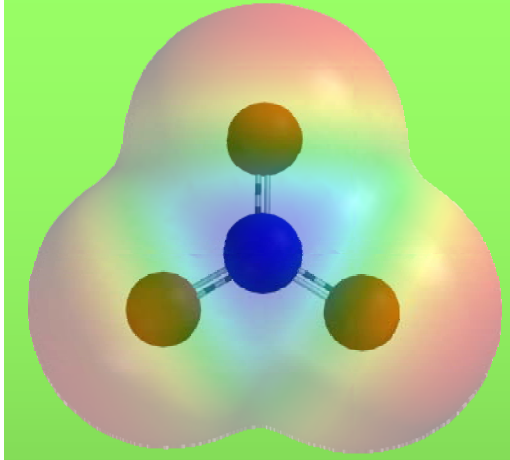


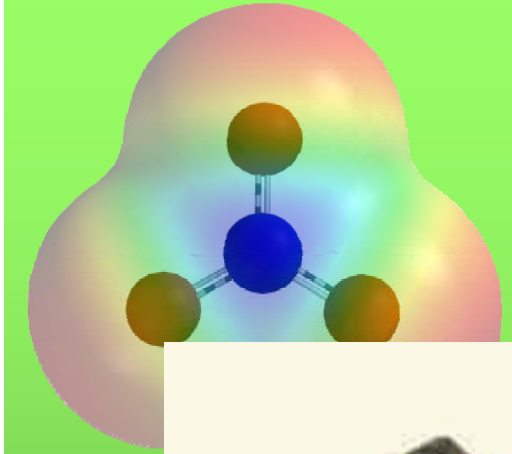
Leave it cleaner than they found it:

Perennial forages and water quality

Michael Russelle
USDA-ARS, St. Paul, MN

High water use
Little N removal
Dense rooting
Low profitability

High water use
High nitrate uptake capacity
Deep rooting
High profitability



Leave it cleaner than they found it:

Perennial forages and water quality

Michael Russelle
USDA-ARS, St. Paul, MN

High water use
High nitrate uptake capacity
Deep rooting
High profitability

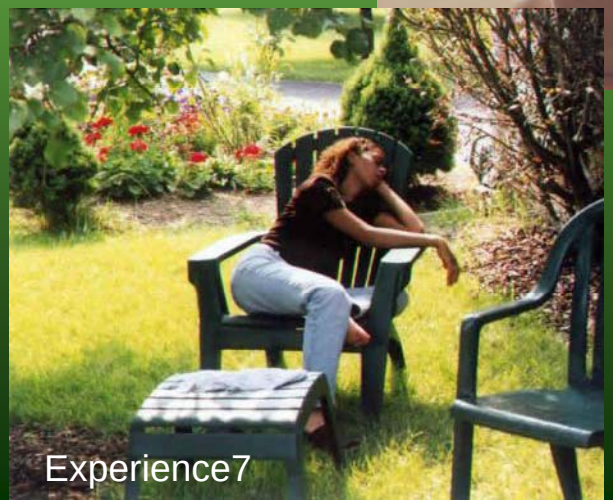
Stougard, 2007

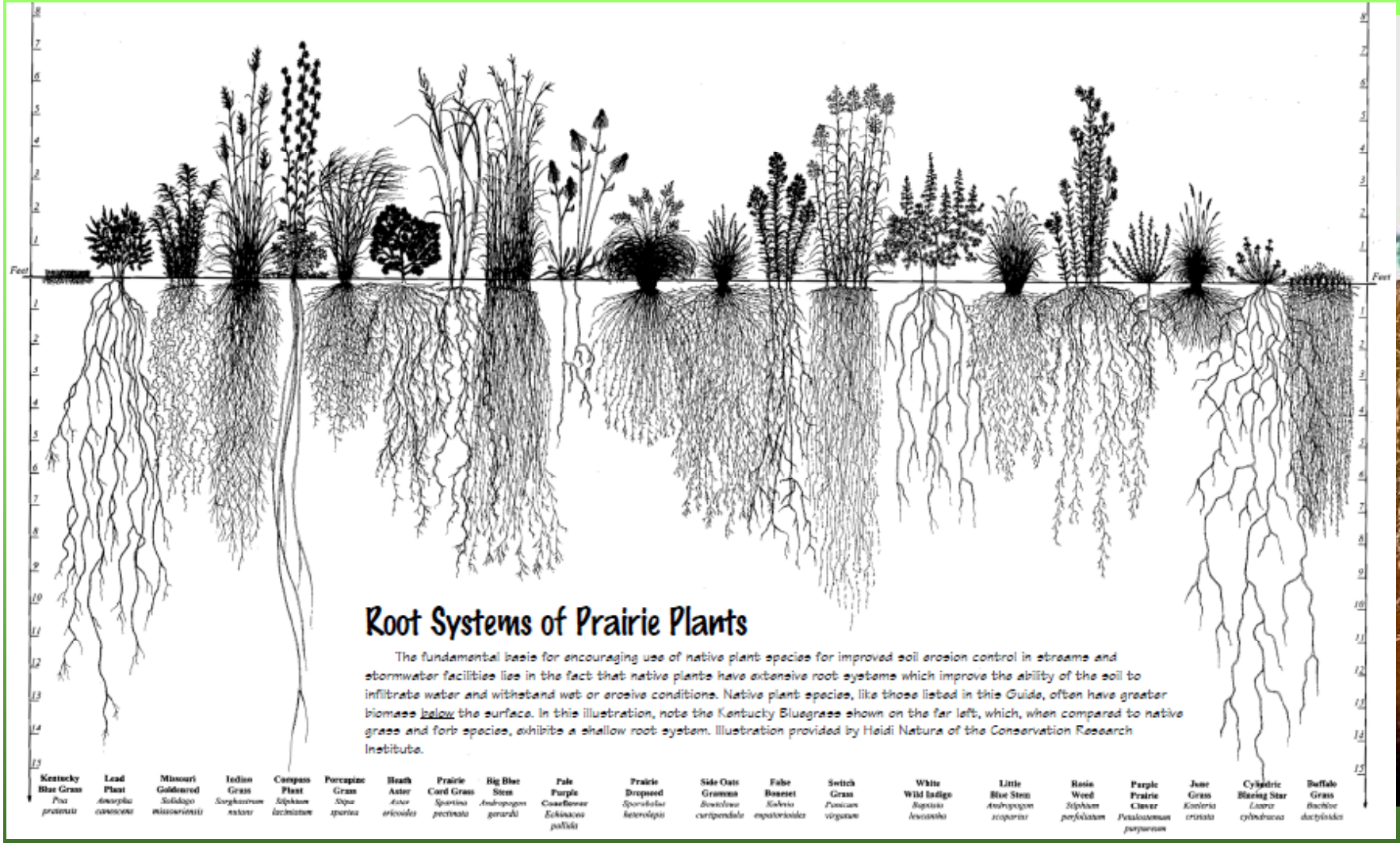
Getty Images

gettyimages

LauraC

Radford

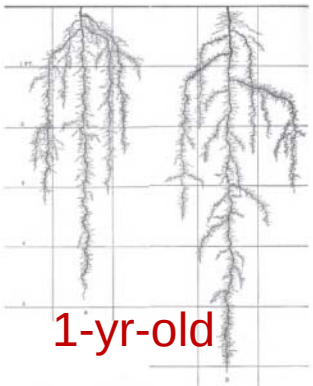

Experience7



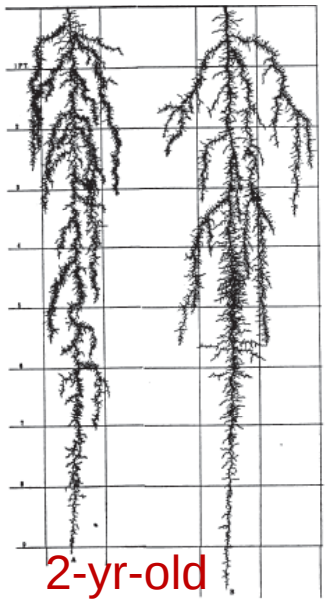
Cottrell (1902) “They extend 15 to 30 feet and more in depth in fairly good soil.”

Weaver (1920) in 2-year-old alfalfa near Lincoln, NE:

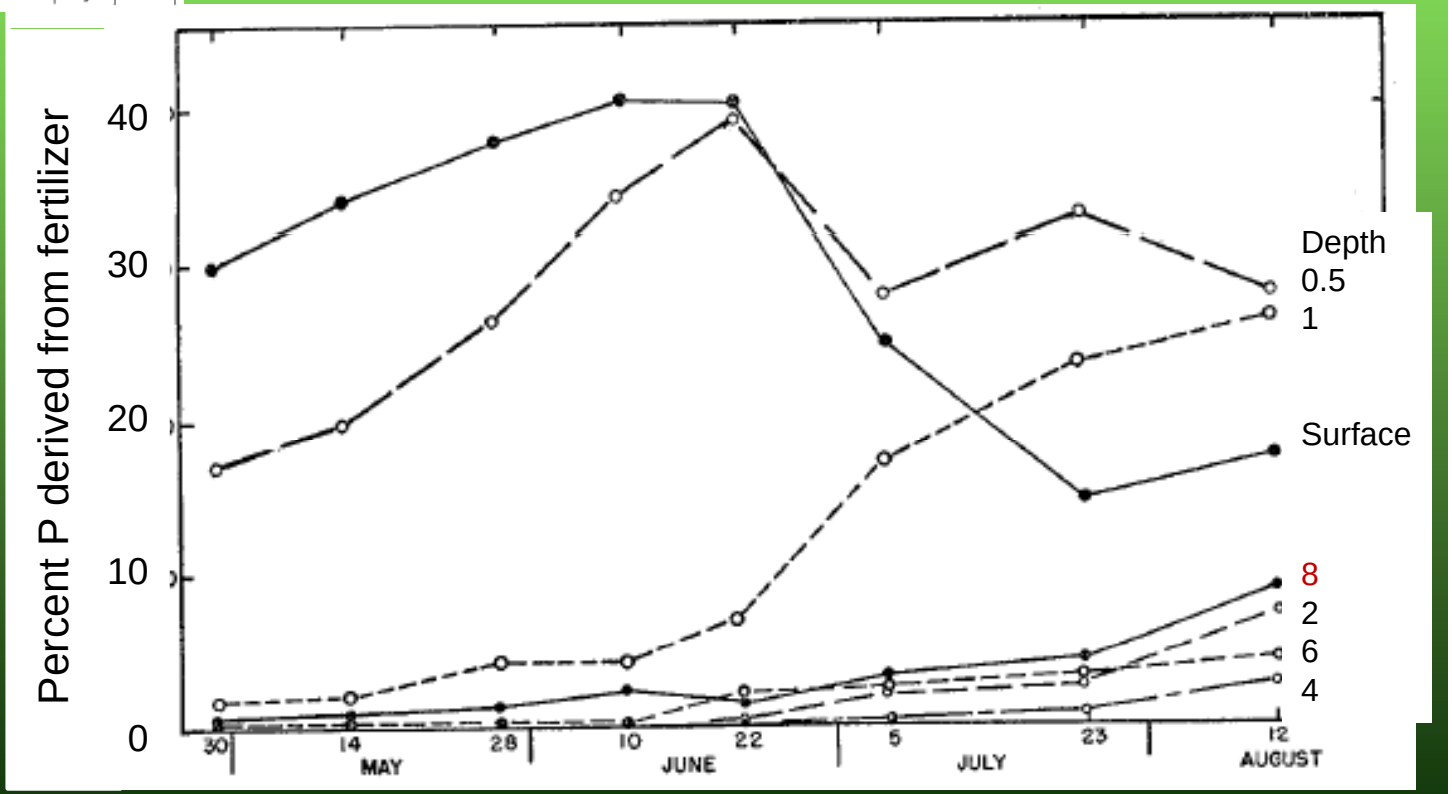
“While many [tap-roots] ended at depths of 7 to 10 feet, others extended to the water-level at a depth of 12 feet…’



