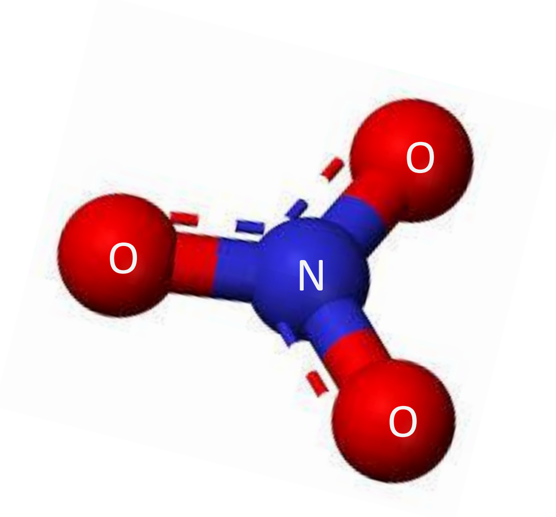
Nitrate:
An ion for all seasons



Kevin Masarik



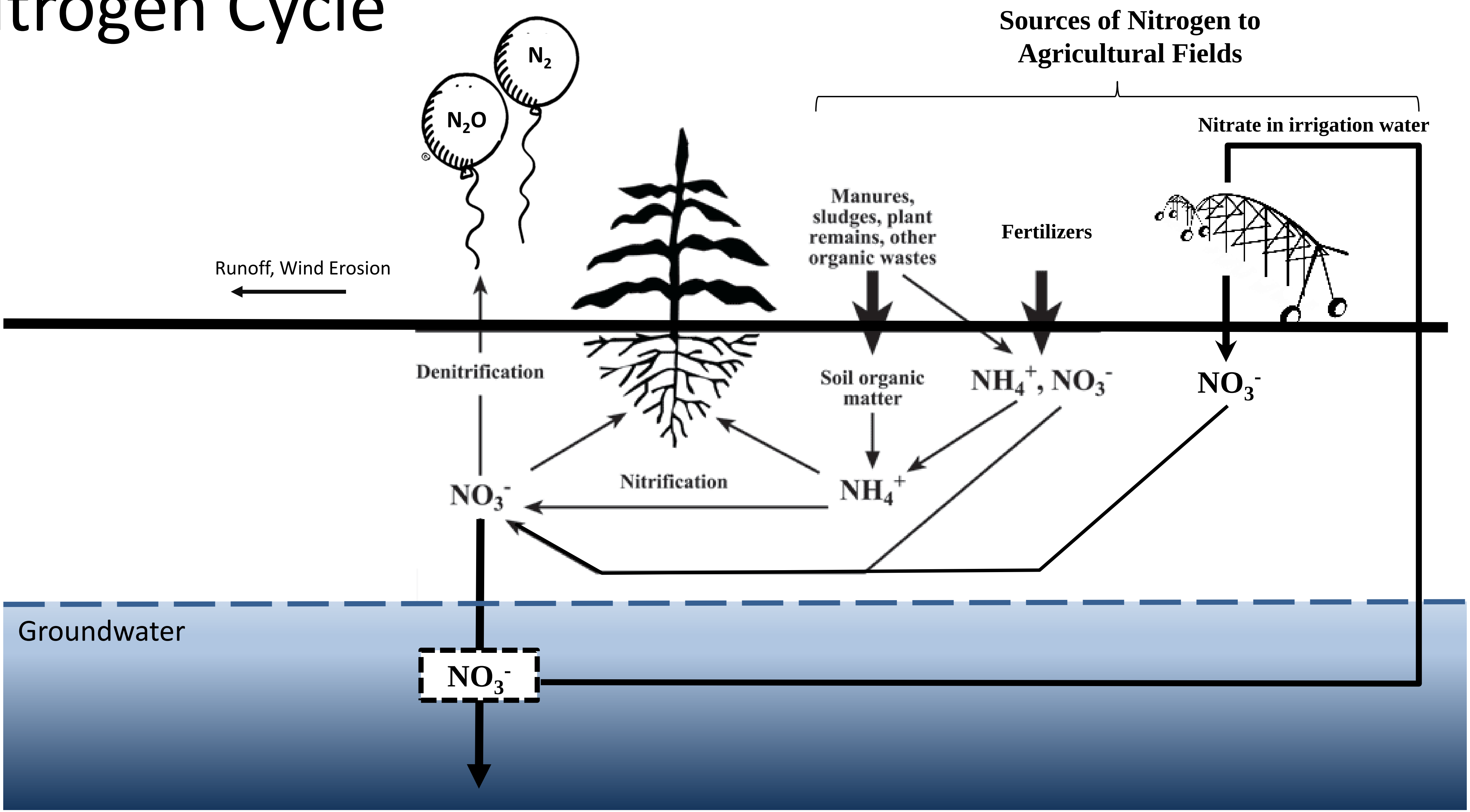




Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin-Stevens Point

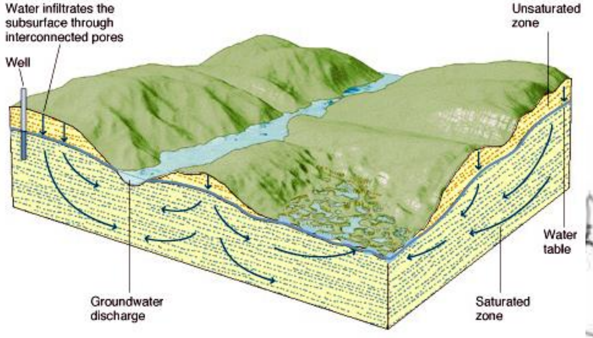
Extension
UNIVERSITY OF WISCONSIN–MADISON

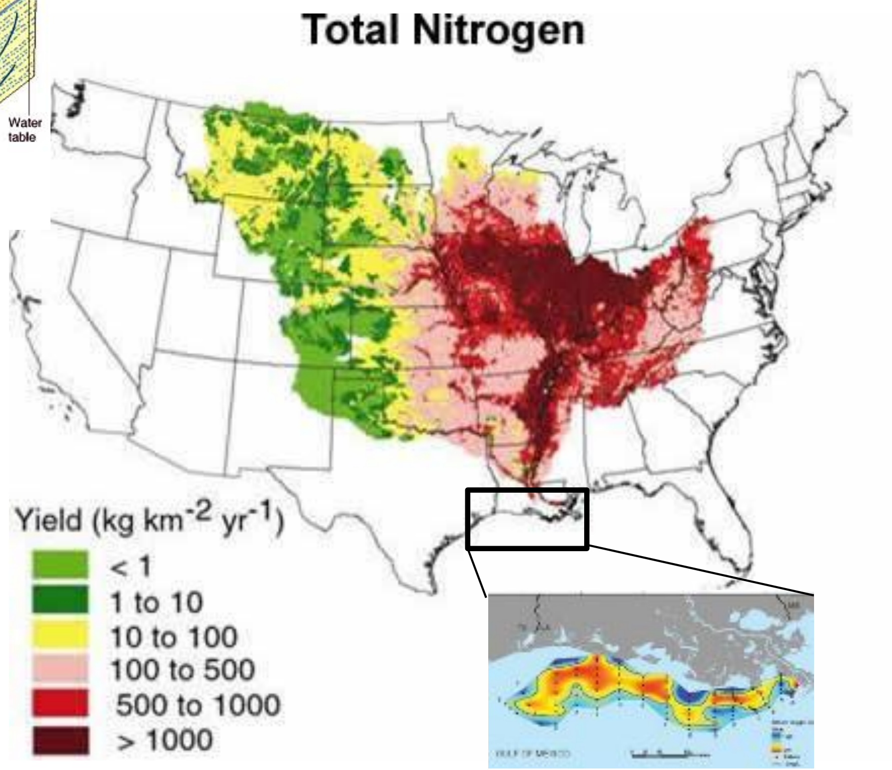
Nitrogen Cycle



Modified from: https://nevegetable.org

Nitrate exported to surface waters





http://water.usgs.gov/nawqa/sparrow/gulf_findings/delivery.html

- Excessive nutrients contribute to growth of large amounts of algae that decay and consume oxygen – hypoxia.
- Some algal blooms can be harmful to health

Algae bloom on Wisconsin's Lake Tainter.
(photo: Peg McAloon)

Nitrate and Human Health

Infants and pregnant women

- Methemoglobinemia or “blue-baby syndrome”
- Central nervous system malformations (birth defects & miscarriages)

Adults

Possible correlations to:

- Non-Hodgkin’s lymphoma
- Various cancers (ex. gastric, bladder)
- Thyroid function
- Diabetes in children

Nitrate often indicator of other possible contaminants
(ex. other agricultural contaminants, septic effluent, etc.)

