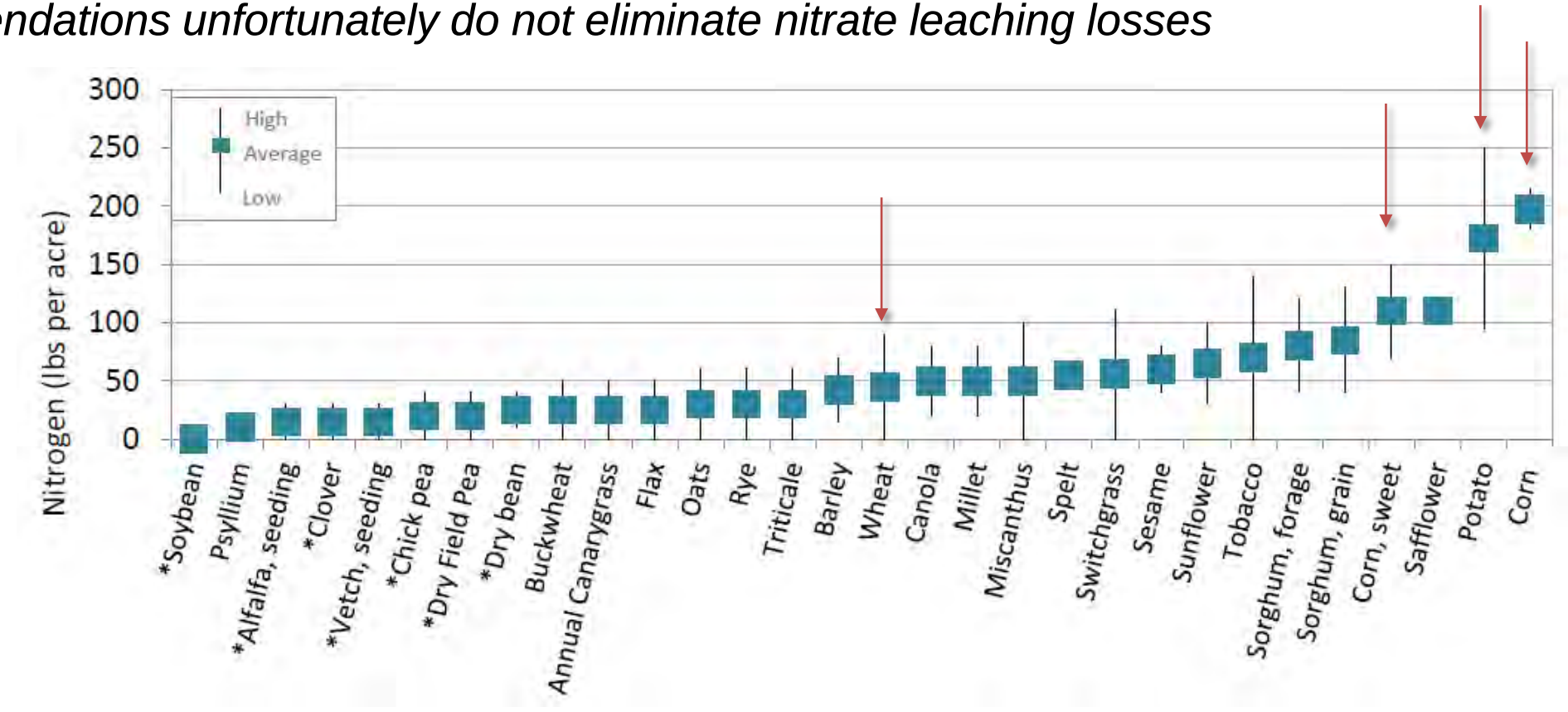
#1 dairy farms
#1 cheese
#1 cranberries
#3 potatoes

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

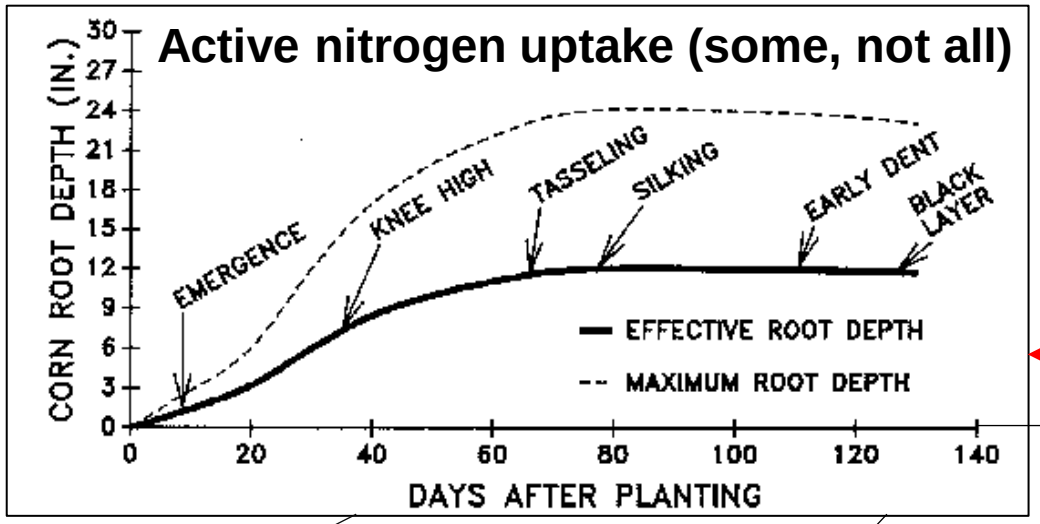


* Legumes have symbiotic relationship with N fixing bacteria

Alternative Field Crops Manual, 1989. University of Minnesota and University of Wisconsin -Madison

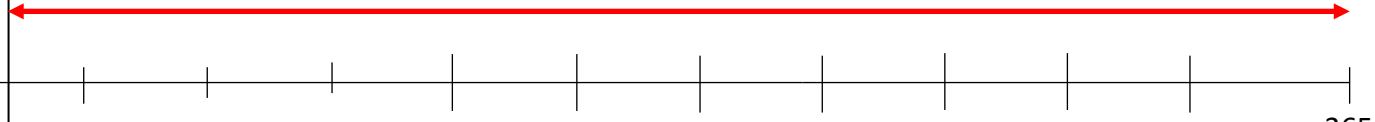
Nutrient application guidelines for field, vegetable and fruit crops in Wisconsin. A2809. 2012. University of Wisconsin-Madison

Miscanthus and switchgrass recommendations: Anderson et al., 2013; McIsaac et al., 2010; Vogel et al., 2002; Arundale et al, 2014

