Source areas of N to the Gulf of Mexico

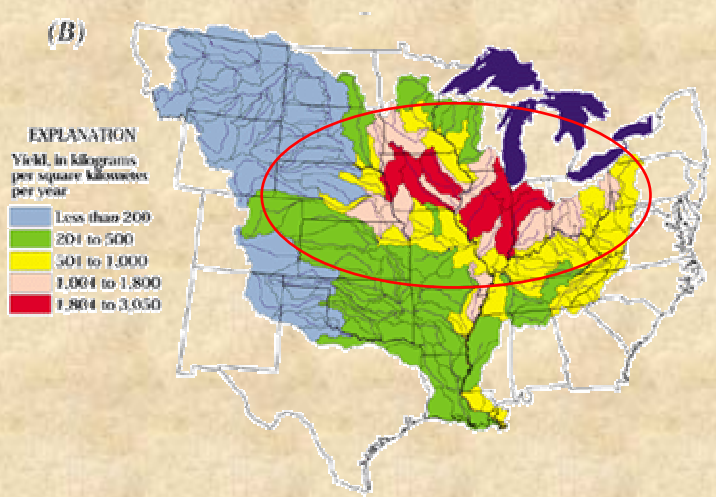
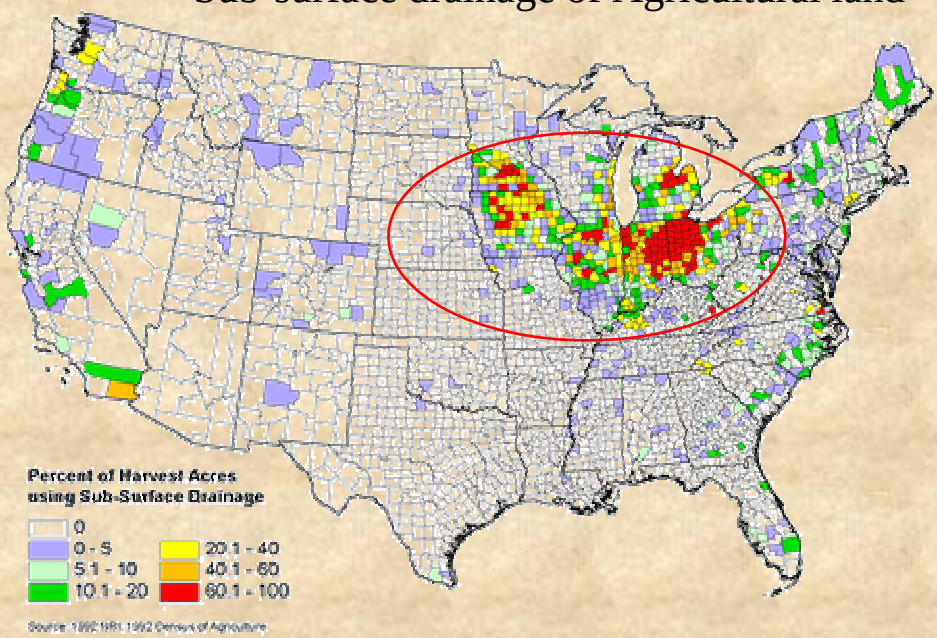
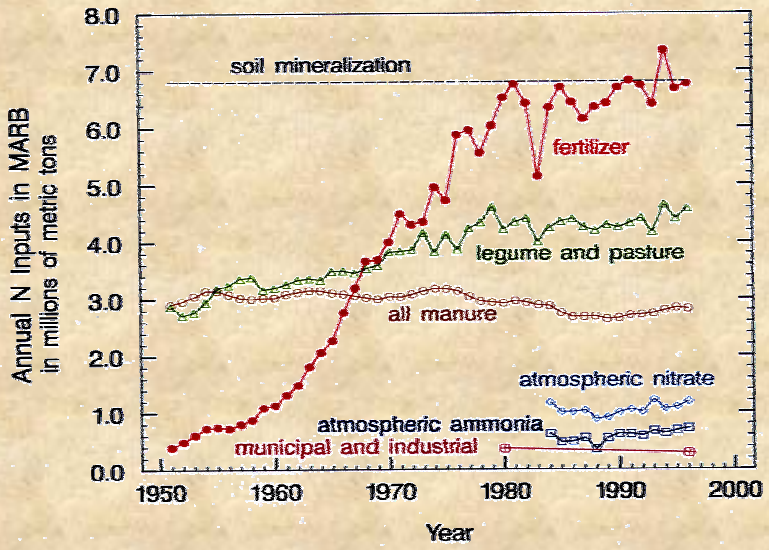