Jean and Weaver, 1924

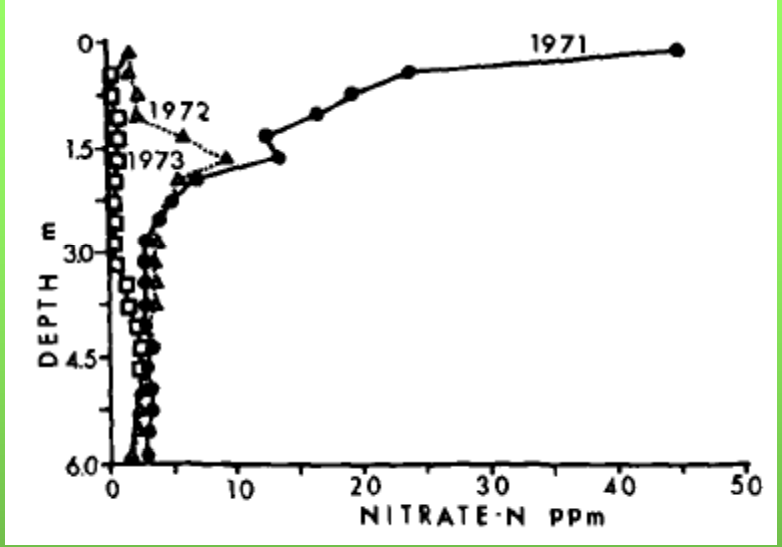


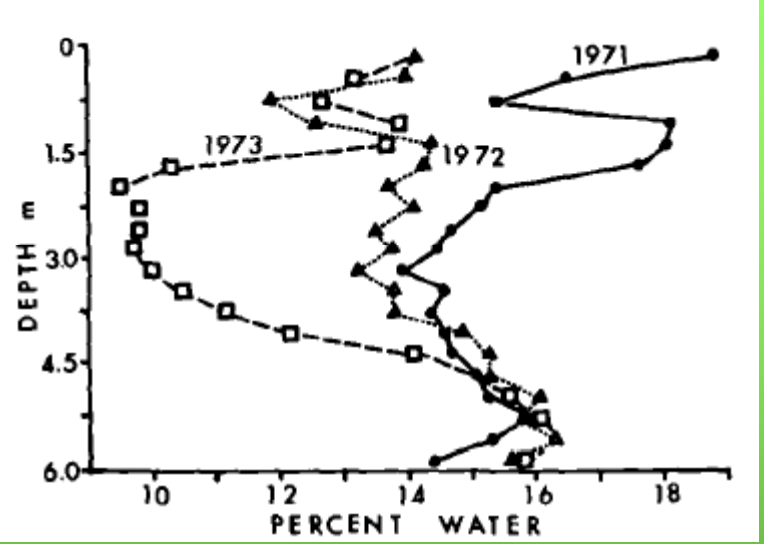
Early research focused on root distribution for native soil nutrient uptake and subirrigation