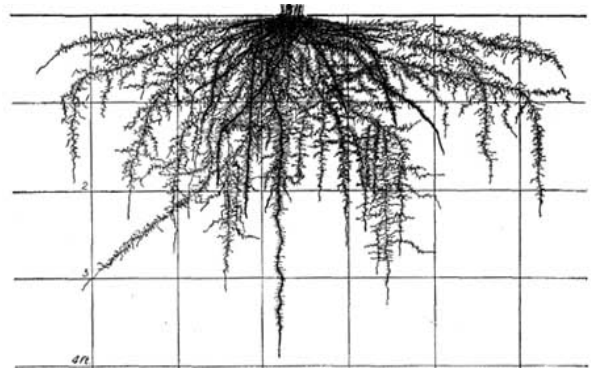


Corn only takes up ~40-60% of fertilizer applied

No nitrogen uptake from soil



Nitrate leaching potential is high

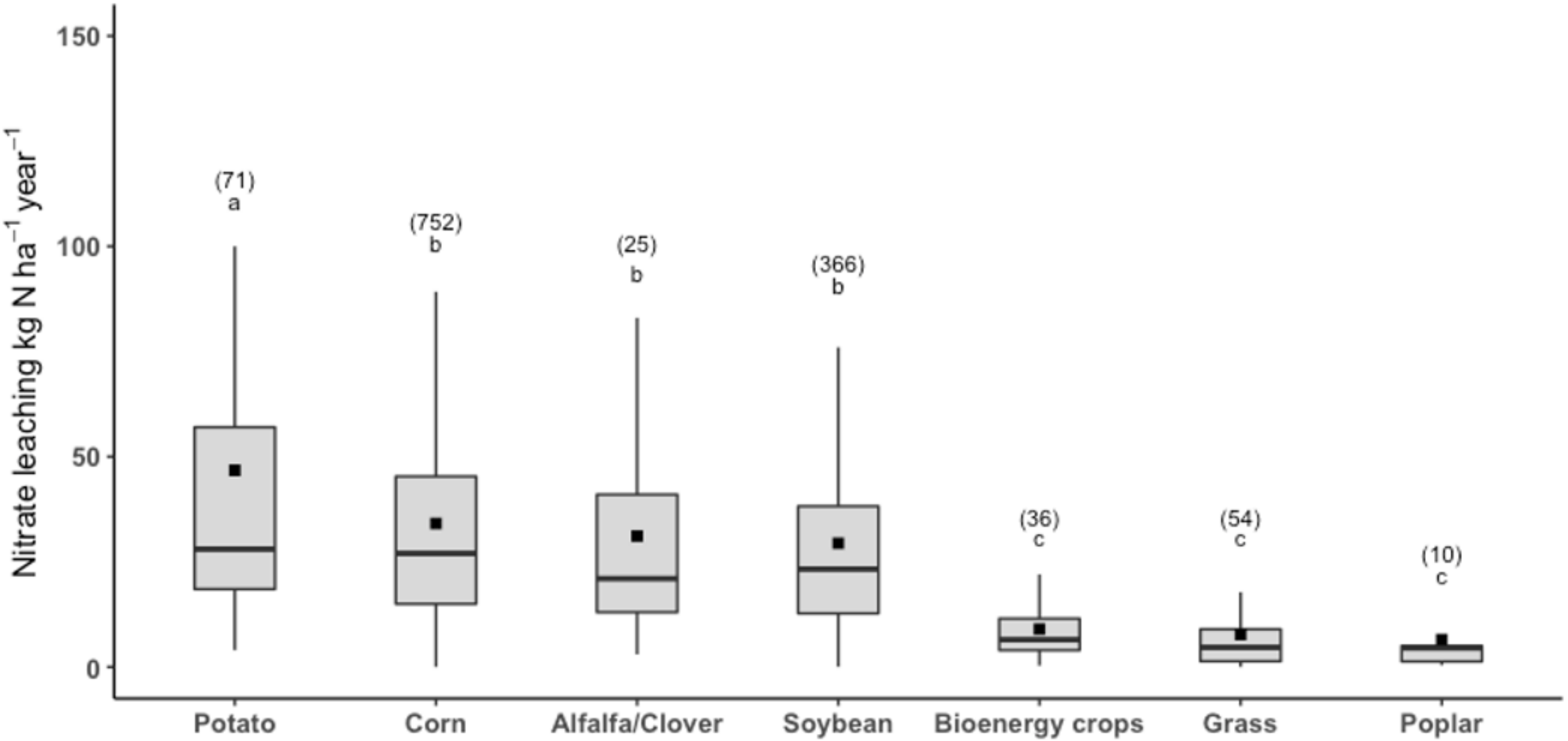


Root Depth

Graph of root depth: http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html

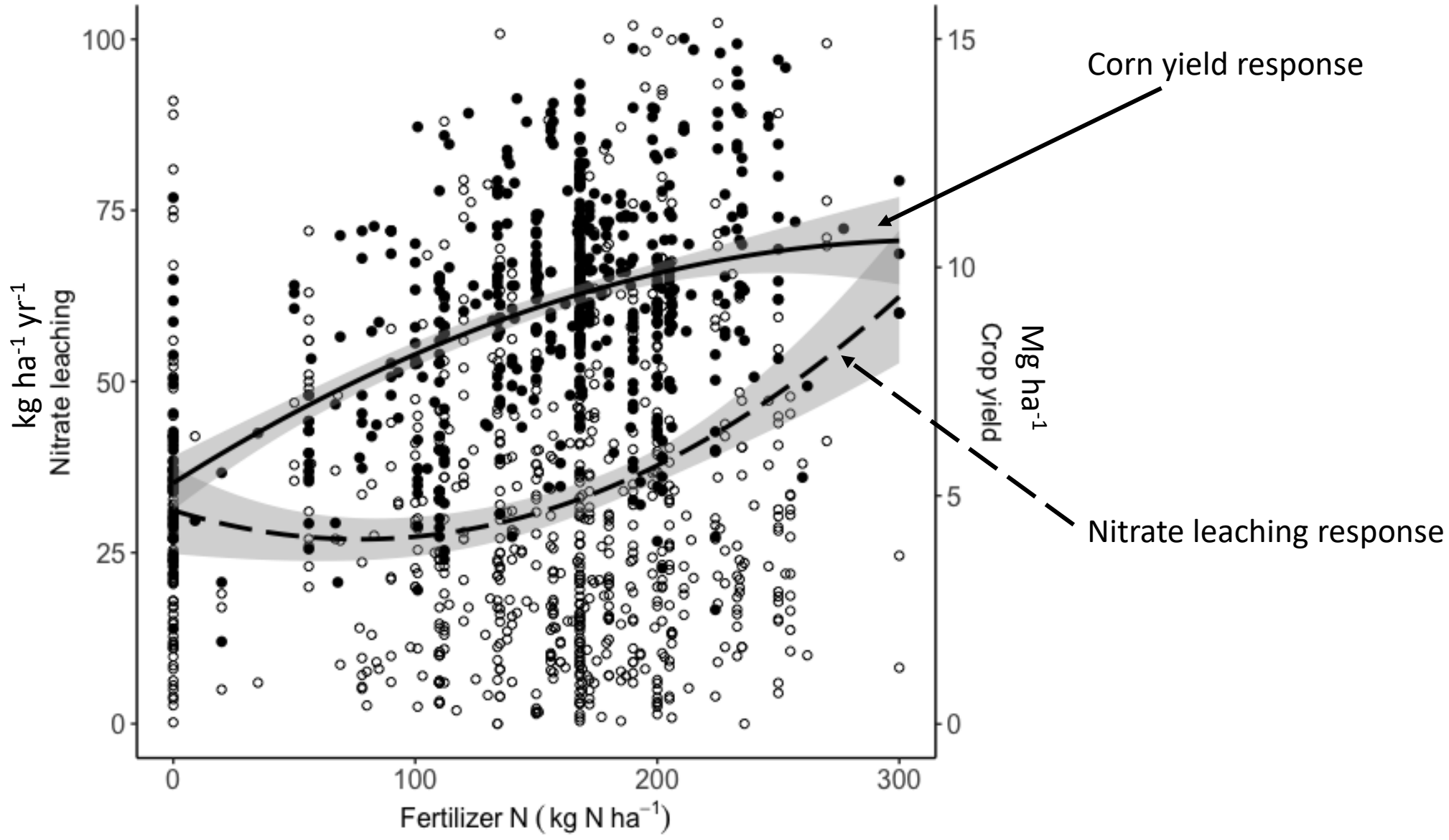
Picture of corn roots: http://www.soilandhealth.org/01aglibrary/010137veg.roots/010137ch2.html