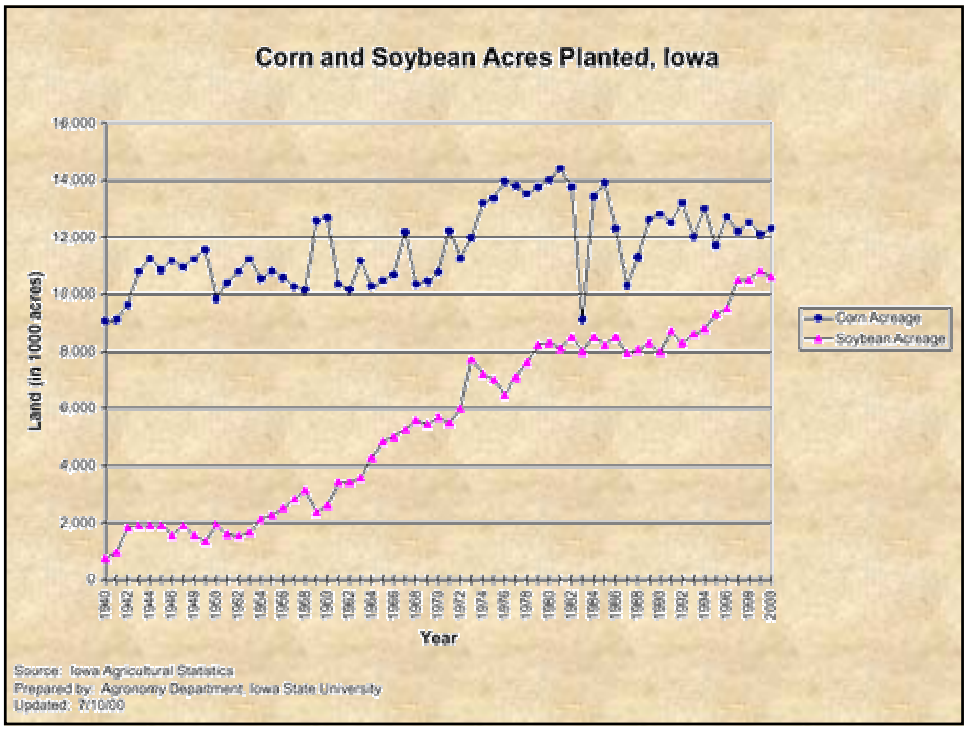
Figure 6. (A) Nitrogen inputs during 1992 and (B) average annual nitrogen yields of streams for 1990–96 (modified from Goolsby and others, 1999).

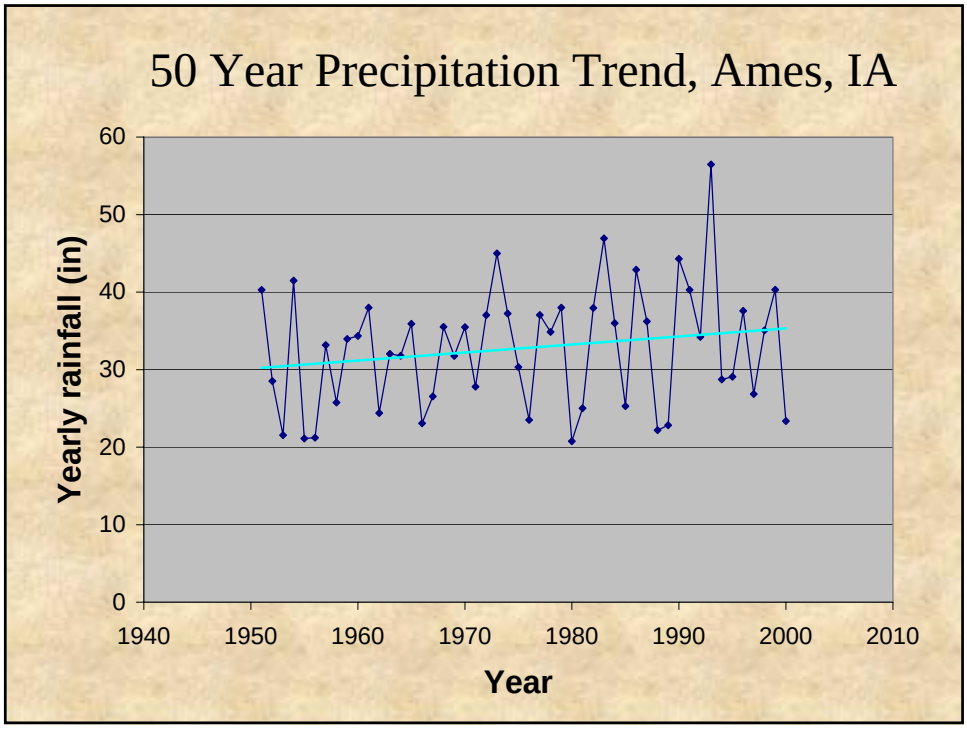
Sub-surface drainage of Agricultural land

