Proceedings of the 3rd Annual Nitrogen: Minnesota's' Grand Challenge & Compelling Opportunity Conference

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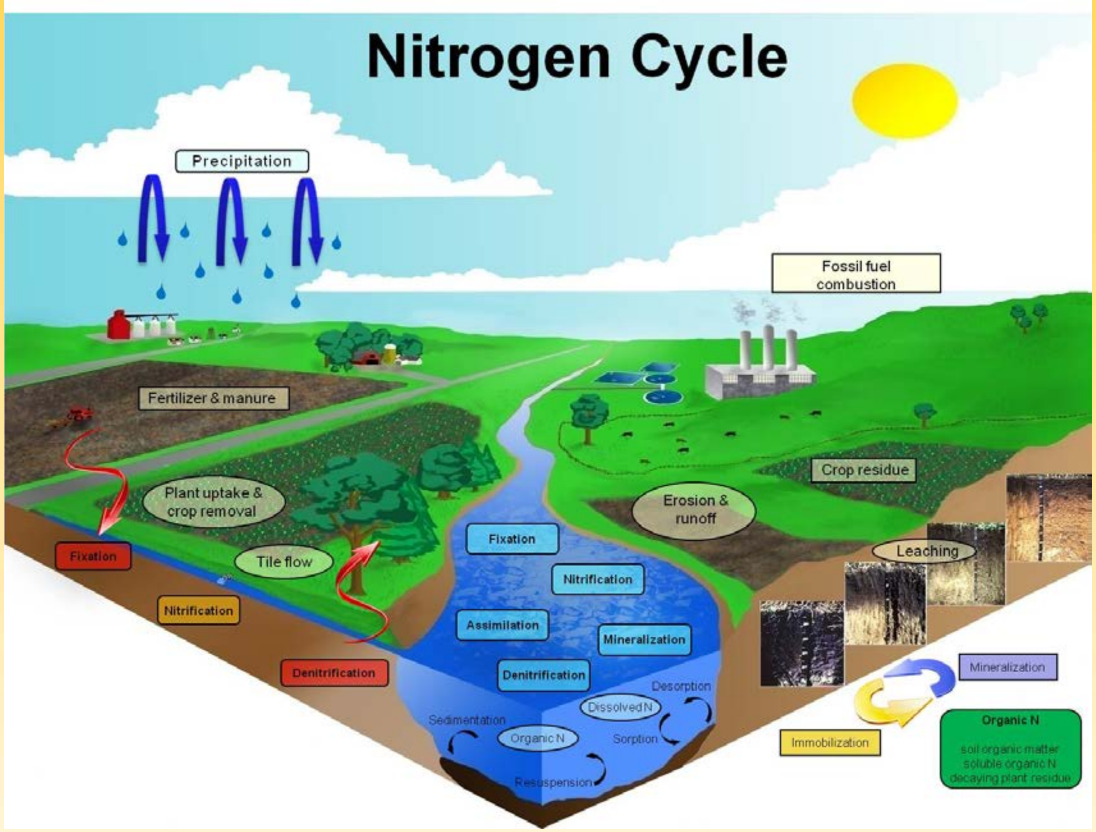
Nitrogen cycle components for continuous corn in southwest Minnesota

Dr. Jeff Strock,
Department of Soil, Water & Climate
and
Southwest Research & Outreach Center

The Nitrogen Cycle

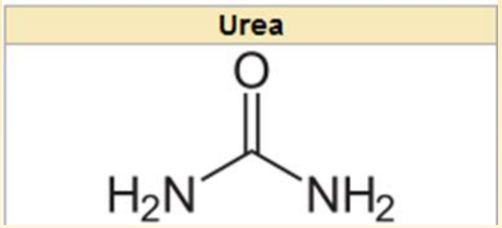
- Forms of nitrogen and their fate
- Fluxes between nitrogen pools



The Nitrogen Cycle (continued)

- Atmosphere
  - N_2 (nitrogen)
    - 78% of the atmosphere
      - O_2 = 21%,
      - CO_2 = 0.04%
    - Fixed by legumes into plants and soil
  - N_2O (nitrous oxide)
    - 0.00003% (32 ppm)

- Main forms of soil & plant N
  - NH_3 – Ammonia
    - Organic matter
    - Fertilizers
      - Urea, DAP, UAN etc.
    - Major source of plant N



The Nitrogen Cycle (continued)

- Main forms of soil & plant N
  - NH_4^+ – Ammonium
    - Soil solution
    - Loosely bound on cation exchange
      - Positive charge attached to clay
        - » Exchangeable
        - » Clay-fixed (non-exchangeable)
        - » Does not readily leach
    - Major source of plant N
    - Preferential uptake in colder, wetter soils
    - Rapidly converts to NO_3^- (nitrate ion)
      - In warm, well-drained soils

The Nitrogen Cycle (continued)

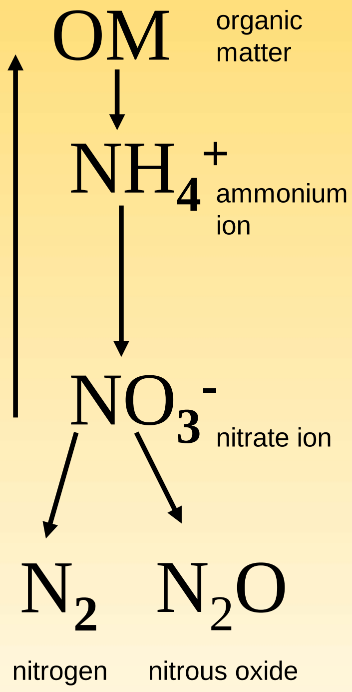
- Main forms of soil & plant N
  - NO_3 – Nitrate
    - Major source of plant nutrition
      - Drier soils
    - Accumulates in some plants
      - e.g. Brassicas, annual ryegrass, cereal grains
      - Breaks down to NO_2 in rumen – toxicity
    - Soluble in water – leaches
  - NO_2 – Nitrite
    - Transient in plants and soils
    - Main form of toxicity in ruminants

The Nitrogen Cycle (continued)

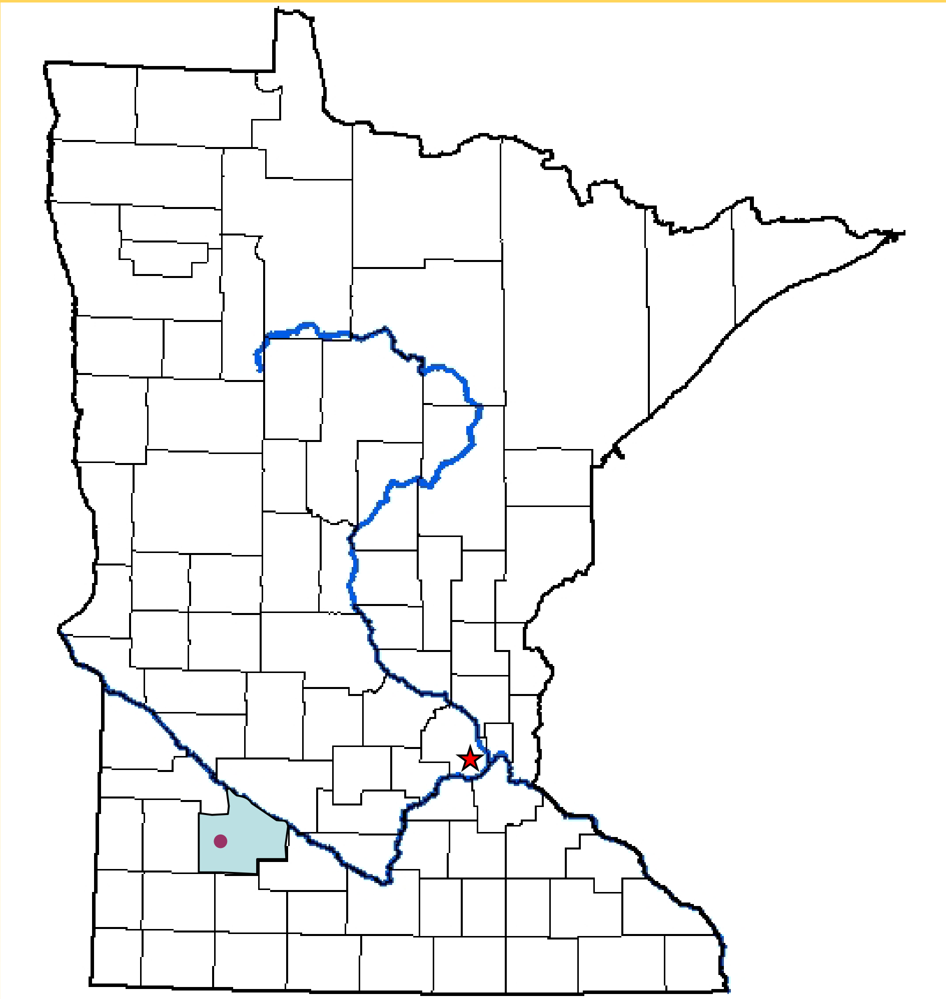
- Main forms of soil & plant N
  - Soil organic matter N
    - Decomposed residues
      - Amides, proteins etc
    - Microorganisms (microbial biomass)
    - C: N ratio
      - Usually 10:1 to 40:1
    - Major source of plant N
      - Through mineralization

The Nitrogen Cycle (continued)

- Mineralization
  - Microbial breakdown of soil organic matter to ammonium
  - The main mechanism for supplying N to plants
- Nitrification
  - Microbial conversion of ammonium to nitrate
    - Ammonia sources
      - Urine, decaying organic matter, fertilizer
    - Warm, moist (not waterlogged) soils
- Denitrification
  - Microbial conversion of nitrate to N_2 and N_2O gases
    - Warm, waterlogged soils
    - N_2O is a powerful greenhouse gas
- Immobilization
  - Microbial assimilation of soil nitrogen into OM



Redwood Co. Research Site



Corn & Soybean Digest
October 2009

COSTCUTTER

GAIN FROM A BETTER DRAIN

DRAINAGE WATER MANAGEMENT REDUCES NITRATE AND MOISTURE LOSS.

