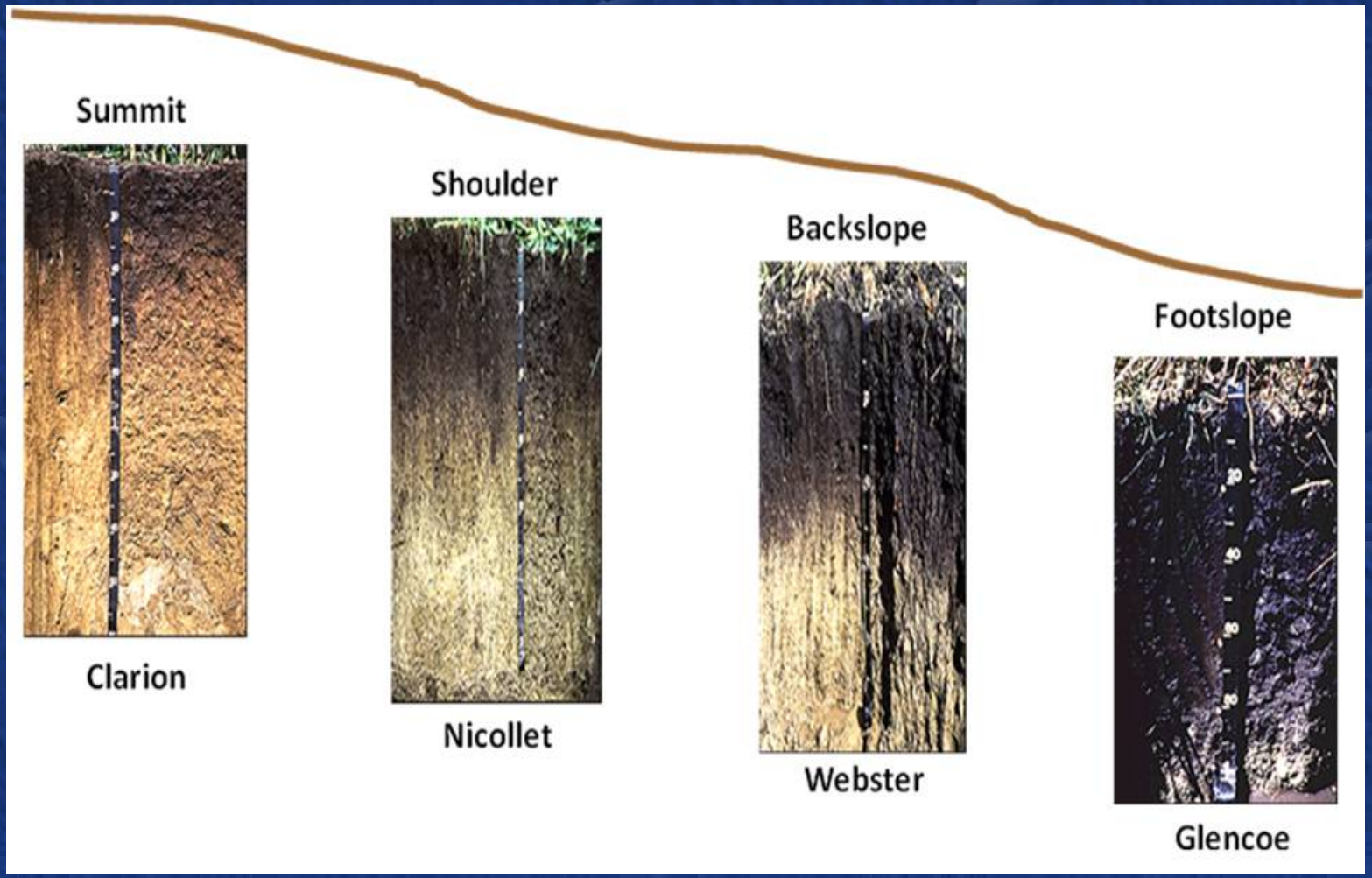
Water Quality in Organic Systems

Cynthia A. Cambardella, USDA-ARS-NLAE

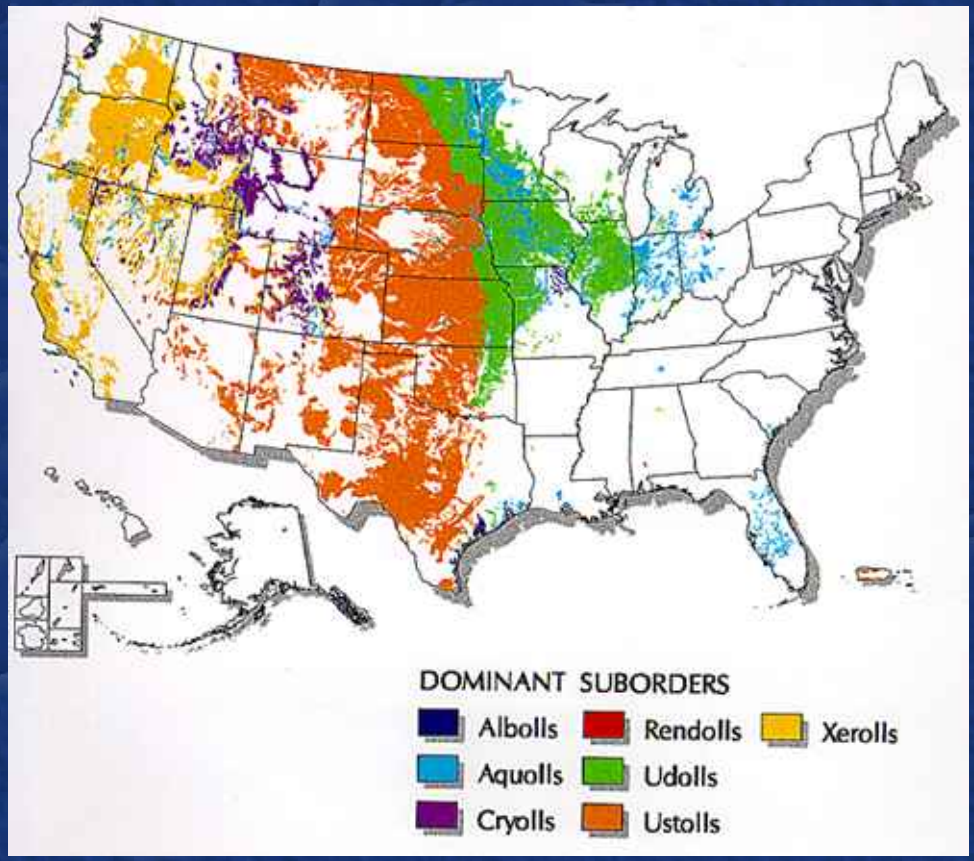
SOIL FORMATION occurs over geological time shaped by climate, parent material, topography, and vegetation

Most soils in Iowa formed in the past 10,000-14,000 years on parent material derived from glacial till and wind-blown loess



MOLLISOLS

Midwestern Mollisols: among the most productive soils in the world



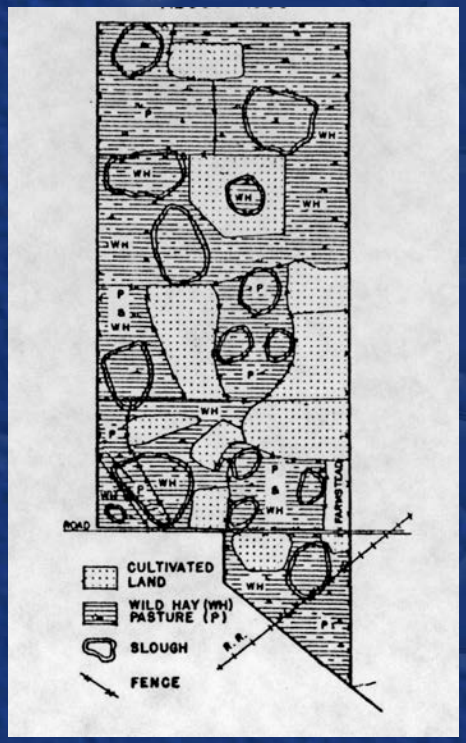
Tile Drainage

Subsurface tile drainage established 100 years ago created a direct conduit for leached chemicals to enter surface water

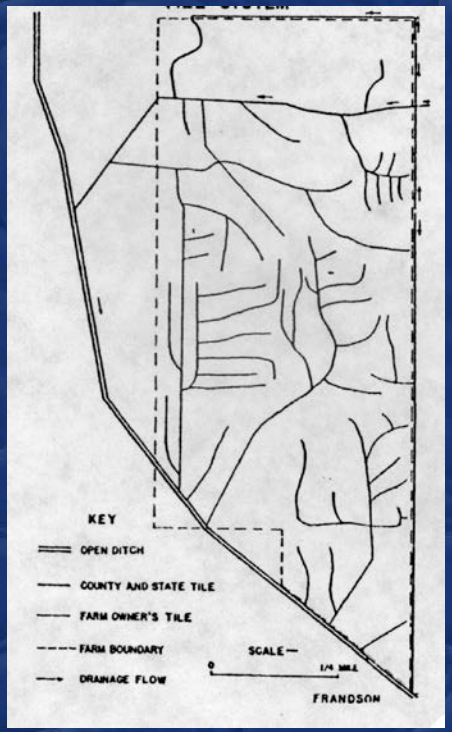
Hand digging tile, Boone Co. IA. ca 1914

Frandsen Farm, Story City, IA

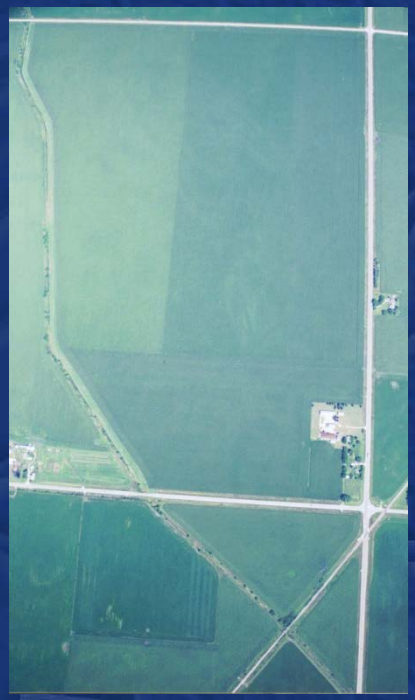
Pre-drainage (1900)



Drainage system



Row crop production



The new landscape functions very differently than the pre-drainage landscape mosaic, resulting in widespread contamination of surface water with agricultural chemicals

Nitrate N is primary contaminant of Iowa surface waters

April 2013 Des Moines Iowa
Nitrate concentrations of Des Moines River (18 ppm) and Raccoon River (24 ppm) were higher than drinking water standard (10 ppm)