Wisconsin Groundwater Coordinating Council, 2015; Weyer, 1999

Average Nitrate-Nitrogen Concentration by Township

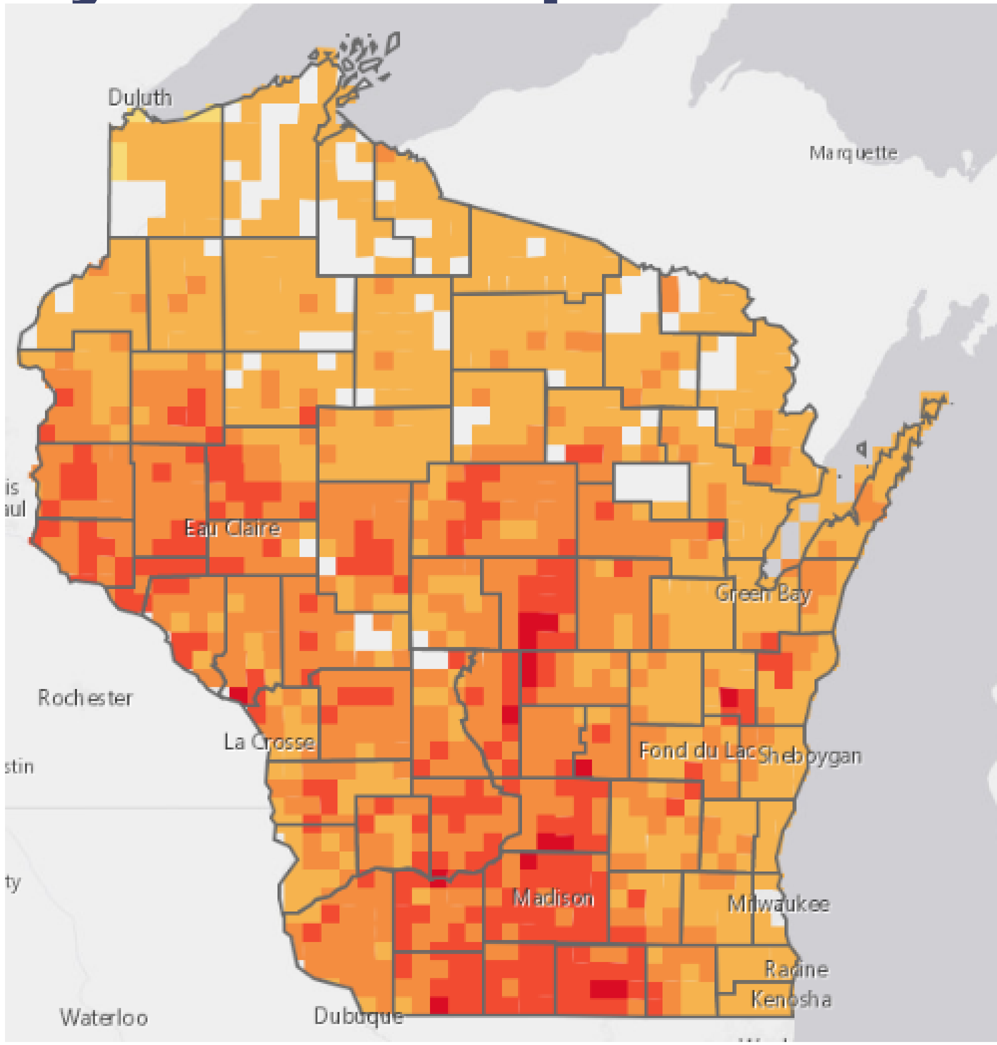
10.1 - 20.0

5.1 - 10.0

2.1 - 5.0

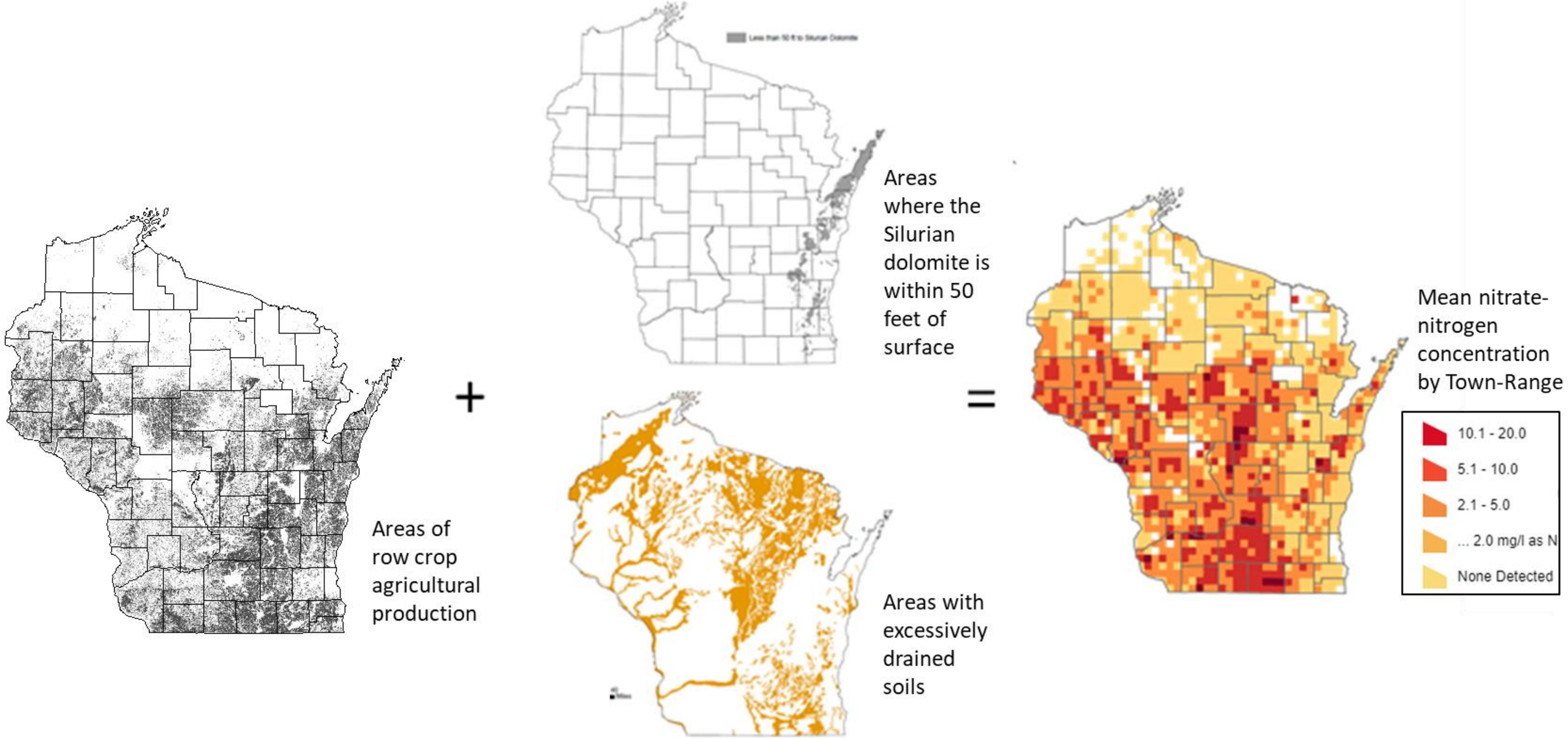
... 2.0 mg/l as N

None Detected



WI Well Water Viewer, 2019

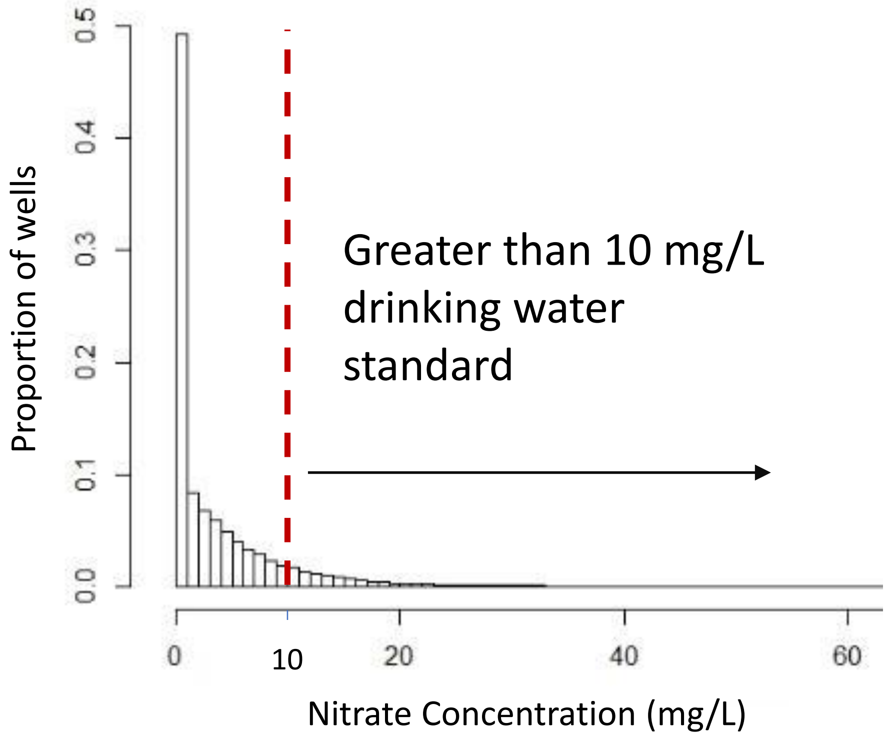
Nitrate Variability in Wisconsin’s Groundwater



Nitrate-N breakdown

- 57% of private wells have concentrations less than 2 mg/L

- >40 mg/L: 0.12%*; 960 wells[1]
- >30 mg/L: 0.56%*; 4,480 wells[1]
- >25 mg/L: 1.0%*; 8,000 wells[1]
- >20 mg/L: 2.2%*; 17,600 wells[1]
- >10 mg/L: **8.2%**; 10%*,** 65,600-80,000 wells[1]



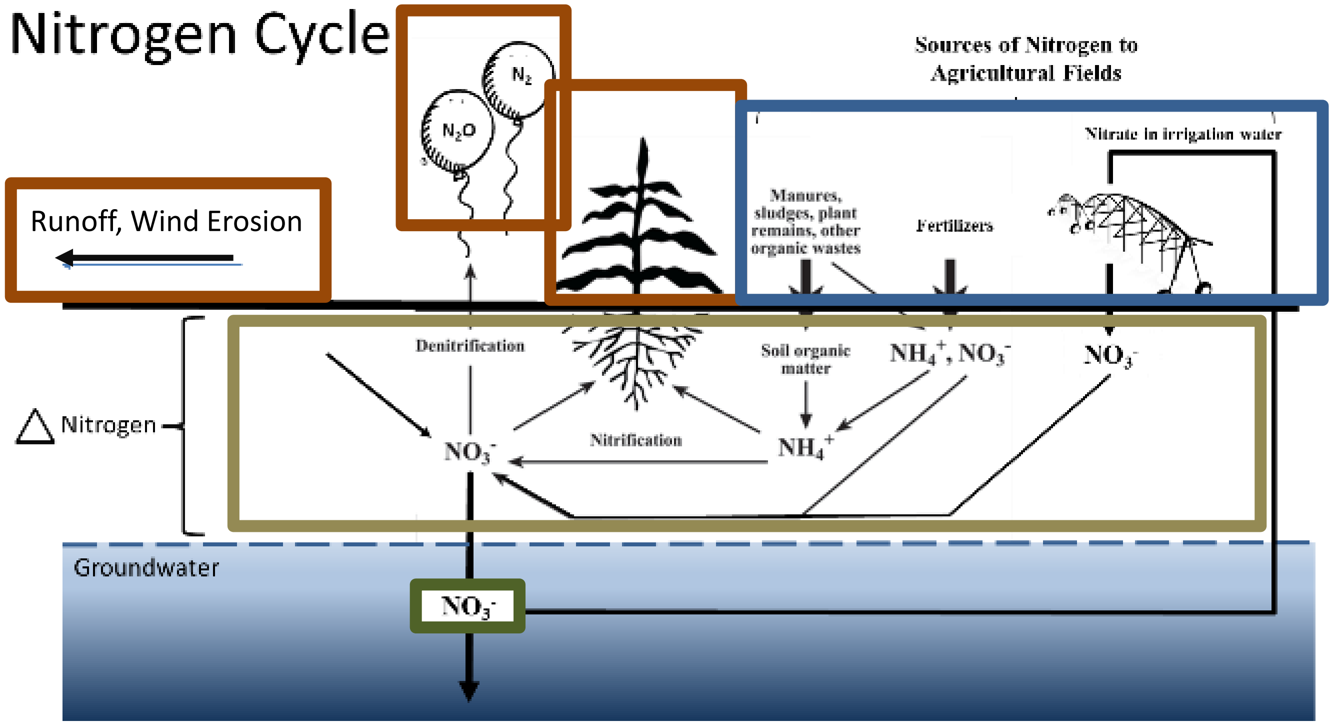
*estimate from Center for Watershed Science and Education database, UW-Extension/UW-Stevens Point