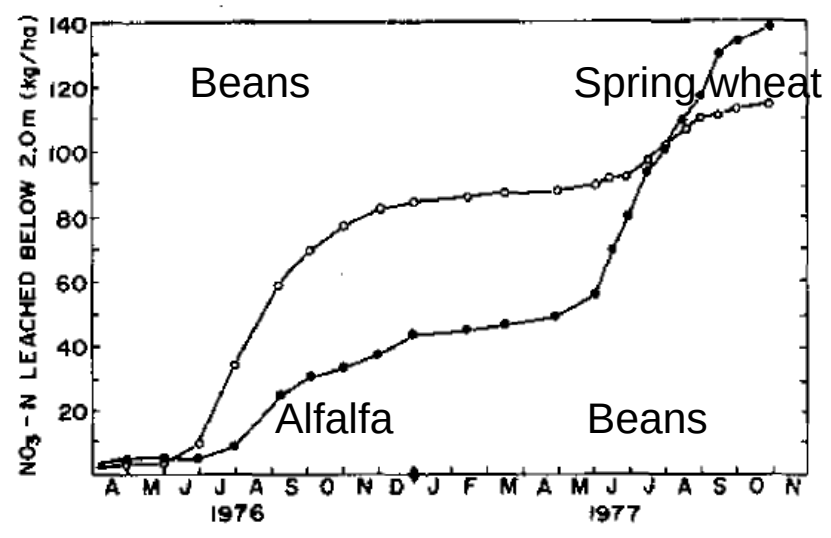
Lipps et al., 1957, Soil Sci. 84:195

Early evidence of nitrate removal and reduction in leaching



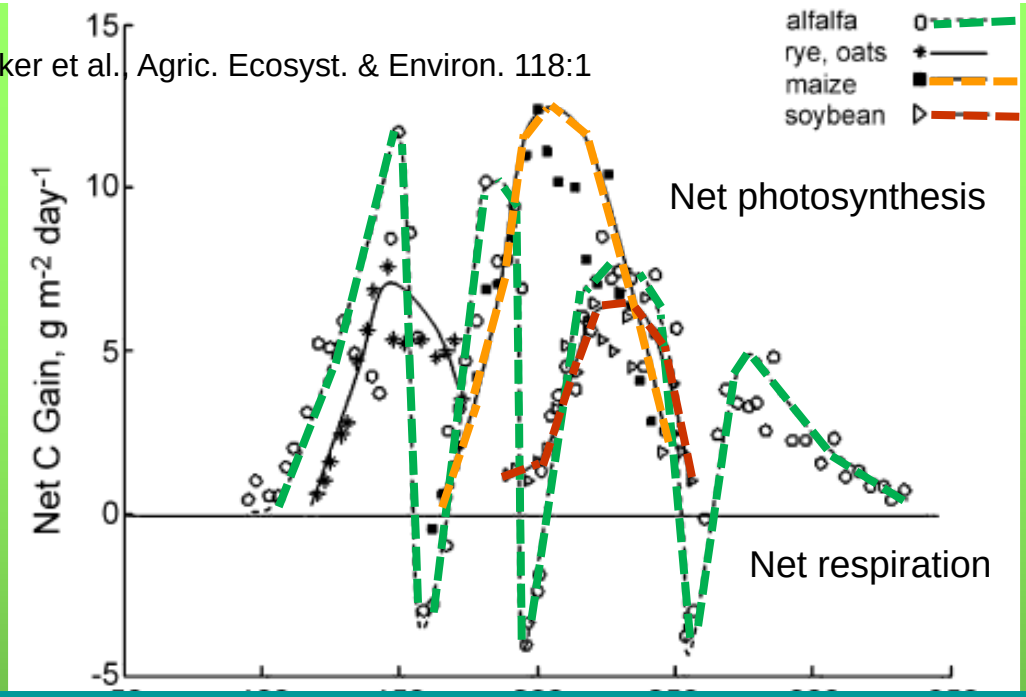


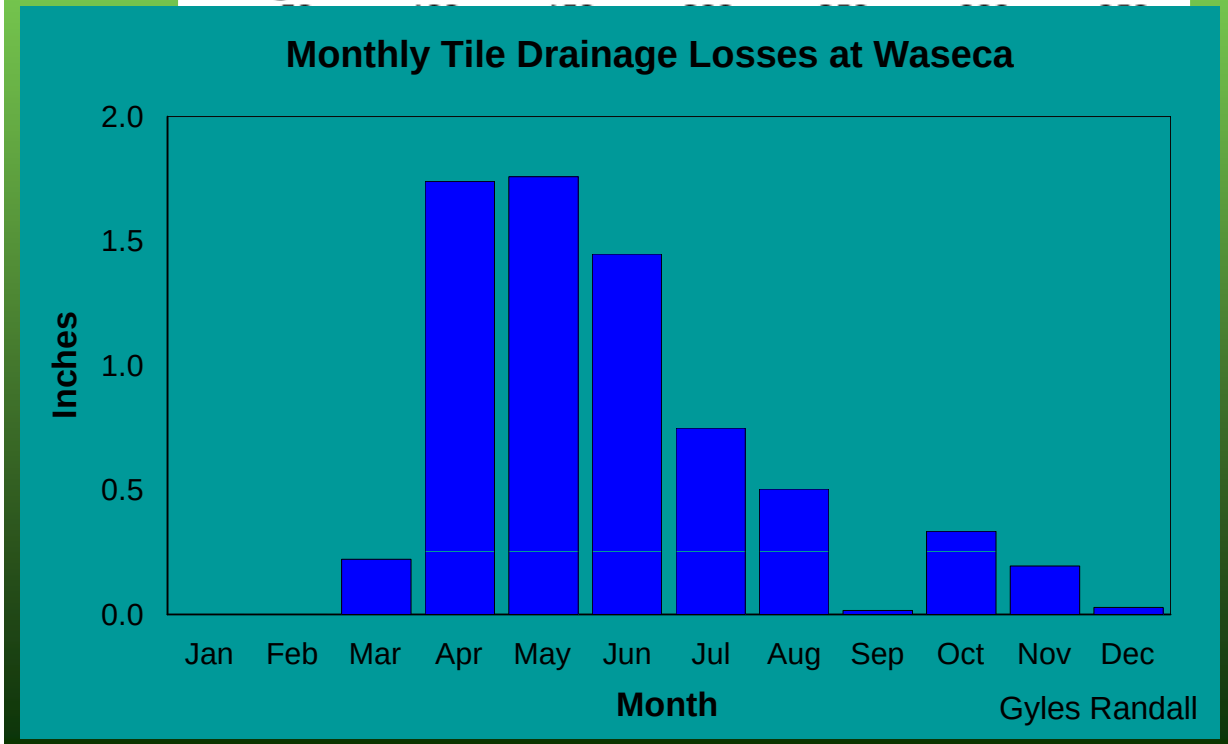
Mathers et al., 1975, JEQ 4:403



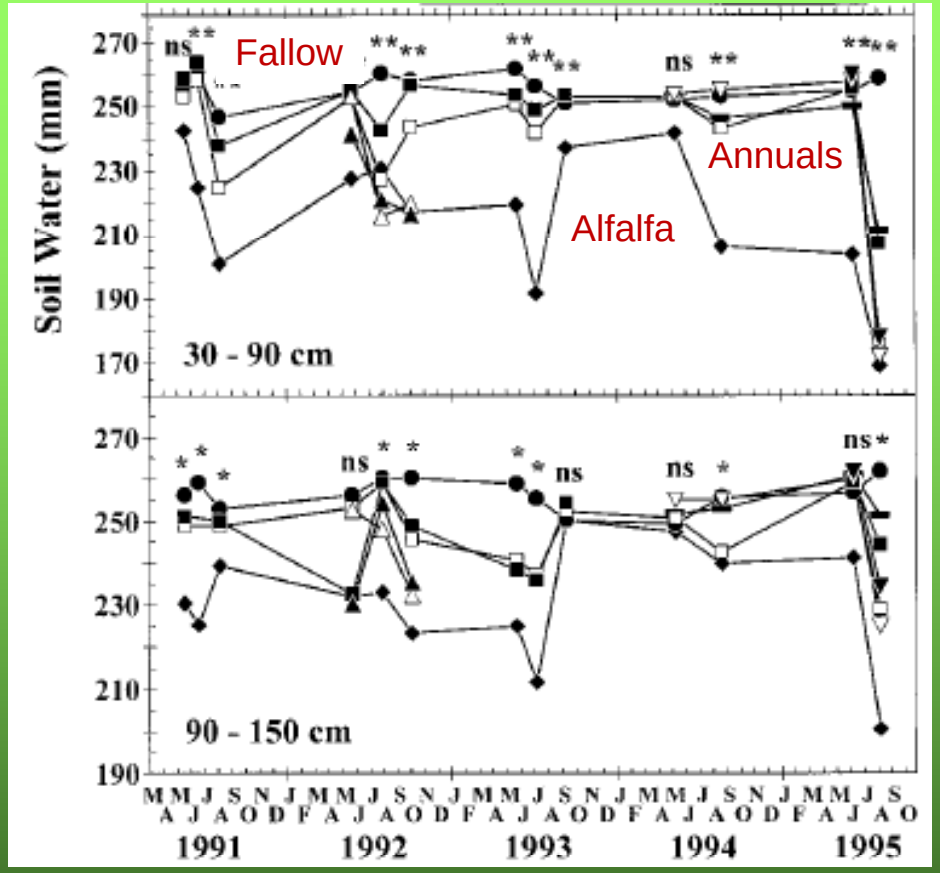
Robbins and Carter, 1980, JEQ 9:337

J.M. Baker et al., Agric. Ecosyst. & Environ. 118:1



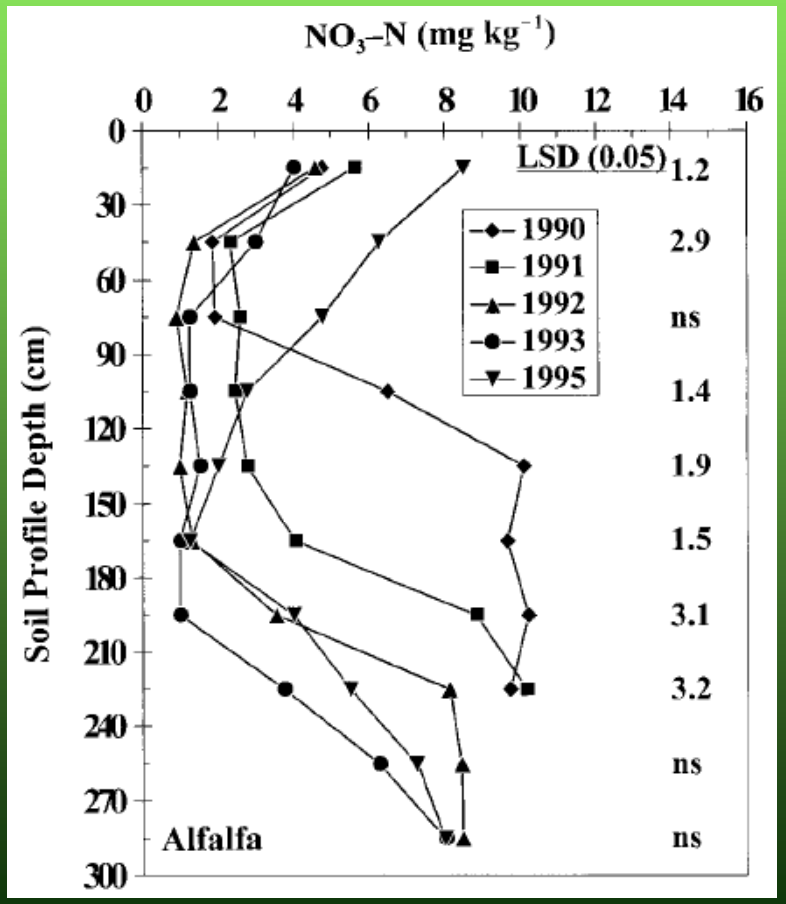


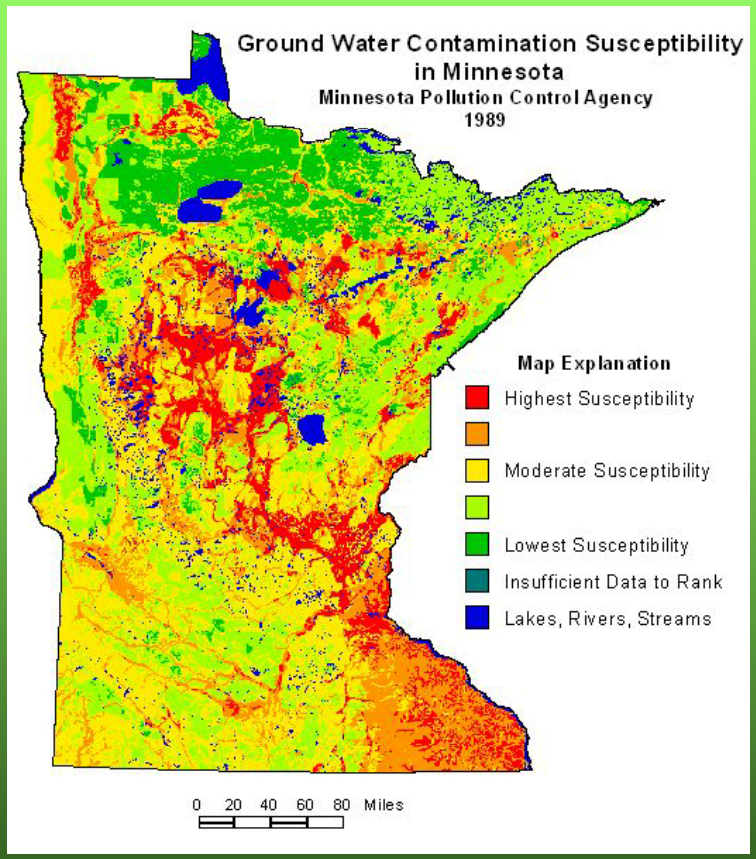
Less soil water – lower flux, higher storage capacity

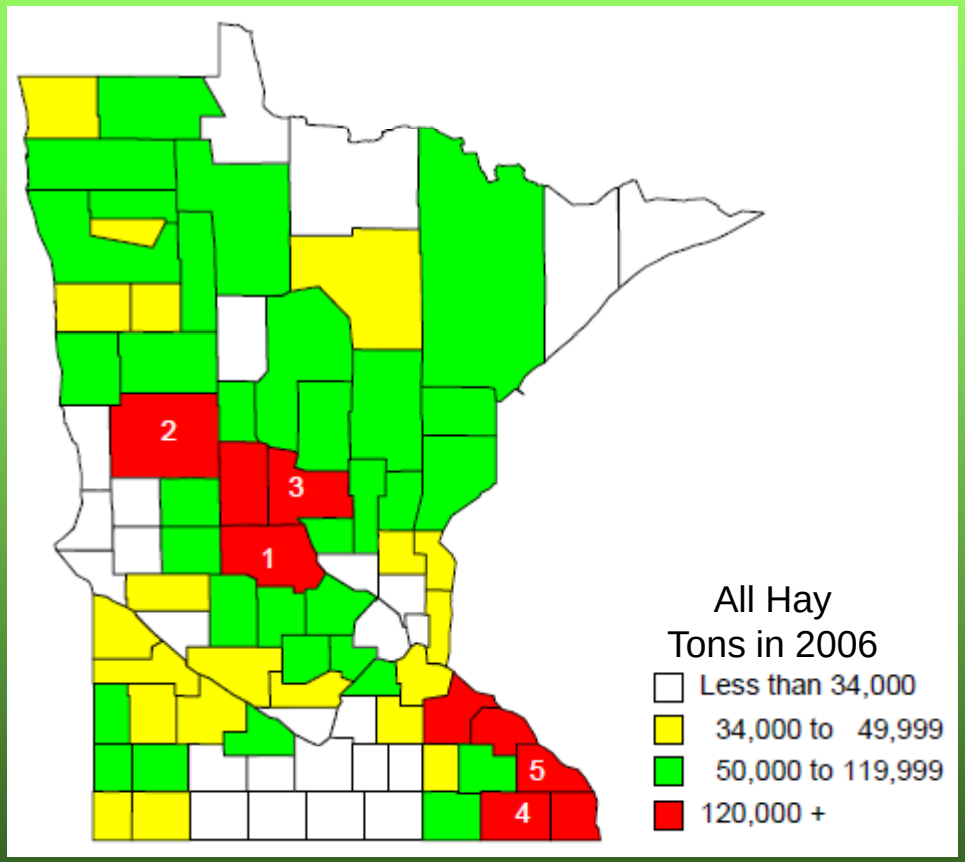


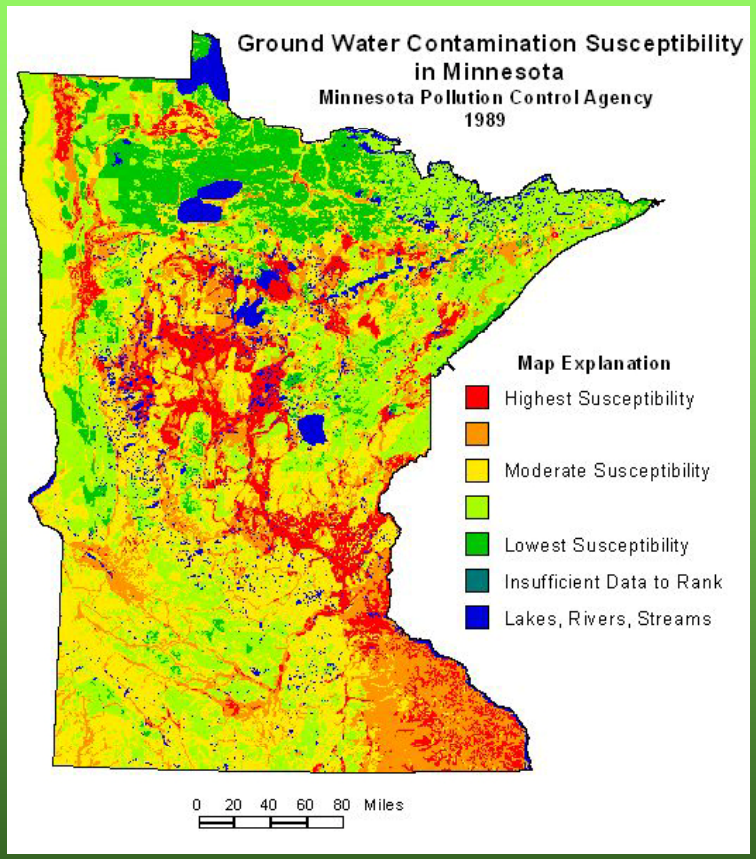
Entz et al., 2001, Agron. J. 93:495

But, nitrate can accumulate as alfalfa stands decline




Ground Water Contamination Susceptibility in Minnesota
Minnesota Pollution Control Agency
1989
Map Explanation
Highest Susceptibility
Moderate Susceptibility
Lowest Susceptibility
Insufficient Data to Rank
Lakes, Rivers, Streams
0 20 40 60 80 Miles