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*



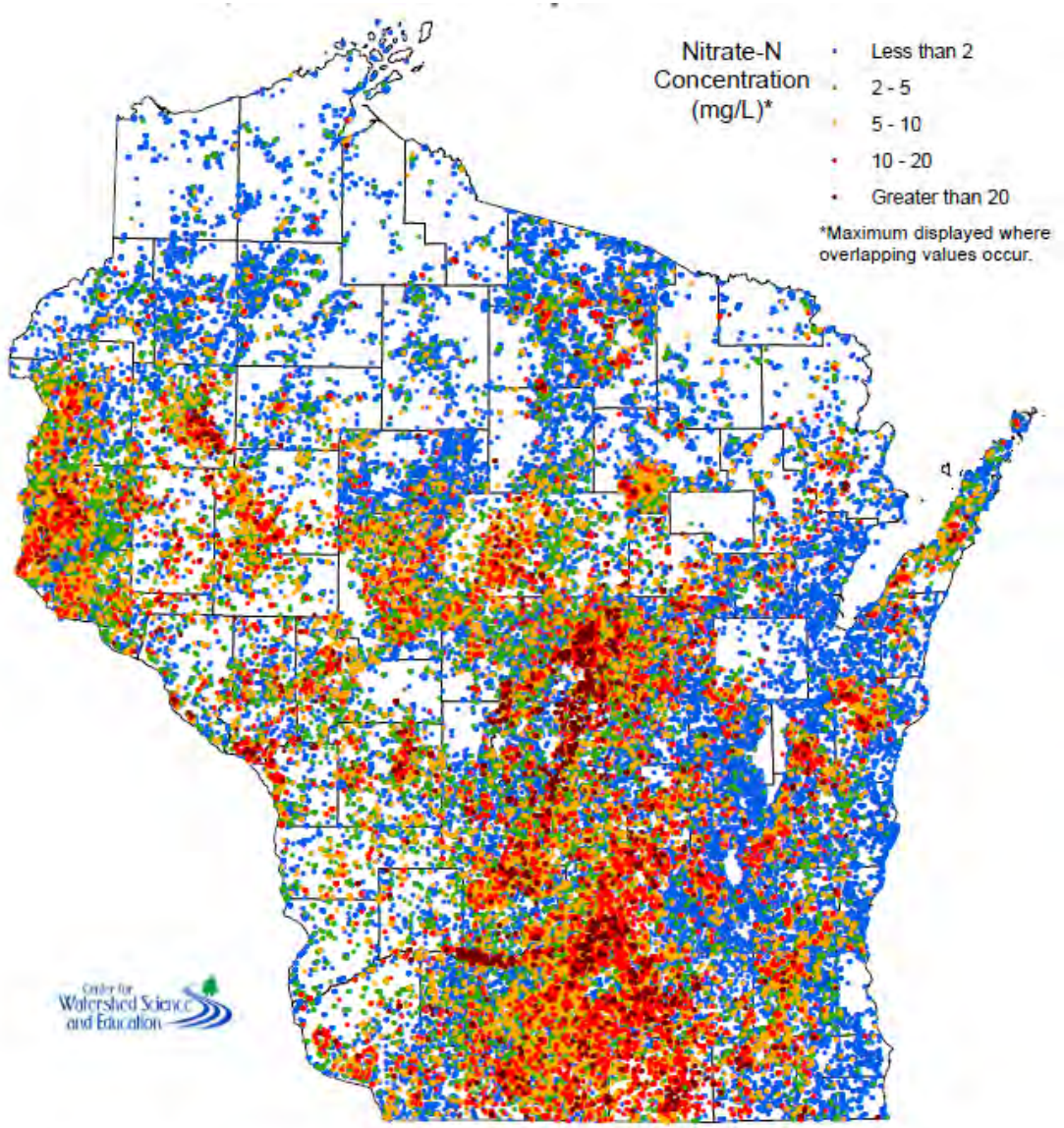
*Source: Shrestha et al., to be submitted to JSWC - Meta-analysis of > 1300 measurements in Midwest US Agroecosystems

Private Well Nitrate Concentrations

Nitrate-N Concentration (mg/L)*

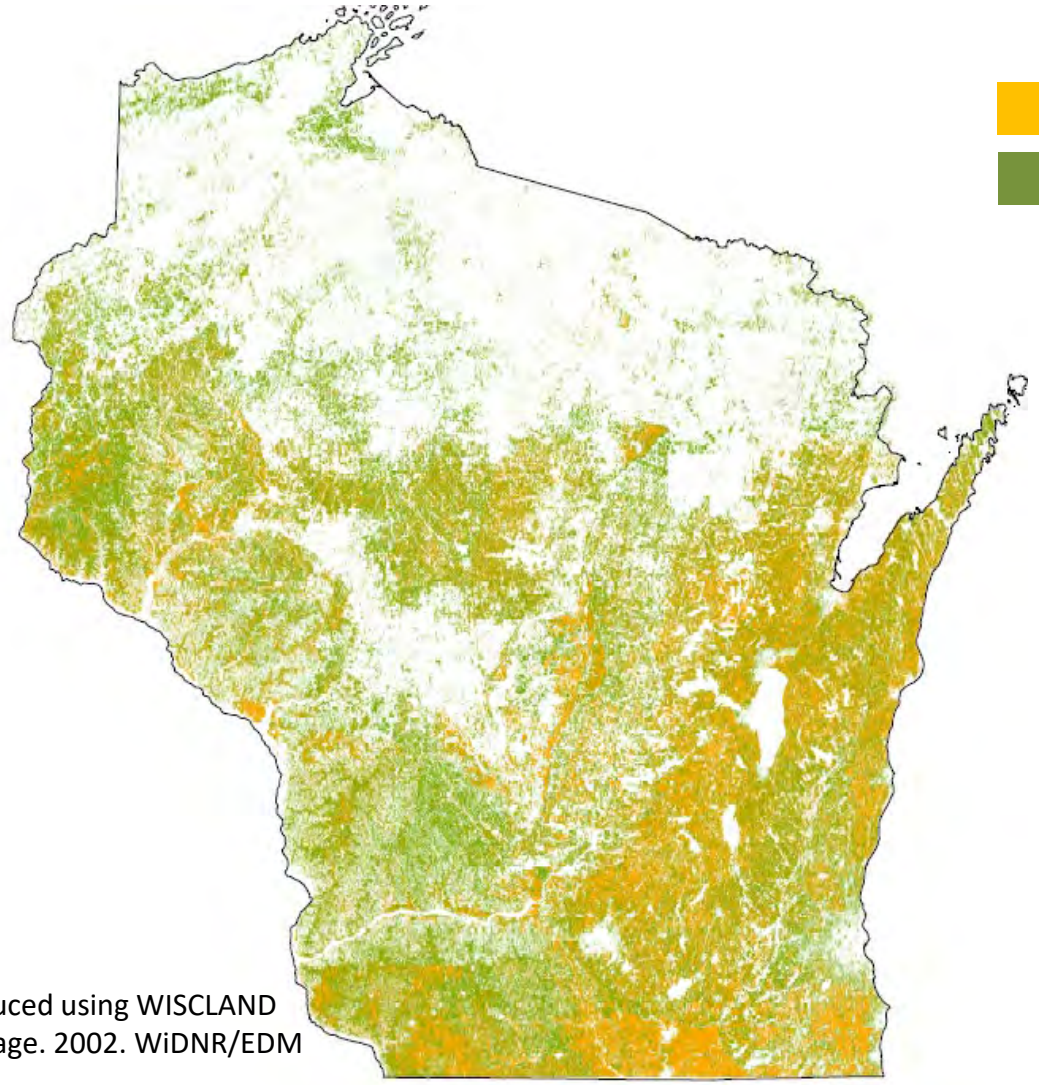
- Less than 2
- 2 - 5
- 5 - 10
- 10 - 20
- Greater than 20

*Maximum displayed where overlapping values occur.