BY LIZ MORRISON

It was the drought of 1988 that got John Wilken thinking about the wisdom of draining his "liquid assets."

Wilken, who farms in east-central Illinois, had partly tiled a field before the season started. That dry summer, the undrained portion of his field produced significantly better corn than the drained portion. "That tripped a trigger in my mind, that we should be conserving some of our water for when it's needed," he says.

Today, Wilken does just that. He controls how much – and when – tile drainage water leaves 340 acres of flat cropland in Iroquois County.

Using eight outlet control structures in his main tile lines, Wilken can raise and lower the water table depth in two fields. He holds back water in the soil all winter, when drainage isn't needed for crop production, then releases it about two weeks before field operations begin in the spring.

After planting, he raises the outlet height above the tile depth in order to capture some of the rainfall that would ordinarily drain out. Just before harvest, he drops the outlet back down to the tile depth. In November, after fall strip-tillage and fertilizer application, Wilken raises the outlet height once more, lifting the water table almost to the surface.

This practice – known as drainage water management, or controlled drainage – cuts nitrate loads flowing into surface waters through the tile system, especially during the fallow period, says Don Pitts, a drainage expert for the Natural Resource Conservation Service in Illinois. And during the growing season, controlled drainage stores moisture and nutrients for the crop, offering the potential for higher yields in dry years, he says.

RESEARCHERS ALL AROUND the Midwest are looking for ways to cut pollutants in subsurface drainage water without lowering drainage efficiency. As public concern over water quality intensifies, there is "more interest in what we can do to minimize drainage water volumes and nitrate losses," says

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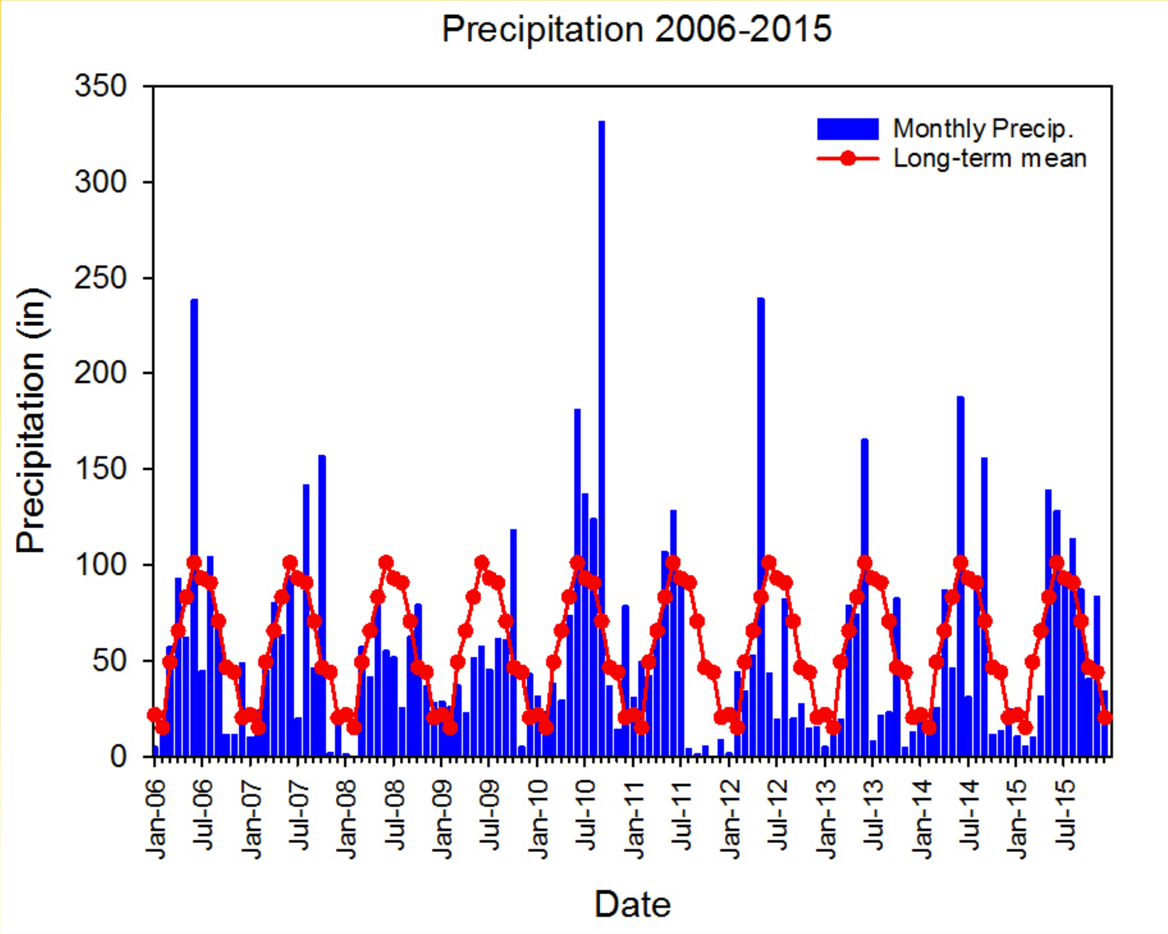
Field Experiment

- Mollisol, Havelock series
  - Tilled ca 1918
  - No previous drainage prior to 2005.
    - Drain depth: 4 ft.
    - Drain spacing: 50 ft.
- Two management zones
  - Conventional free drainage (35 ac)
  - Controlled drainage (55 ac)

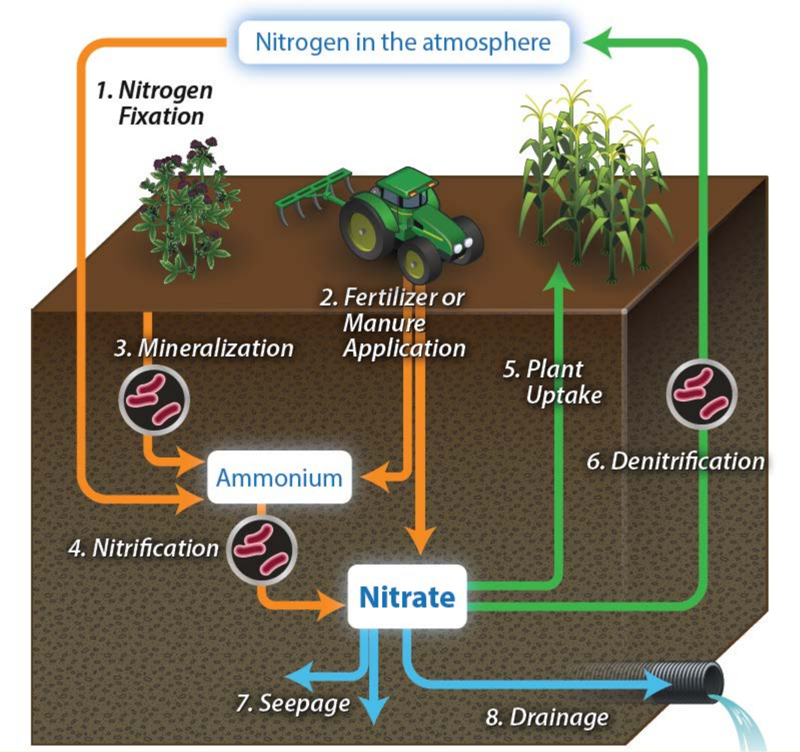
Monthly Precipitation



Total annual precipitation (mm)

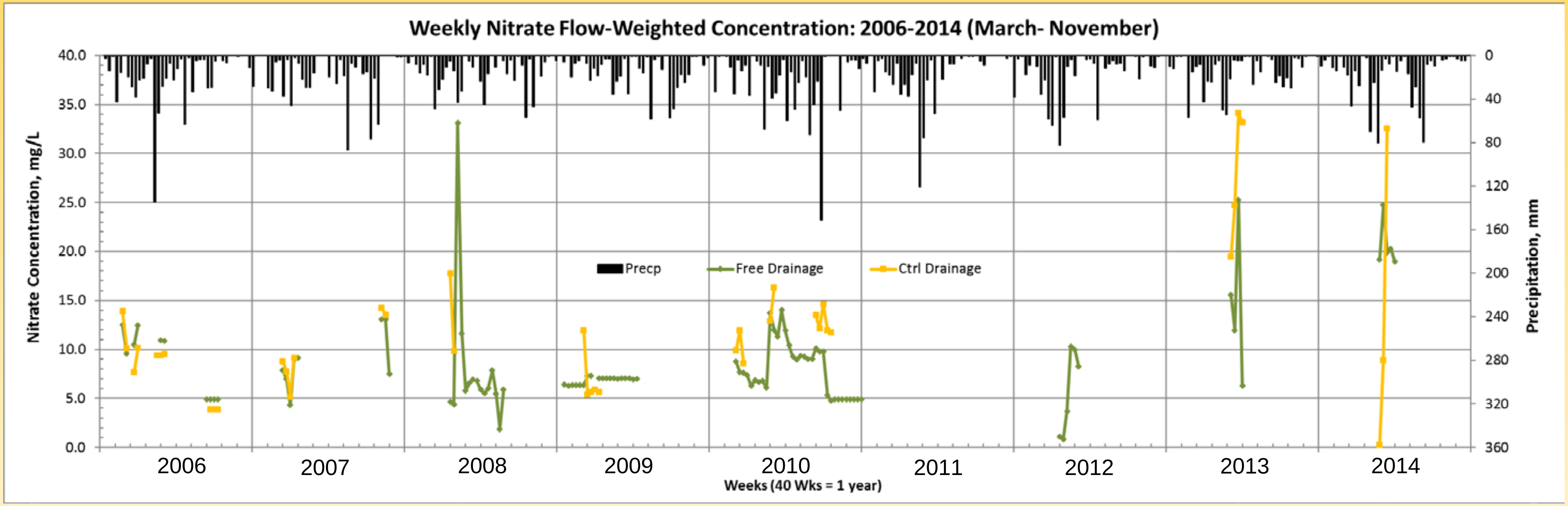
2006: 758
2007: 692
2008: 593
2009: 610
2010: 967
2011: 649
2012: 645
2013: 590
2014: 707
2015: 780
Long-term mean: 678