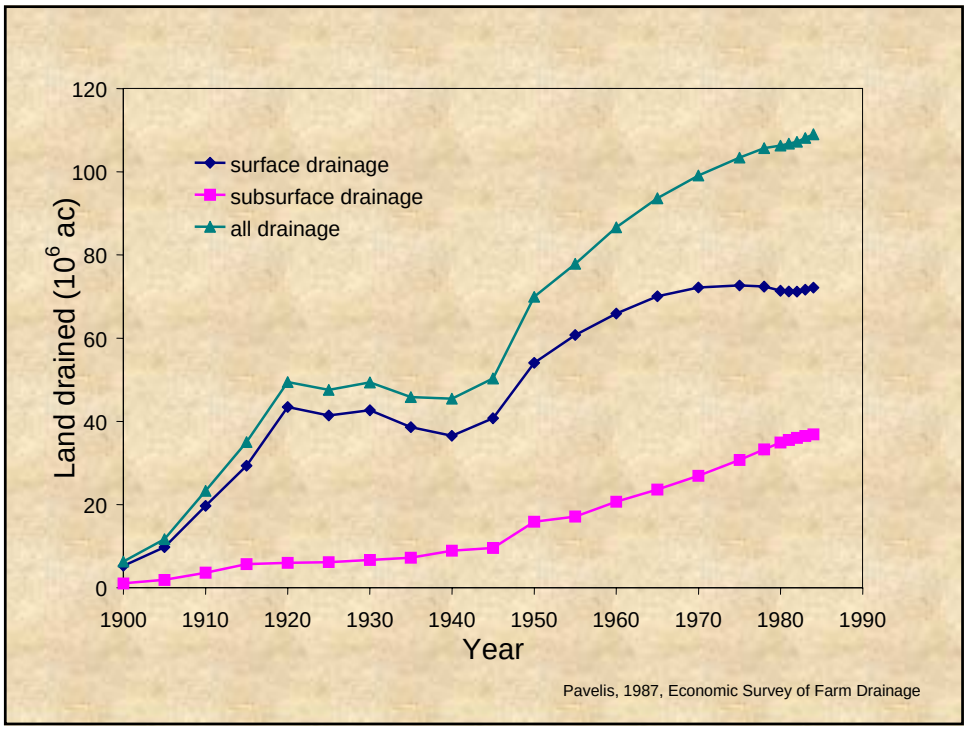


Trends

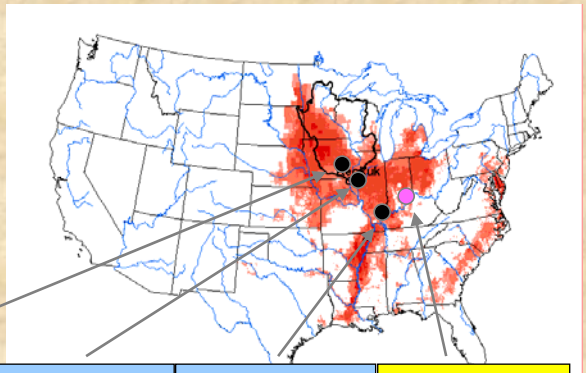

Annual N Inputs in MARB
in millions of metric tons
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1950
1960
1970
1980
1990
2000
Year
soil mineralization
fertilizer
legume and pasture
all manure
atmospheric nitrate
atmospheric ammonia
municipal and industrial