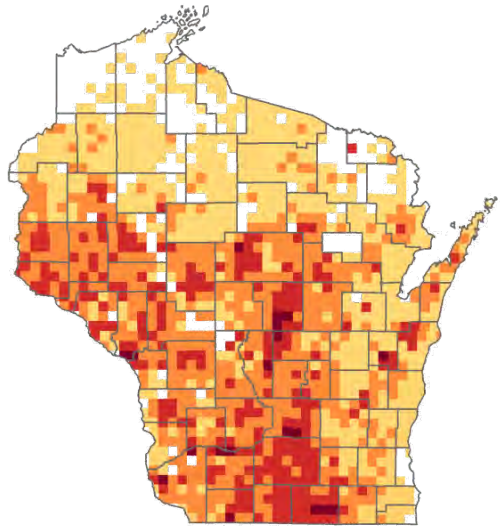
Disclaimer: This map represents well water data in the Center for Watershed Science and Education database, WI DNR Groundwater Retrieval Network. It does not represent all known private wells.

Land management and groundwater nitrate connection



Annual Row Crops

Forage Crops/Pasture/CRP



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)

The New York Times

Rural America's Own Private Flint: Polluted Water Too Dangerous to Drink

Nitrates,

FAILURE AT THE FAUCET

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

By SUSAN BINGE

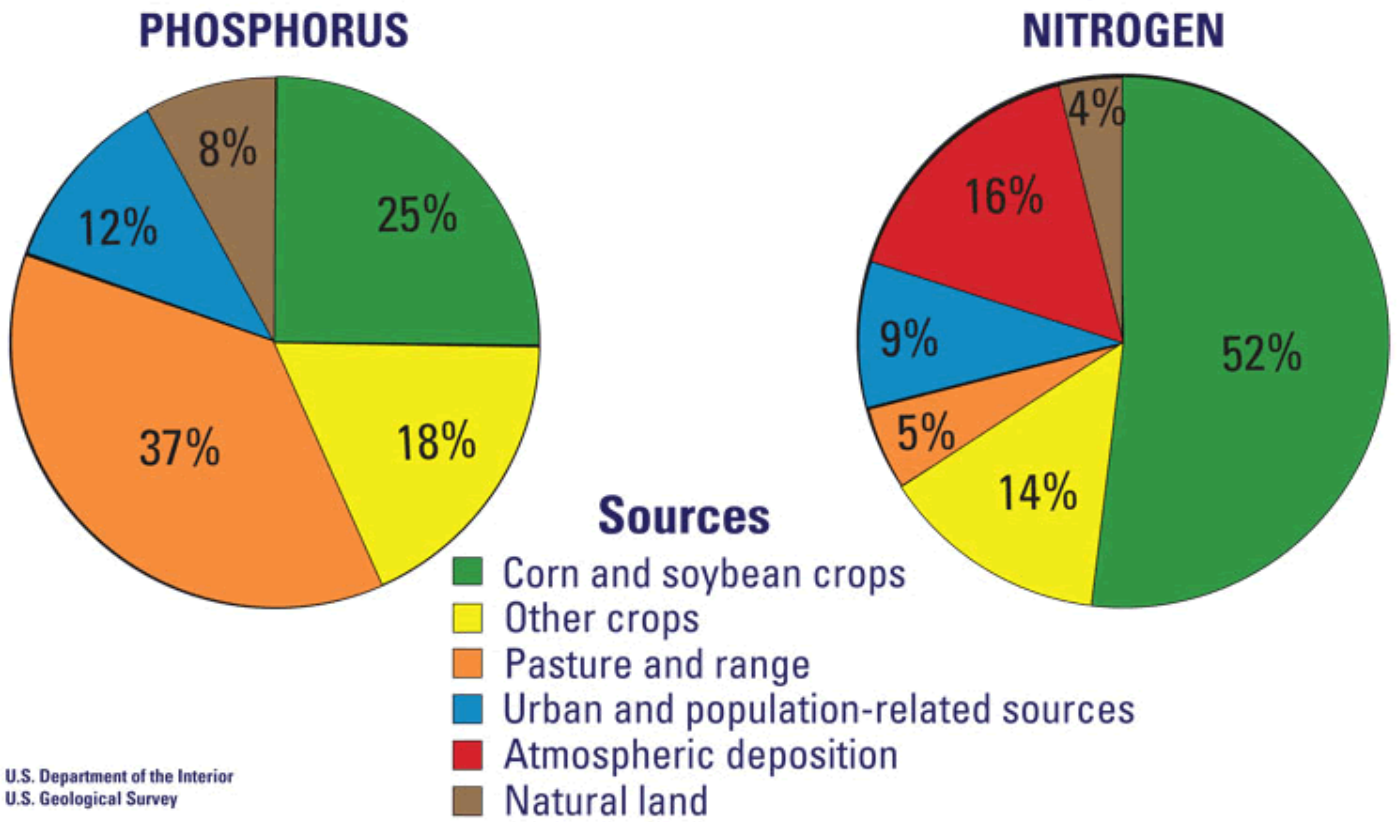
EPA investigates possible groundwater contamination in central Wisconsin as worries grow

Lee Bergquist, Milwaukee Journal Sentinel Published 6:56 a.m. CT May 4, 2018 | Updated 2:10 p.m. CT May 4, 2018