Nitrate Leaching

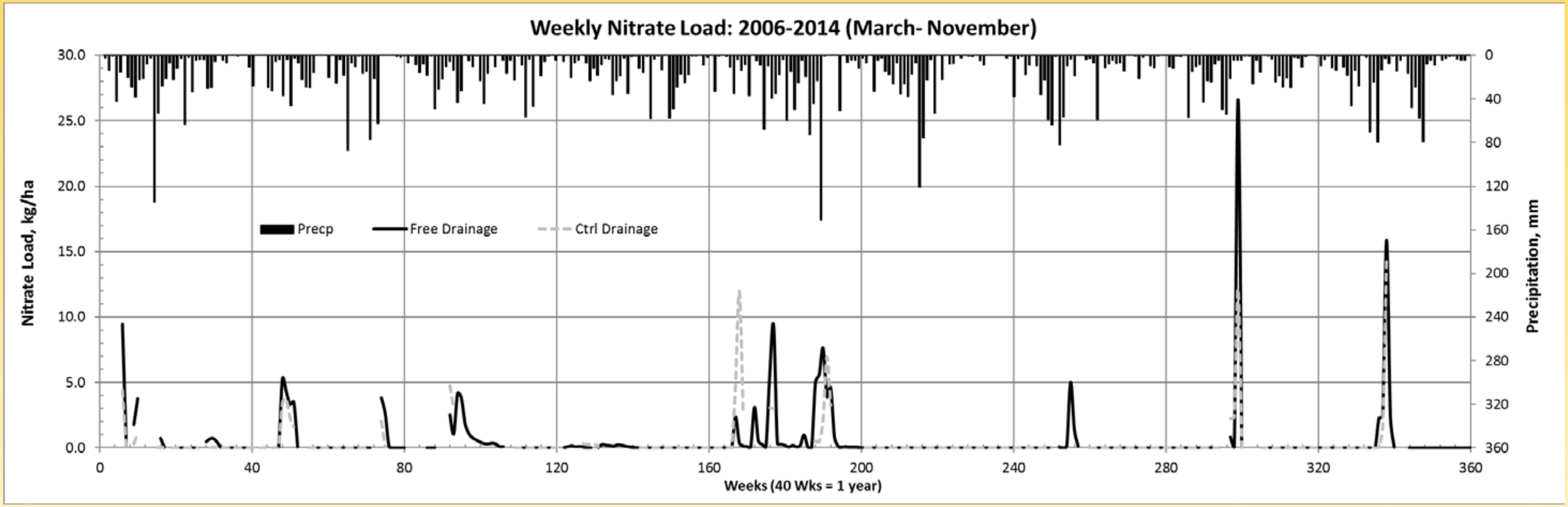


Christensen L.E., J. Frankenberger, C. Hay, M.J. Helmers and G. Sands. 2016. Ten ways to reduce nitrogen loads from drained cropland in the Midwest. Pub. C1400, University of Illinois Extension.

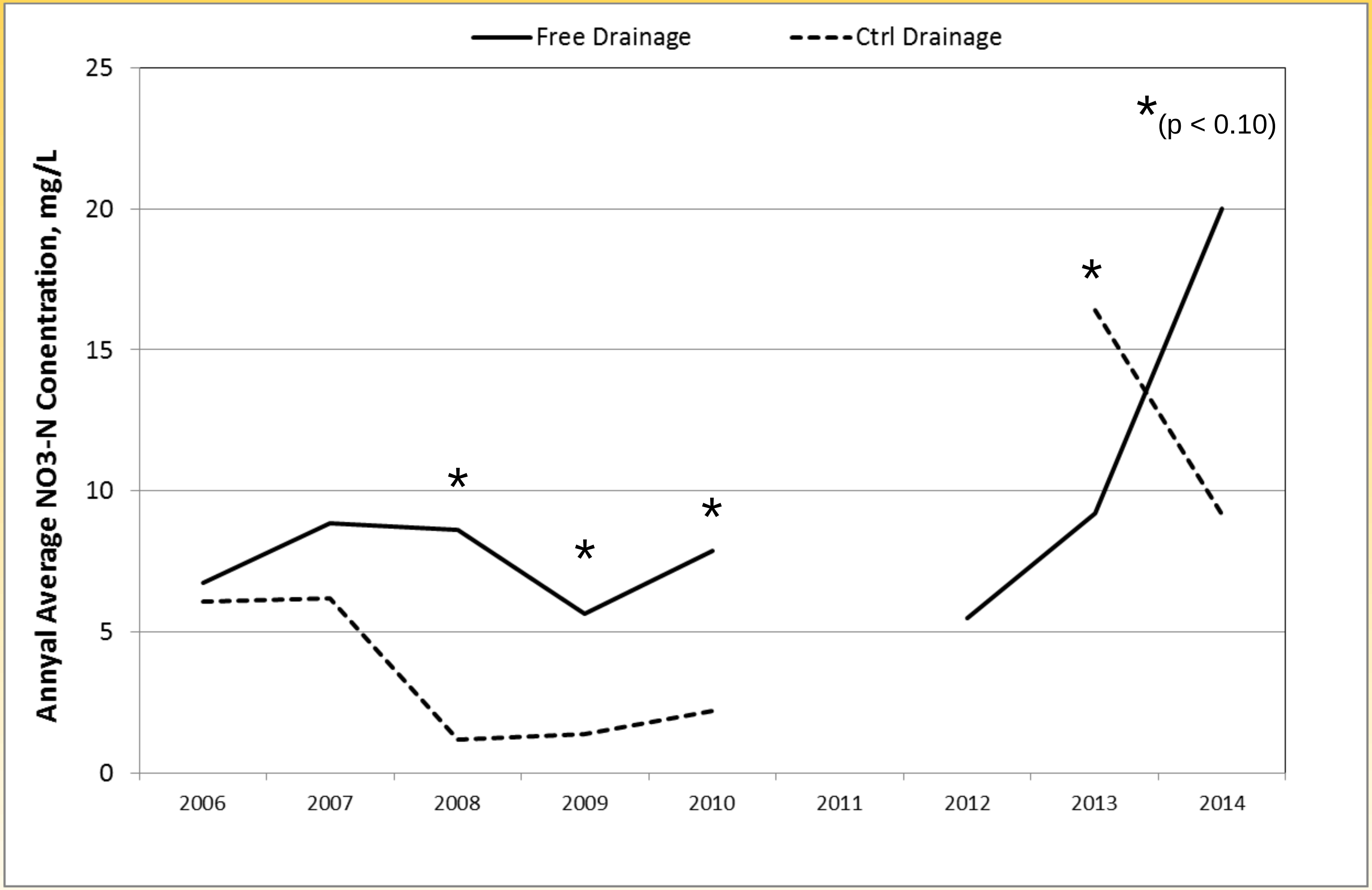
Weekly Flow-weighted Mean Nitrate Concentration: 2006-2014