Source areas of N to the Gulf of Mexico

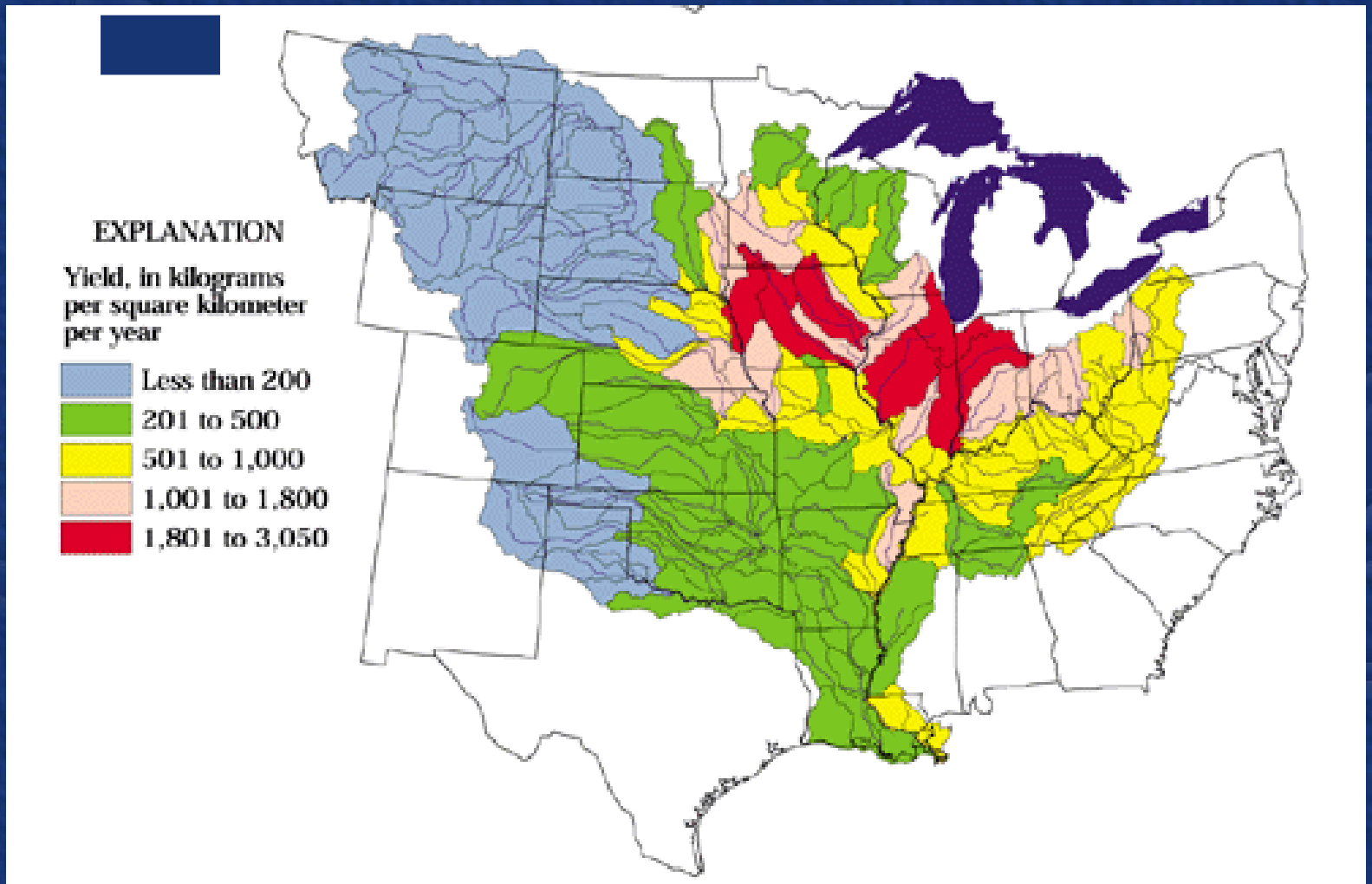


Figure 6. *(A)* Nitrogen inputs during 1992 and *(B)* average annual nitrogen yields of streams for 1980–96 (modified from Goolsby and others, 1999).

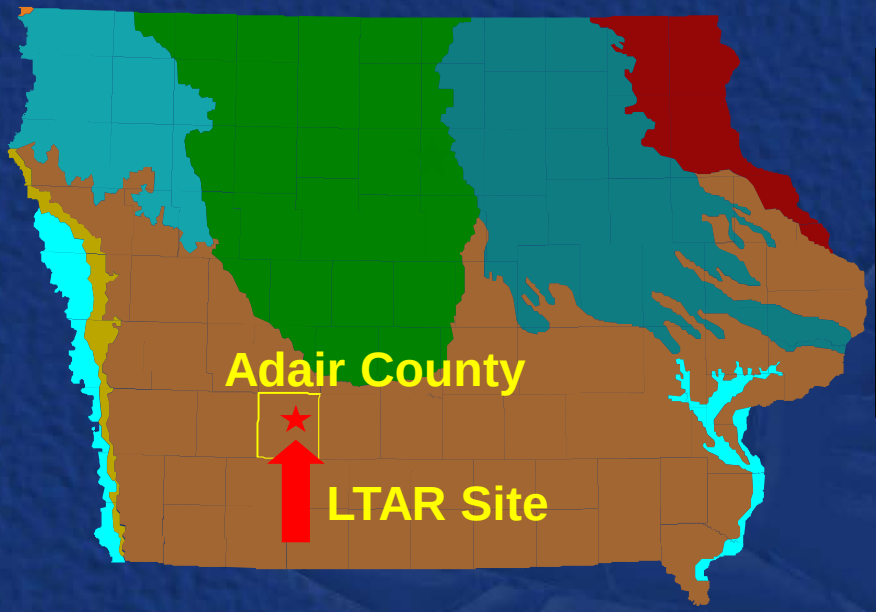
Gulf of Mexico – Zone of Hypoxia

Source: Nancy Rabalais,
Louisiana Universities Marine Consortium

Large-scale, widespread disruption of ecosystem function and loss of ecosystem services

Mississippi River plume meets Gulf of Mexico water at Southwest Pass, a primary shipping channel in Louisiana waters. (Photo by N. Rabelais courtesy USGS)

Long-Term Agroecological Research (LTAR) Site Neely-Kinyon Research Farm, Greenfield IA



Southern IA Drift Plain

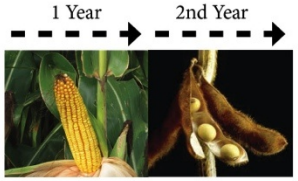
Started in 1998
Kathleen Delate, ISU, PI
Cindy Cambardella, ARS, co-PI

LEOPOLD CENTER
FOR SUSTAINABLE AGRICULTURE

Neely-Kinyon LTAR

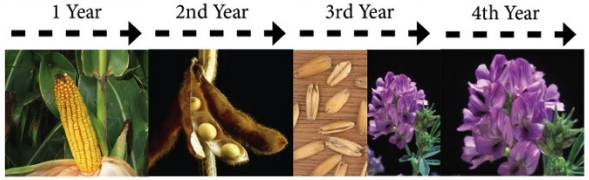
Treatments

8 Plots
Conventional C - SB

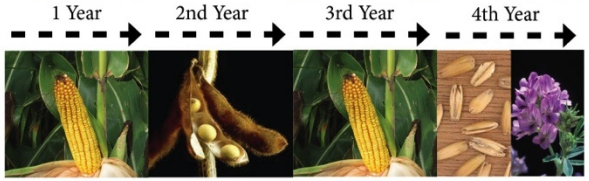


12 Plots
Organic C - SB - O/A

16 Plots
Organic C - SB - O/A - A

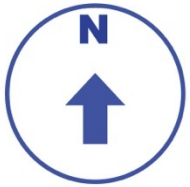


8 Plots
Organic C - SB - C - O/A
(changed from SB-W/RC in 2010)

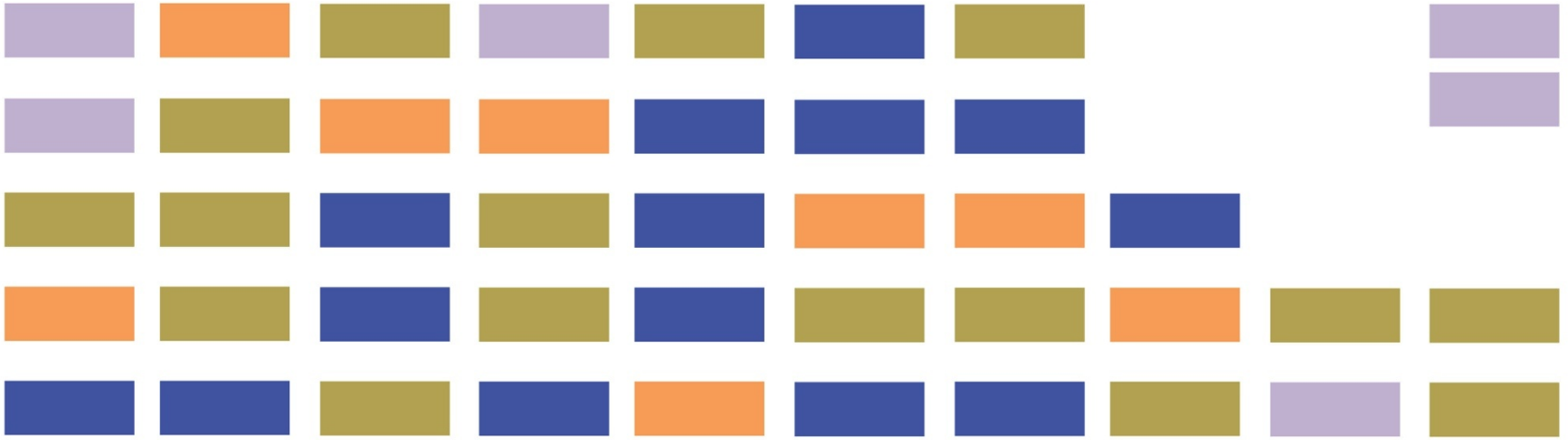


-44 plots total
-4 reps of each crop in each treatment
-70' x 140' plots
-30' borders in each direction
-Completely randomized design based on uniform slope and soil type