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

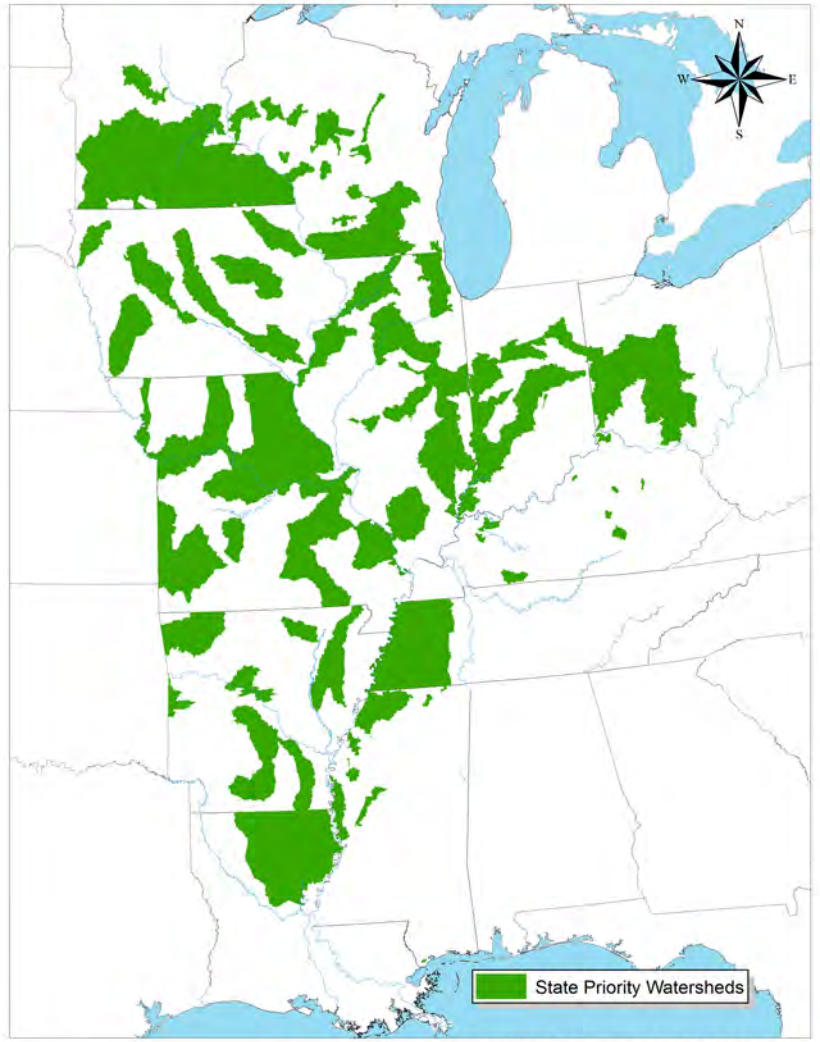
USGS
science for a changing world

Sources of nutrients delivered to the Gulf of Mexico



U.S. Department of the Interior
U.S. Geological Survey

Priority Watersheds of the Hypoxia Task Force States



Mississippi River/Gulf of Mexico
Watershed Nutrient Task Force

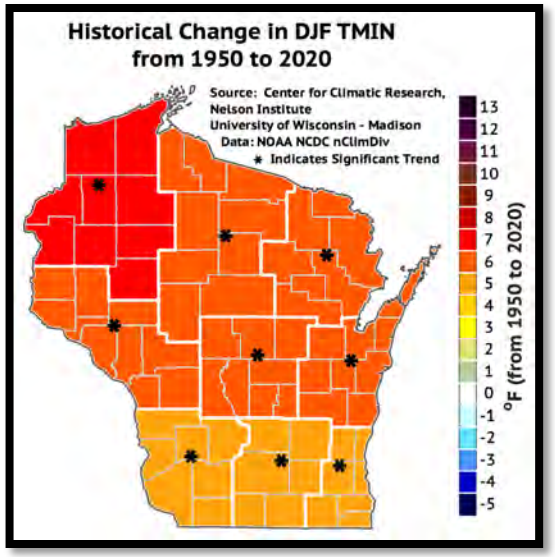
This map was developed with the assistance of the Hypoxia Task Force States, Tetra Tech and the U.S. Environmental Protection Agency (EPA) Office of Wetlands, Oceans and Watersheds's Hypoxia Team. Priority watershed data were supplied by each Hypoxia Task Force state and developed into GIS format by each state or Tetra Tech. Data such as state boundaries, rivers, and lakes were obtained from publically available sources. For further information regarding the Priority Watershed Map or a list of complete data sources, please see https://www.epa.gov/ms-htf/hypoxia-task-force-nutrient-reduction-strategies.

Updated March 2016

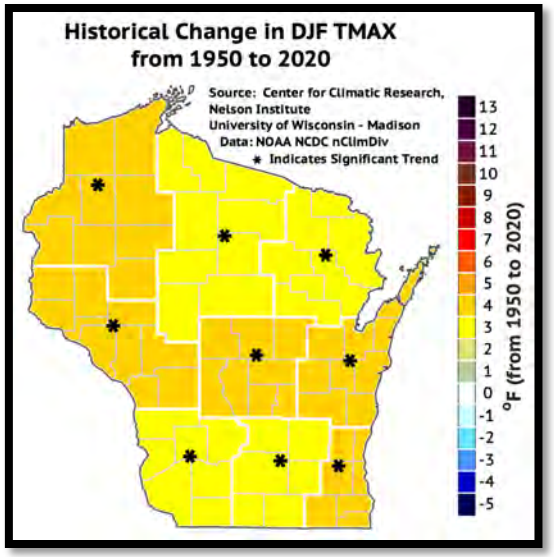
Our weather & climate is changing

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/

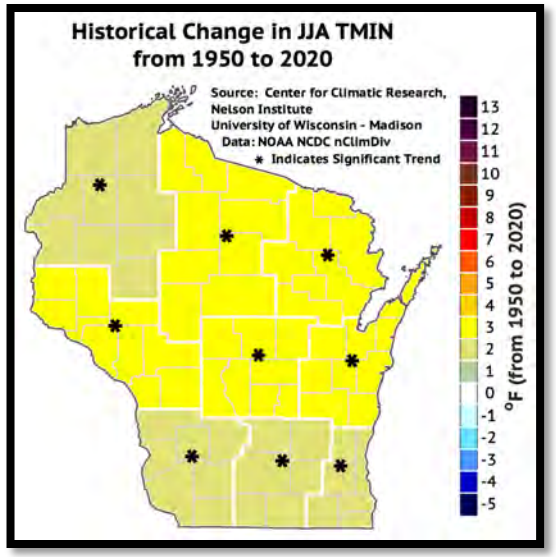
Temperature trends: Day vs. Night (1950-2020)