Corn and Soybean Acres Planted, Iowa
Land (in 1000 acres)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Year
Corn Acreage
Soybean Acreage
Source: Iowa Agricultural Statistics
Prepared by: Agronomy Department, Iowa State University
Updated: 7/10/00

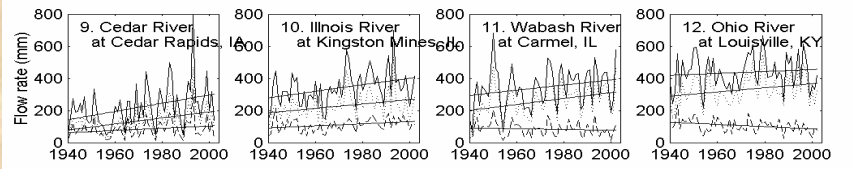

50 Year Precipitation Trend, Ames, IA
Yearly rainfall (in)
0
10
20
30
40
50
60
1940
1950
1960
1970
1980
1990
2000
2010
Year


Land drained (10^6 ac)
0
20
40
60
80
100
120
surface drainage
subsurface drainage
all drainage
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year
Pavelis, 1987, Economic Survey of Farm Drainage

Q, BF & OF in 4 tributaries in the MR basin since 1940



9. Cedar River at Cedar Rapids, IA	10. Illinois River at Kingston Mines, IL	11. Wabash River at Camel, IL	12. Ohio River at Louisville, KY

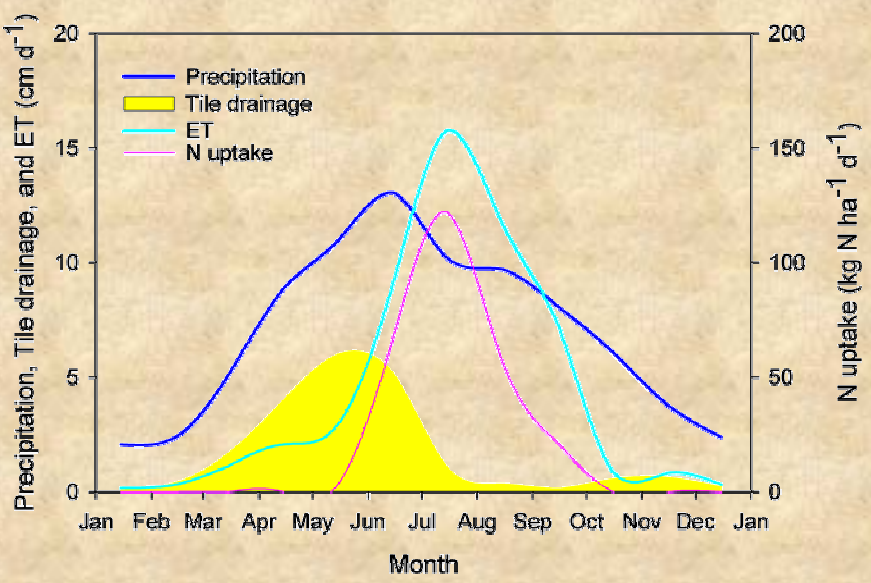


102%	46%	35%	9.2%

Zhang and Schilling (2006) J. Hydrol.