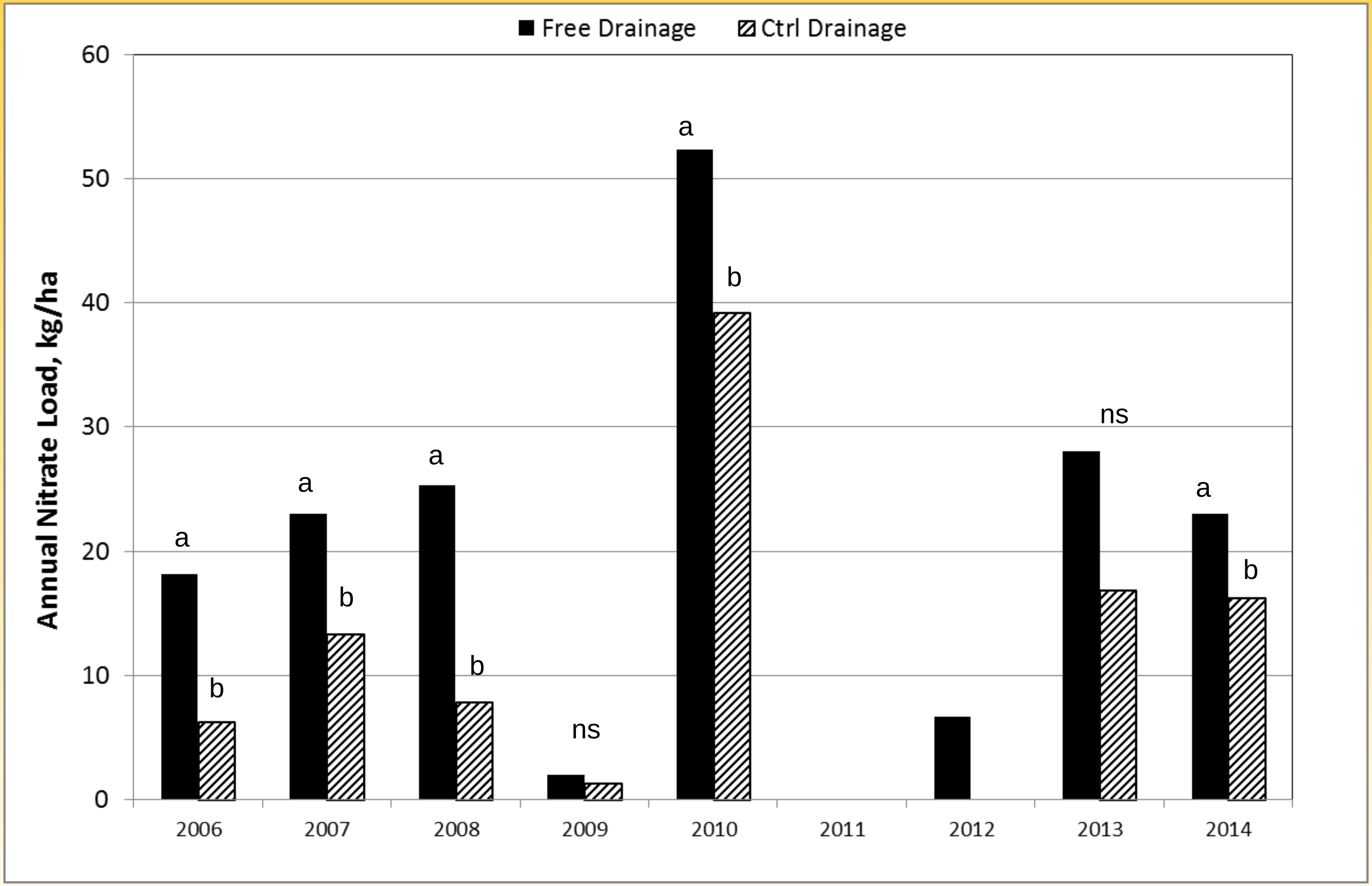
Mean Weekly Nitrate-N Load: 2006-2014



Annual NO_3-N Concentration : 2006-2014

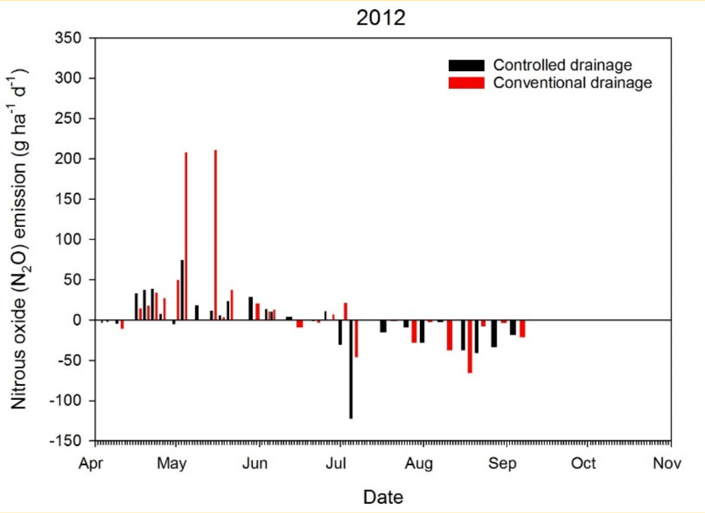


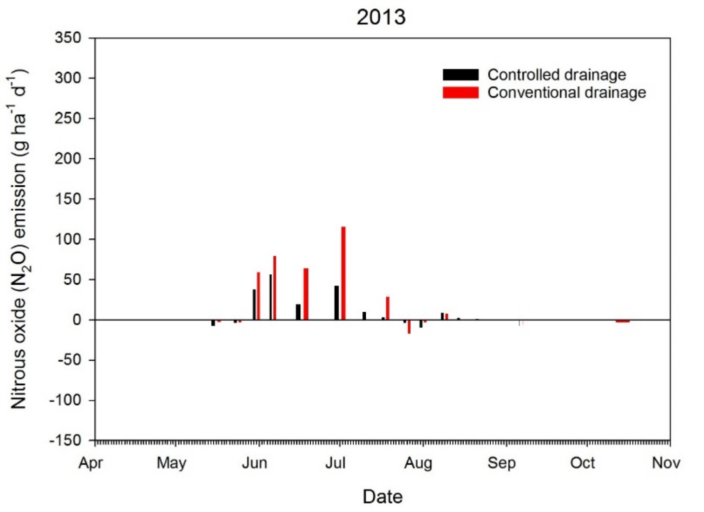
Annual Nitrate-N Load: 2006-2014

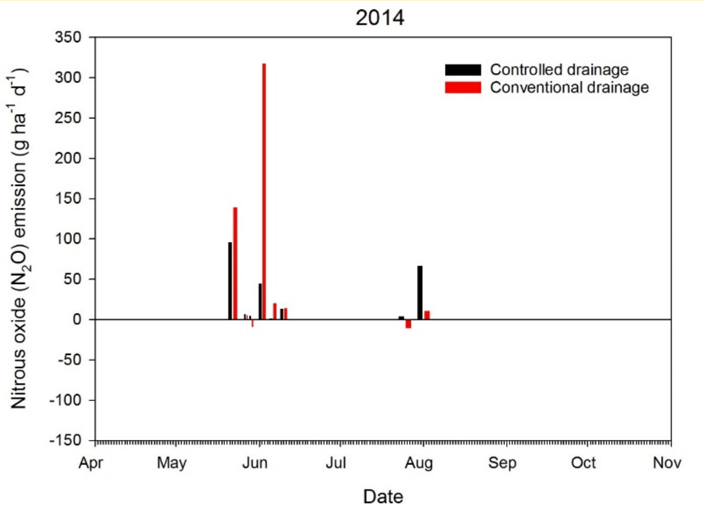


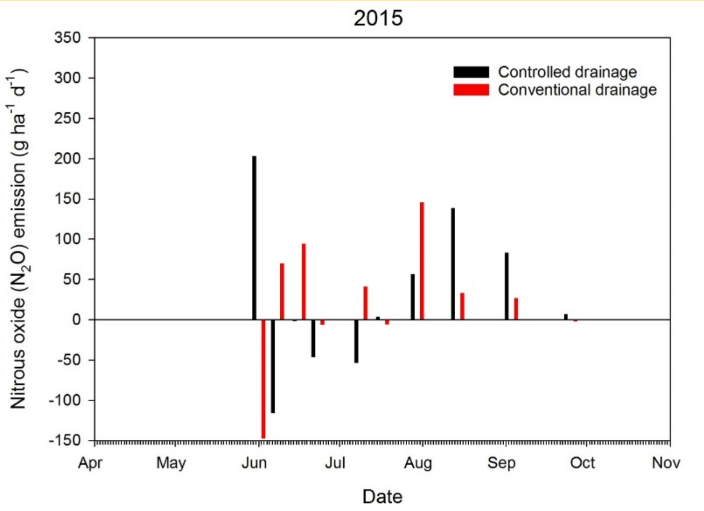
Greenhouse gas emission

Nitrous oxide emission

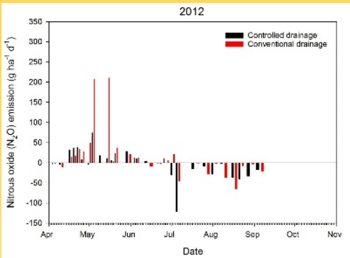


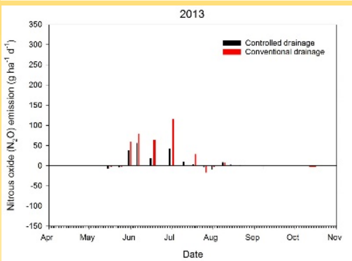


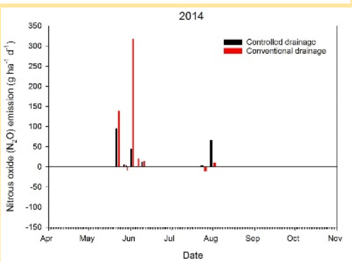