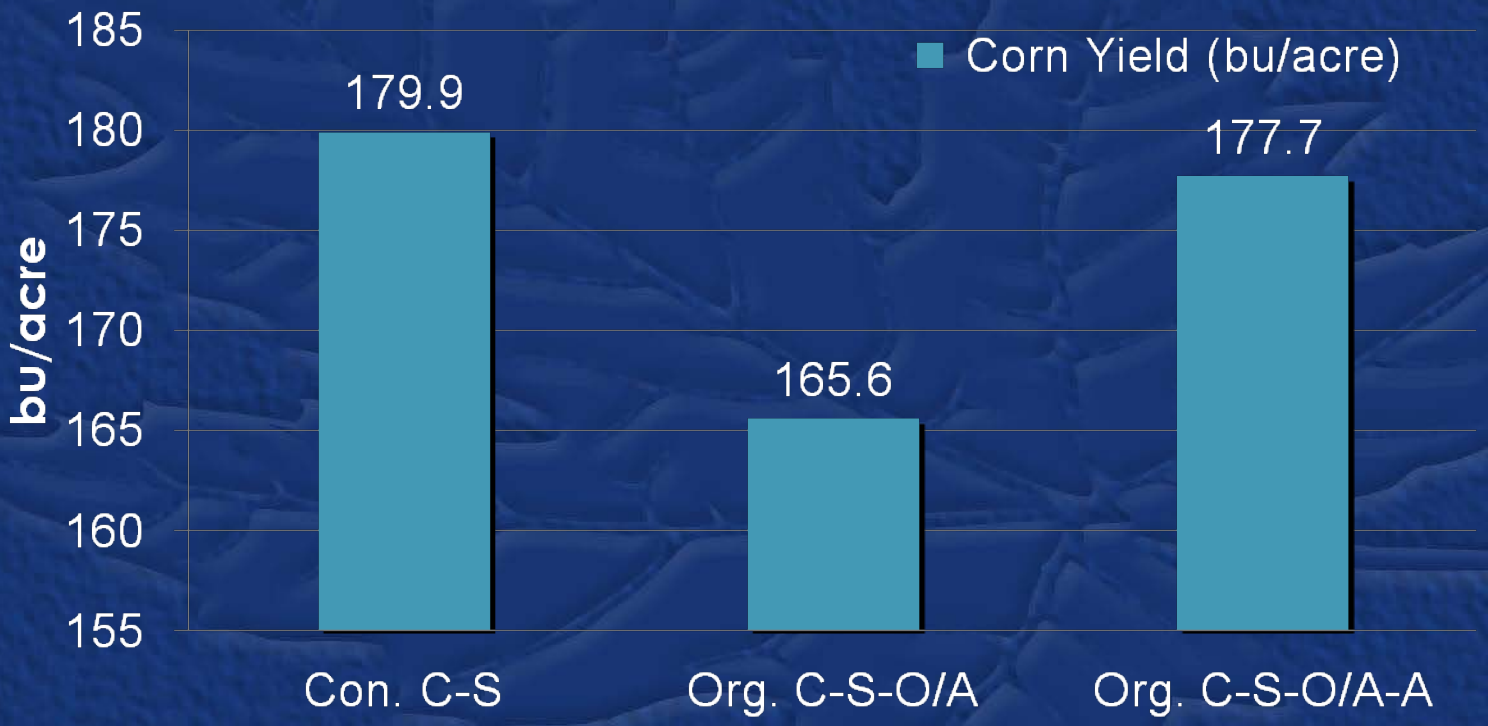
Soil cores in fall every year after harvest from each plot to a depth of 15 cm



Plot Plan

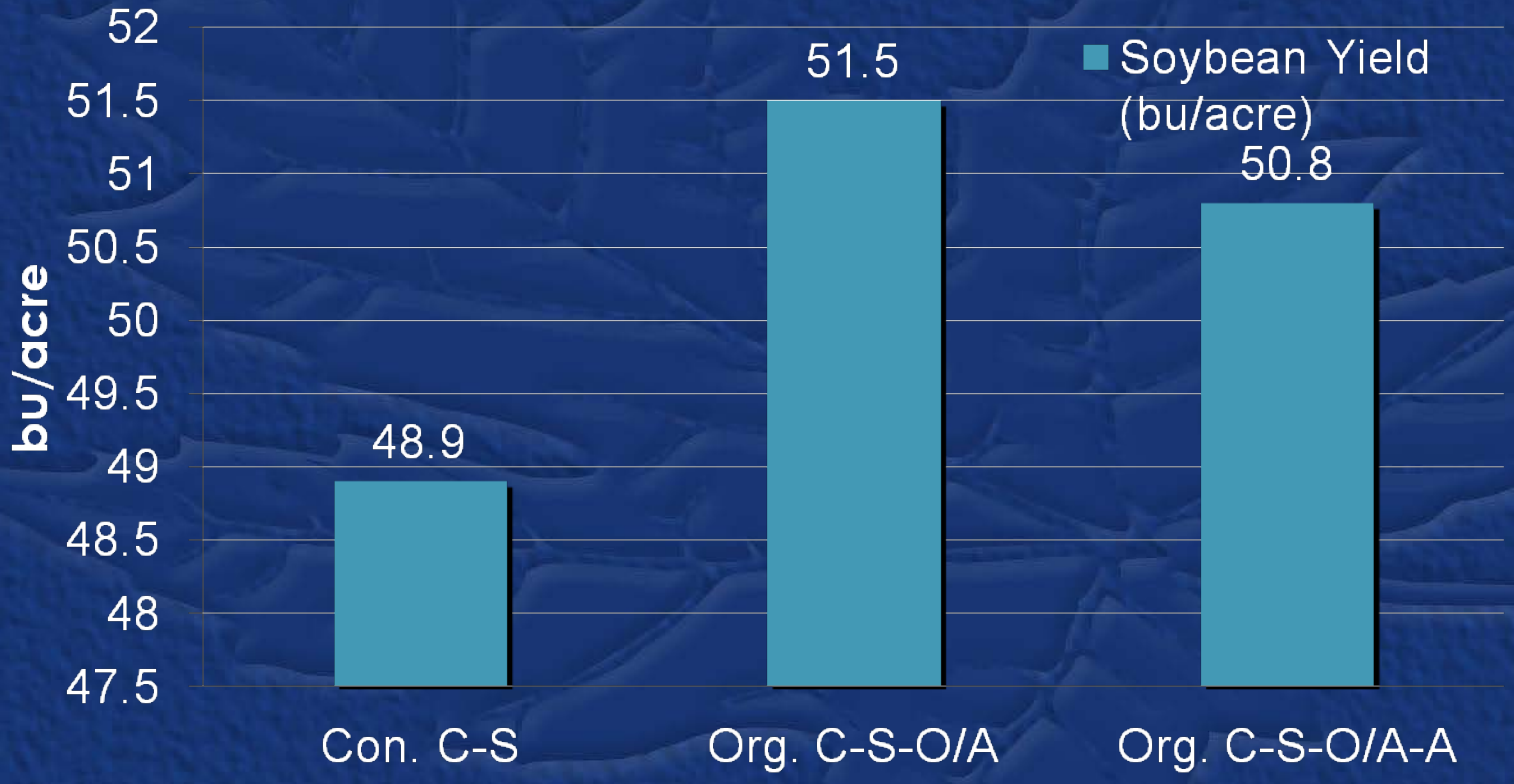


Average Corn Yields LTAR-2002-2010



- Corn yields at 15.5% moisture
- NSD, but trend toward higher organic yields with 2 yr of alfalfa

Average Soybean Yields LTAR–2002-2010



- Soybean at 13% moisture

NSD, but trend toward higher yields in organic

Fall 2010	Organic	Conventional
SOC (g/kg)*	25.5a	23.7b
TN (g/kg)	2.5a	2.3b
POMC (g/kg)	3.6a	3.2a
MBC (mg/kg)	358a	321b
PotMinN (mg/kg)	53a	39b
InorgN (mg/kg)	8.2a	10.5a
Macroaggs (%)	32a	29a

*** Depth 0-15 cm**

Means followed by same letter within a row are not different at 95%

Fall 2010	Organic	Conventional
pH*	6.5a	6.0b
Bray P (mg/kg)	45a	19b
K (mg/kg)	292a	212b
Mg (mg/kg)	410a	358b
Ca (mg/kg)	3755a	3377b
EC (µS/cm)	212a	176b
BD (g/cm3)	1.25a	1.24a

*** Depth 0- 15 cm**

Means followed by same letter within a row are not different at 95%

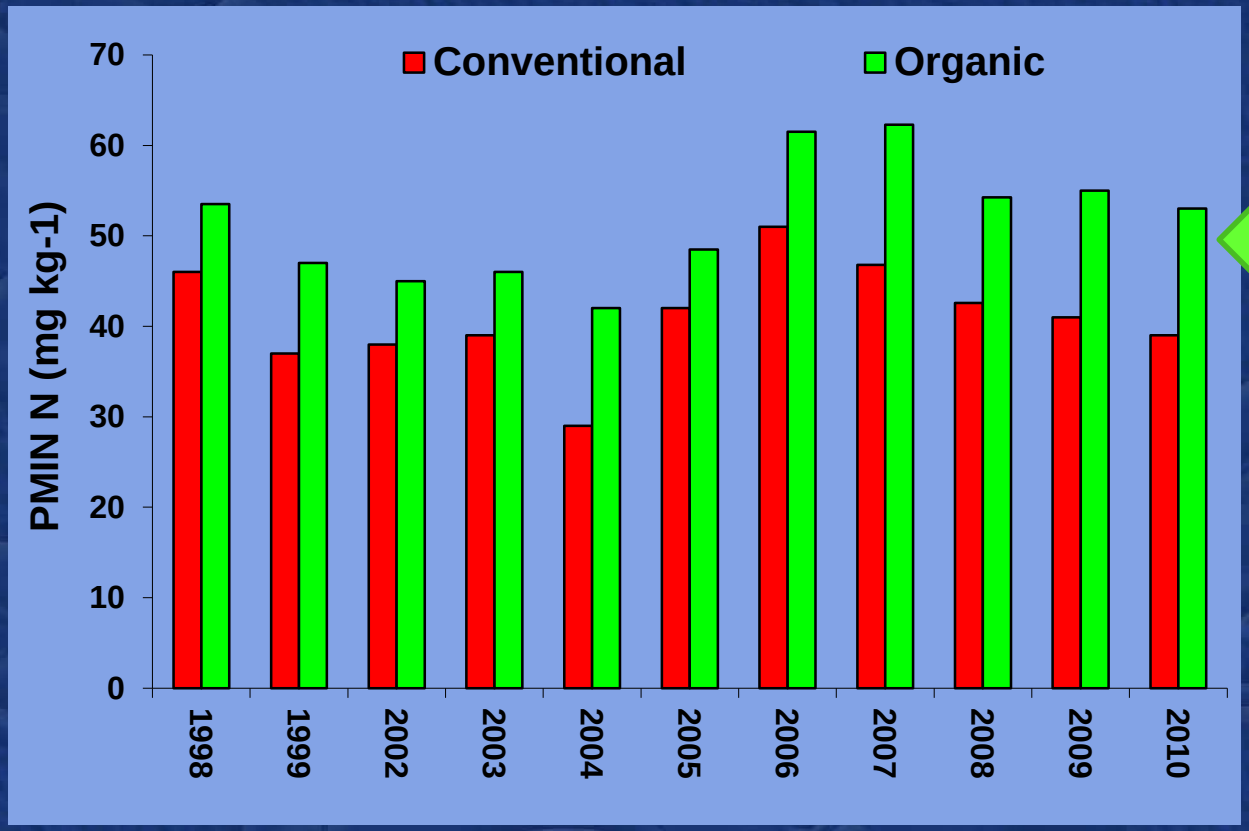
Soil Health Improvement
Organic Management

Organic soils had

- **> total soil C & N**
- **> biologically active soil C and N**
- **> plant nutrients (P,K,Mg)**
- **< soil acidity**
- **= aggregate stability**
- **= bulk density**

than conventional soils.

LTAR N Mineralization Potential



36% more biologically active N in organic surface soil in fall 2010

What if…..

Adopting organic farming practices could help reduce N loss to surface water??