1
2
3
4
5
All Hay
Tons in 2006
Less than 34,000
34,000 to 49,999
50,000 to 119,999
120,000 +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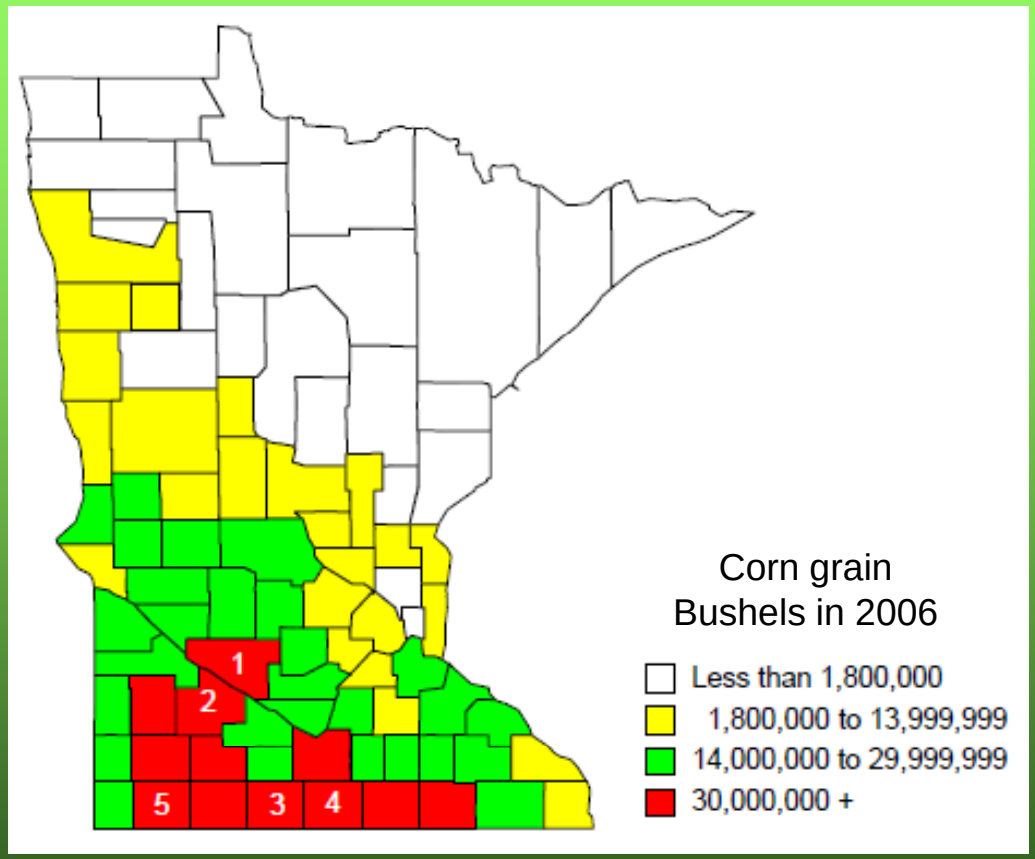
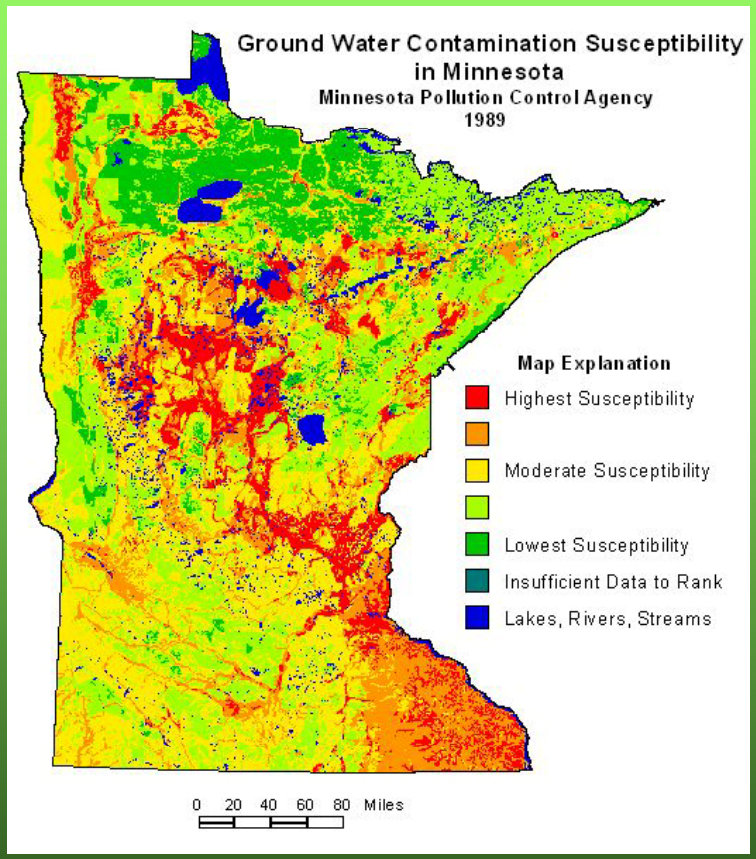
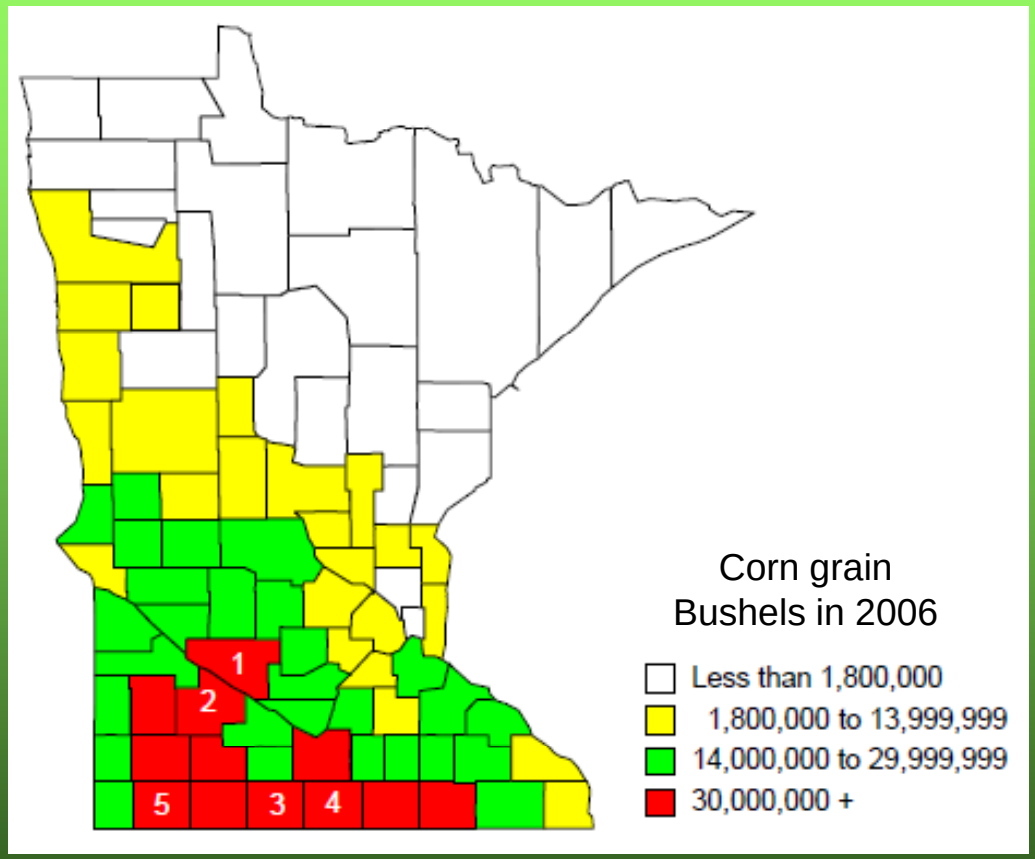
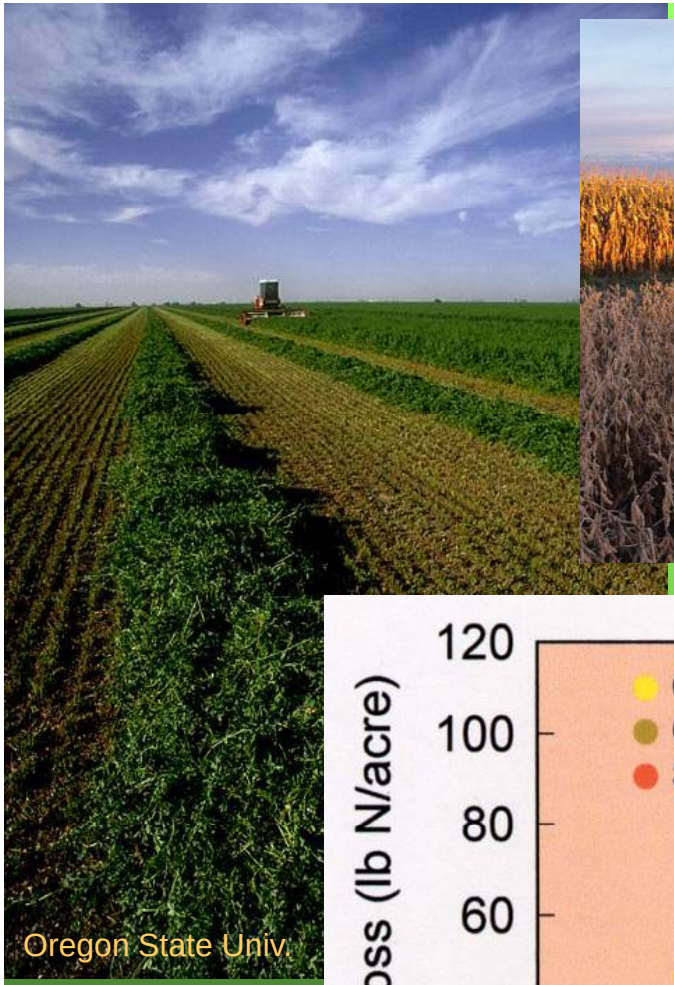
0 20 40 60 80 Miles

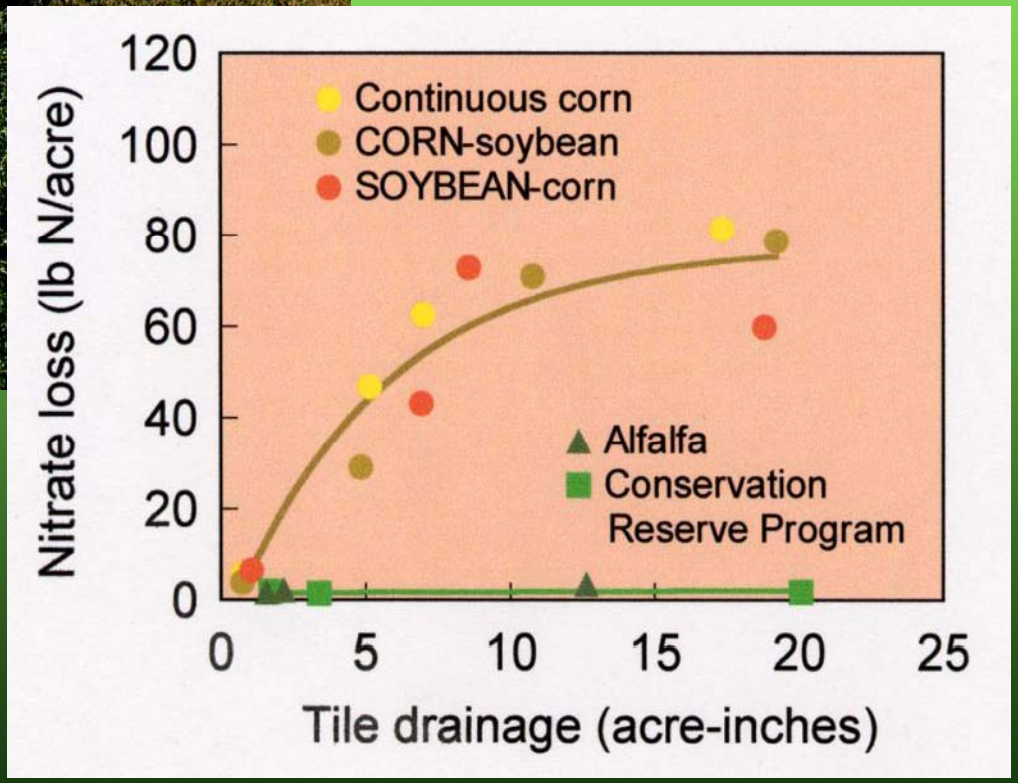

1
2
5
3
4
Corn grain
Bushels in 2006
Less than 1,800,000
1,800,000 to 13,999,999
14,000,000 to 29,999,999
30,000,000 +