**estimate from Agricultural Chemicals in Wisconsin Groundwater, DATCP. 2017

Based on estimate of 800,000 private wells, GCC Report to the Legislature, https://dnr.wi.gov/topic/groundwater/GCC/wells.html

Estimating Nitrogen Leaching Potential

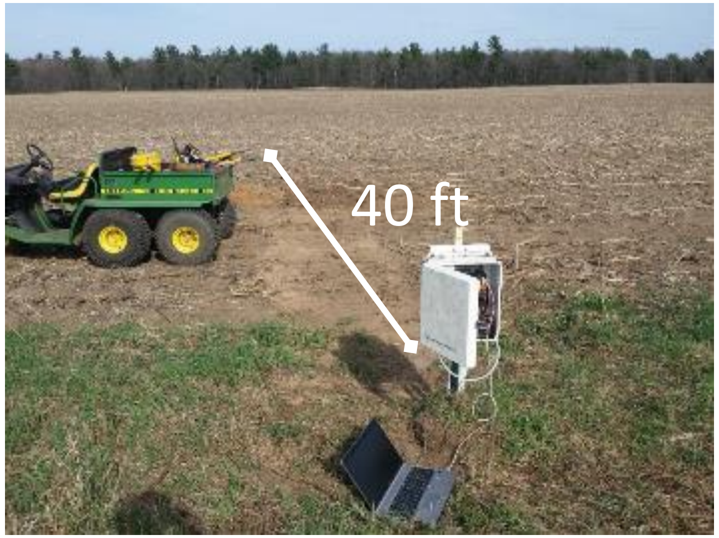
Potential N Leaching = N Inputs - N Outputs (excluding leaching) - Change in N Stored

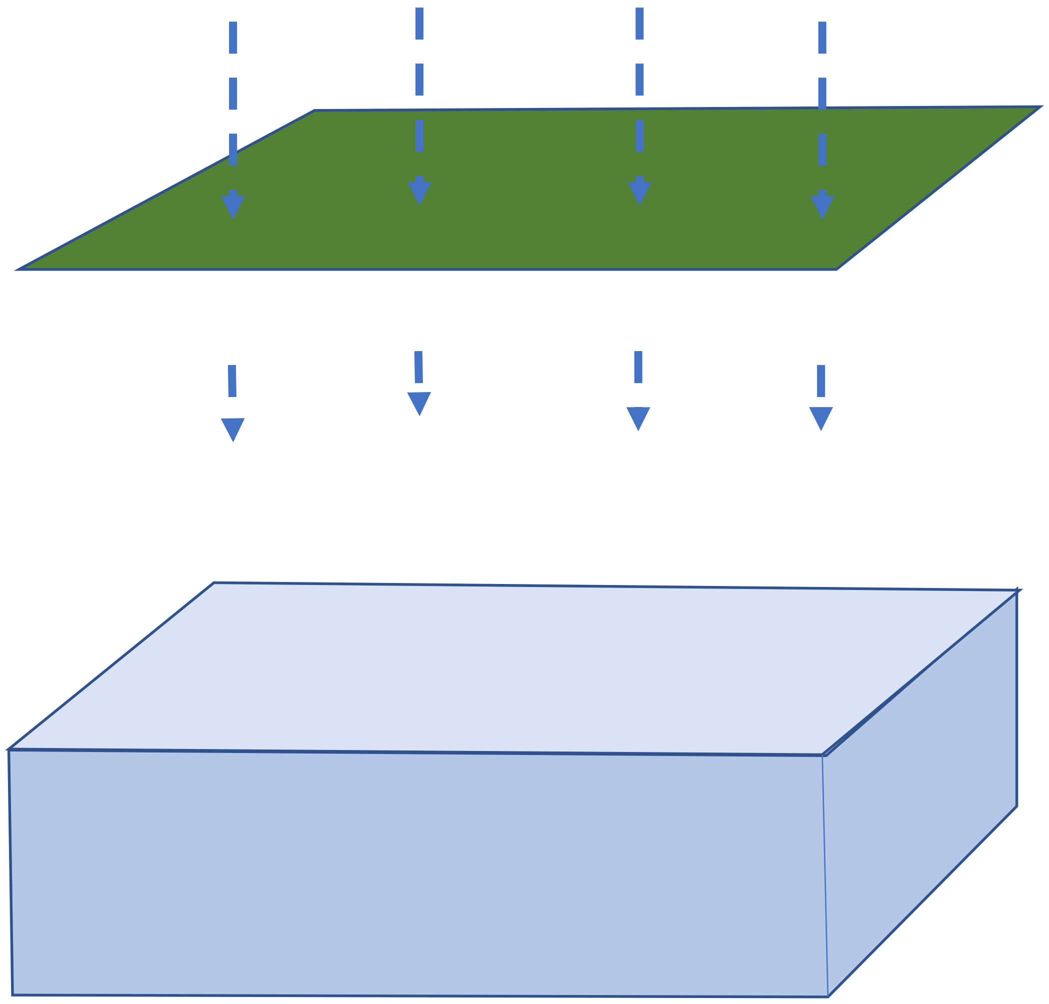


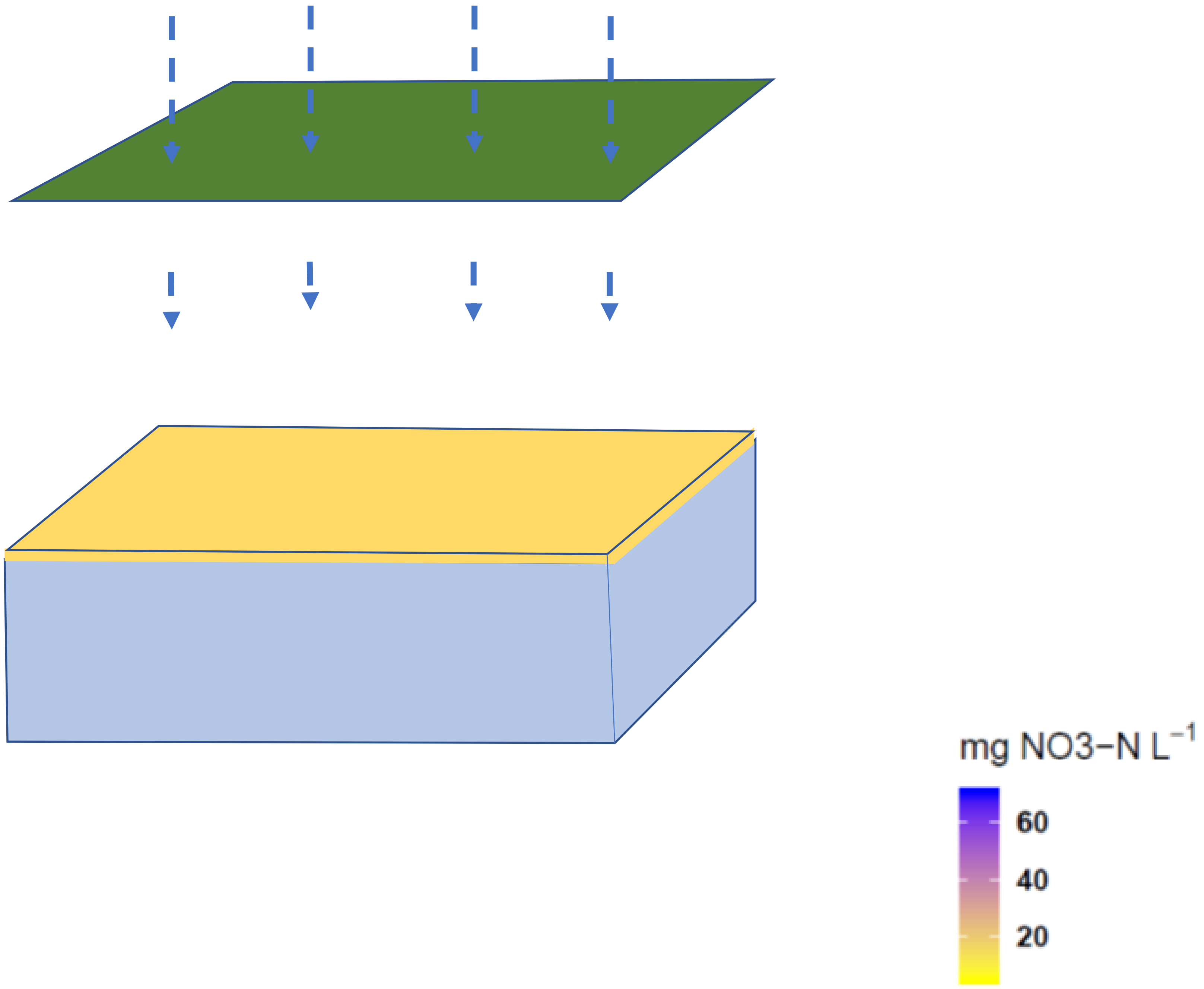
Modified from: https://nevegetable.org

From Meisinger, J.J and Randall G.W. 1991. Chapter 5: Estimating Nitrogen Budgets for Soil-Crop Systems. In Managing Nitrogen for Groundwater Quality and Farm Profitability, editors: Follett, Keeney, and Cruse. Soil Science Society of America.