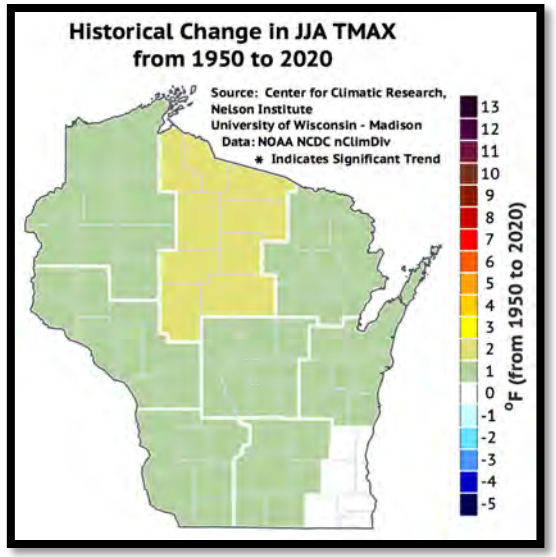
WINTER NIGHT
+5-7ºF



WINTER DAY
+3-4ºF



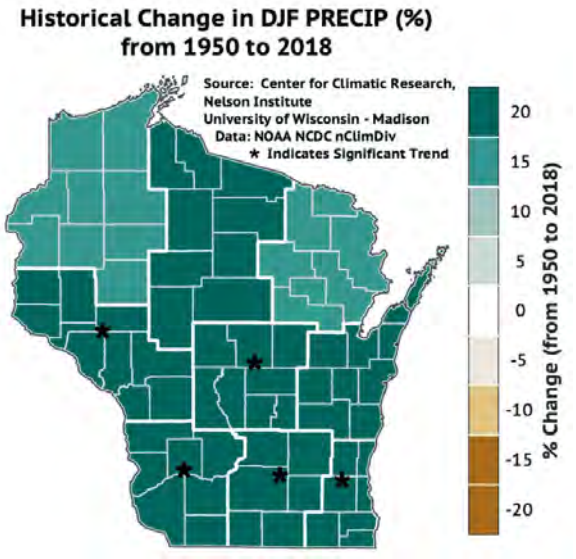
SUMMER NIGHT
+2-3ºF



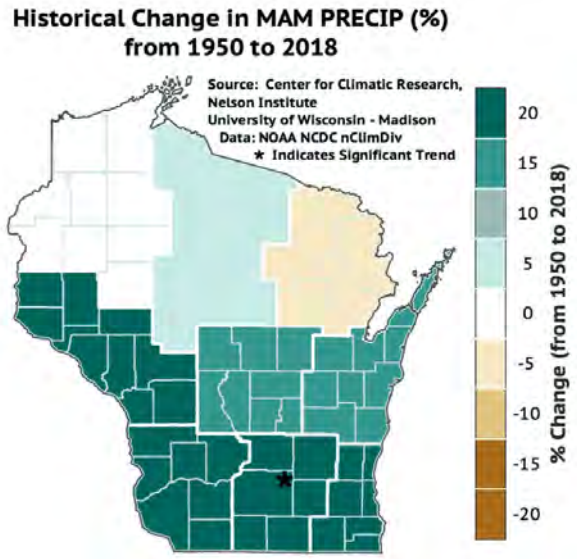
SUMMER DAY
+1-2ºF

Night has warmed more than day; **most significant in winter**

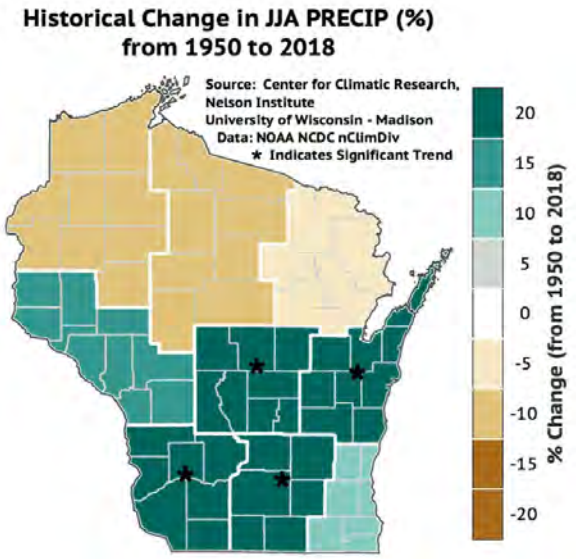
Seasonal Precipitation Trends (1950-2018)



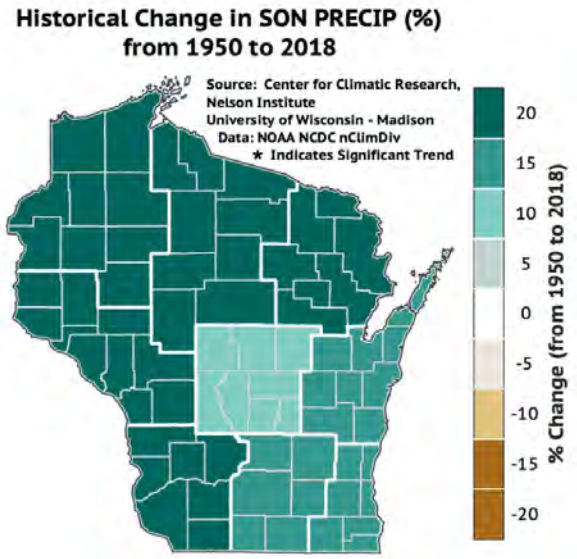
WINTER
+15-20%



SPRING
-5 to 20%



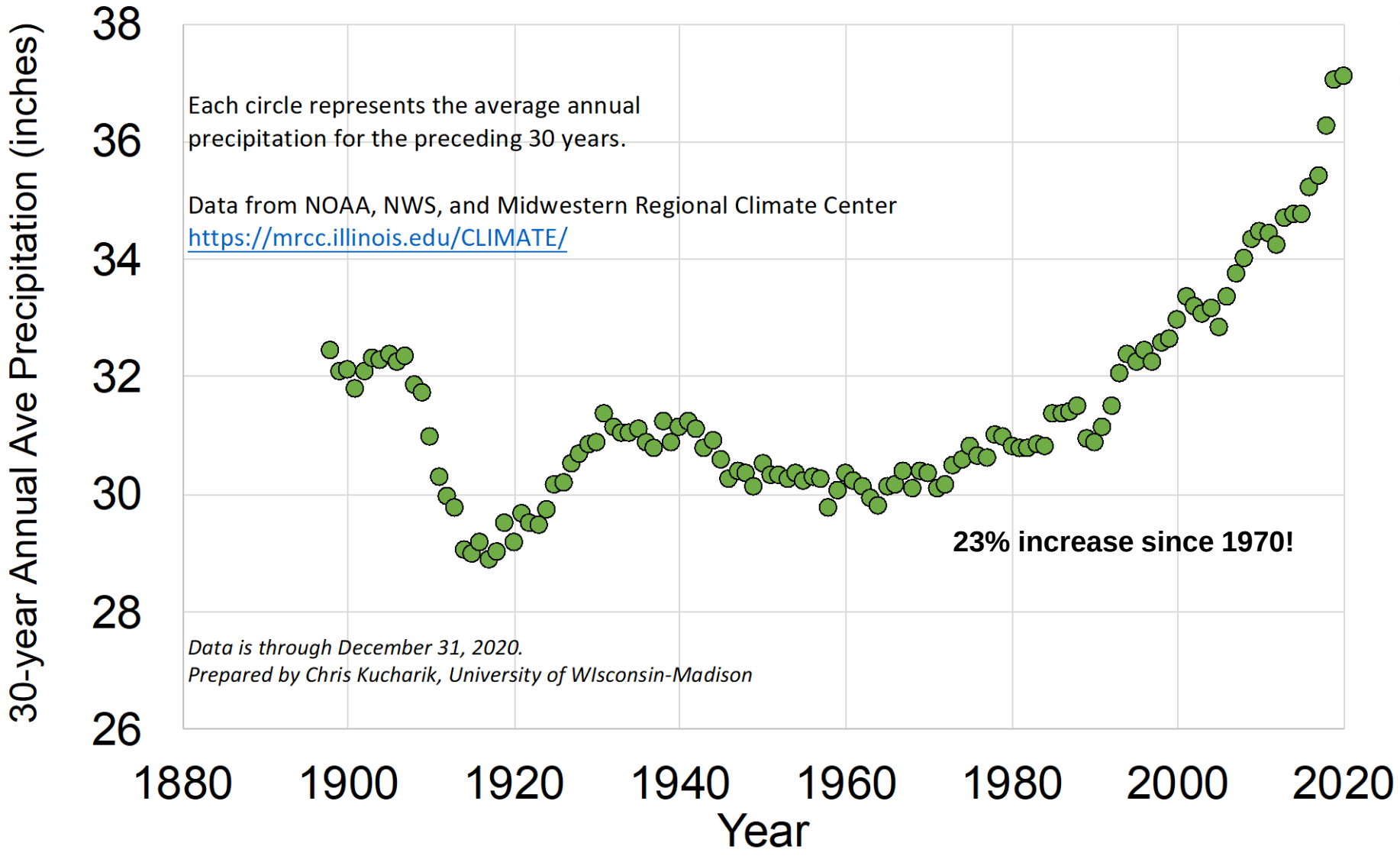
SUMMER
-10 to 20%

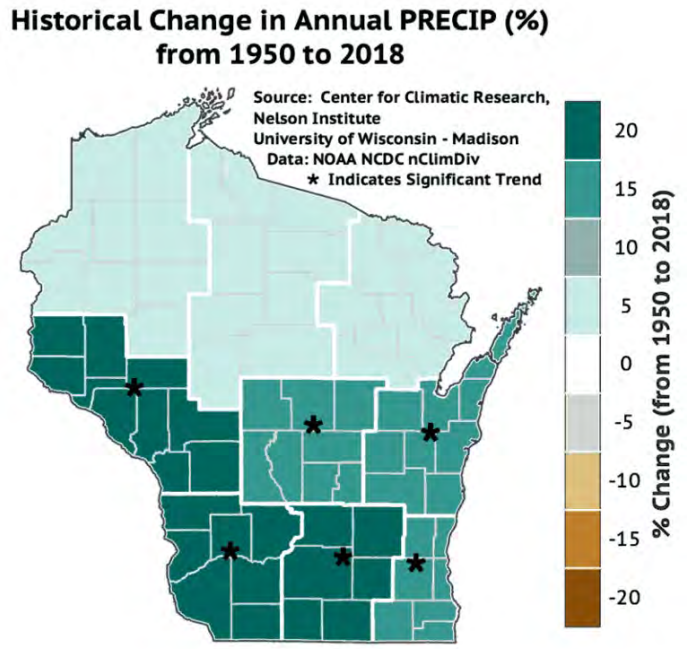


FALL
+10-20%

Significant increases during winter, spring, and summer in many agricultural regions of southern and central WI

Madison Annual Precipitation Trend





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”)

2021: 22.82”, 13th driest ever since 1869

ENVIRONMENT

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*

Annual precipitation range (inches)	Annual N leaching (kg N ha^{-1})	Sample size	Annual Fertilizer N (kg N ha^{-1})
< 29.5 in	24.0 ± 1.4 a	317	103
29.5 - 36.6 in	29.9 ± 1.3 b	349	100
> 36.6 in	34.7 ± 1.2 c	327	107

Increasing precipitation = increased nitrate leaching

Shrestha et al., to be submitted to JSWC **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 its 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.