But ground water contamination is more site specific

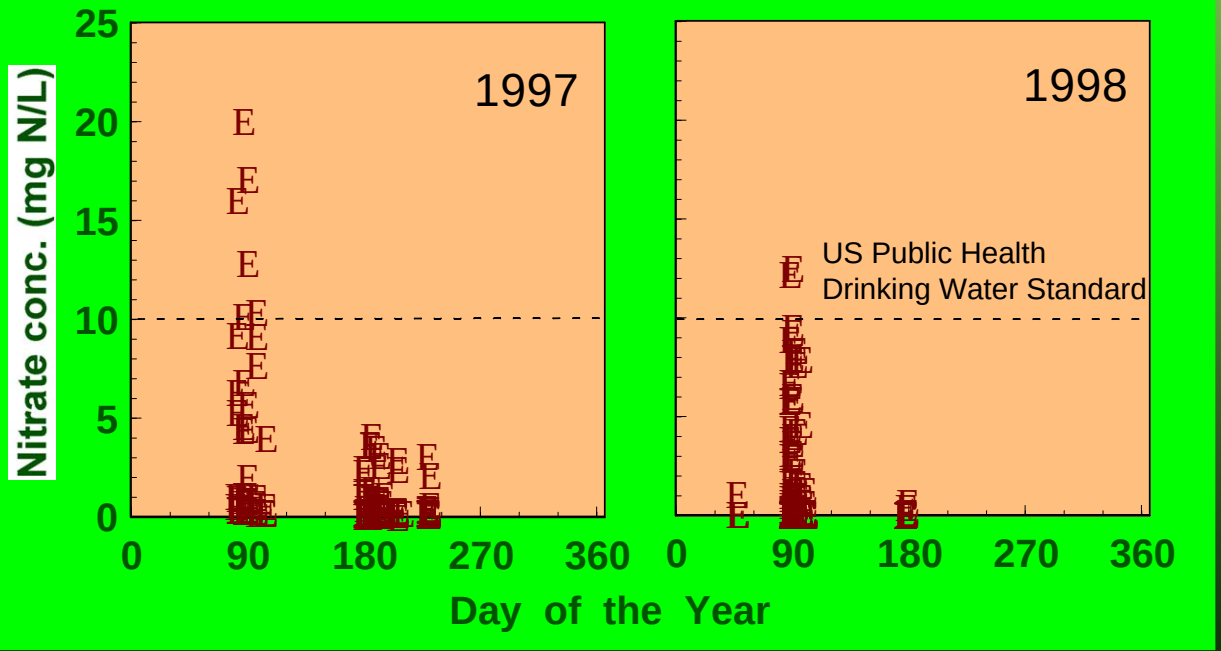




Randall et al., 1997, JEQ 26:1240

Even grazed sites can conserve nitrate

Species	Grazed	Mowed
	- - - - mg N/g soil - - - -	
BFT	17.0	3.4
RCG-BFT	7.4	1.8



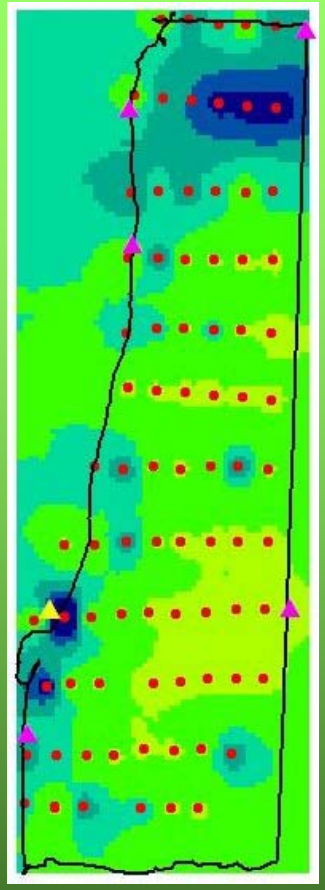
Nitrate leaching

Drainage < 5.7 a-in

NO_3 loss <1.5 lb N/a

Less than occurs in humid regions

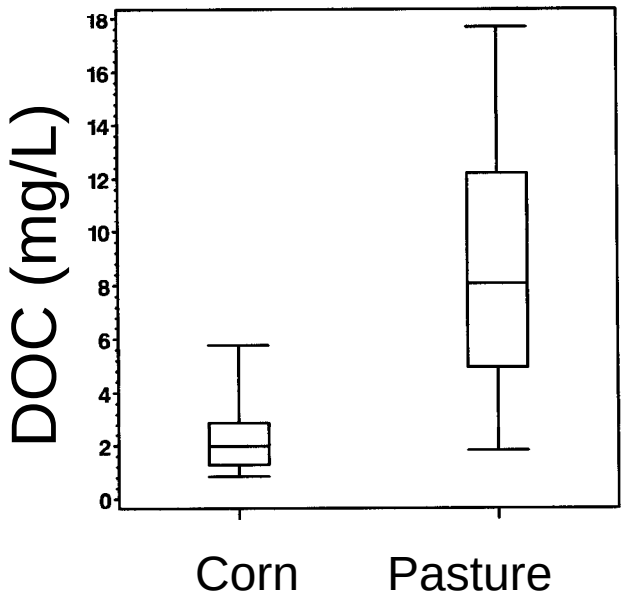
Groundwater analyses, 2002

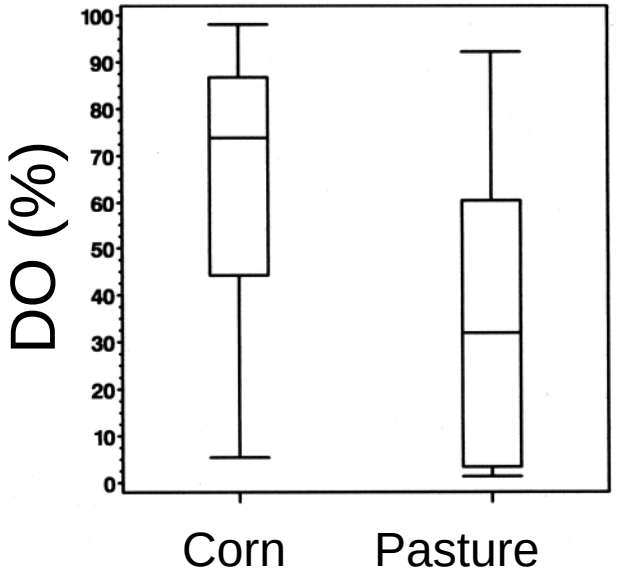


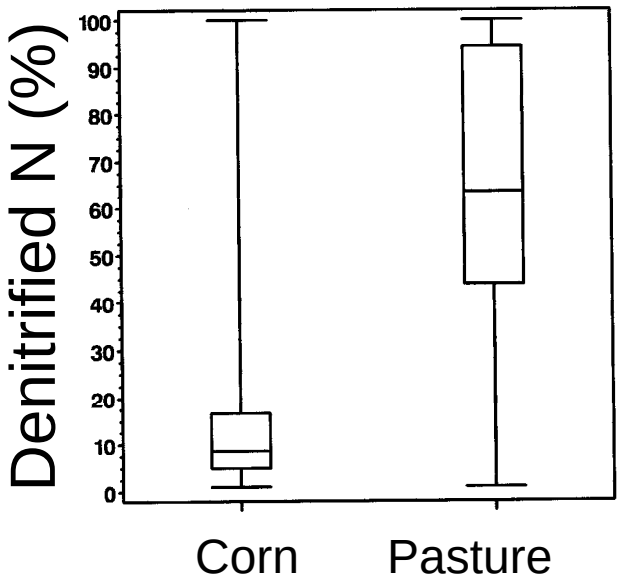
10 acres;