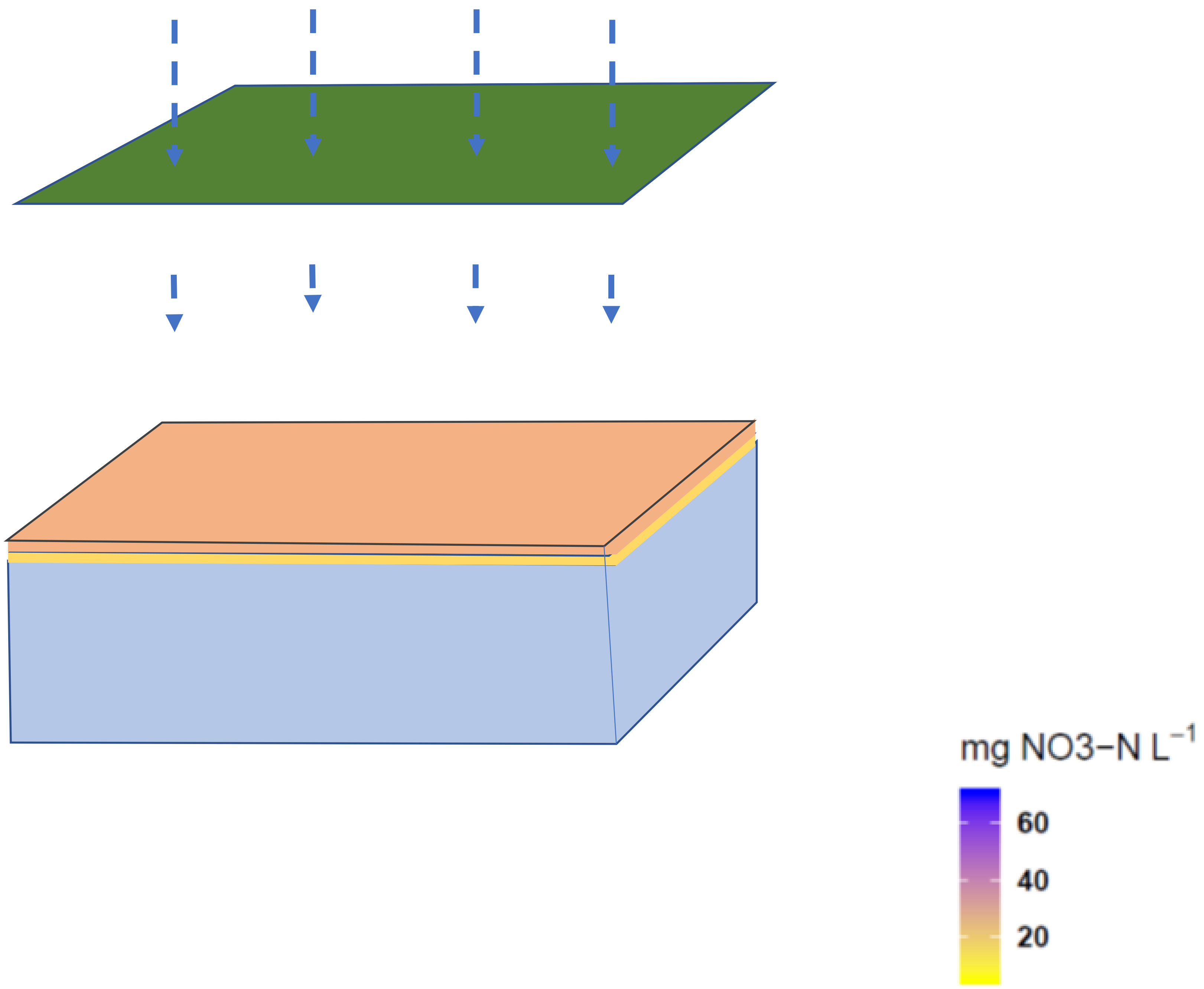
Measuring nitrate leaching below an irrigated field in the Central Sands Region