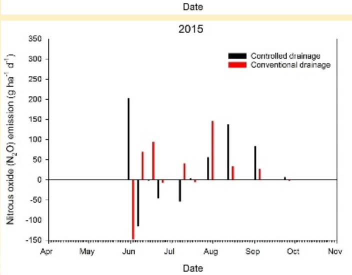


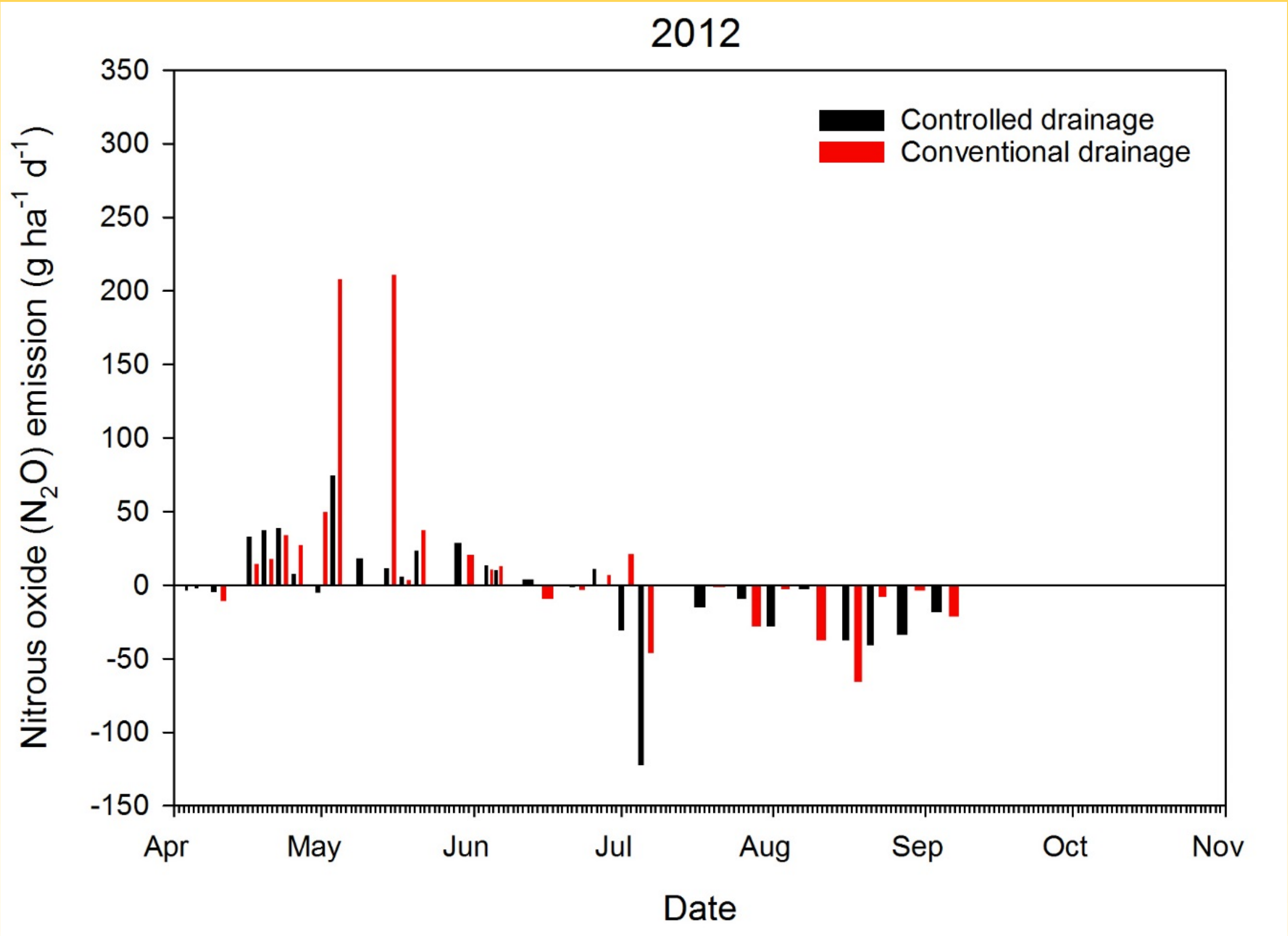
Nitrous oxide emission



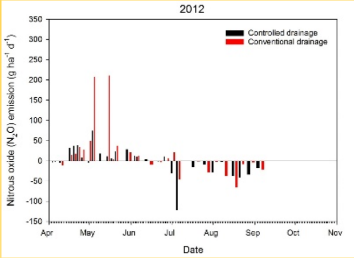


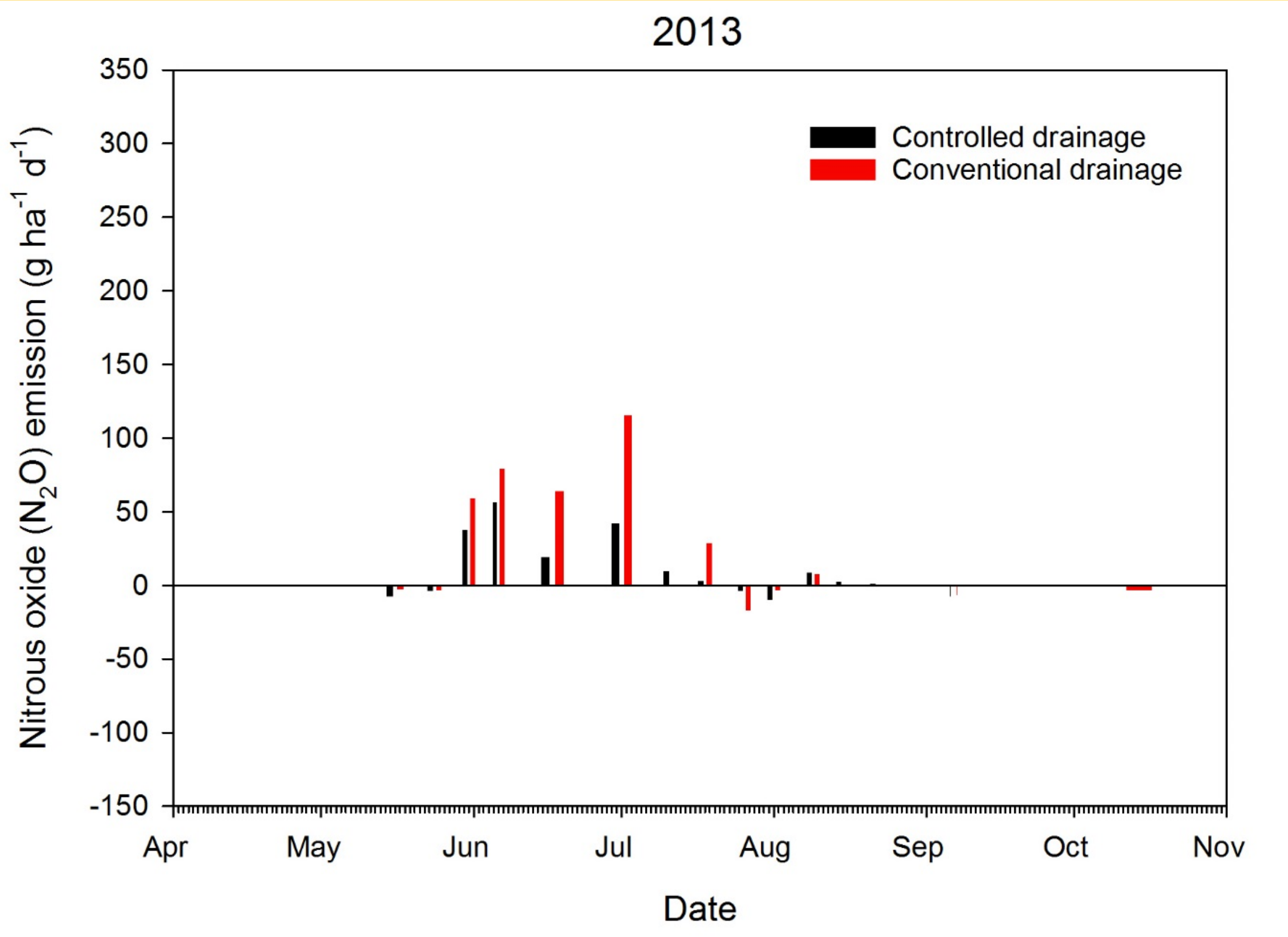


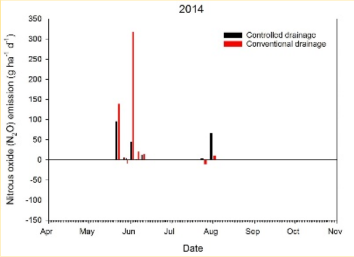


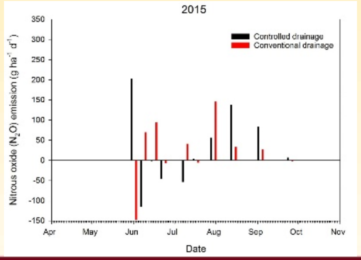


Nitrous oxide emission

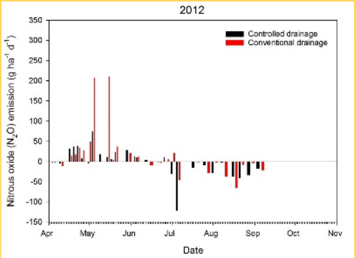


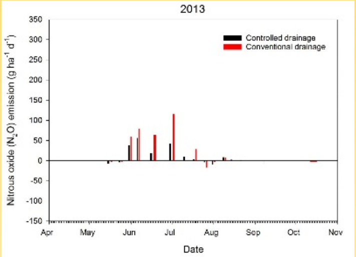


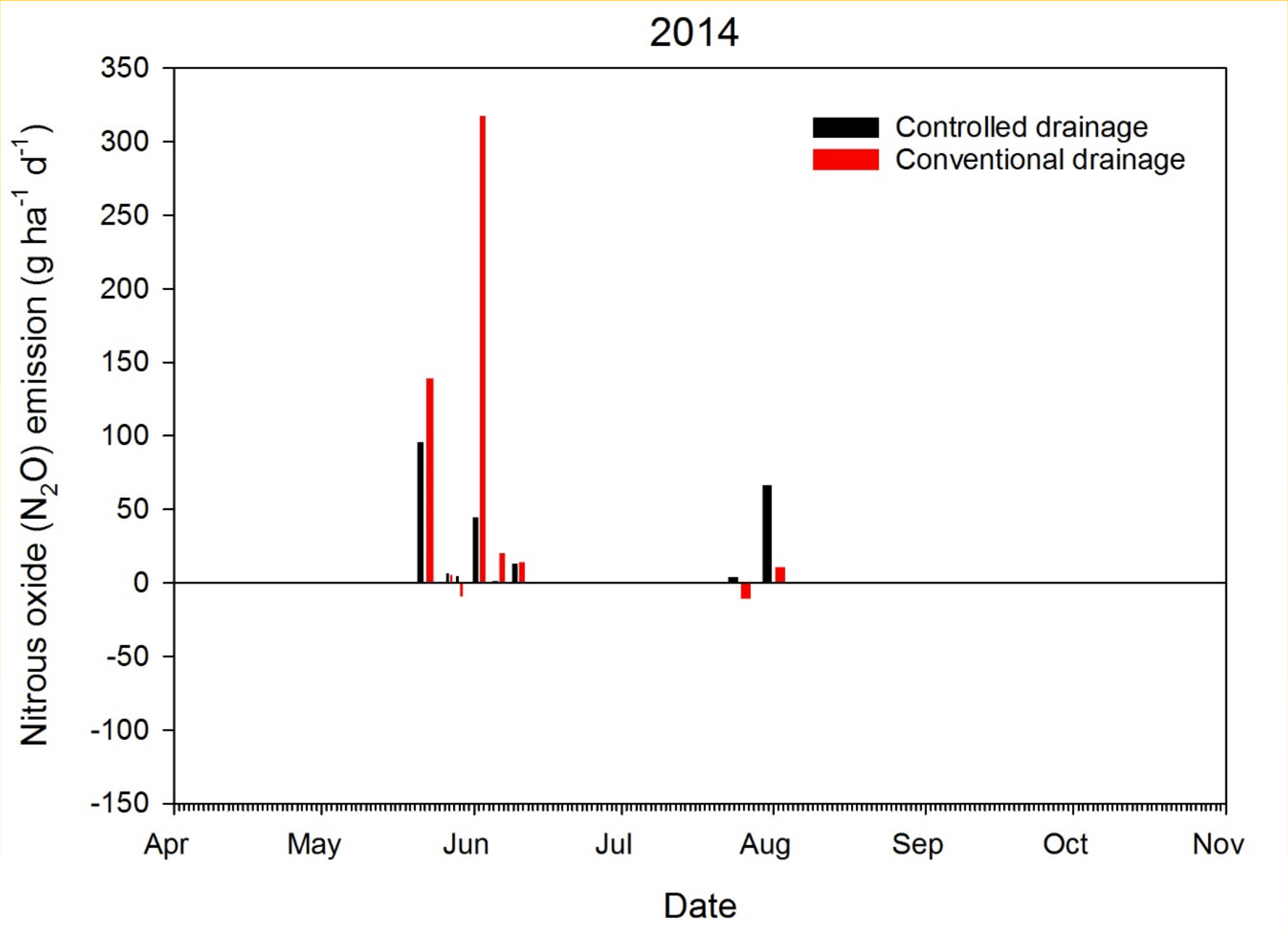


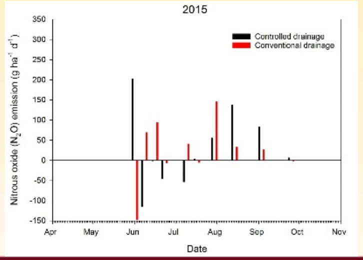