Pros: extended rotations, small grains, cover crops, no fertilizer N

Cons: tillage, cultivation, animal manure

IOWA NUTRIENT REDUCTION STRATEGY

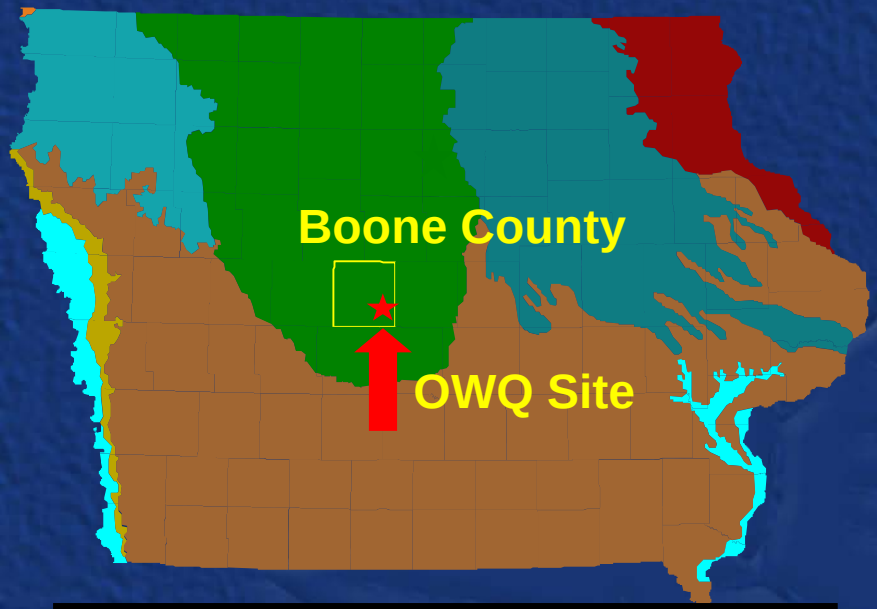
A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico

May 2013

Iowa Department of Agriculture and Land Stewardship
Iowa Department of Natural Resources
Iowa State University College of Agriculture and Life Sciences

Plant extended rotations and diversify landscape

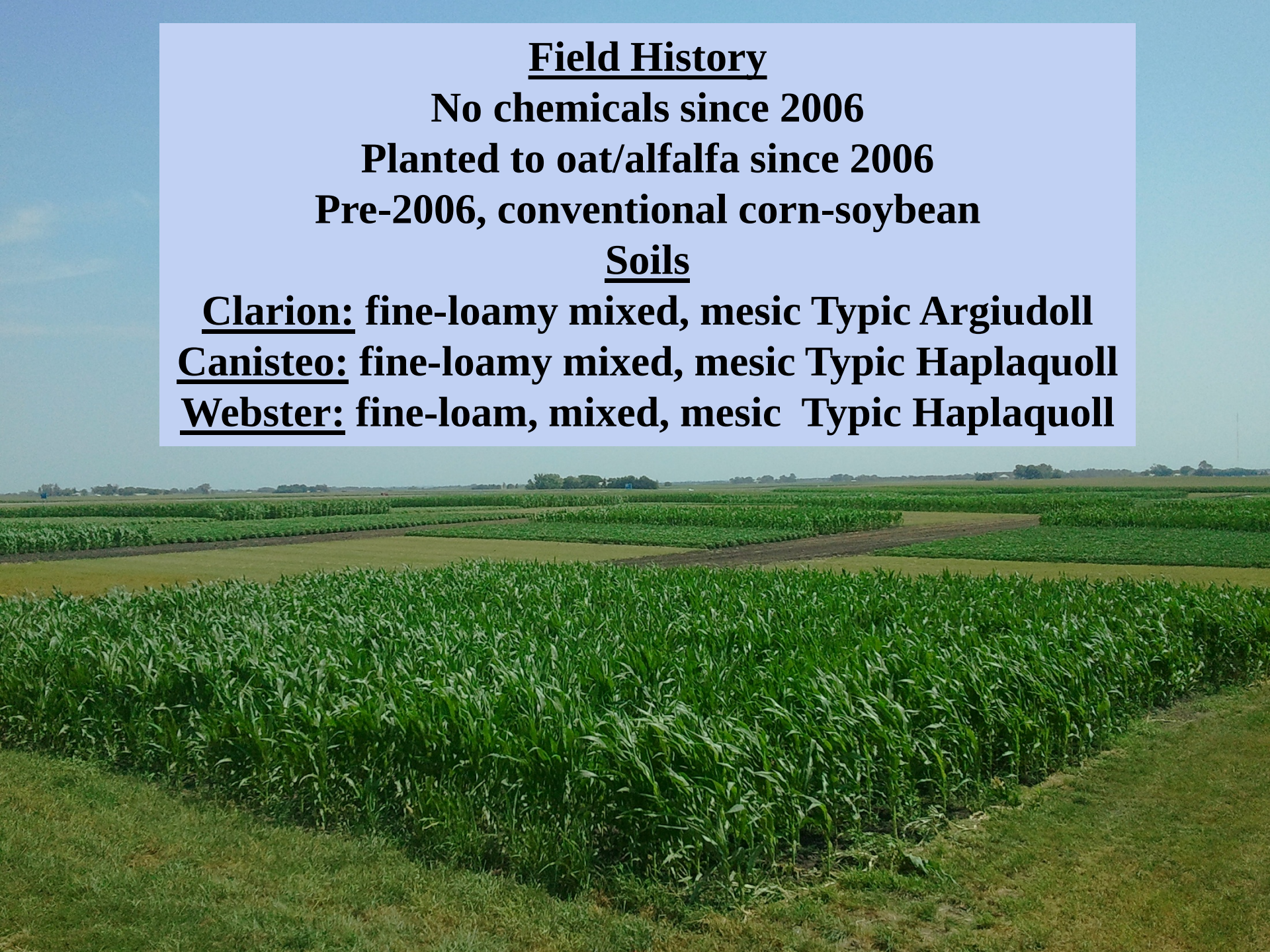
Retain residue, reduce tillage, cover crops



Des Moines Lobe

Organic Water Quality Research (OWQ) Site ISU Ag Engineering and Agronomy Research Farm Boone IA

Started in 2012
Cindy Cambardella, ARS, PI
Kathleen Delate, ISU, co-PI



Field History

No chemicals since 2006

Planted to oat/alfalfa since 2006

Pre-2006, conventional corn-soybean

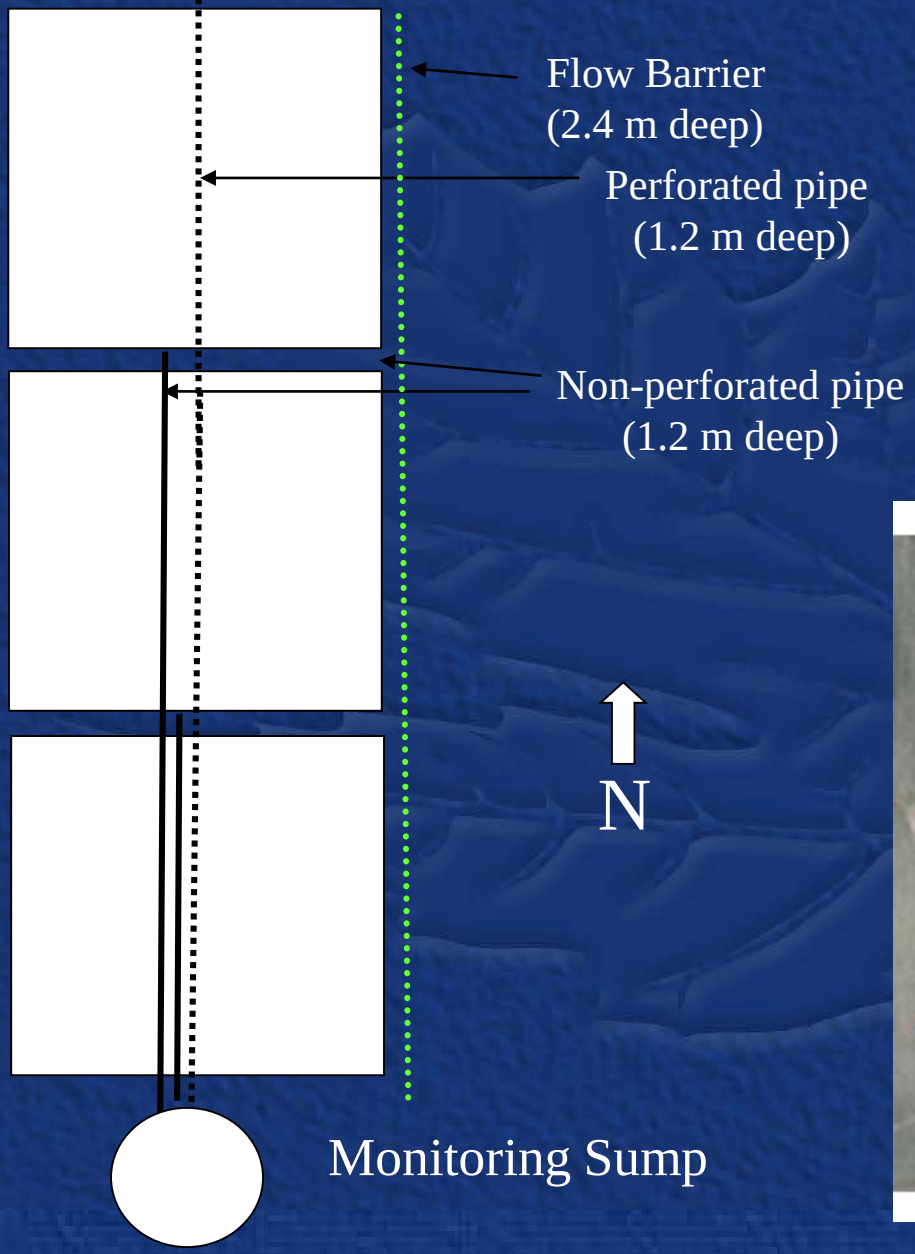
Soils

Clarion: fine-loamy mixed, mesic Typic Argiudoll

Canisteo: fine-loamy mixed, mesic Typic Haplaquoll

Webster: fine-loam, mixed, mesic Typic Haplaquoll

30 Plots (30.5m x 30.5m)

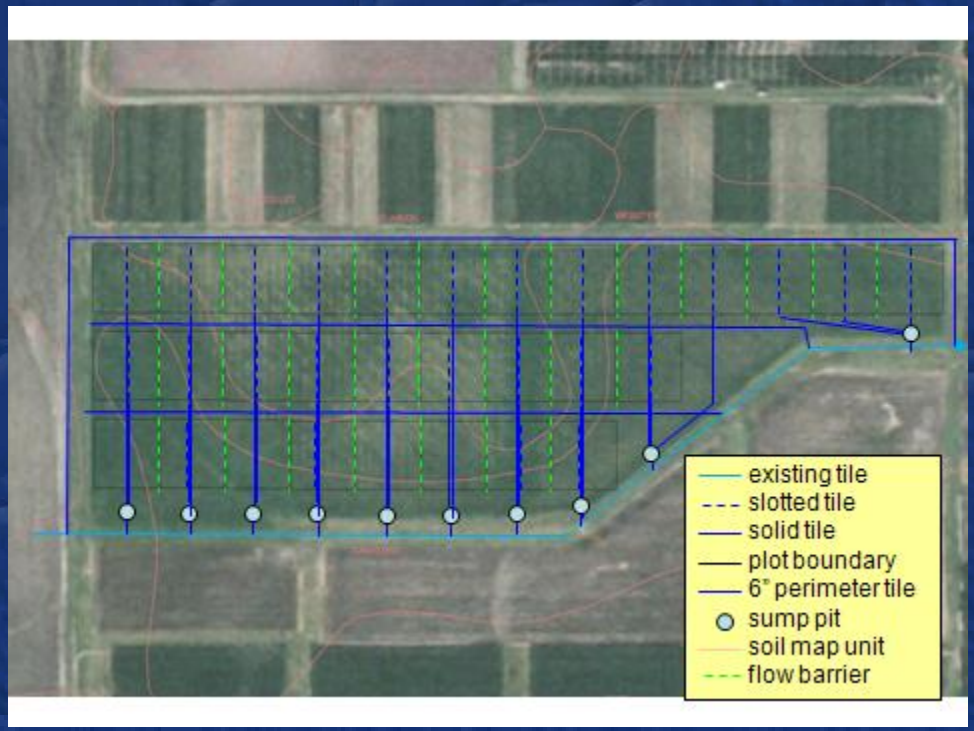


Isolate drainage from each plot

Perimeter tile drain (0.15m diam) around entire field

Tile drain (0.08 m diam) at N and S end of each plot

Plastic flow barrier at E and W end of each plot












Cropping Systems

Organic C-S-O/A-A

Organic pasture/hay

(alfalfa, fescue, timothy, orchard grass)