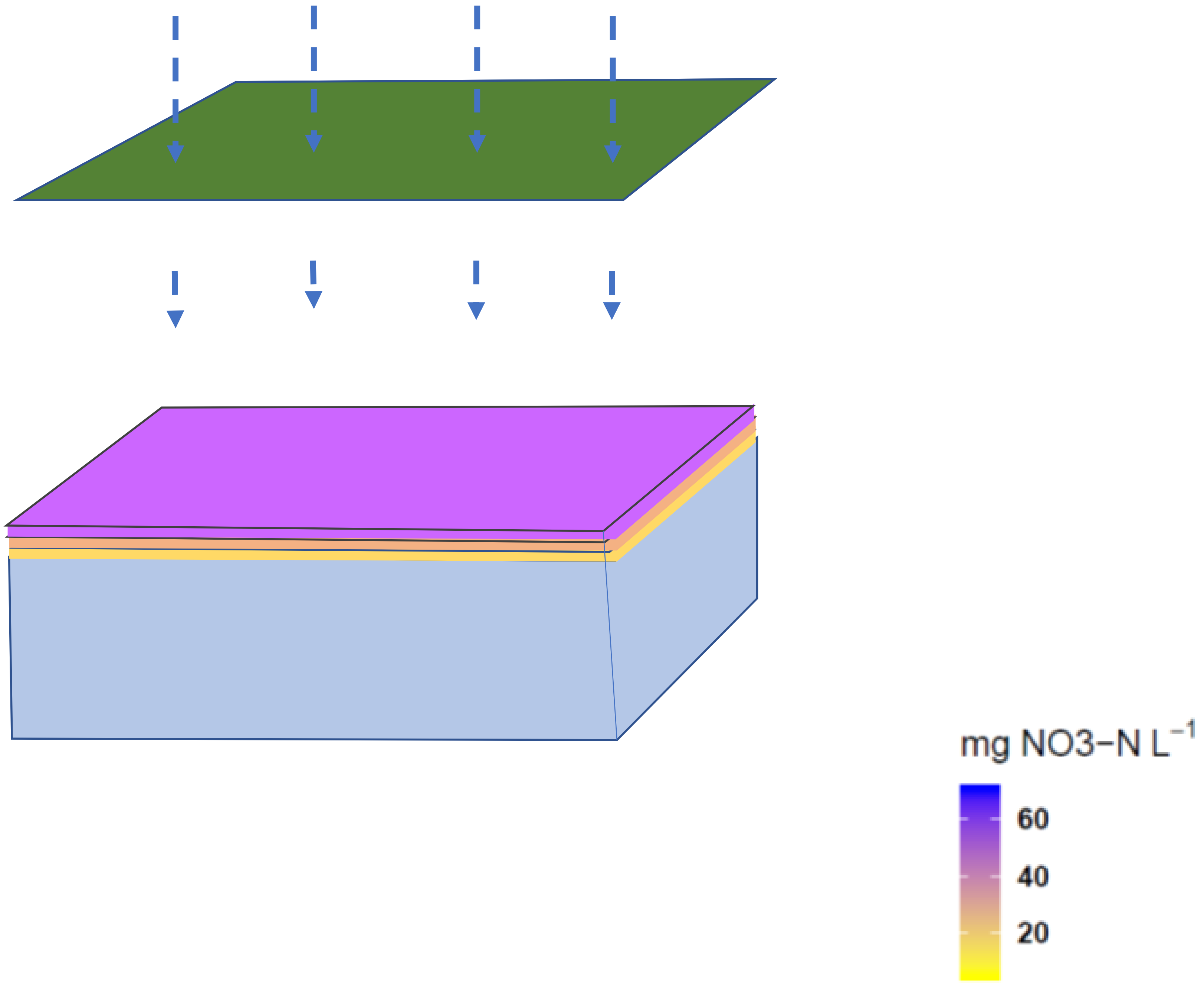


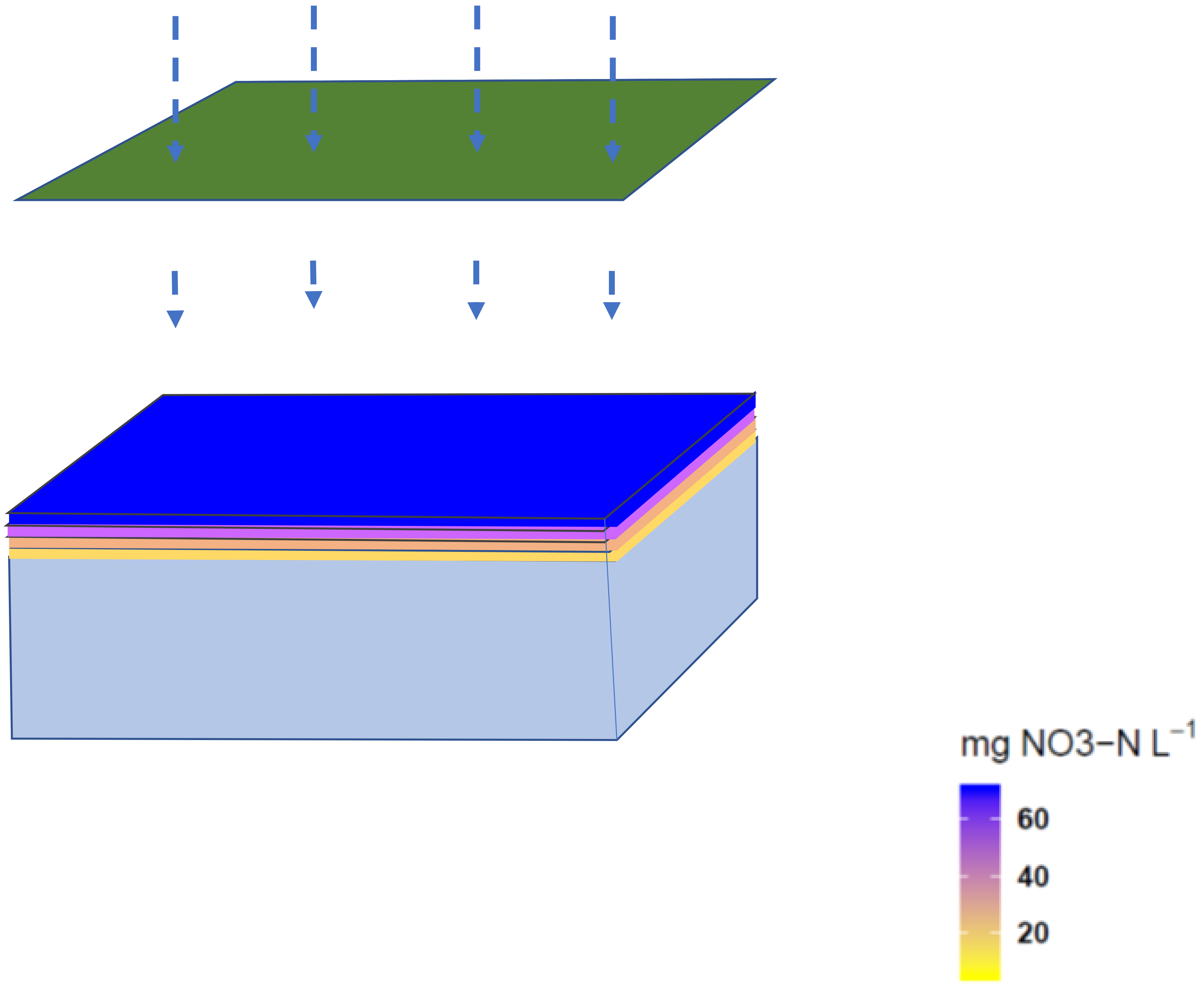




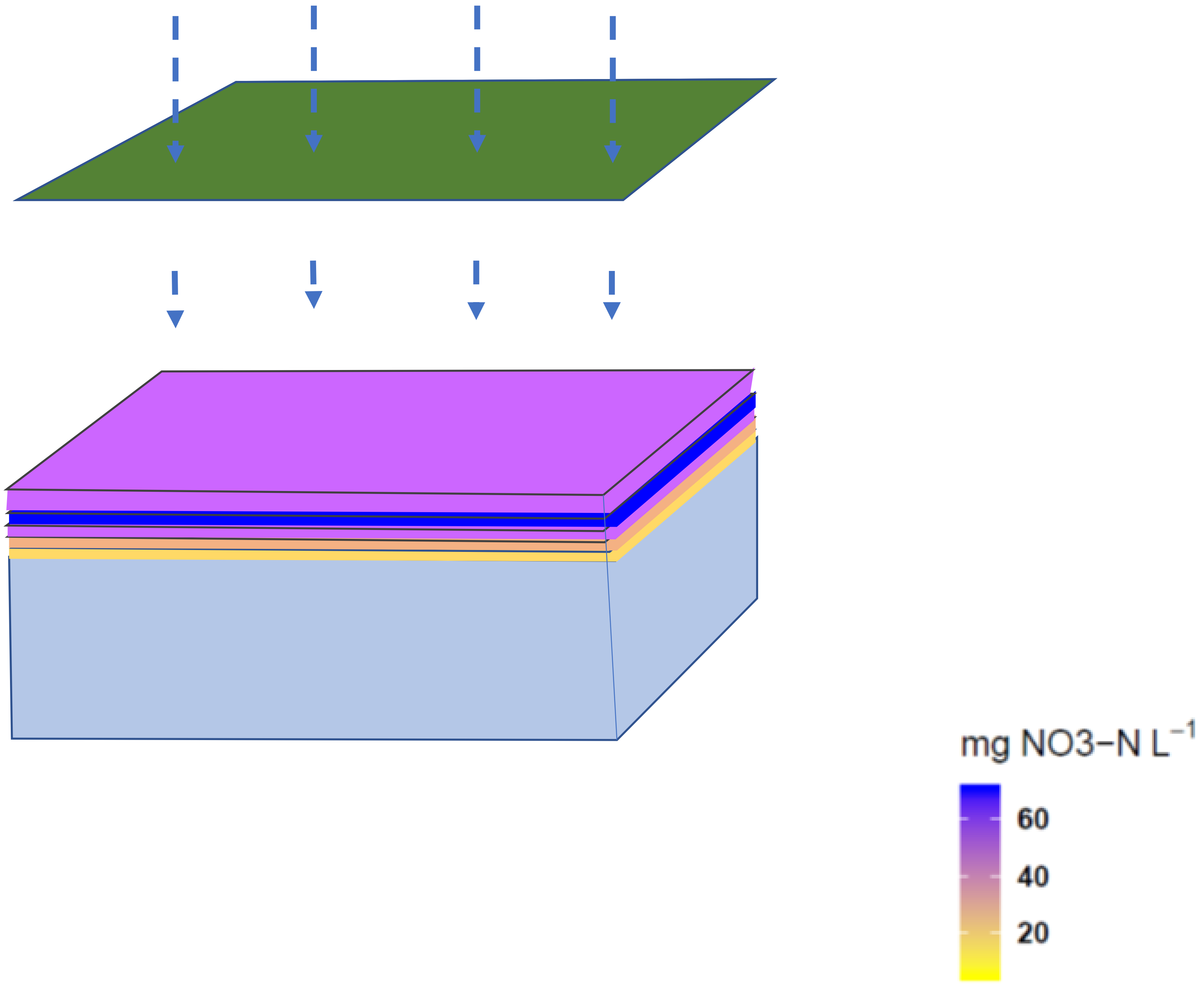
mg NO3−N L−1
60
40
20

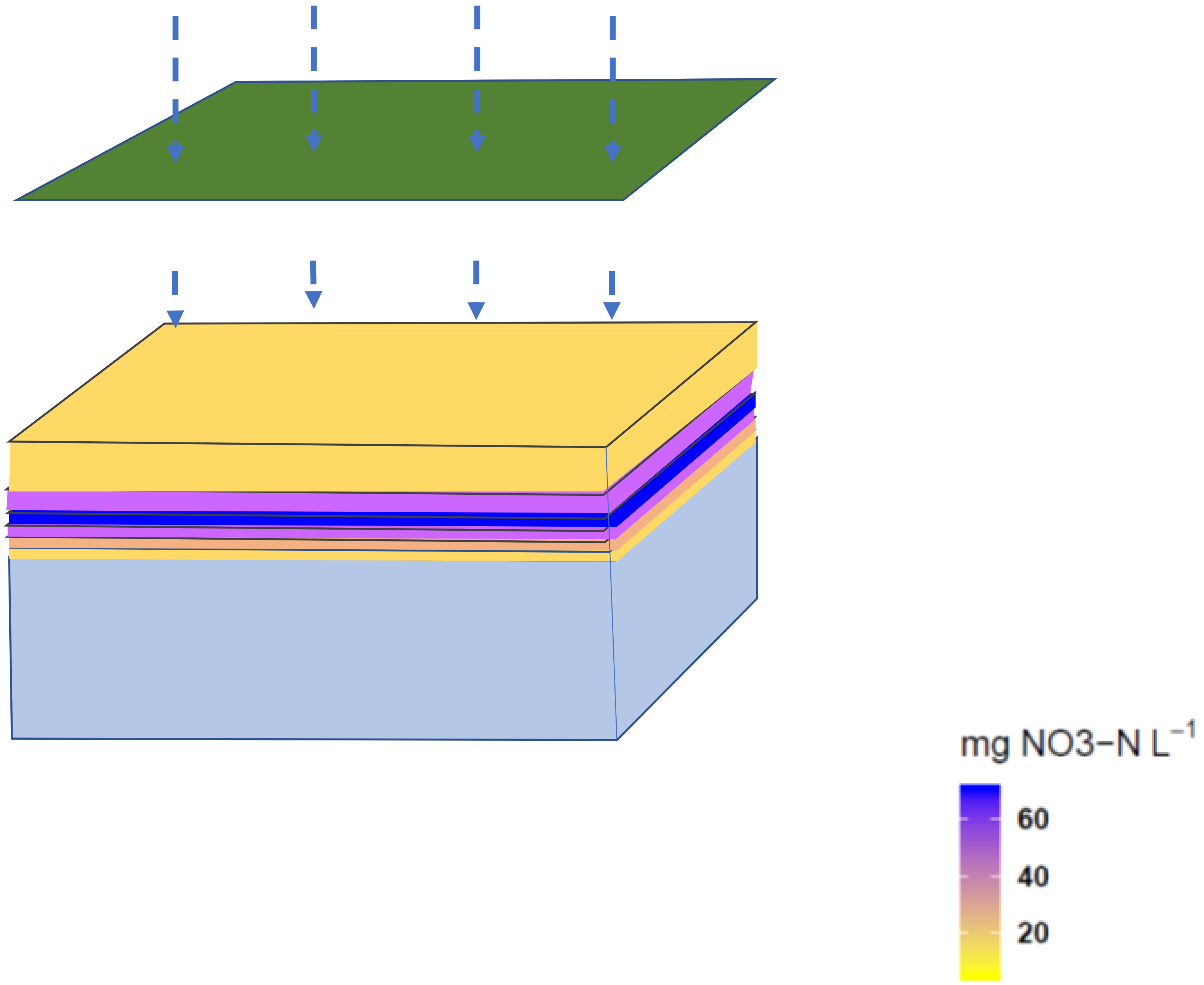

mg NO3−N L^{-1}
60
40
20


mg NO3−N L−1
60
40
20

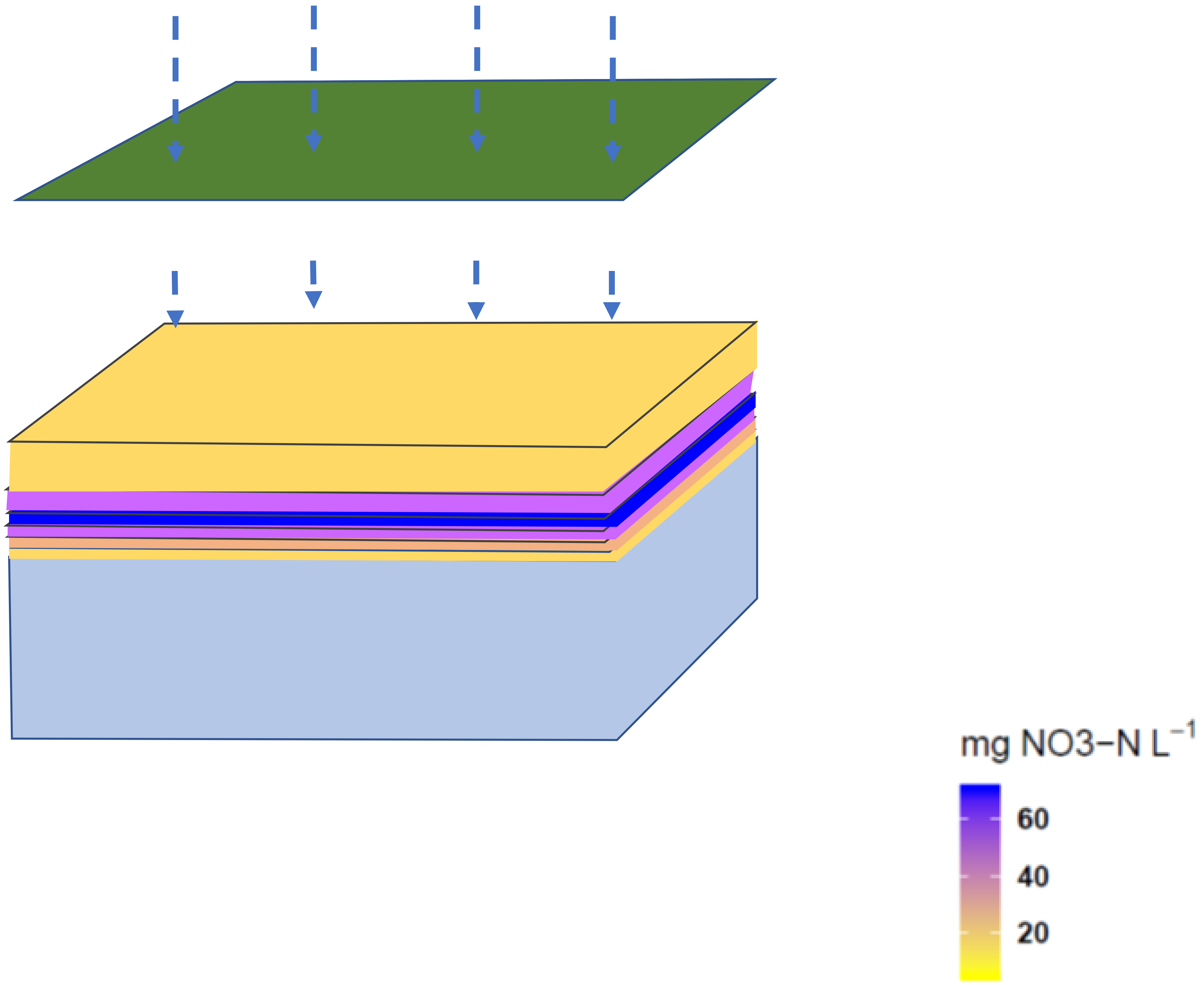


mg NO3−N L⁻¹
60
40
20

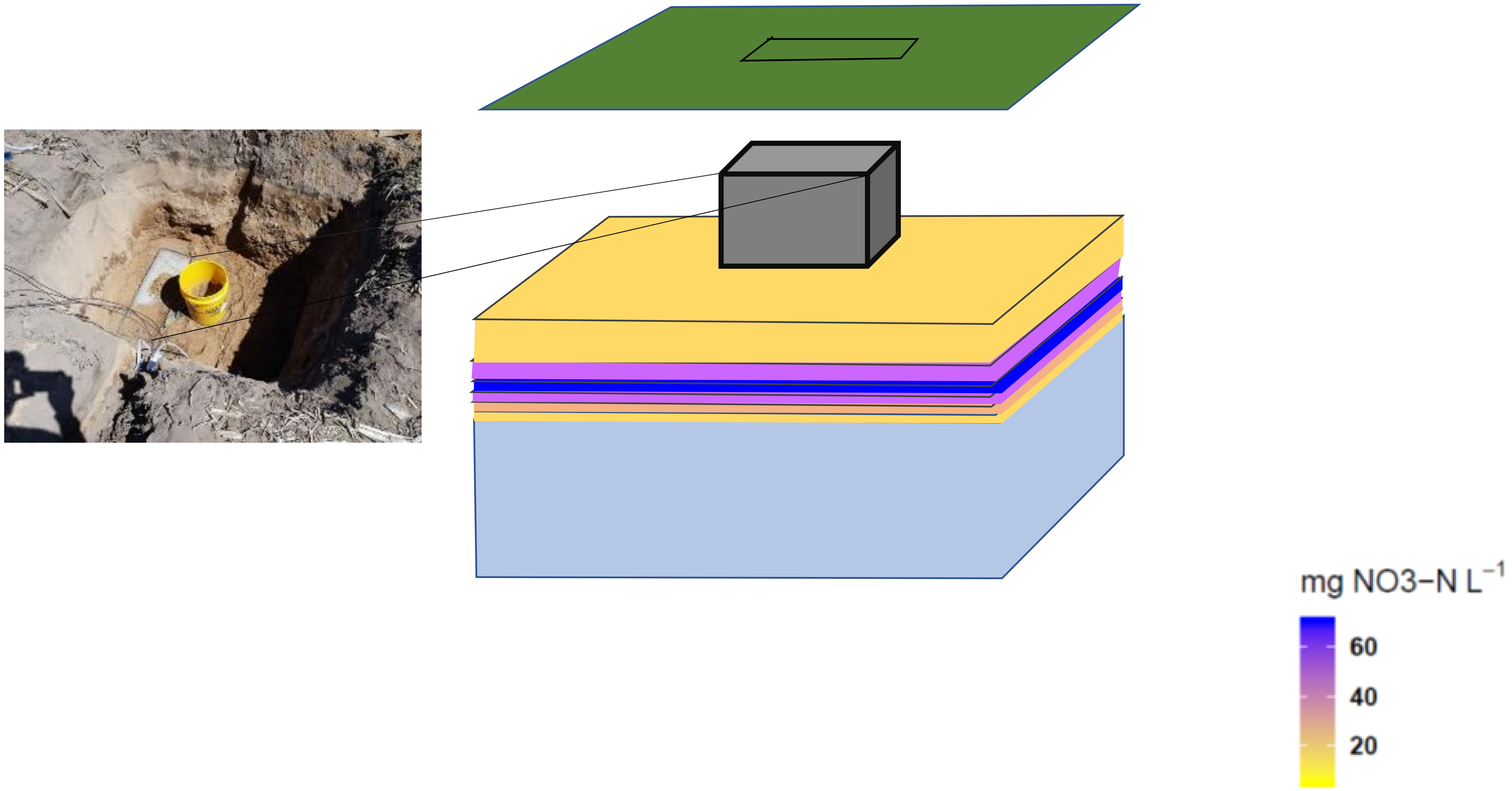

mg NO3−N L−1
60
40
20

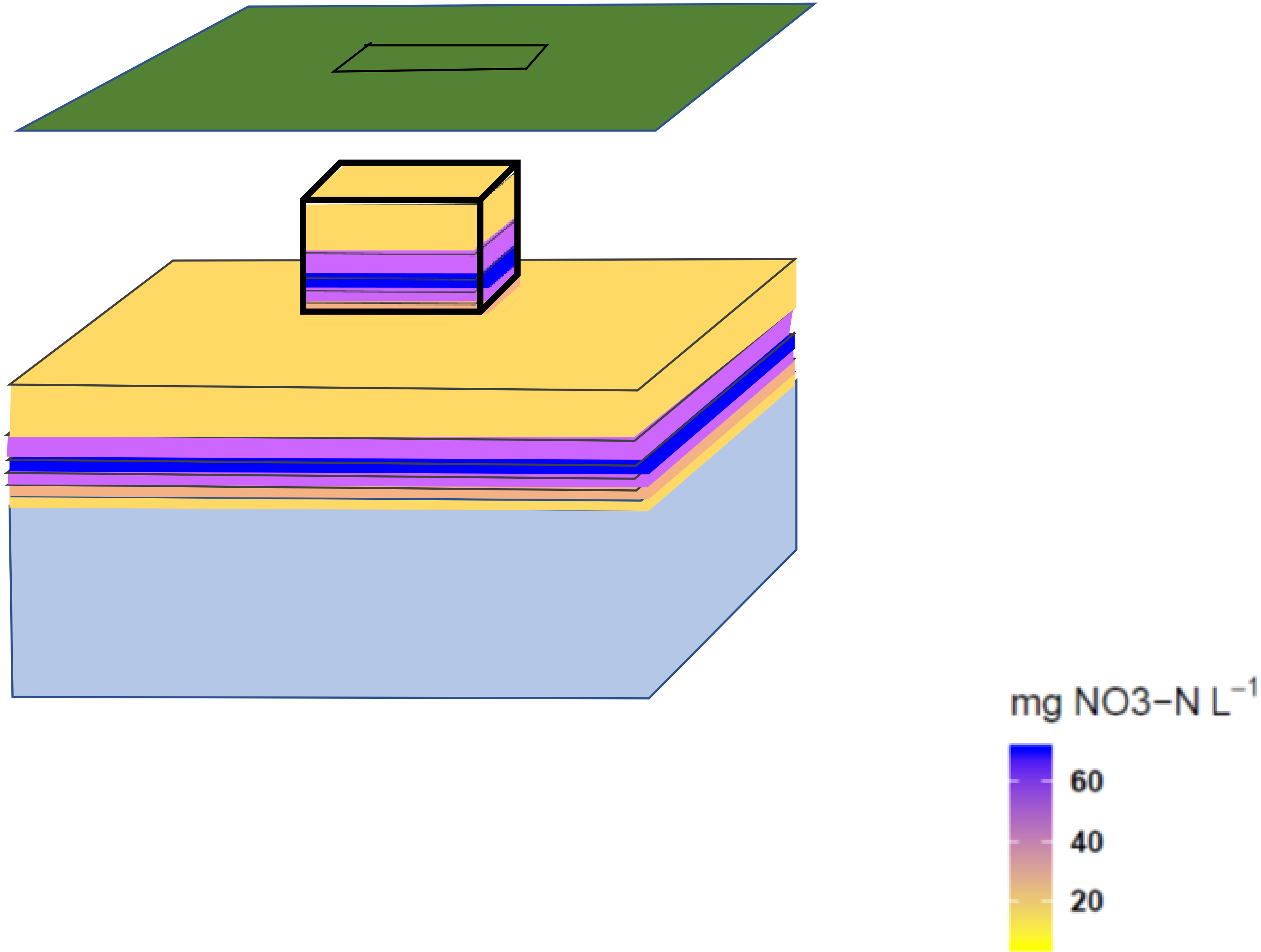


mg NO3−N L^{-1}
60
40
20



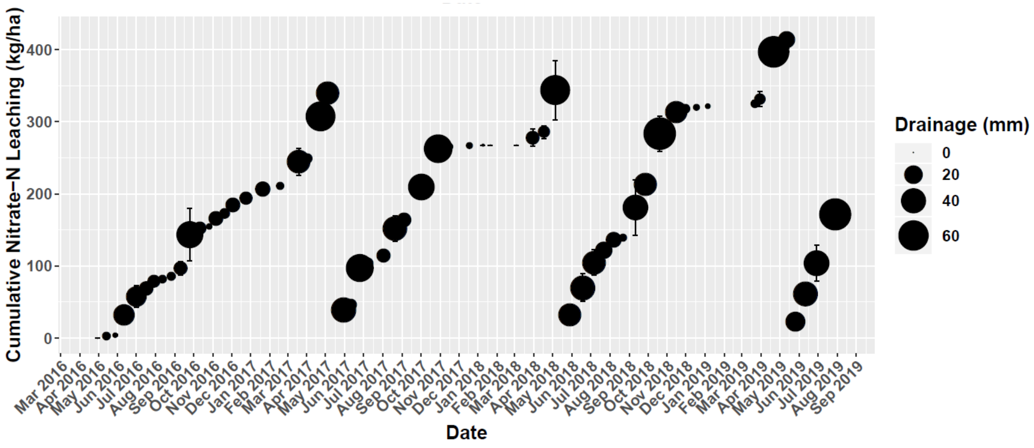
mg NO3−N L^{-1}
60
40
20

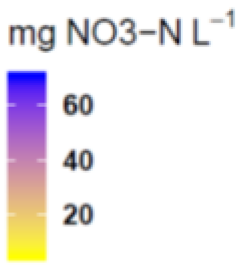

mg NO3−N L^{-1}
60
40
20

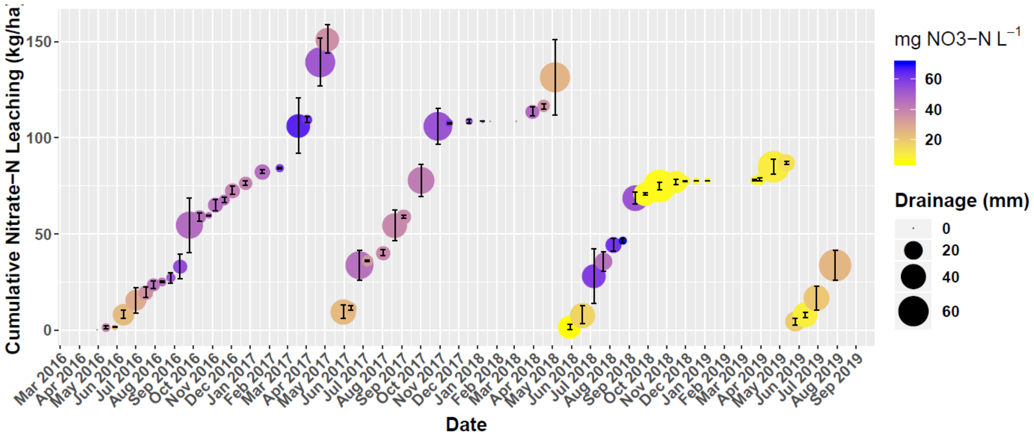


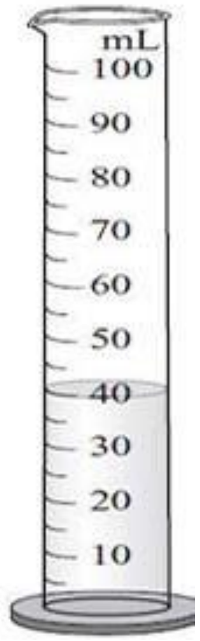
mg NO3−N L−1
60
40
20

Drainage Volume X Concentration = Nitrate Leaching

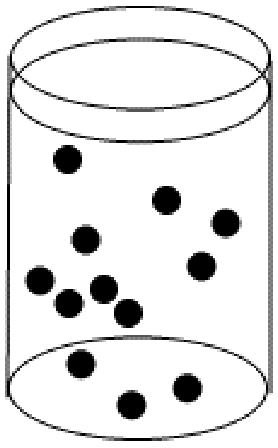




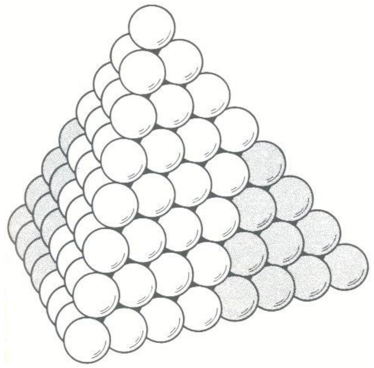




X

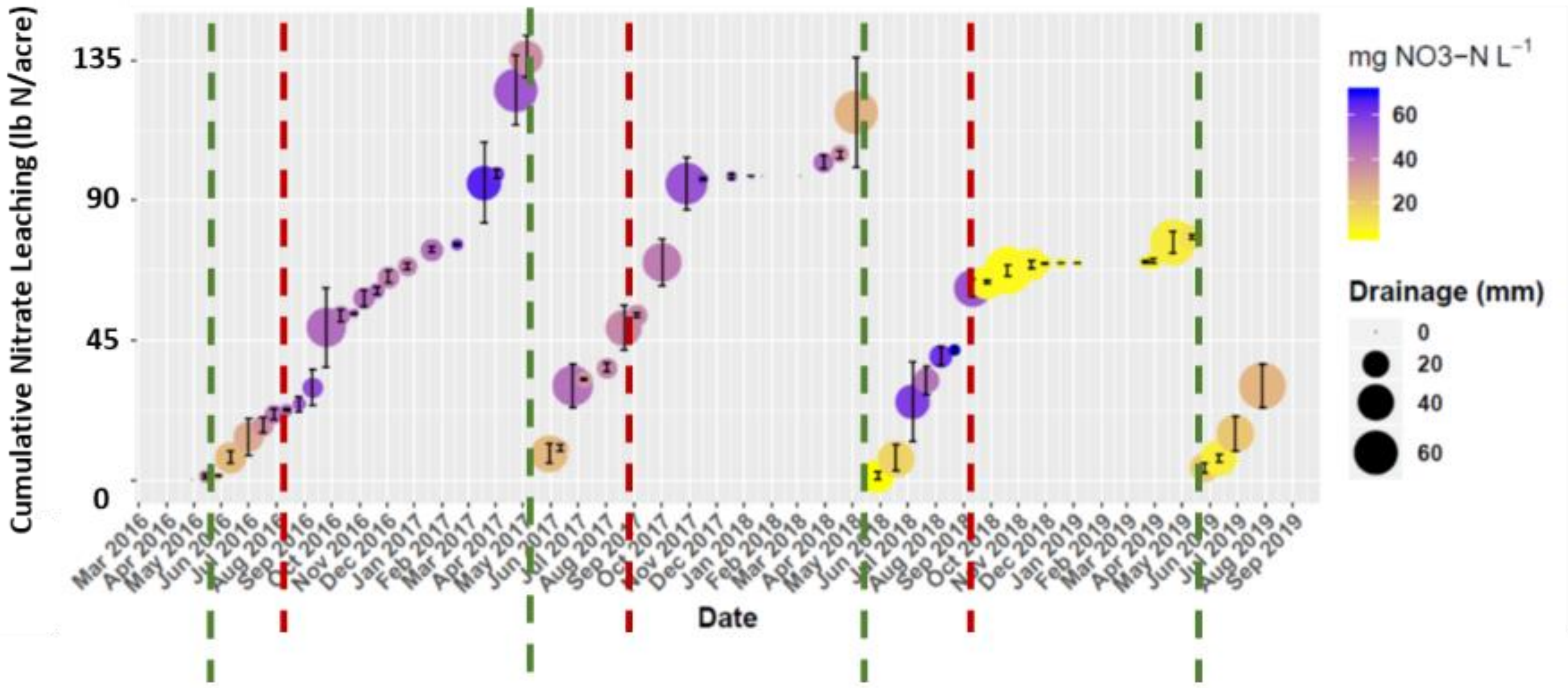


=



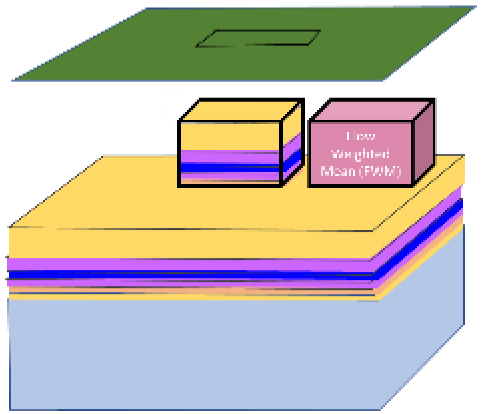
Nitrogen Leaching Losses

Sweet Corn	Potatoes	Field Corn	Peas/Pearl Millet
+143 lb/ac (fert)	+230 lb/ac (fert)	+205 lb/ac (fert)	+15 lb/ac (fert)
+~41 lb/ac (irr)	+~41 lb/ac (irr)	+~41 lb/ac (irr)	+~41 lb/ac (irr)