Nitrous oxide emission

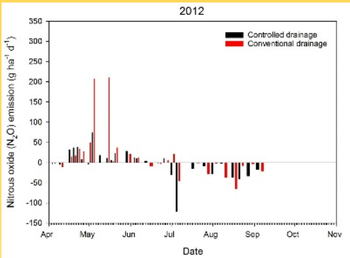


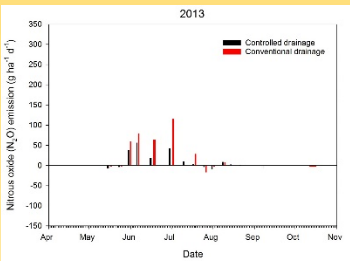


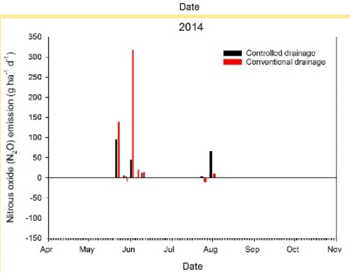


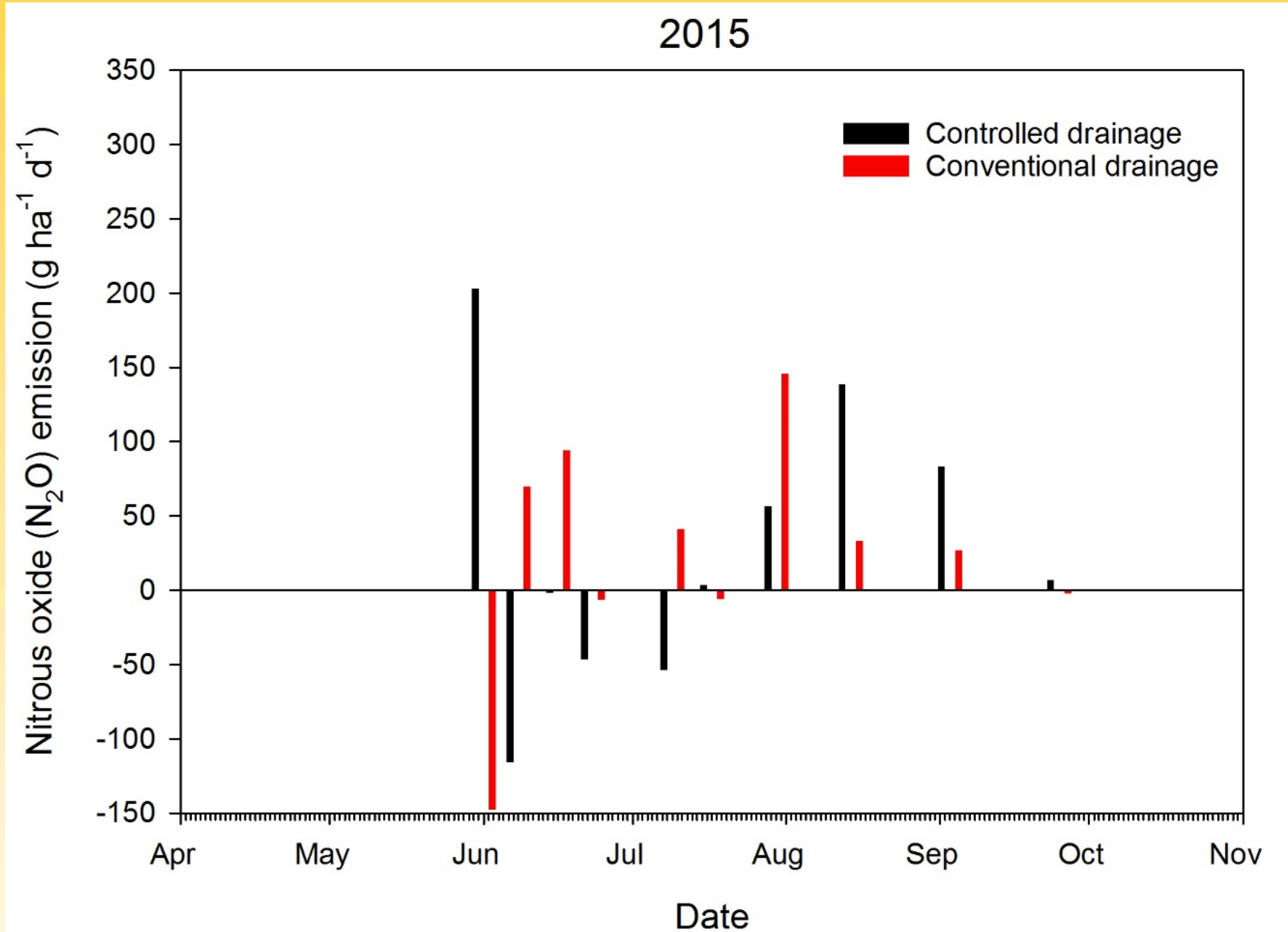


Nitrous oxide emission









Effect of drainage on N_2O emissions:

2012 N_2O (g ha^{-1} d^{-1})

	Continuous corn
Controlled	-1.3
Conventional	14.5

2013 N_2O (g ha^{-1} d^{-1})

	Continuous corn
Controlled	9.3
Conventional	19.8

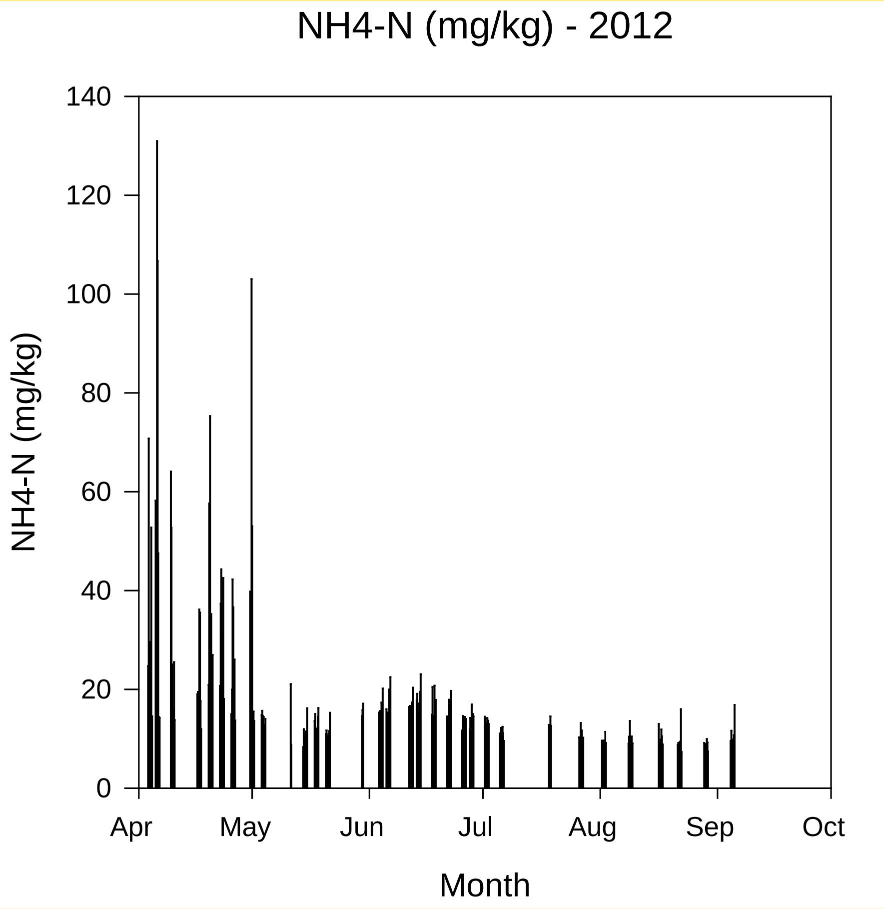
2014 N_2O (g ha^{-1} d^{-1})