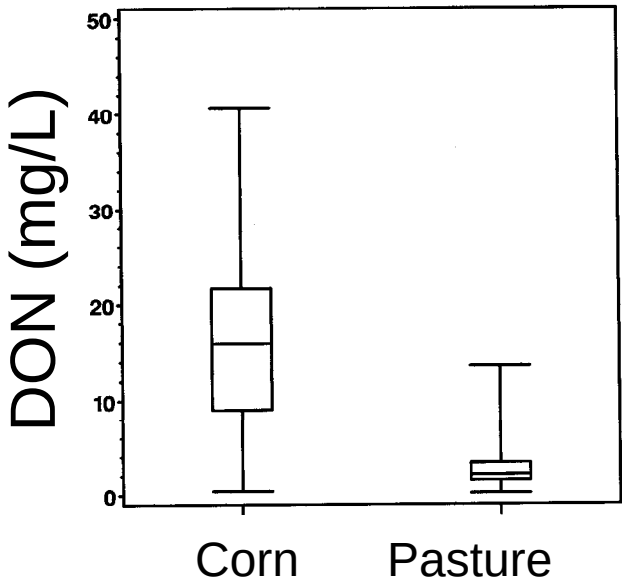
Dairy cows

Browne et al., 2002, unpublished data

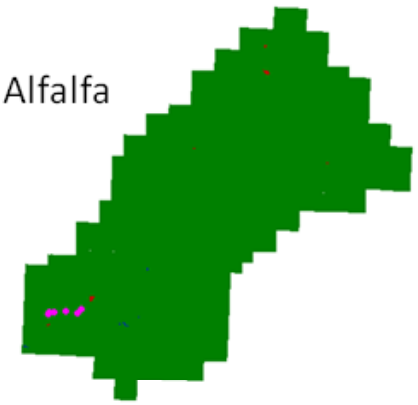


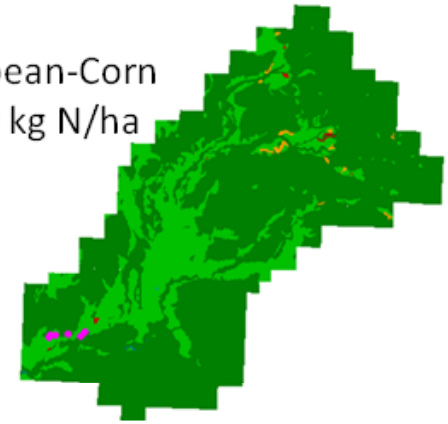


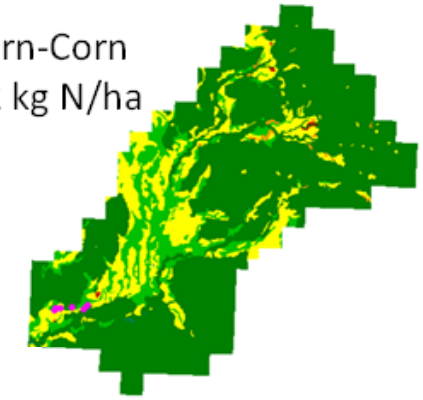


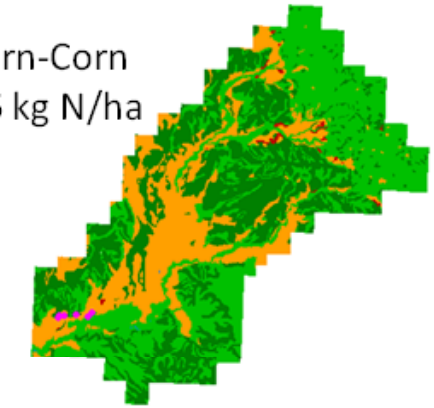


Predicted nitrate loss
Holland wellfield
no irrigation
GLEAMS

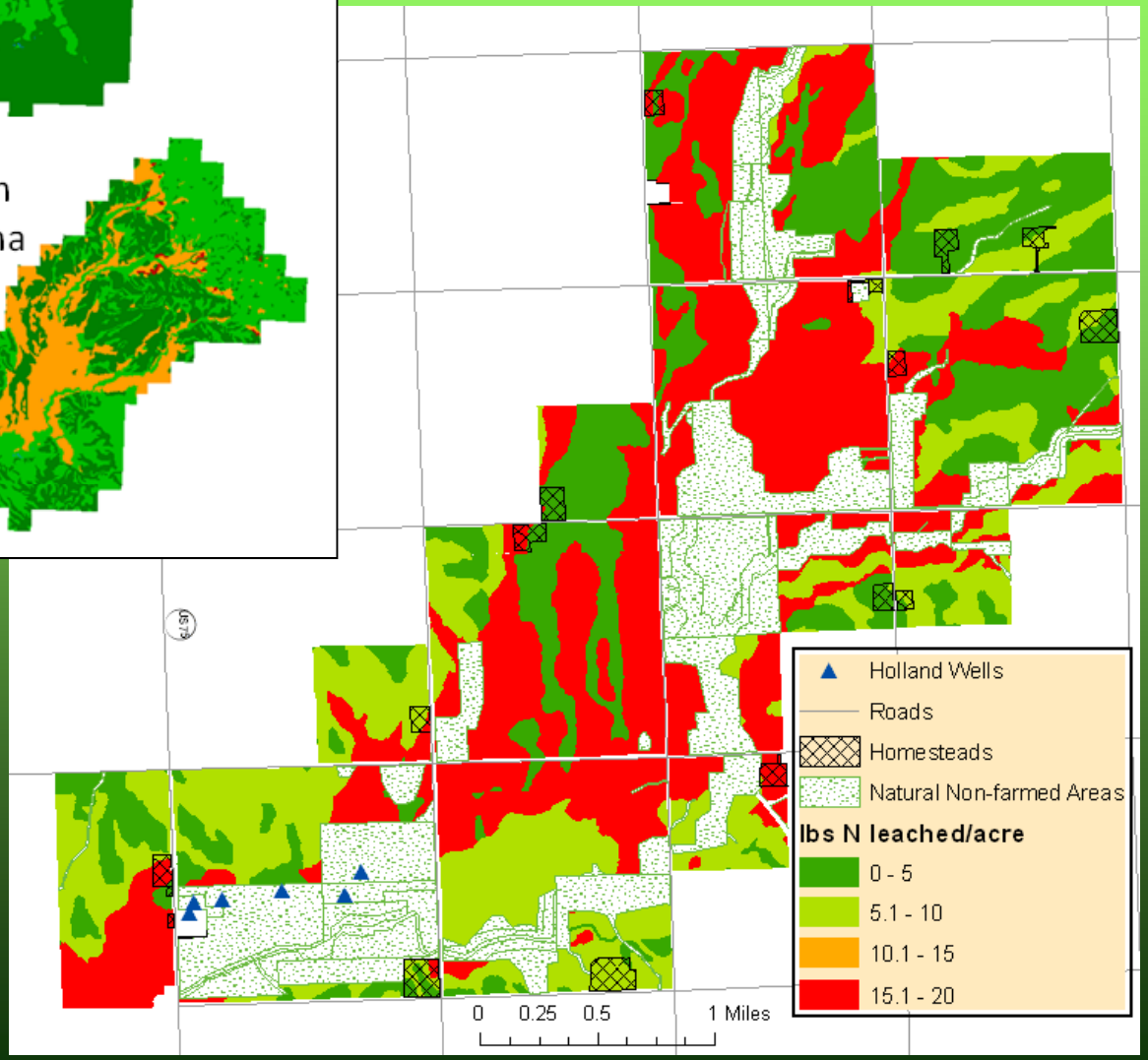






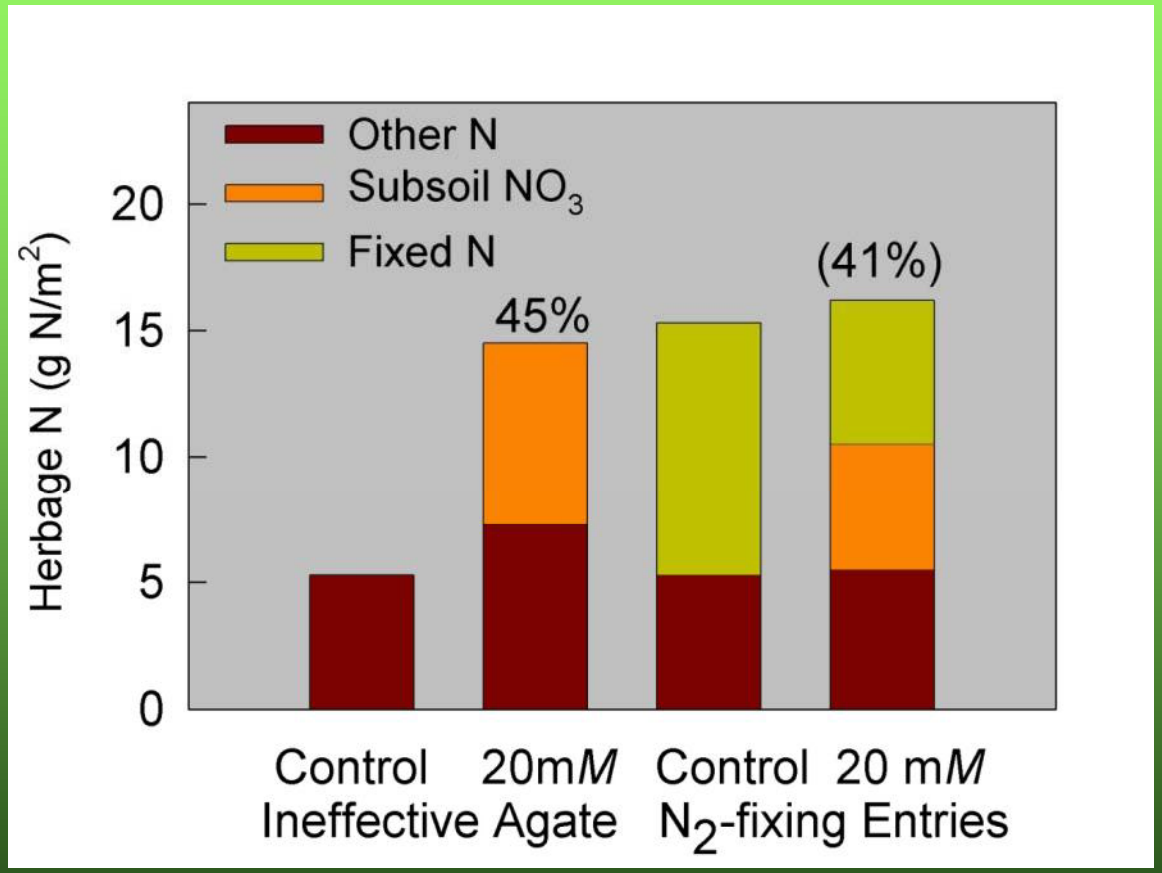


	lb N/a
Dark green	< 2
Light green	2-4
Yellow	4-8
Orange	8-16
Red	>16



Alfalfa absorbs N from the soil AND fixes N from the air

Subsoil fertigation of 8 alfalfas using ^{15}N-labeled nitrate



Non-fixing alfalfa removed more subsoil nitrate than normal alfalfa

Blumenthal et al., 1999, Agron. J. 91:269

Derailment site

NH_4 and NO_3 in soil and shallow ground water

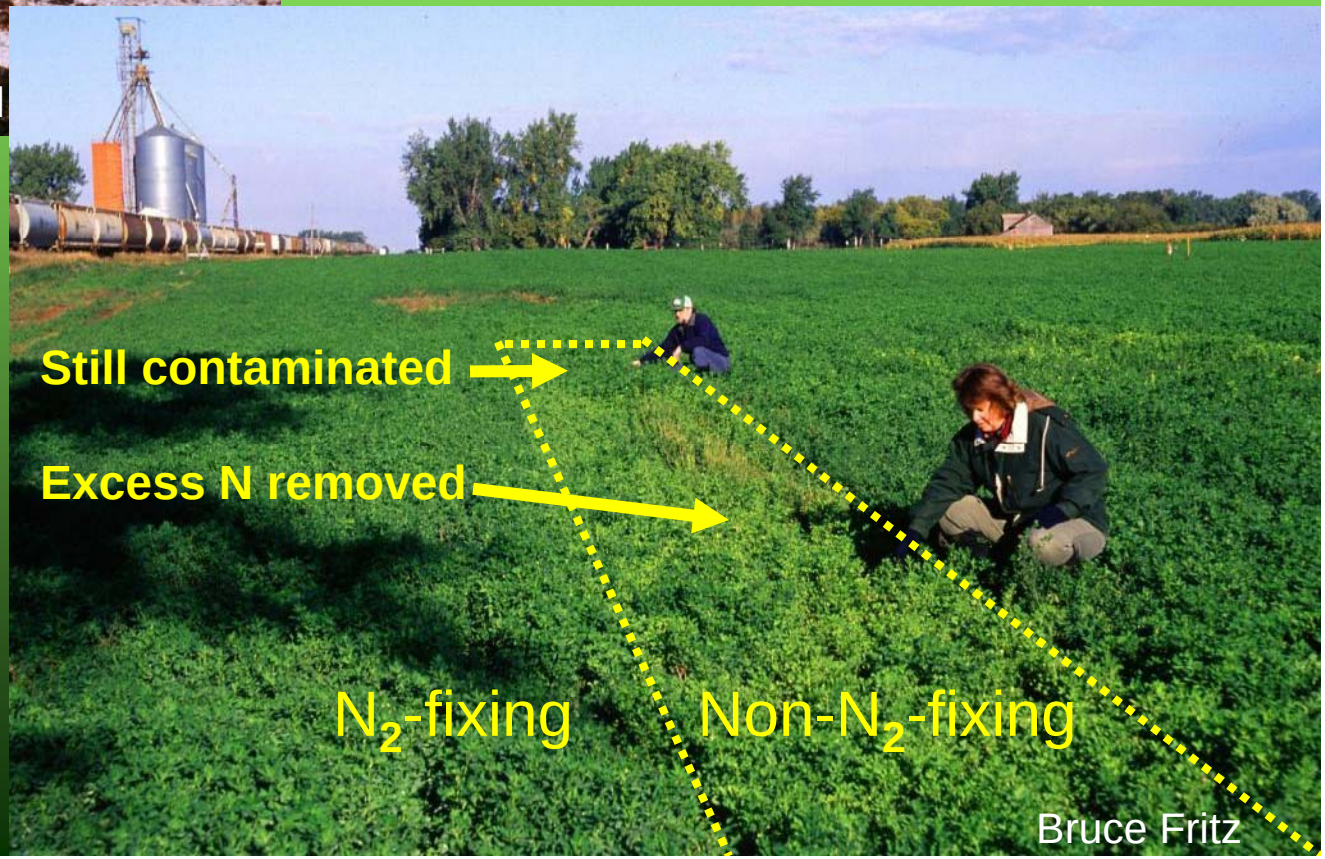
Not remediated after 7 years of various treatments.

CP Rail

Site remediated in 3 years with alfalfa.

Fixing and non-fixing equal

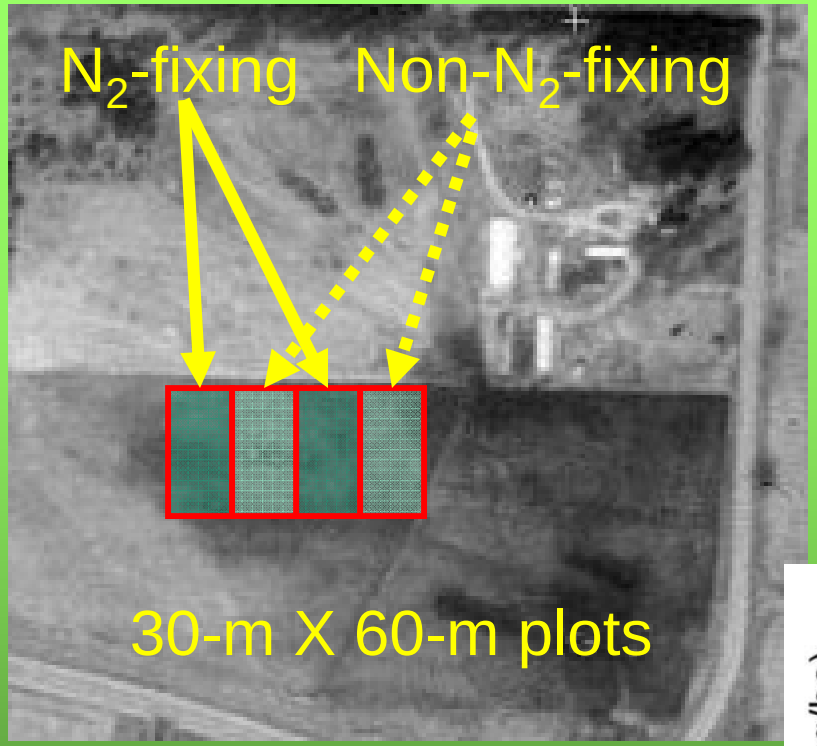
Russelle et al., 2001, JEQ 30:30

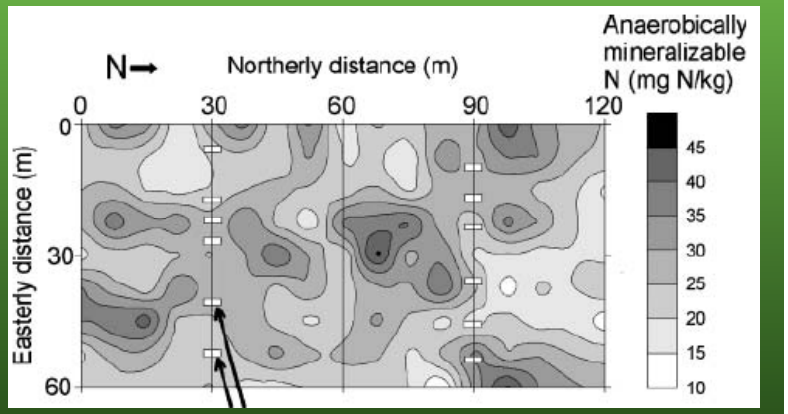


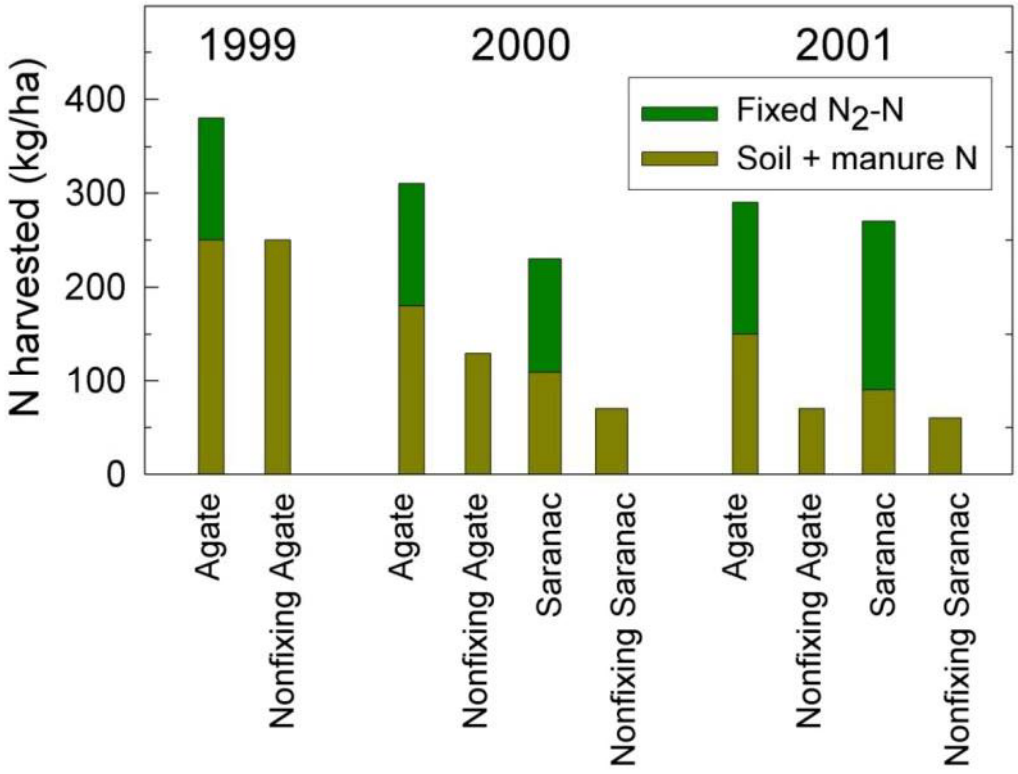
Bruce Fritz

Abandoned barnyard

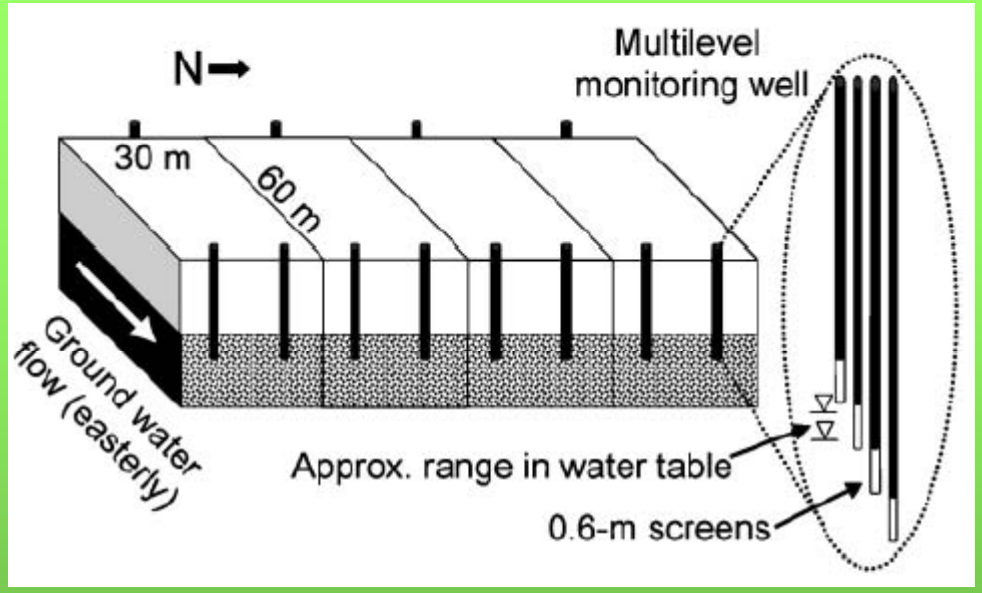
Variable manure buildup;
Sandy soil;
Ground water at 10 m