44.3 38.2 21.1

Flow-weighted Mean Nitrate-N Concentration (mg/L)



Estimating Leaching Losses Using a Nitrogen Budget

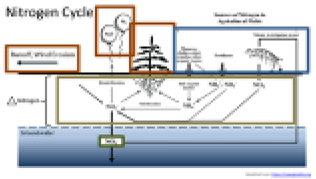
Nitrogen Budget Calculator (Follett et al., 1991)

Potential N Leaching = N Inputs - N Outputs (excluding leaching) - Change in N Storage

INPUTS (lbs N/acre)		
Fertilizer	230	Fertilizer Applied
Manure	0	No Manure
Symbiotic N fixation (legumes)	0	No Legumes Grown
Irrigation	41	calculate this by entering irrigation nitrate and inches applied
Precipitation	0	calculate this by entering precip nitrate and annual precip
Dry Deposition	0	Assume equal to precipitation
Crop Seed	0	Assume Not Significant (<1 lb/N acre)
Nonsymbiotic Fixation	3	Estimated Value
Total Inputs	**274**	
OUTPUTS (lbs N/acre)		
Harvested material	140	calculate using by entering harvest/N content data
Ammonia Loss	10	206 lbs fertilizer N x 5% loss (soil ph < 7), range from 0-40
Denitrification	6	Excessively well drained (3%), range from 2-55%
Erosion	0	ton/acre soil loss x % O.M. x 2
Runoff	0	< 3 lb N / year
Miscellaneous Gaseous	2	
Ammonia at senescence	10	