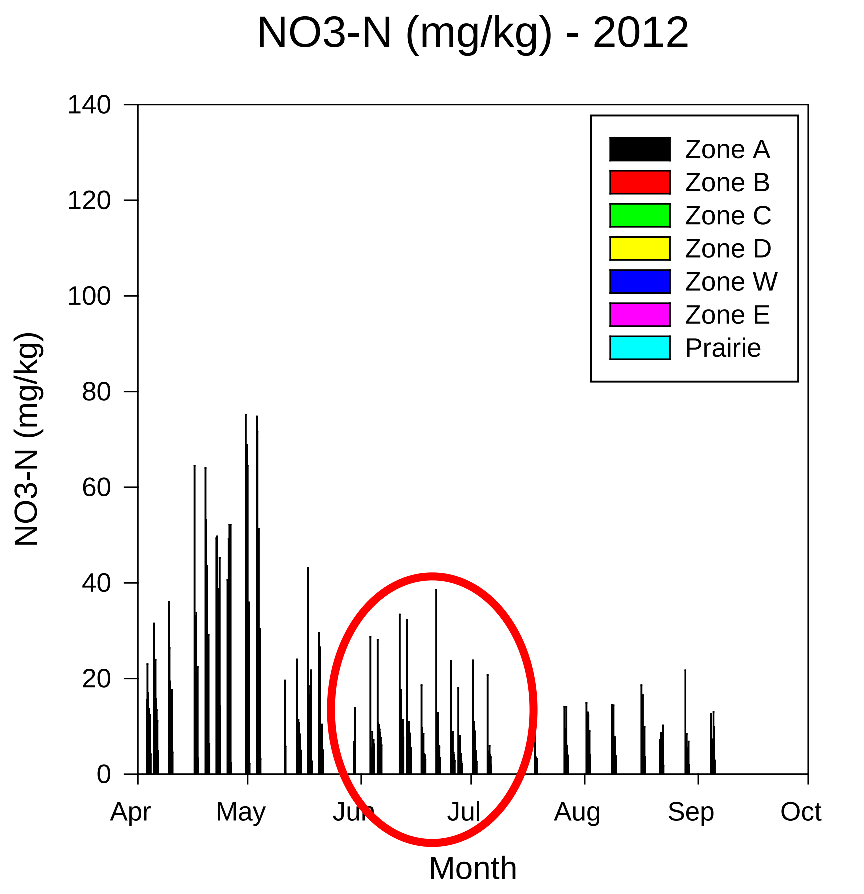
	Continuous corn
Controlled	25.9
Conventional	51.4

2015 N_2O (g ha^{-1} d^{-1})

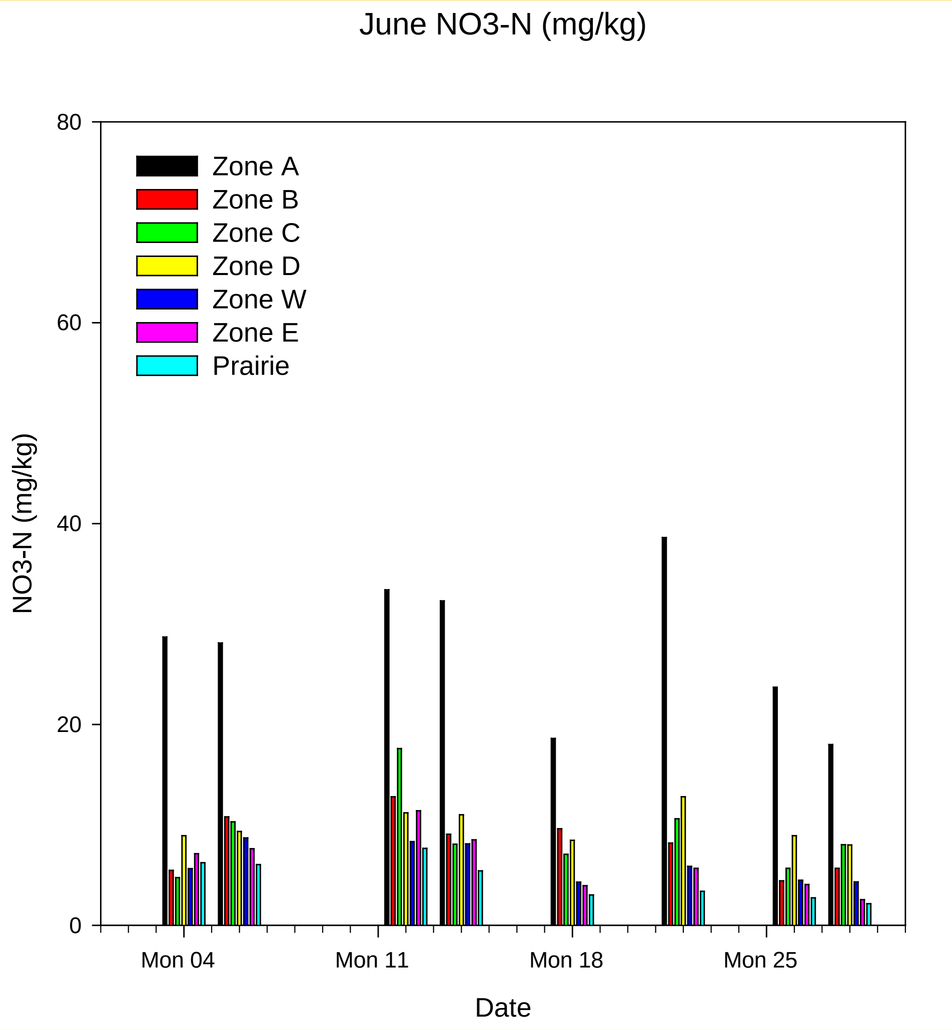
	Continuous corn
Controlled	28.5
Conventional	32.0

Weekly soil inorganic N



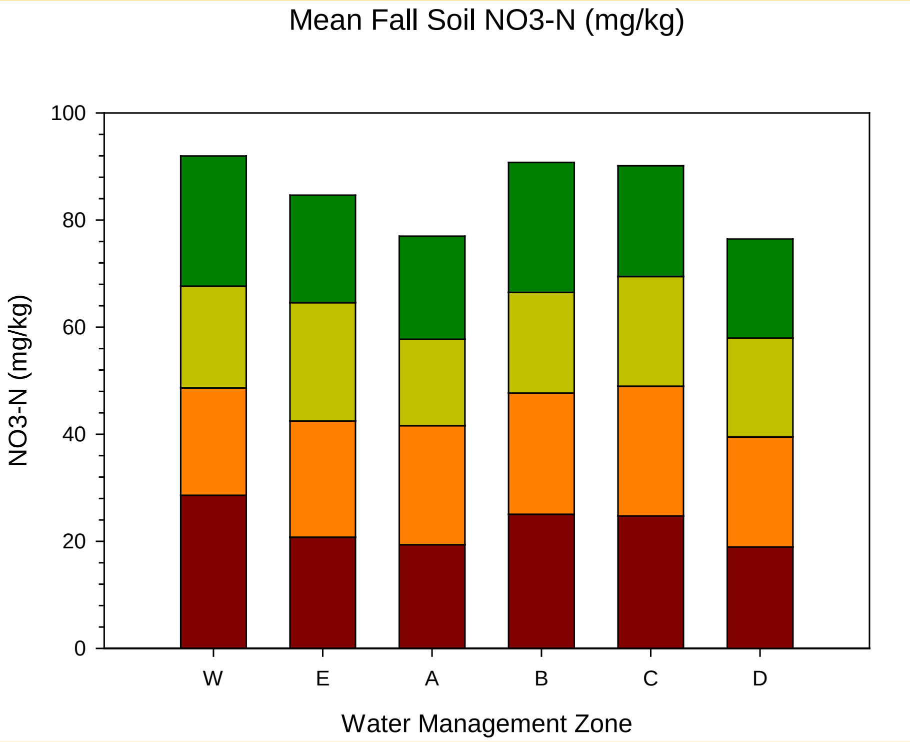


June soil inorganic N

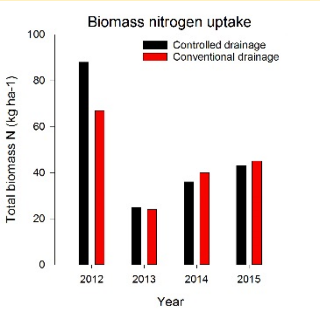


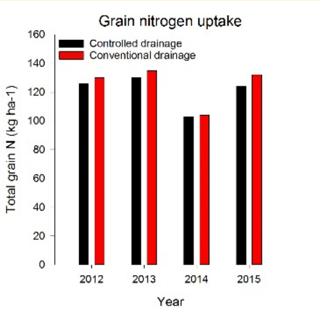
Fall soil nitrate by depth

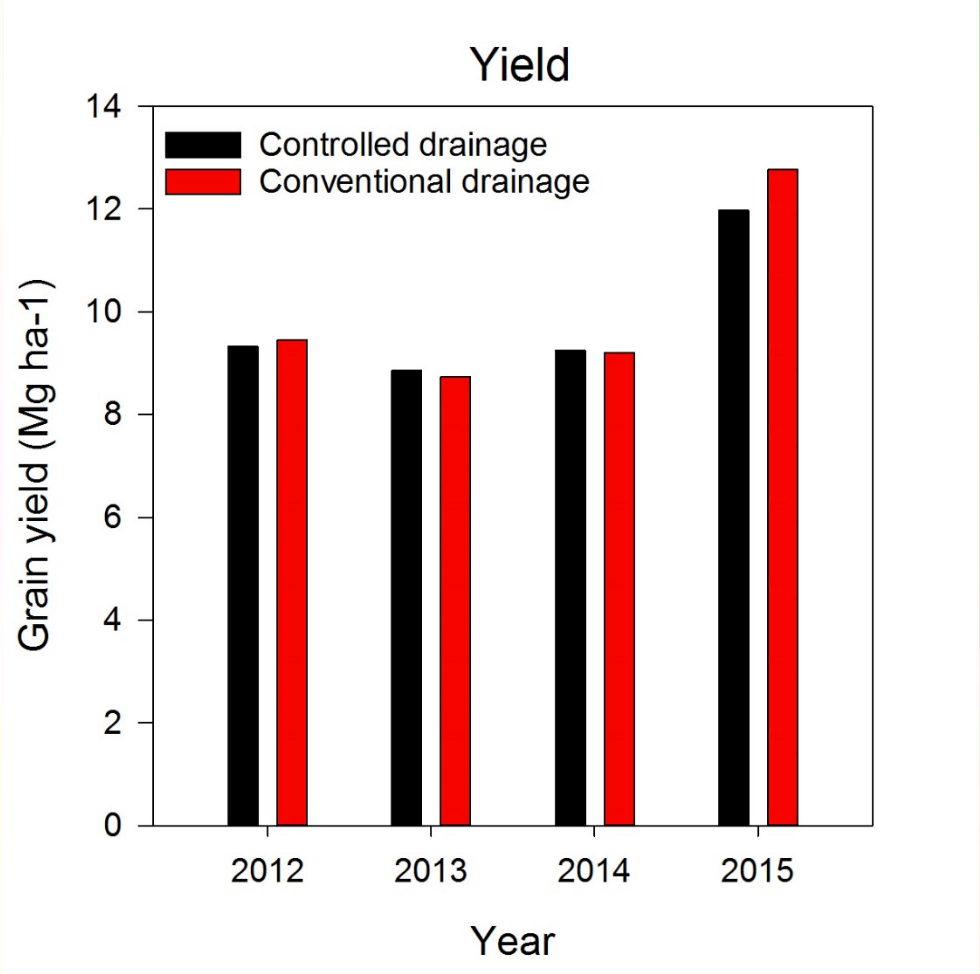
- E and A = conventional drainage
- W and B = controlled drainage
- C = subirrigation
- D = no drainage