Conventional C-S

Randomized block design

5 replicates per system

Continuous tile flow monitoring

Tile water quality samples collected weekly

Fertility

Dairy compost before organic corn (170 kgN/ha) and oats (57 kgN/ha)

28%UAN before conventional corn; side dress (170 kgN/ha)

Weather station on site with continuous monitoring

Weed Management

Spring chisel plow/disk

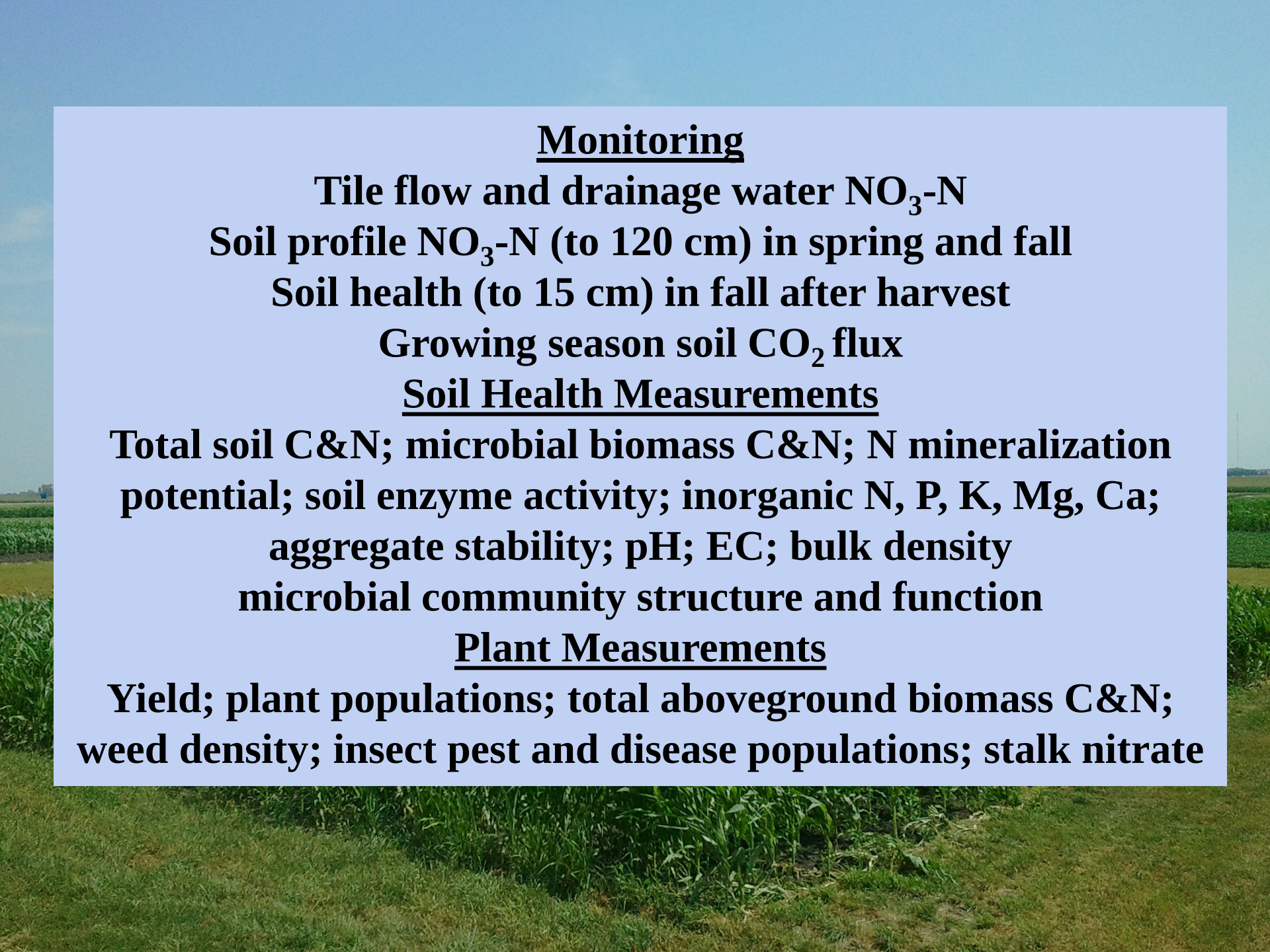
Rotary hoe and cultivator ~3X

Walk soybean every other week

Herbicide in conventional

Prefix®, soybean; Lumax®, corn

Soil CO_2 flux every other week during growing season



Monitoring

Tile flow and drainage water NO_3-N

Soil profile NO_3-N (to 120 cm) in spring and fall

Soil health (to 15 cm) in fall after harvest

Growing season soil CO_2 flux

Soil Health Measurements

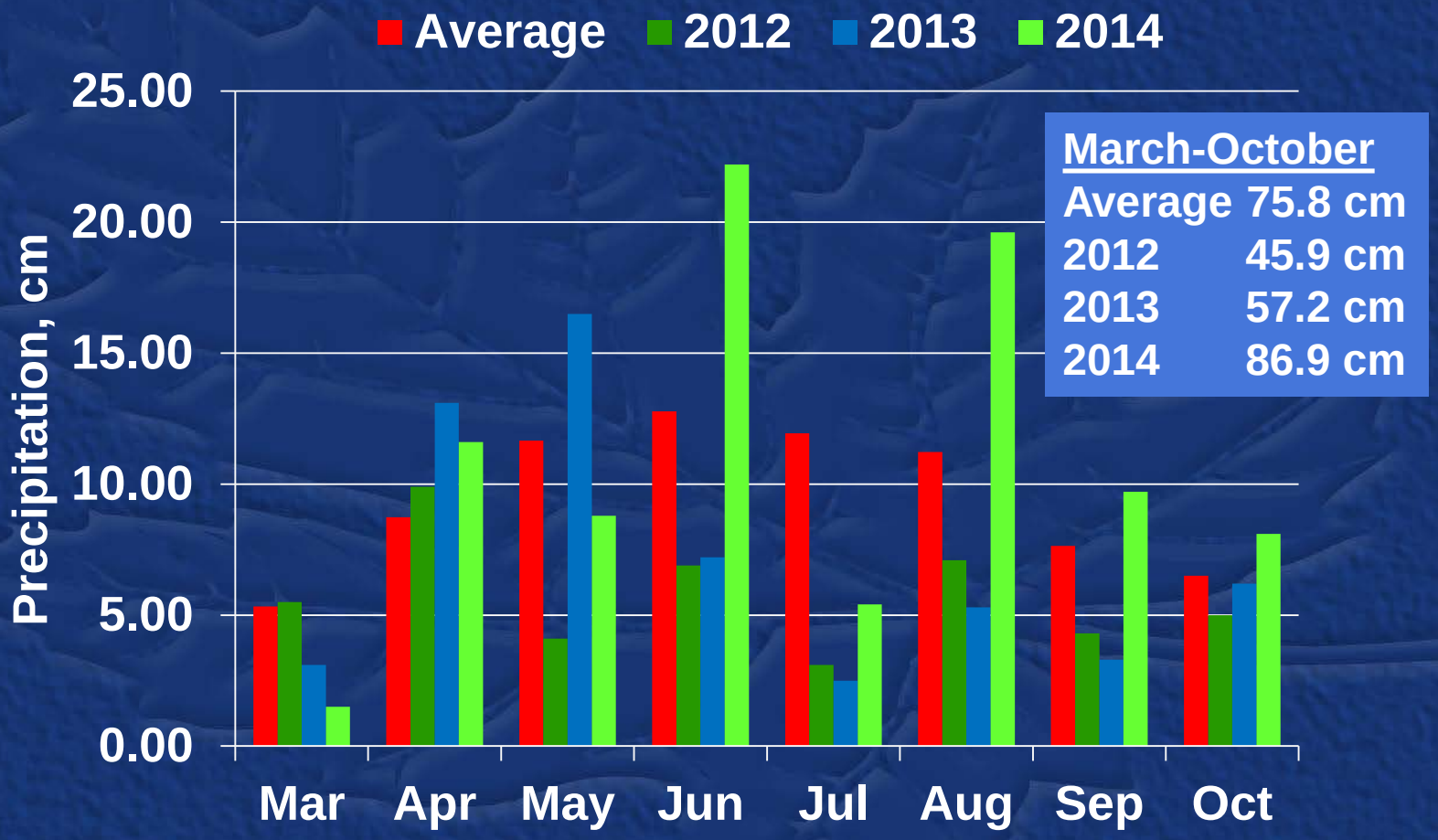
Total soil C&N; microbial biomass C&N; N mineralization potential; soil enzyme activity; inorganic N, P, K, Mg, Ca; aggregate stability; pH; EC; bulk density

microbial community structure and function

Plant Measurements

Yield; plant populations; total aboveground biomass C&N; weed density; insect pest and disease populations; stalk nitrate