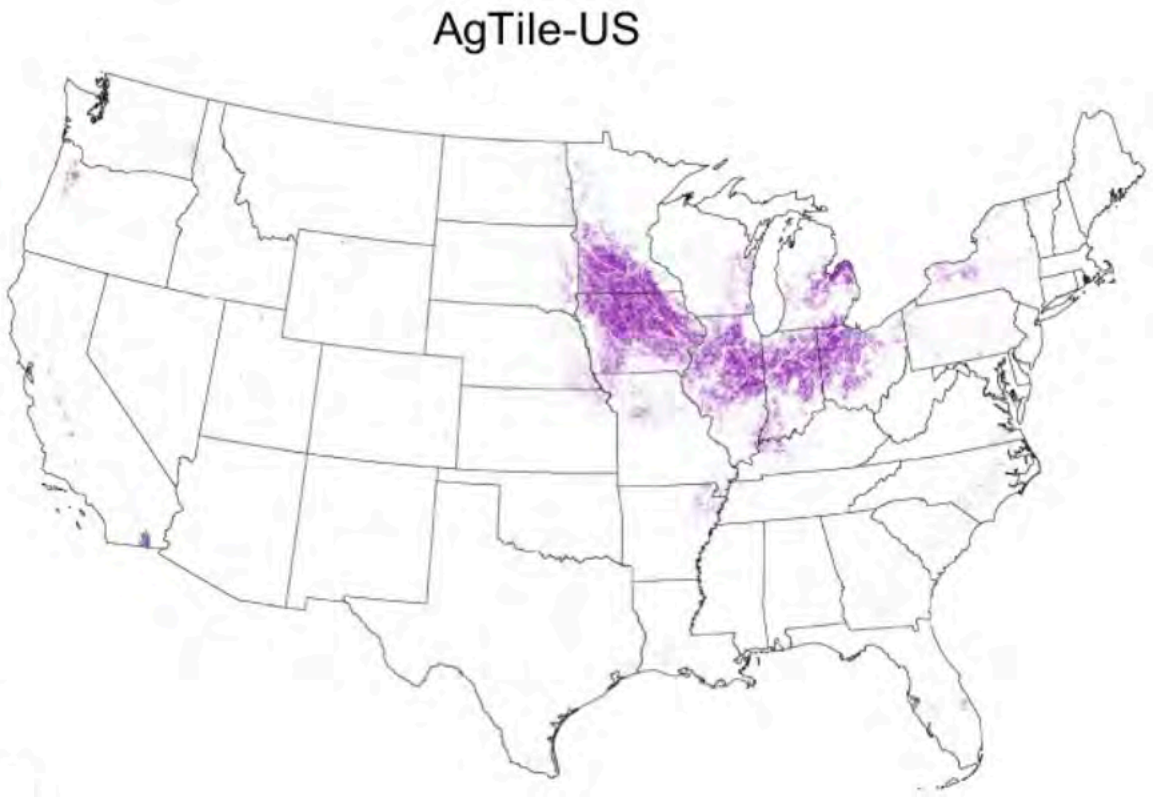
"I never want to be short on nitrogen, let's put it that way. You don't want nitrogen to be your limiting factor" – Iowa Farmer.

Source: Houser, M., Gunderson, R. and Stuart, D., 2019. *Farmers' Perceptions of Climate Change in Context: Toward a Political Economy of Relevance*. Sociologia Ruralis, 59(4), pp.789-809.

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

https://www.wisfarmer.com/story/news/2017/05/08/new-sites-added-tile-monitoring-project/101421238/

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



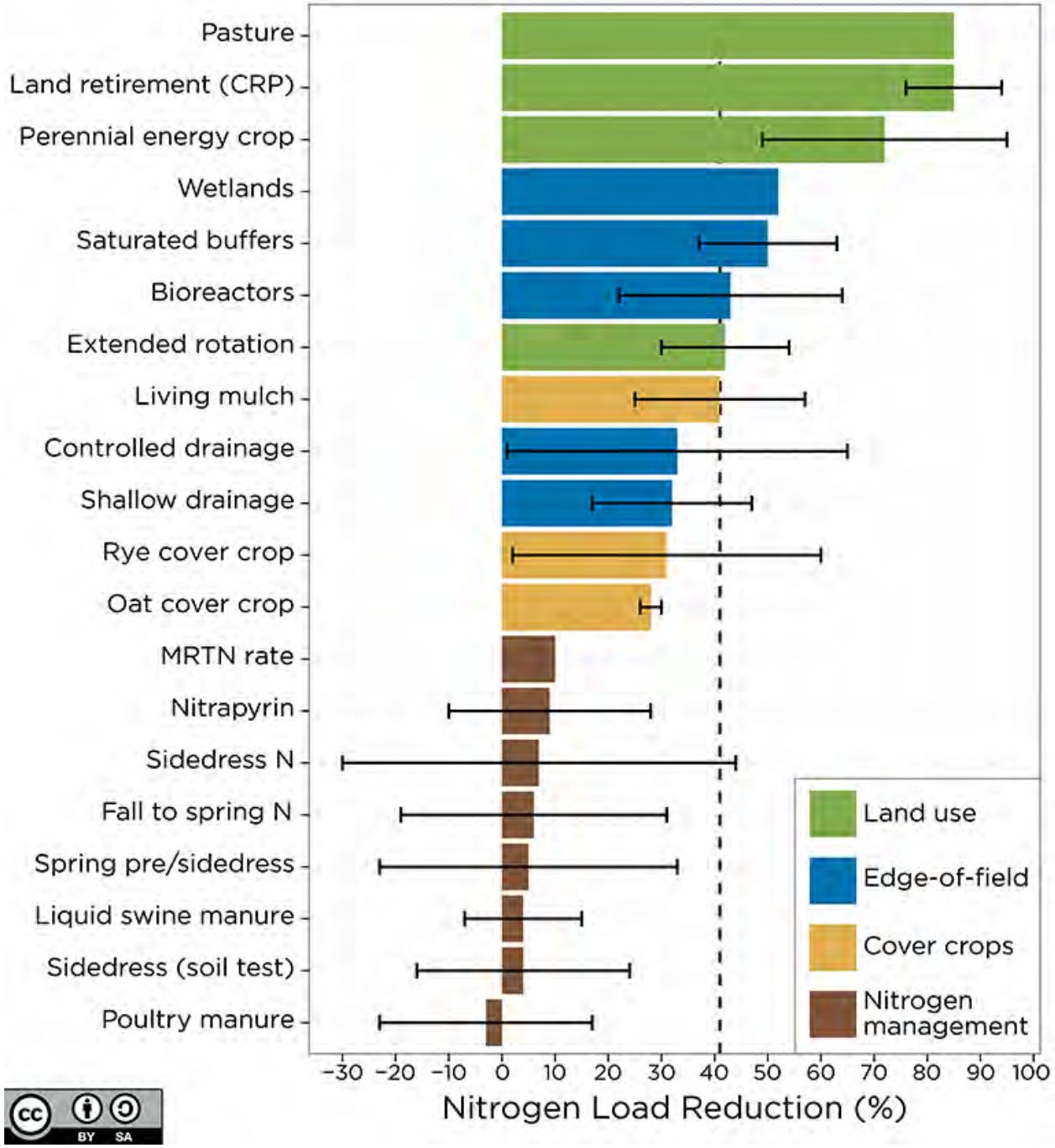
Source: Valayamkunnath et al. 2020, Mapping of 30-meter resolution tile-drained croplands using a geospatial modeling approach, *Scientific Data*

What can farmers do to help meet water quality goals?