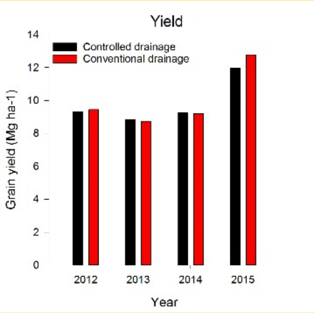
Corn Grain Yield

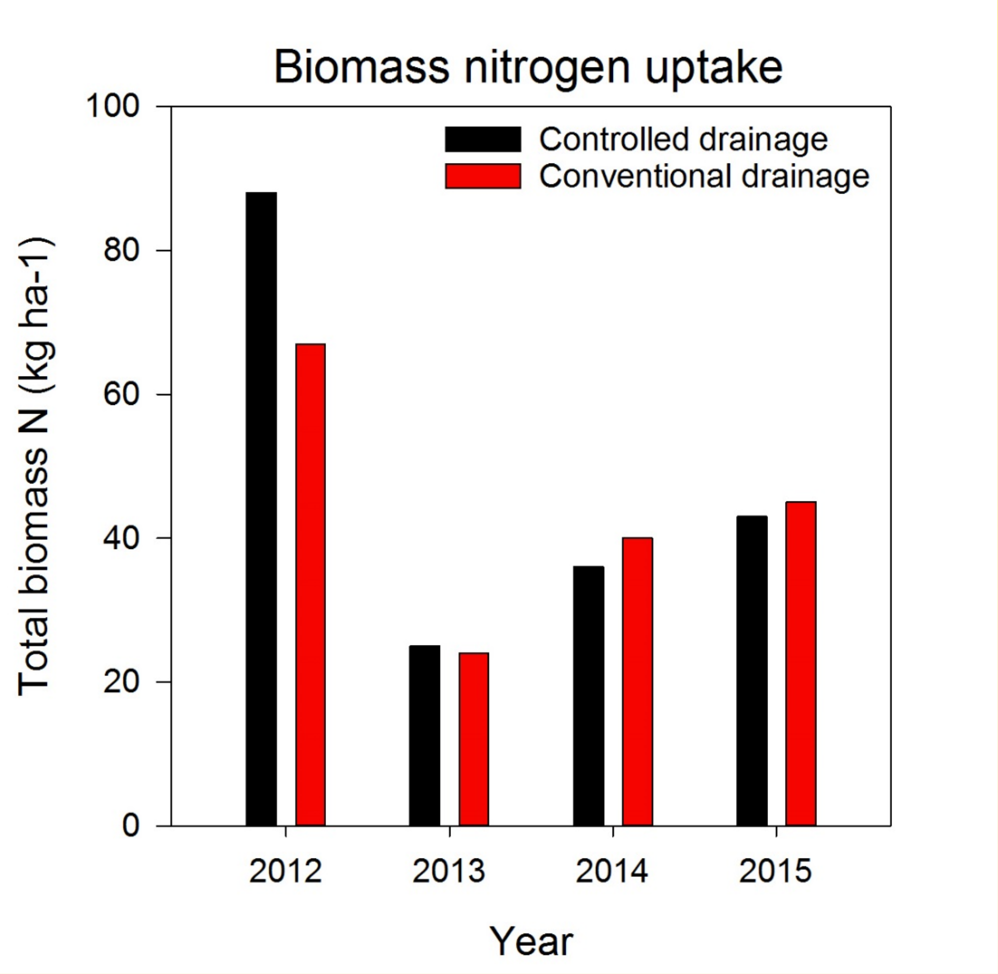


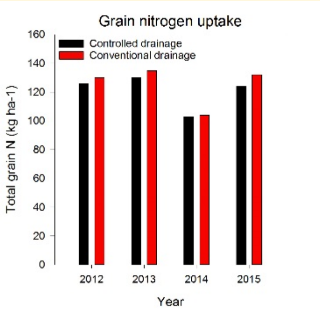




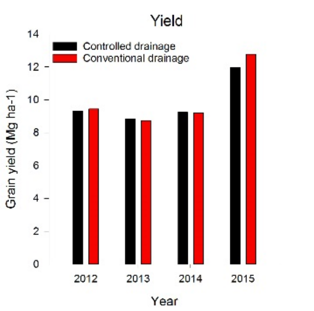
Corn Biomass N Uptake

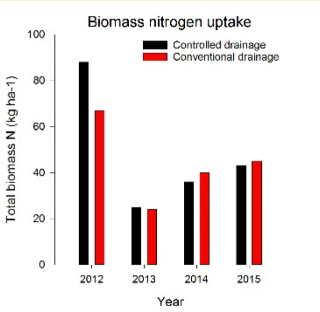


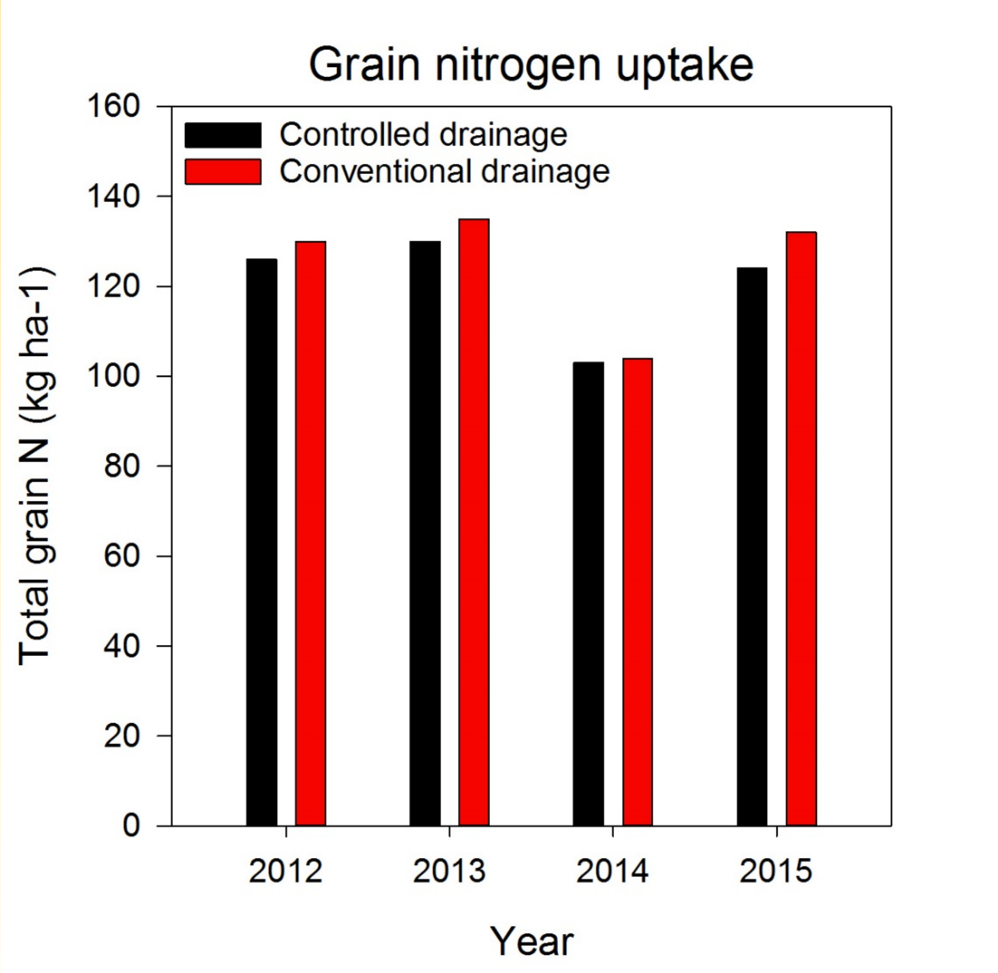




Corn Grain N Uptake







Summary

- Trend analysis showed statistical differences between controlled and conventional free drainage at this site for annual NO_3-N concentration and load.
- Seasonal variation in precipitation contributed to annual differences observed over the nine years of analysis.
- Controlled drainage resulted in statistically lower annual NO_3-N loads in 5 out of 7 years when there was drain flow from the systems.
- Annual nitrate-N concentration from controlled drainage was significantly greater than conventional free drainage following two years of growing season drought.

Summary (continued)

- Paired weekly N_2O data showed differences between conventional and controlled drainage.
- Annual mean N_2O data showed differences between conventional and controlled drainage in 3 out of 4 years.
- Soils managed under conventional drainage and controlled drainage generally acted as sources of N_2O.
- Controlled drainage exhibited slightly more residual soil nitrate at the end of the growing season.
- Corn grain N uptake was slightly greater for conventional compared to controlled drainage

Acknowledgements

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- Ms. Stacey Feser, Former graduate student
- Ms. Lynn Lendt, Former Technician
- Ms. Emily Evans, Former Technician

THANK YOU!

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MinnesotaCorn GROWERS ASSOCIATION

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