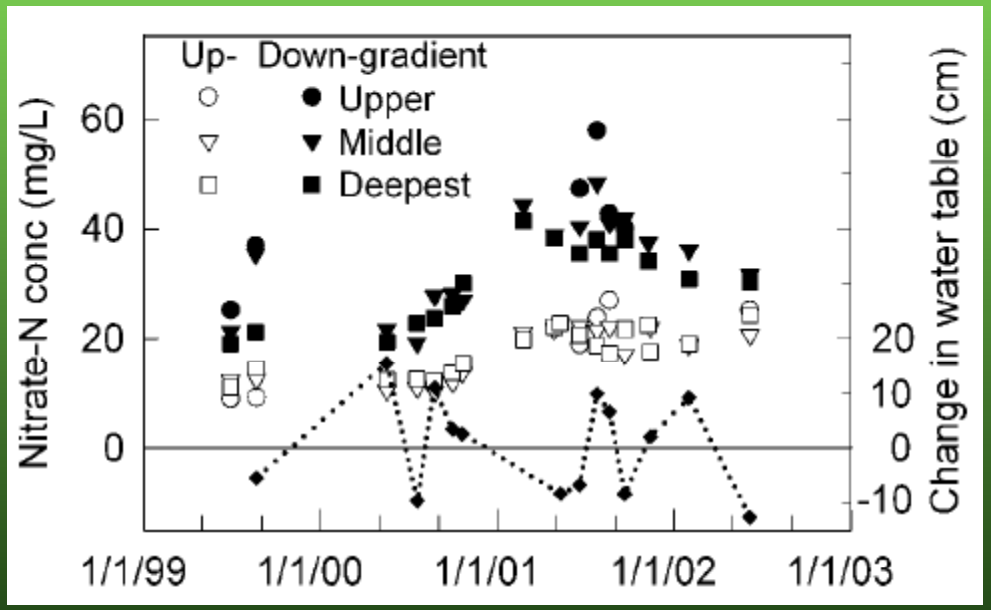






Russelle et al., 2007, Agron. J. 99:738





Use best adapted alfalfa for the conditions

Leaching risk remains — Sandy or shallow soils, humid or irrigated

Russelle et al., 2007, Agron. J. 99:738

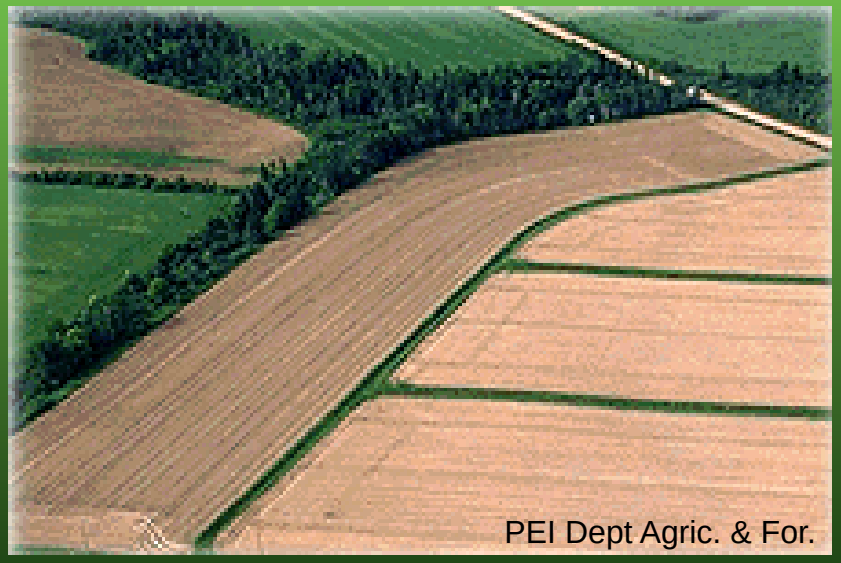
What about using grassed waterways?

Goal ~

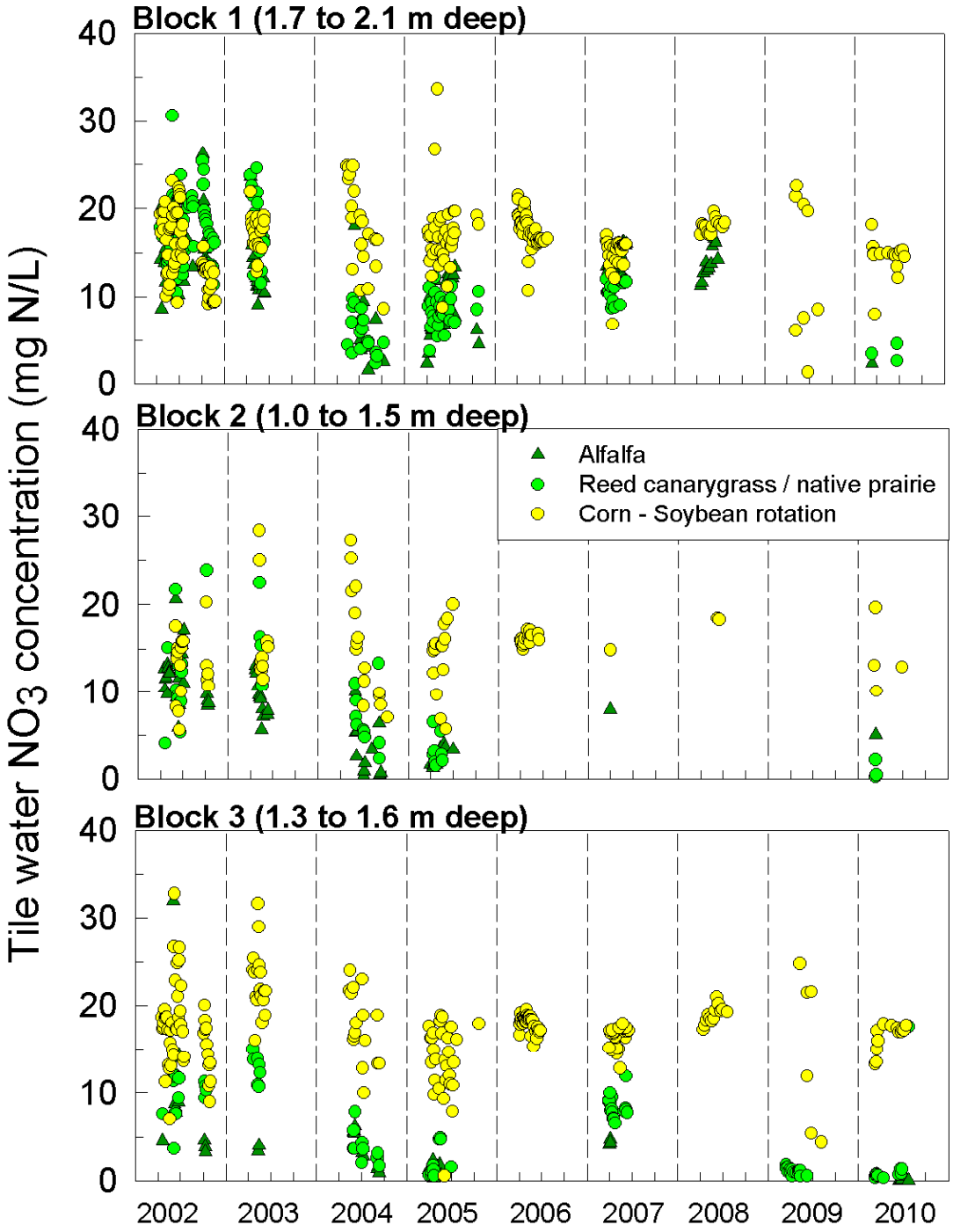
Improve drainage water quality and
minimize area removed from annual crop production

Random

Patterned



Relatively large plots
Established tiles
Variable tile depths
Easy access
Reliable assistance



Two experiments

Corn/soybean
Alfalfa
Reed canarygrass

Corn/soybean
Alfalfa-grass, biomass
12-species 'prairie'
biomass
burned

Nitrate concentrations

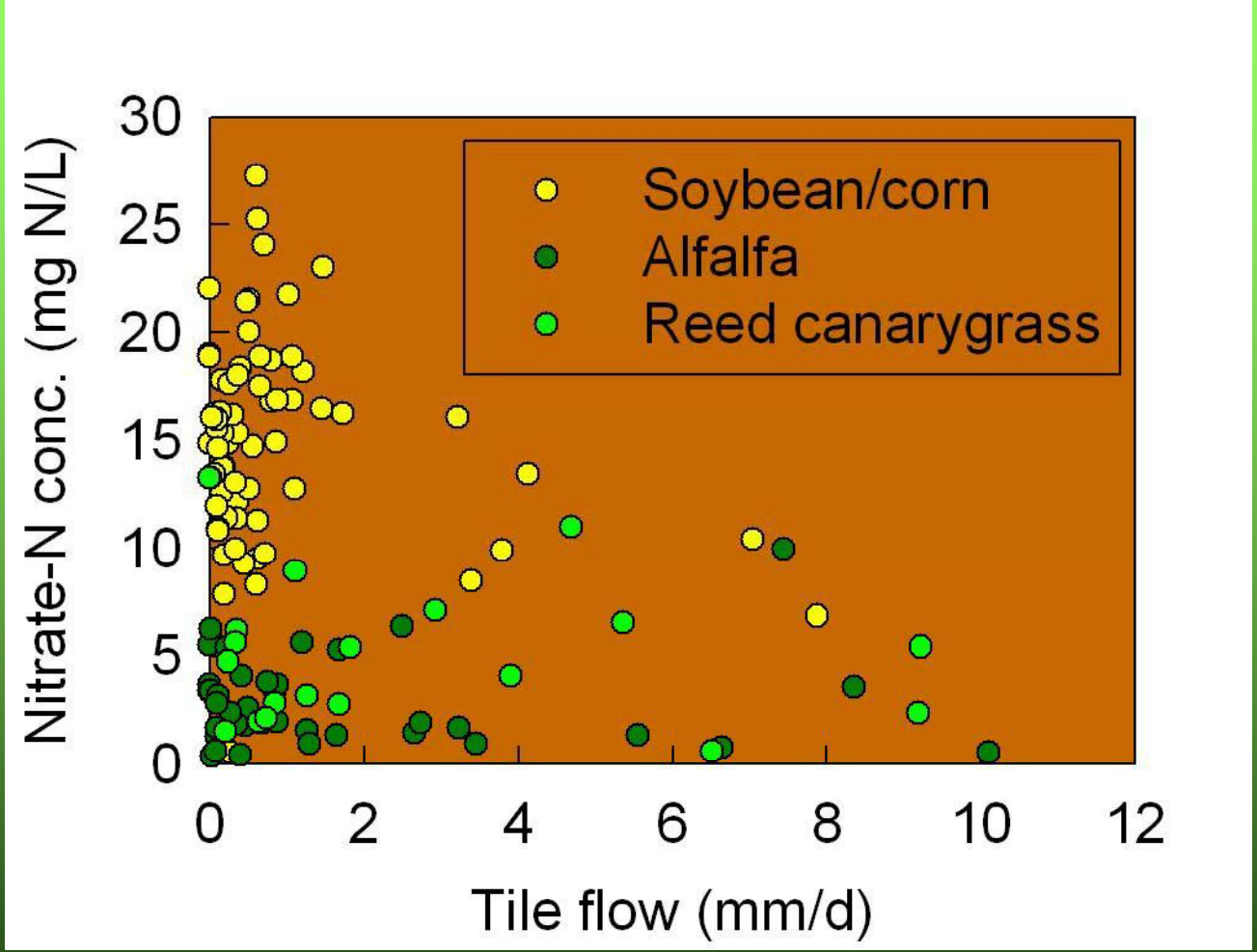
> Smaller after the strips were well established

> Smaller with shallower tile

> Higher for corn and soybean (14.8 mg N/L) than for the perennial strips (3.8 mg N/L) during 2004 and 2005.