From Iowa Nutrient Reduction Strategy

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



https://4rplus.org/iowa-nutrient-reduction-strategy

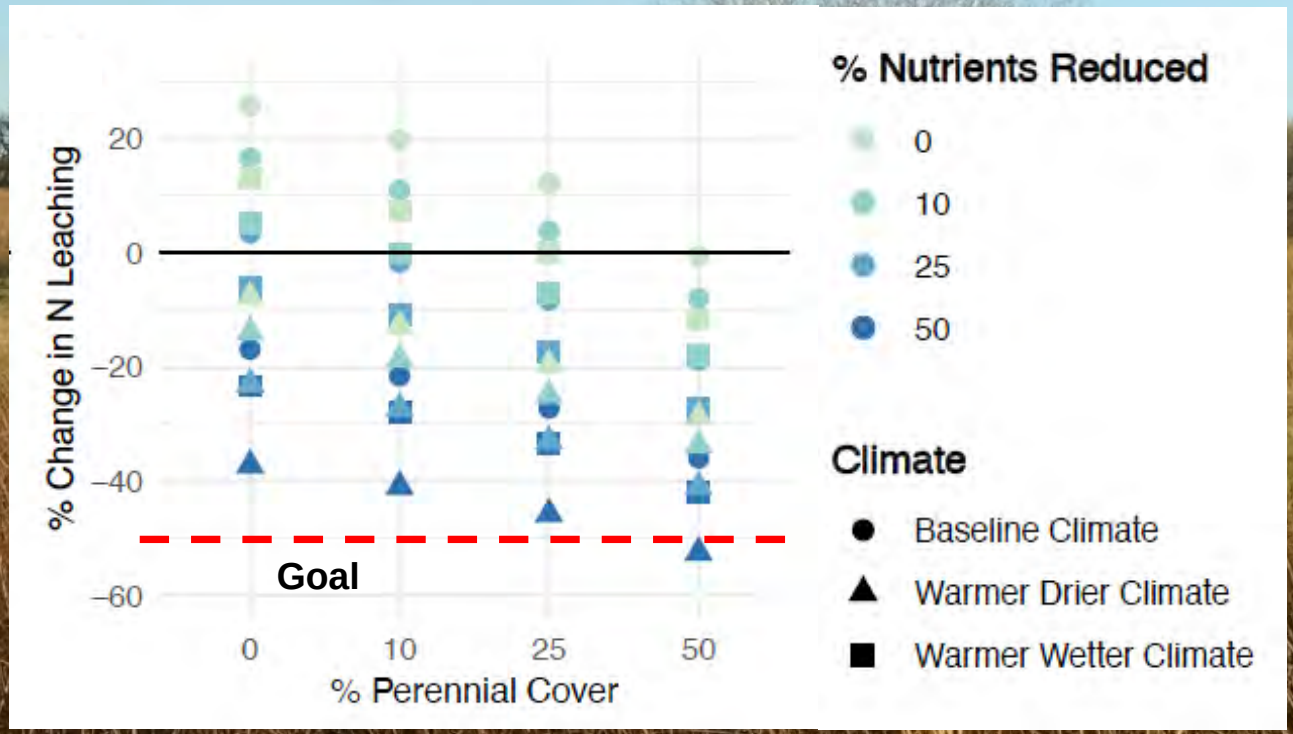
Recent modeling study of Yahara Watershed illustrated water quality goals met with increased perennials and reduction in fertilizer amounts*

Ecosystems
https://doi.org/10.1007/s10021-021-00668-y

ECOSYSTEMS

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

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



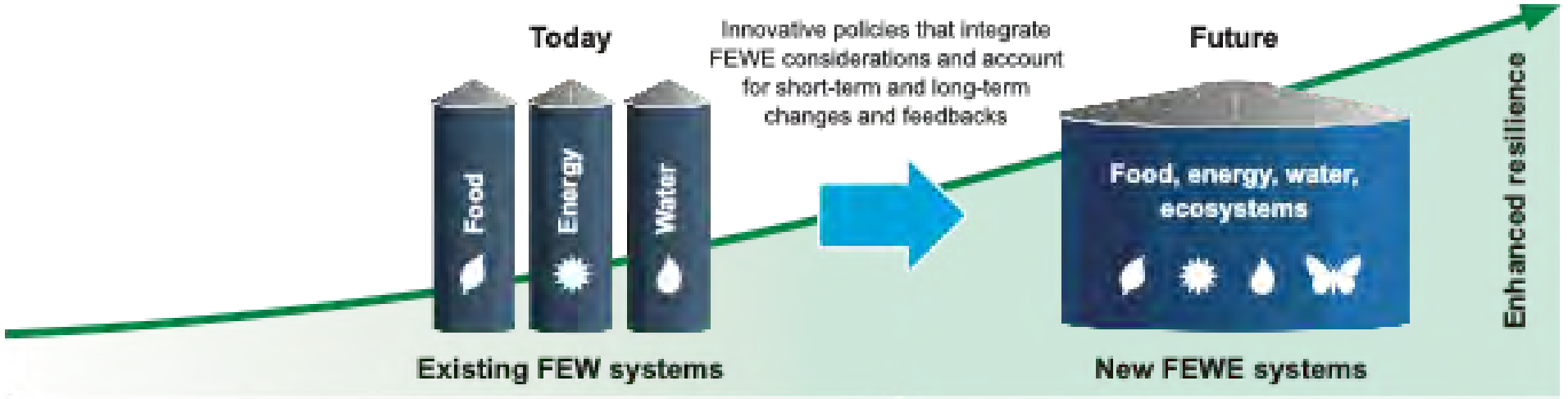
- Yahara watershed modeling results for increasing perennials planted and reducing nutrient applications to row crops – have to do both and in large quantities!!!
- Together these can reduce erosion, P yield, and nitrate leaching
- Achieve water quality goals (50% reduction)

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

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



	Existing FEW systems	New FEWE systems
Broad goal	Inexpensive food and energy for consumers in the short term	FEWE production and livelihoods resilient to uncertain change
Dominant characteristics	Crop monocultures, consolidated livestock, abandoned rural communities, declining biodiversity	Crop polycultures, integrated crop-livestock systems, perennial agriculture, thriving rural communities, recovered biodiversity
Consequences	True costs borne by ecosystems and less wealthy people; degraded water quality; reduced biodiversity	True costs and power shared by society; sustainable FEWE systems

Adapting food-energy-water systems to withstand shocks and stressors

Kucharik et al., submitted to Frontiers in Ecology and the Environment

Thank you!

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

http://fewscapes.wisc.edu

http://www.kucharik-lab.com
Twitter: @Chris_Kucharik
Email: kucharik@wisc.edu

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."