Precipitation



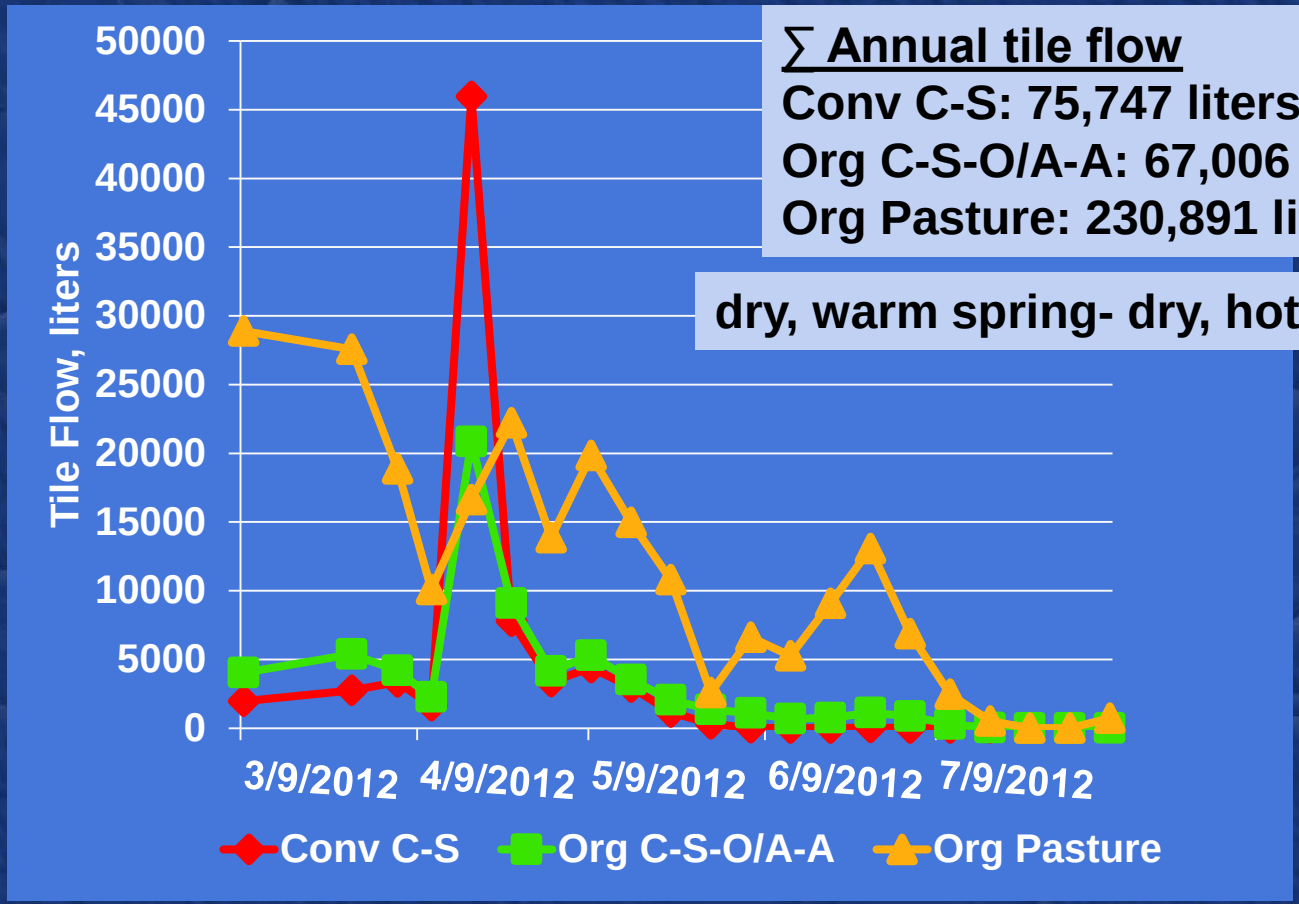
2012, 2013 and 2014 monthly data from on-site weather station
Average monthly data from http://average-rainfall.weatherdb.com

Crop	Yield (Mg/ha) 2012	2013	2014
Organic corn	9.24 ± 1	7.14 ± 0.6	7.91 ± 1.0
Conventional corn	9.79 ± 0.9	9.04 ± 1	7.64 ± 1.4
Boone County IA average corn*	9.99	10.5	12.3
Organic soybean	3.06 ± 0.3	2.24 ± 0.07	3.84 ± 0.4
Conventional soybean	3.86 ± 0.5	2.17 ± 0.3	3.68 ± 0.4
Boone County IA average soybean*	3.06	2.79	3.44
Organic oats	4.28 ± 0.6	4.96 ± 0.5	6.80 ± 0.5
Boone County IA average oats*	4.92	No data	3.56

2012 dry spring, dry summer
2013 wet spring, dry summer
2014 avg spring, wet summer

*www.nass.usda.gov

Tile Flow 2012

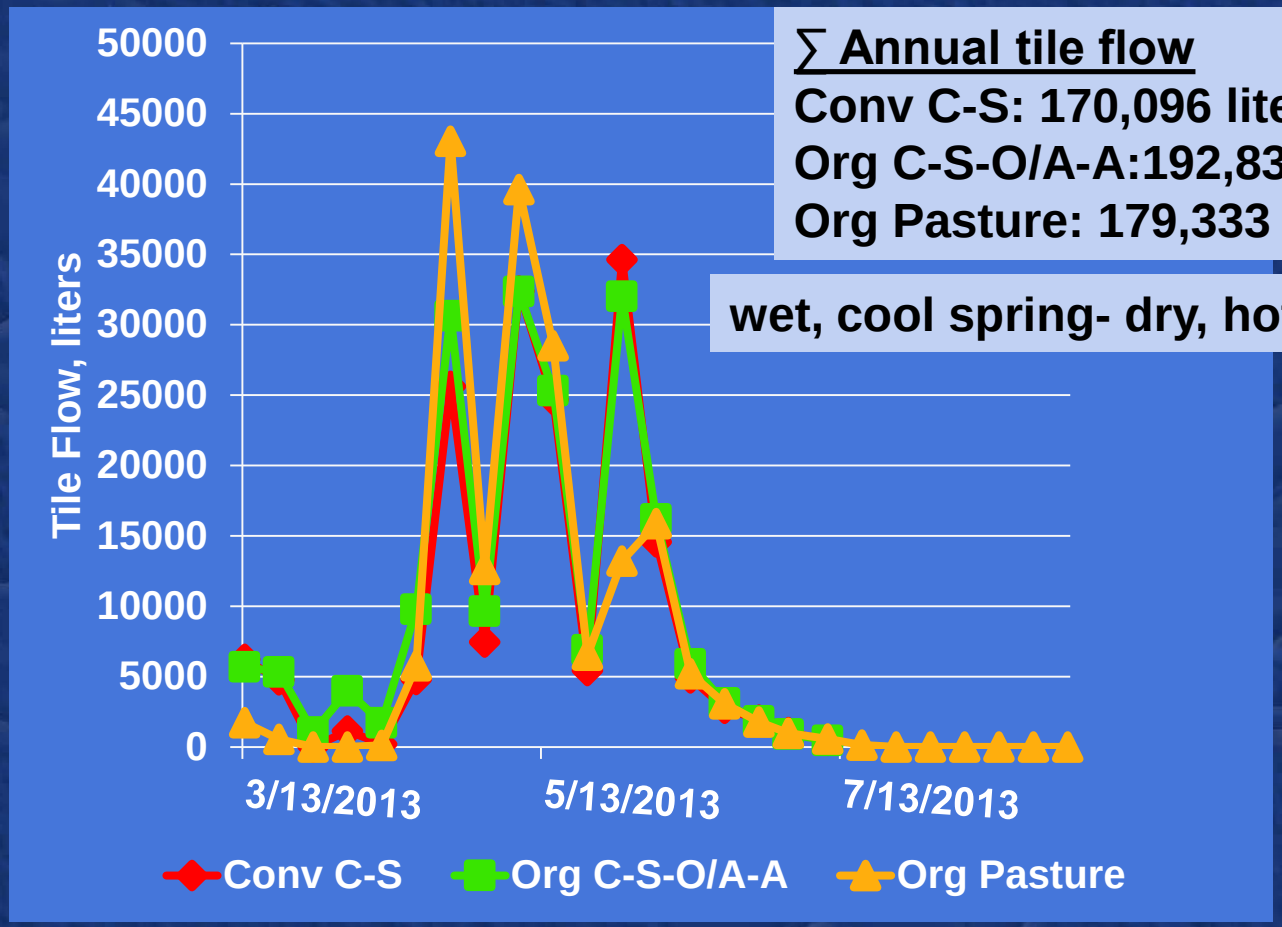


∑ Annual tile flow
Conv C-S: 75,747 liters
Org C-S-O/A-A: 67,006 liters
Org Pasture: 230,891 liters

dry, warm spring- dry, hot summer

Tile flow didn't correlate with rainfall except for a peak in April, following 9 cm of rain; tile flow ceased early-Aug

Tile Flow 2013

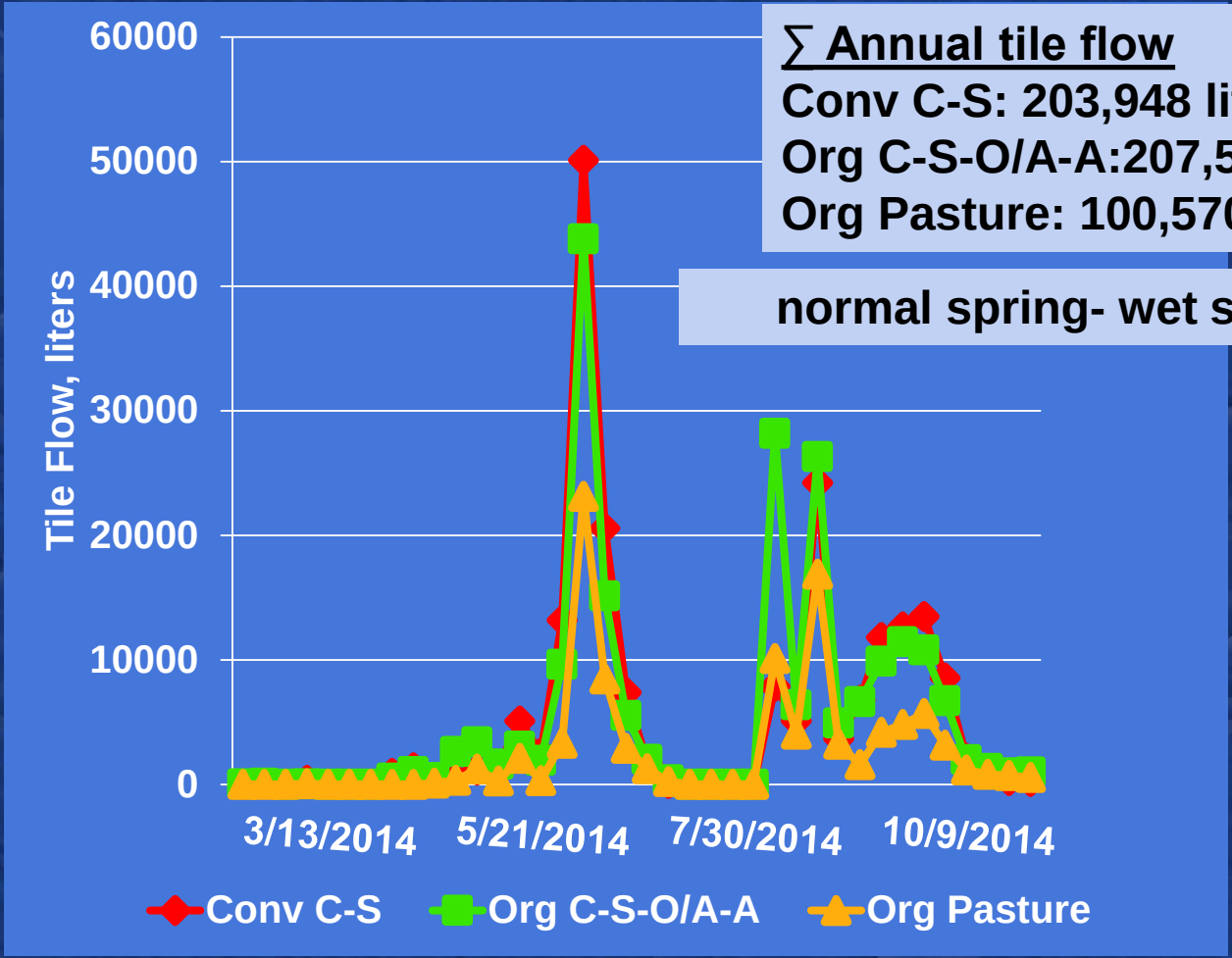


∑ Annual tile flow
Conv C-S: 170,096 liters
Org C-S-O/A-A:192,839 liters
Org Pasture: 179,333 liters

wet, cool spring- dry, hot summer

Peak tile flow and rainfall were correlated in 2013;
April-May rainfall 29.3 cm; tile flow ceased early-Aug