Total Outputs	**168**	All outputs except leaching
Change in N STORAGE (lbs N/acre)		
Change in Inorganic N	0	Estimate using no n plot
Change in Organic N	0	For sand assuming low
Total Storage Change	**0**	
LEACHABLE N		
Leachable N	**106**	**lbs / acre**

Irrigation (mg/L nitrate)	18	inches applied	10	
Precipitation (mg/L nitrate	0	inches precip	32	
ENTER CROP INFORMATION HERE:				
Select Crop	Potato, White Tuber			
Yield (units/ac)	350	N content	0.4	cwt
		get this value from Table 5-4		
convert lb/acre to kg/ha	160	205		
convert kg/ha to lb/acre	180	160.3238866		

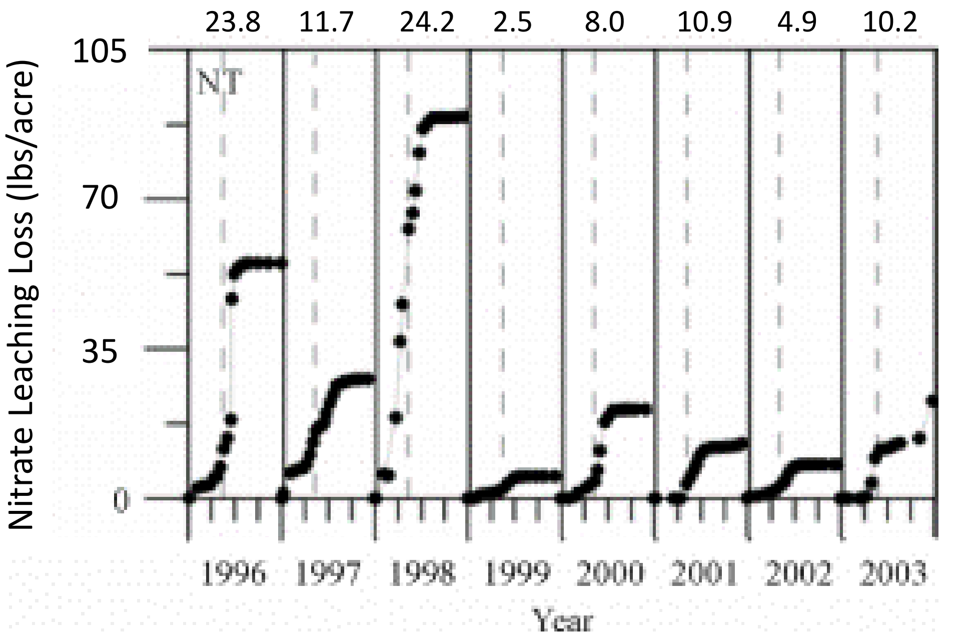
Potential N Leaching = N Inputs - N Outputs (excluding leaching) - Change in N Stored



LEACHING CALCULATOR | Sheet1 | Sheet2

Nitrate Leaching at Arlington, WI

Flow Weighted Mean Nitrate-N Concentration (mg/L)



Journal of Environmental Protection, 2014, 5, 240-254
Published Online March 2014 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2014.54028

Scientific Research

Long-Term Drainage and Nitrate Leaching below Well-Drained Continuous Corn Agroecosystems and a Prairie