Nitrate concentration not related to tile flow

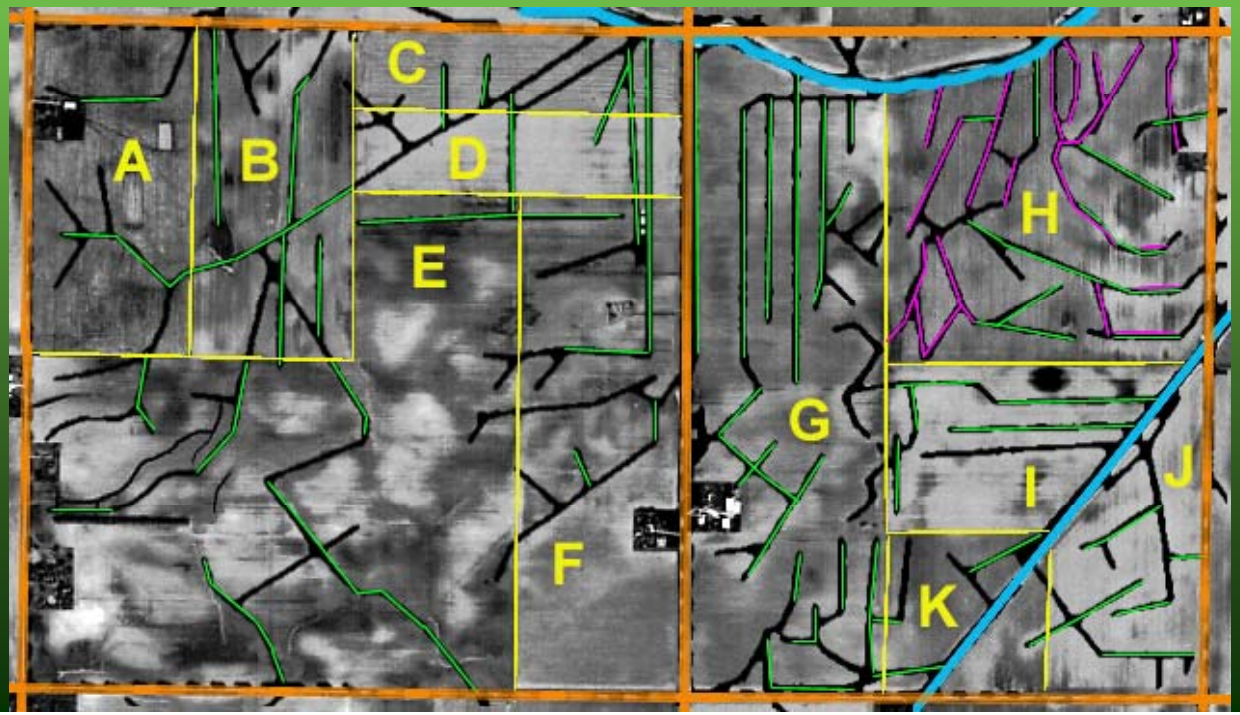
Established perennial strips maintained low concentrations



How many of these are needed?

Risky to conclude based on one set of conditions.
Assumed an overall reduction of NO_3-N loss by 2/3 with a 4.5-m-wide strip:

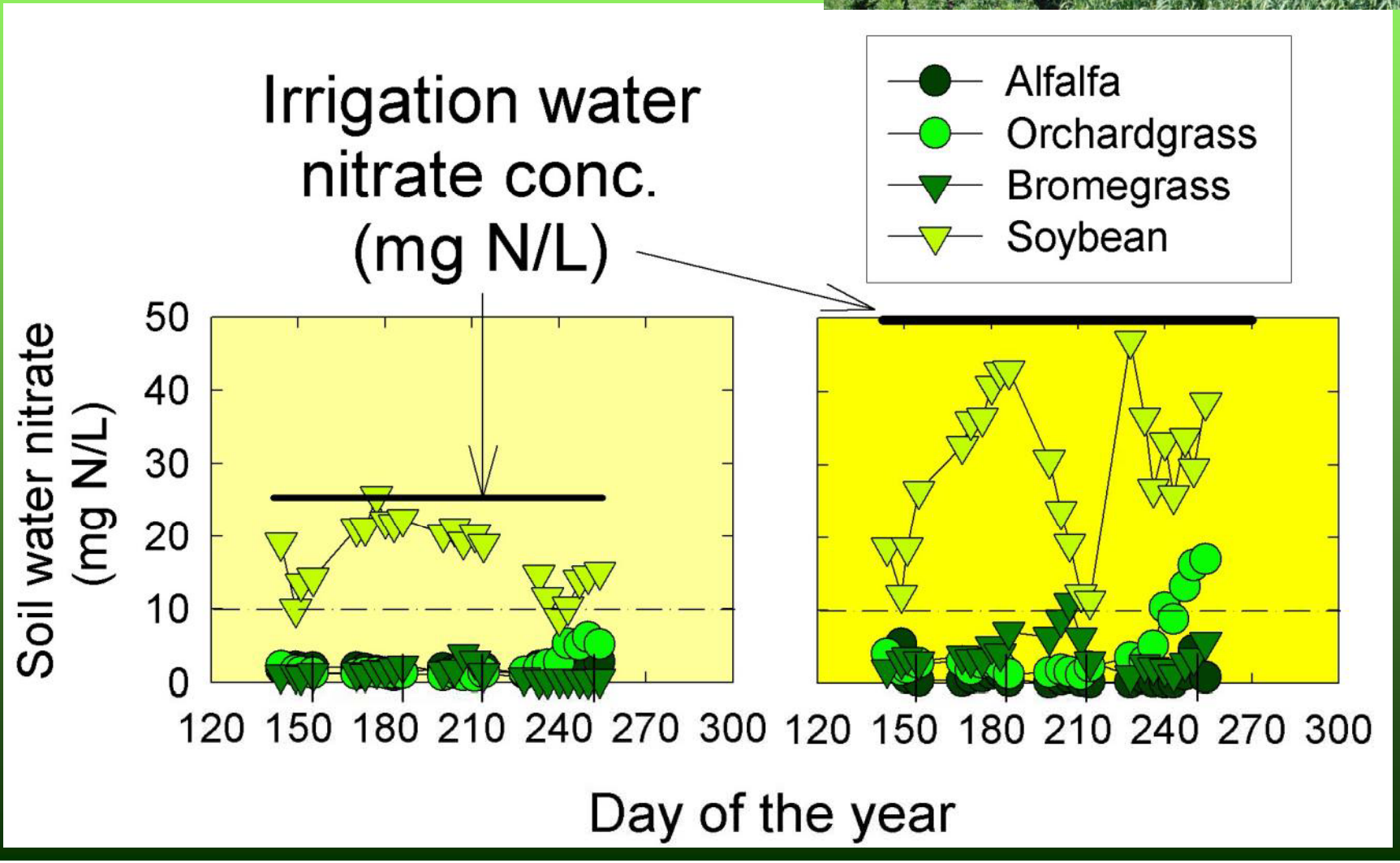
	Reduction		
	10	20	50%
	‘waterways’/tile		
1 random tile	1	1	1
Patterned tiles	0.2	0.4	1

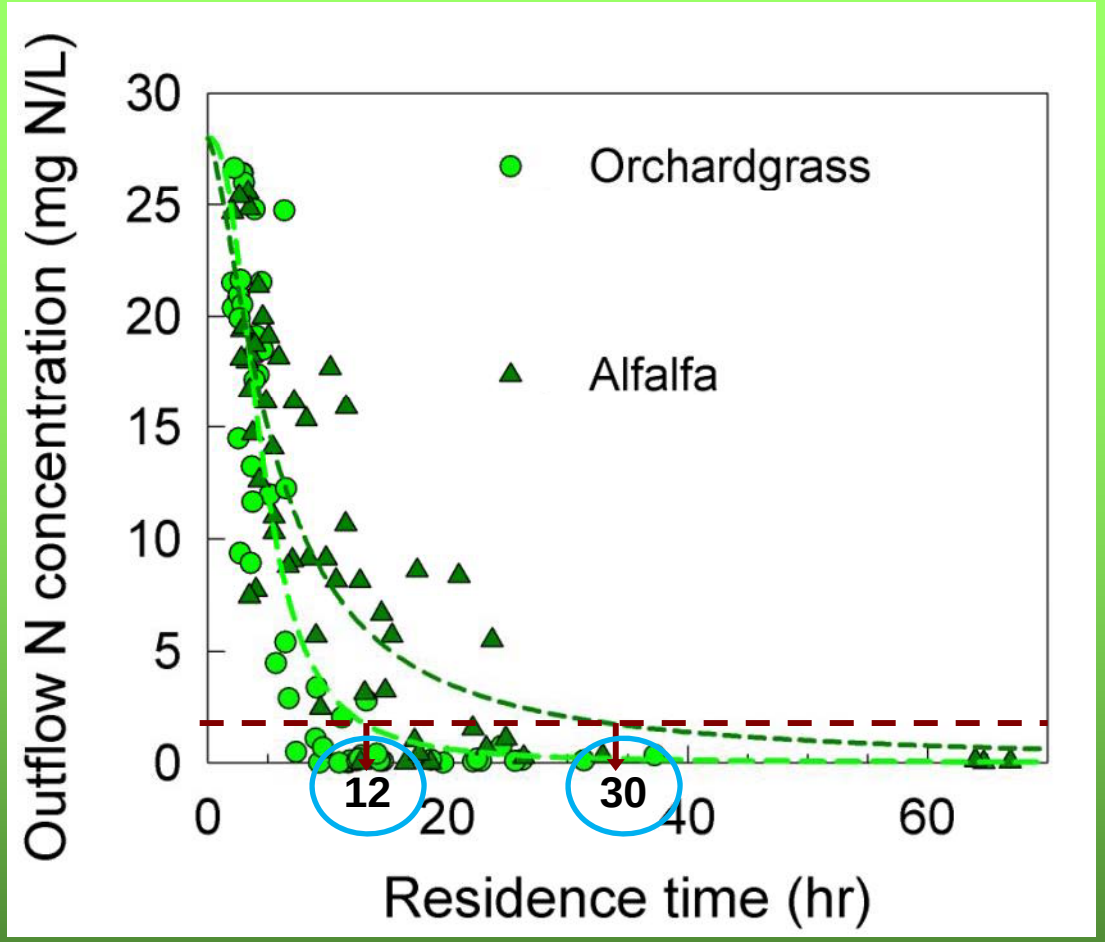


In this example, ***only 5% of the farmland would be required to achieve a 50% reduction in NO_3-N loss.***

Original tile map and aerial photo:
Richard Cooke, Univ. of IL

How far can we push this?





Optimal application rate in coarse sand

Alfalfa 0. 43 cm/hr (1/6 inch/hr)

Orchardgrass 0.95 cm/hr (1/3 inch/hr)

Kathy Bellrichard, 2005

Public drinking water well

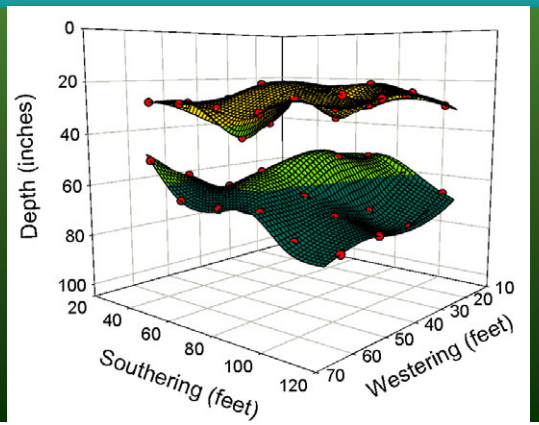
2 ppm

Clean water

20 ppm nitrate-N

Ground water flow

Not ready for prime time



Forages, OR State Univ.

Kathy Bellrichard
Donna Broberg
Lowell Busman
Prasanna Gowda
Tom Hoverstad
Gregg Johnson
David Kelley
Ryan Maher
Bruce Montgomery
John Nieber
Luz Quinoñes
Warren Rugger
Karena Schmidt
Craig Sheaffer
Danielle Then
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