Tile Flow 2014

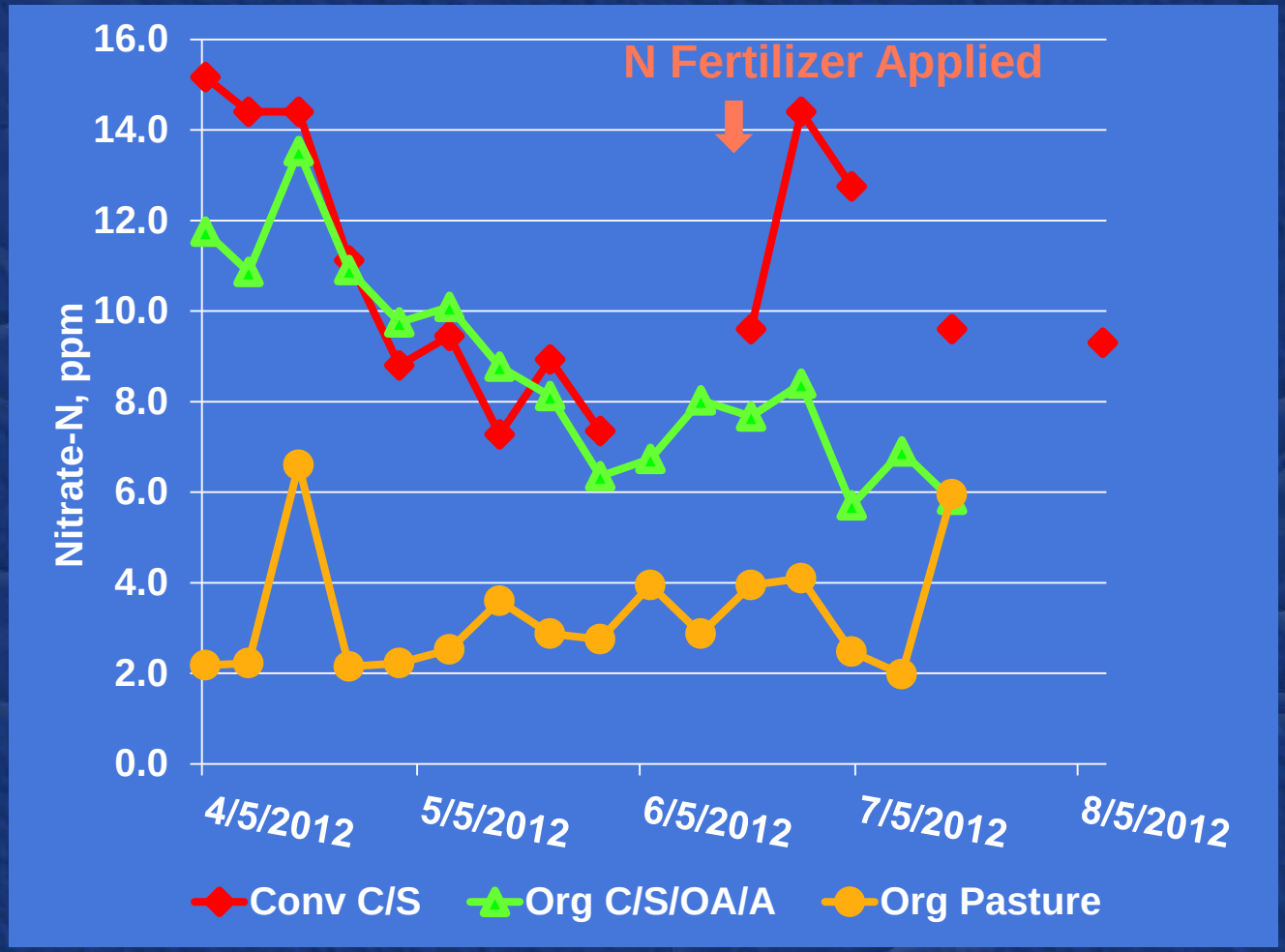


∑ Annual tile flow
Conv C-S: 203,948 liters
Org C-S-O/A-A:207,507 liters
Org Pasture: 100,570 liters

normal spring- wet summer

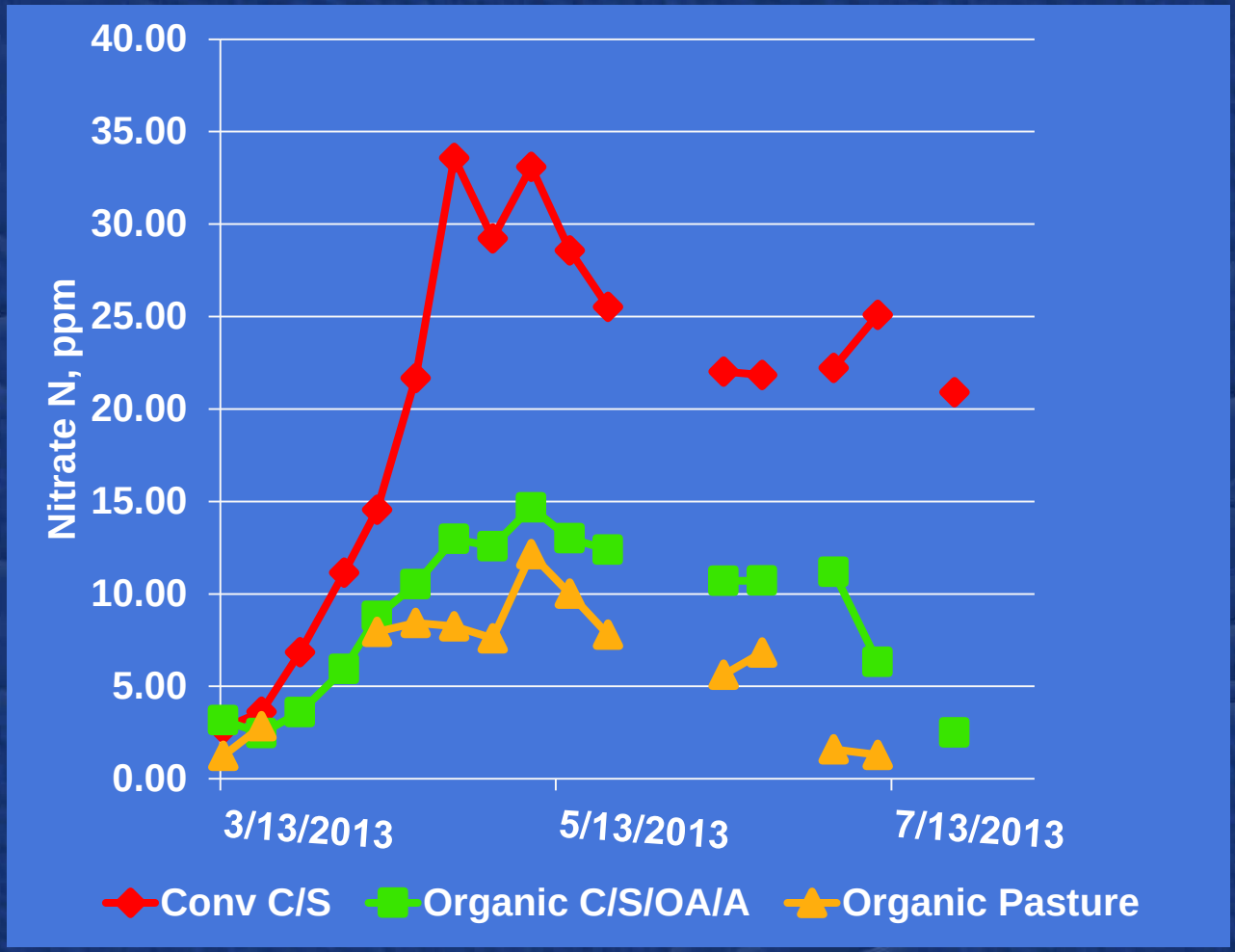
Tile flow peaked early July and late Aug, following 22 cm of rain in June and 20 cm of rain in Aug; tile flow never ceased

Tile Drainage Water Nitrate N 2012



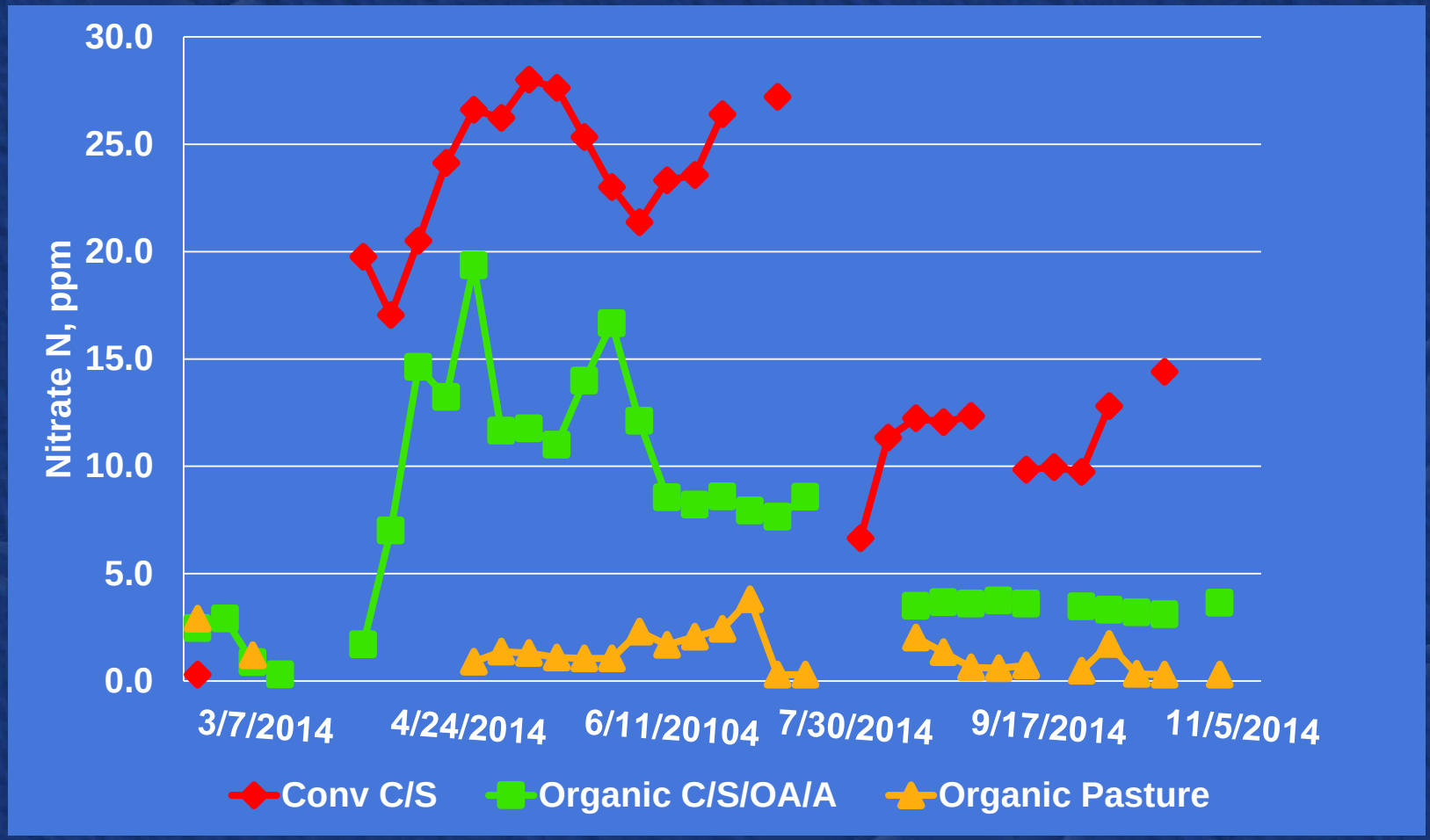
NO_3-N concentrations: ~15ppm in early spring from re-mineralization of N from oat/alfalfa; pasture <5ppm all year