Kevin C. Masarik[1], John M. Norman[2], Kristofor R. Brye[3]

[1]College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, USA
[2]Department of Soil Science, University of Wisconsin, Madison, USA
[3]Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, USA
Email: kmasarik@uwsp.edu

Received 31 December 2013; revised 28 January 2014; accepted 23 February 2014

Abstract

Many studies have evaluated nitrate-N leaching from tile-drained agricultural soils, but little long-term research has been performed on well-drained soils commonly throughout the Midwest. Equilibrium tension lysimeters installed at a depth of 1.4 m were used to measure year-round (12 months) nitrate-N leaching below chisel-plow (CP) and no-tillage (NT) continuous corn (*Zea mays* L.) agroecosystems to determine the potential effects of common agricultural practices on subsurface water quality. The corn systems were fertilized at a rate of 10 kg N ha^{-1} of starter fertilizer and 180 kg N ha^{-1} as NH_4NO_3. For comparison, nitrate-N leaching from a natural ecosystem was performed on a nearby prairie restoration (PR). Drainage, nitrate-N leaching loss, and flow-weighted mean nitrate-N concentrations for 8 years of data (1996-2003) are reported for the CP, NT and PR ecosystems. Results show that 52%, 37%, 16% of cumulative precipitation was collected as drainage, while 18%, 19%, 0.5% of the total N input was leached as nitrate-N in the CP, NT, and PR, respectively. Nearly three-quarters of the total nitrate-N was leached from each ecosystem during the period from 1 April to 30 June. The 8-yr, flow-weighted mean nitrate-N concentration measured in leachate was 9.5, 12.2 and <0.1 mg L^{-1} for the CP, NT and PR treatments. Annual drainage volumes and nitrate-N leaching losses were highly variable, stressing the importance of long-term studies capable of measuring year-round drainage for understanding N leaching dynamics and evaluating effects of cropping practices on potential groundwater quality.

Estimating nitrogen from irrigation or leaching losses using concentration

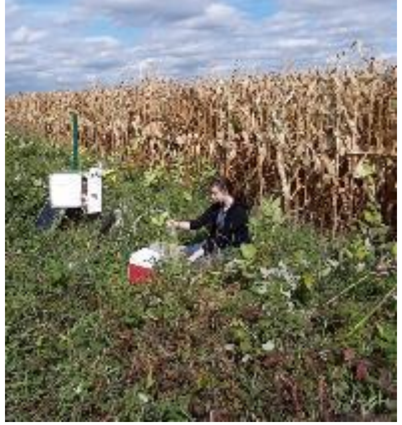
	Nitrate-Nitrogen Concentration (mg/L)									
	1	2	3	4	5	10	15	20	30	40
Water in inches	lbs of Nitrogen per acre									
1	0.2	0.5	0.7	0.9	1.1	2.3	3.4	4.5	6.8	9.0
2	0.5	0.9	1.4	1.8	2.3	4.5	6.8	9.0	13.6	18.1
3	0.7	1.4	2.0	2.7	3.4	6.8	10.2	13.6	20.4	27.1
4	0.9	1.8	2.7	3.6	4.5	9.0	13.6	18.1	27.1	36.2
5	1.1	2.3	3.4	4.5	5.7	11.3	17.0	22.6	33.9	45.2
6	1.4	2.7	4.1	5.4	6.8	13.6	20.4	27.1	40.7	54.3
7	1.6	3.2	4.7	6.3	7.9	15.8	23.7	31.7	47.5	63.3
8	1.8	3.6	5.4	7.2	9.0	18.1	27.1	36.2	54.3	72.4
9	2.0	4.1	6.1	8.1	10.2	20.4	30.5	40.7	61.1	81.4
10	2.3	4.5	6.8	9.0	11.3	22.6	33.9	45.2	67.8	90.5

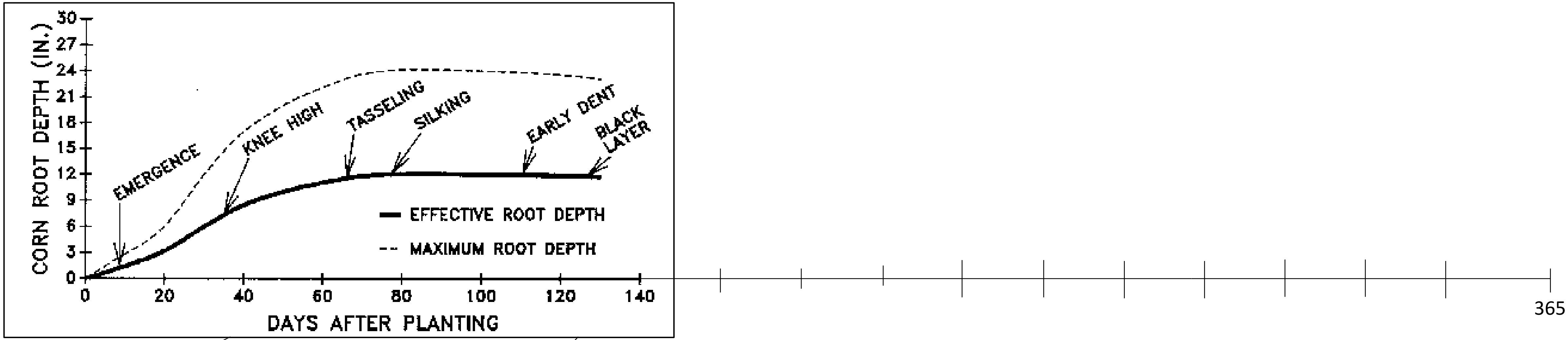
Or

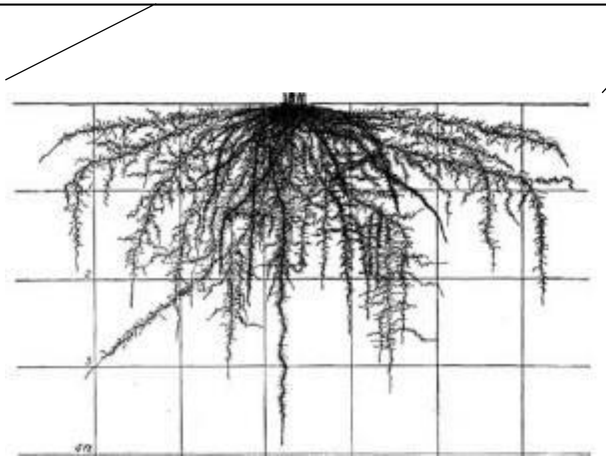
Water (inches) x Nitrate-Nitrogen Concentration (mg/L) x 0.226 = Pounds of Nitrogen per Acre

(8 in.) x (10 mg/L) x 0.226 = 18.1 lbs N/acre



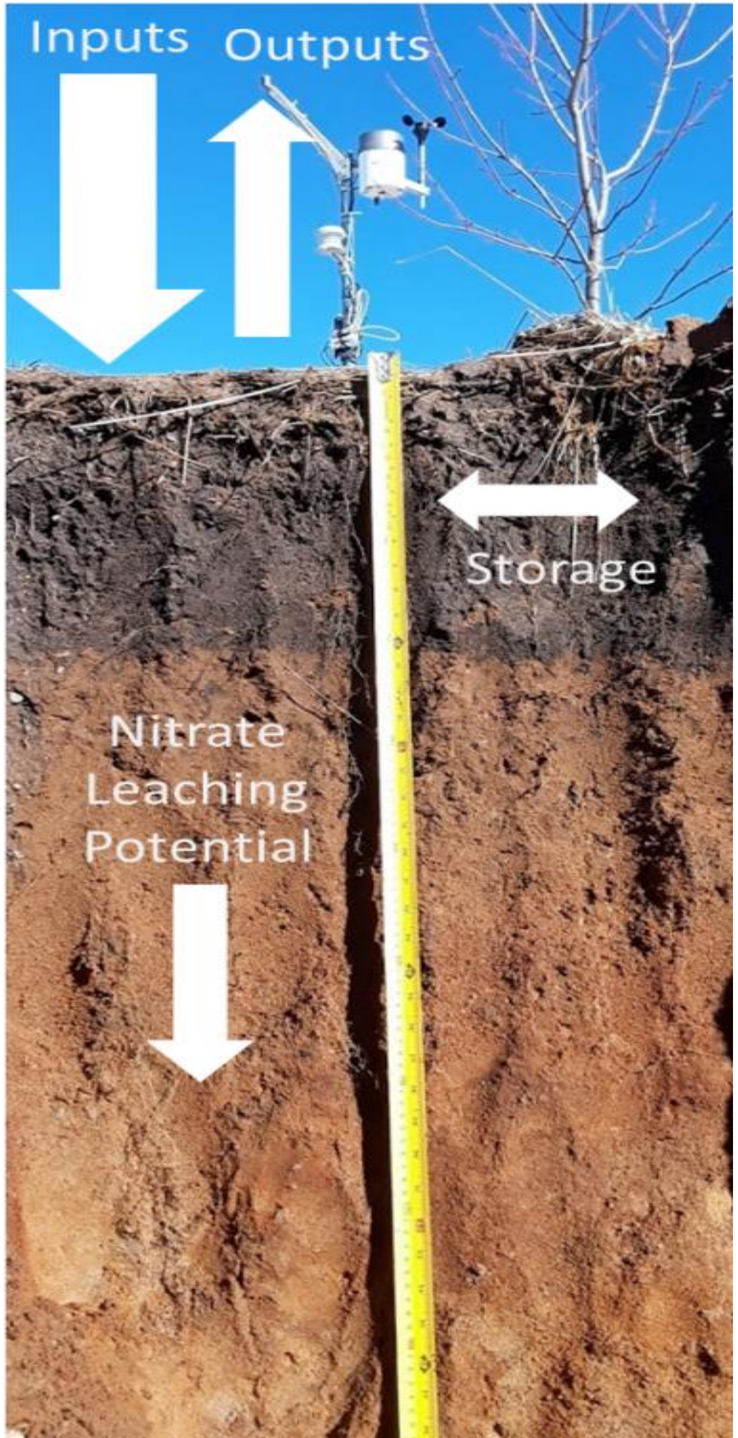


[Graph of root depth: http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html](http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html)

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

Our challenge: The top foot

- Current agricultural systems allow for significant nitrate losses to groundwater – much of it can occur outside the growing season
- Soils and geologic considerations can exacerbate losses from agricultural systems
- Future agricultural management priorities/challenges:
  - 1) Encourage but also need to better quantify nitrate reduction from
    - Cover crops
    - Diversification of crop rotations
    - Etc.
  - 2) Climate change will impact nitrate losses to groundwater
    - More extreme rainfall events
    - Longer growing season
    - Increased soil temperature



Kevin Masarik
kmasarik@uwsp.edu
715-346-4276






Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin-Stevens Point

Extension
UNIVERSITY OF WISCONSIN-MADISON