Tile Drainage Water Nitrate N 2013



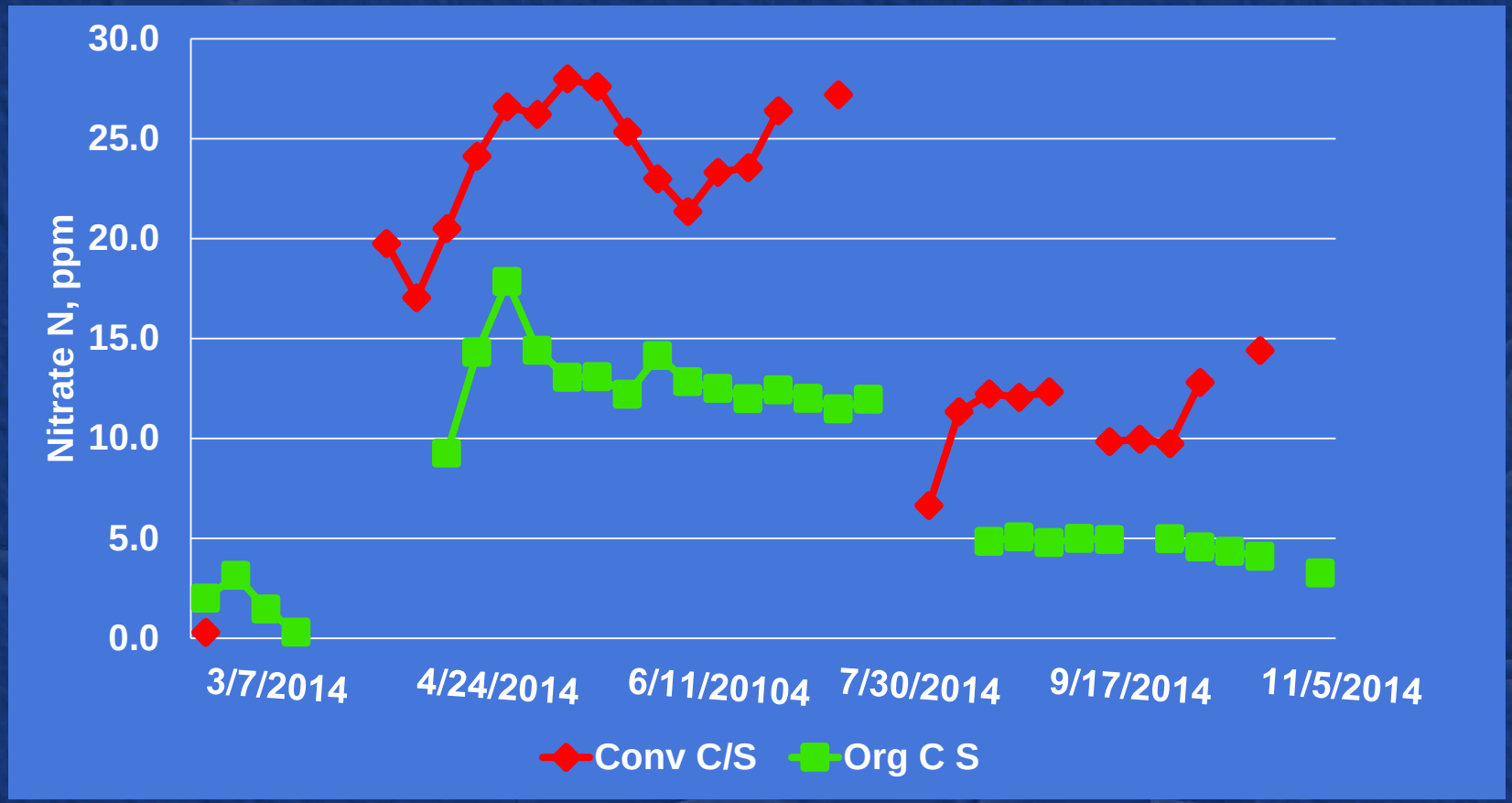
NO_3-N concentrations: <5ppm in early spring; increase to ~30ppm corn-soybean

Tile Drainage Water Nitrate N 2014



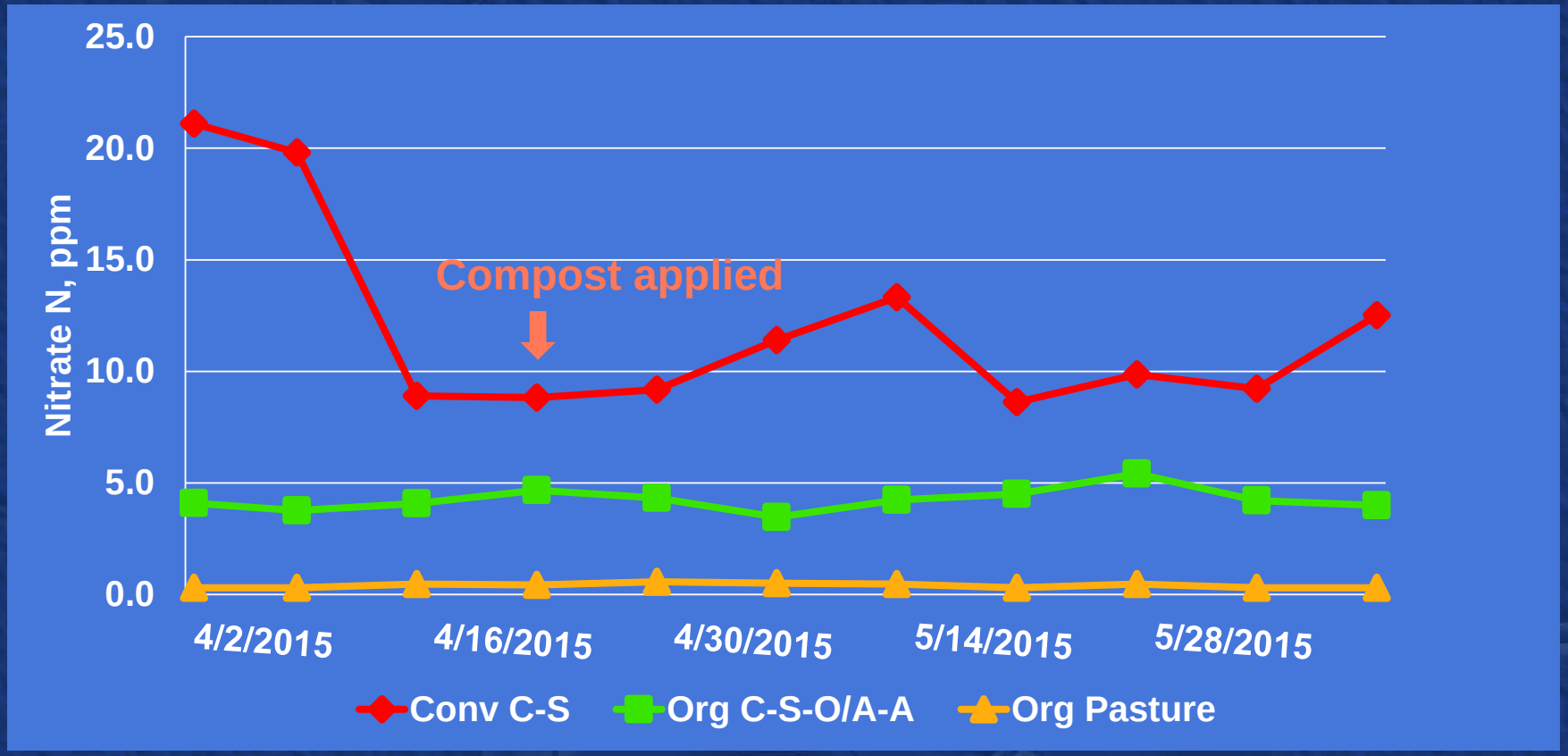
Overwinter Nitrate N concentrations from Nov 28, 2014 – Mar 25, 2015
Conventional C-S 13.0, Organic C-S-O/A-A 3.8, Organic Pasture 0.3 ppm

Tile Drainage Water Nitrate N 2014



Comparing Organic C and S to Conventional C-S

Tile Drainage Water Nitrate N 2015



Org C-S-O/A-A stable since late Aug 2014 at ≤5 ppm; Conv C-S ranged from 10 ppm to more than 20 ppm during same time period.

Crop	N Loss	NO_3-N Conc
2012	kgN ha^{-1}	mg N $liter^{-1}$
Organic C-S-O/A-A	7.9	8.8
Conventional C-S	10.1	10.9
Organic Pasture	7.0	3.3
2013		
Organic C-S-O/A-A	17.7	8.8
Conventional C-S	34.7	19.4
Organic Pasture	9.5	6.3
2014		
Organic C-S-O/A-A	14.5	7.2
Conventional C-S	34.4	18.1
Organic Pasture	1.2	1.3
∑ 2012-2014		
Organic C-S-O/A-A	40.1	
Conventional C-S	79.2	
Organic Pasture	17.7	

Conclusions

- Organic grain cropping rotations in Iowa are stable and resilient systems
  - Retain C and nutrients
  - Maintain crop yield
- Organic C-S-O/A-A rotations show great promise to improve surface water quality in Iowa
  - Reduce tile drainage water [NO_3-N]
  - Reduce annual N loading loss

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