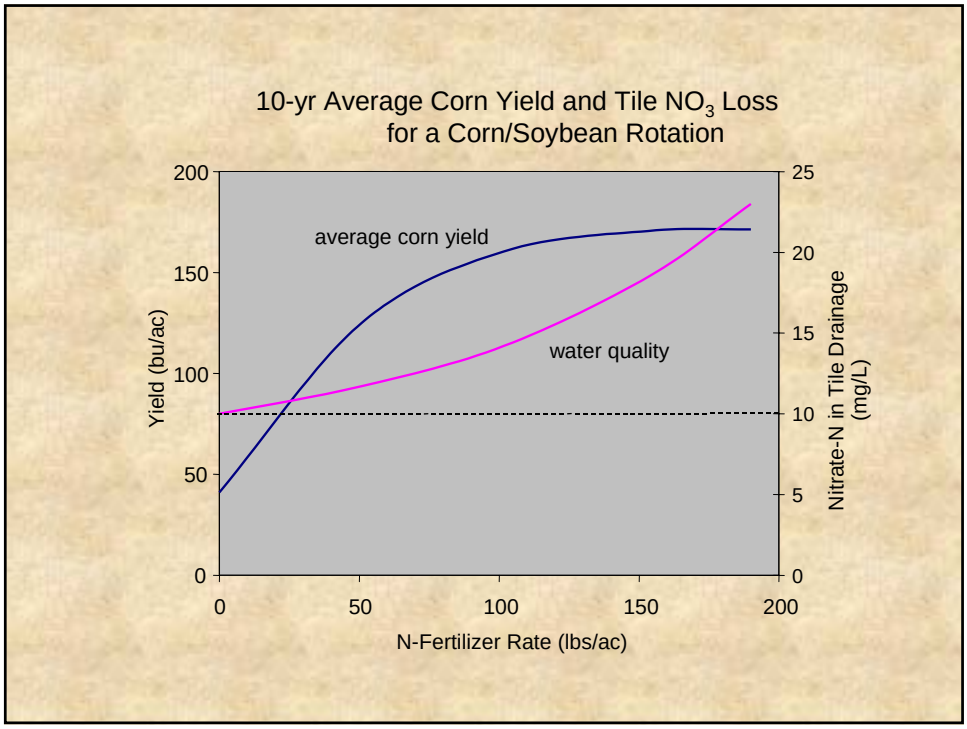
System

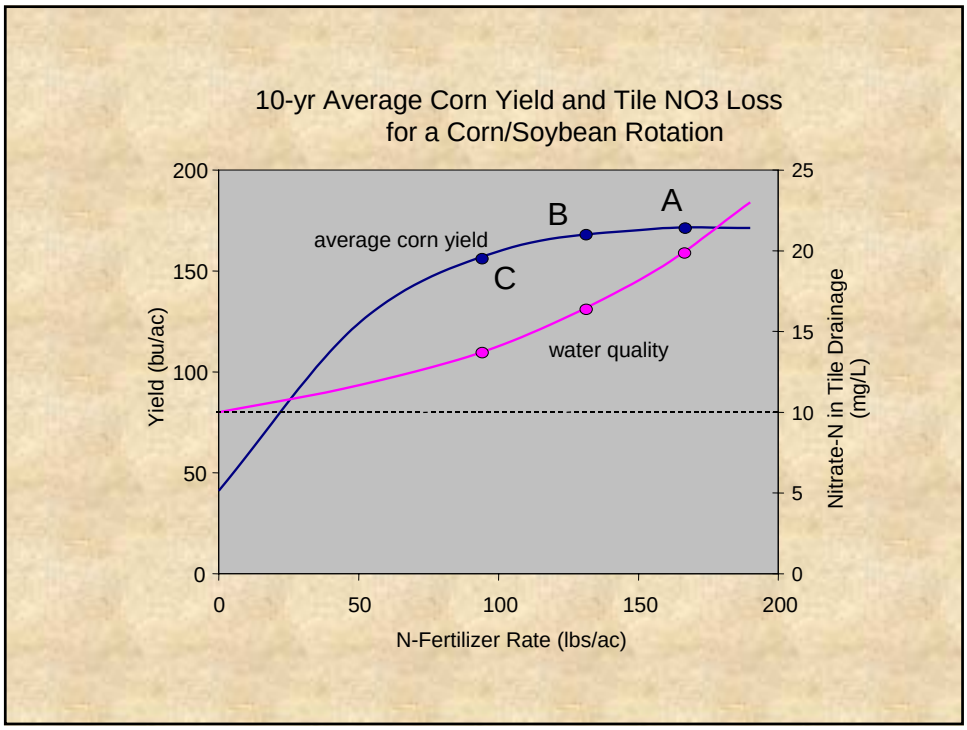
Annual Patterns for Corn, Ames, IA

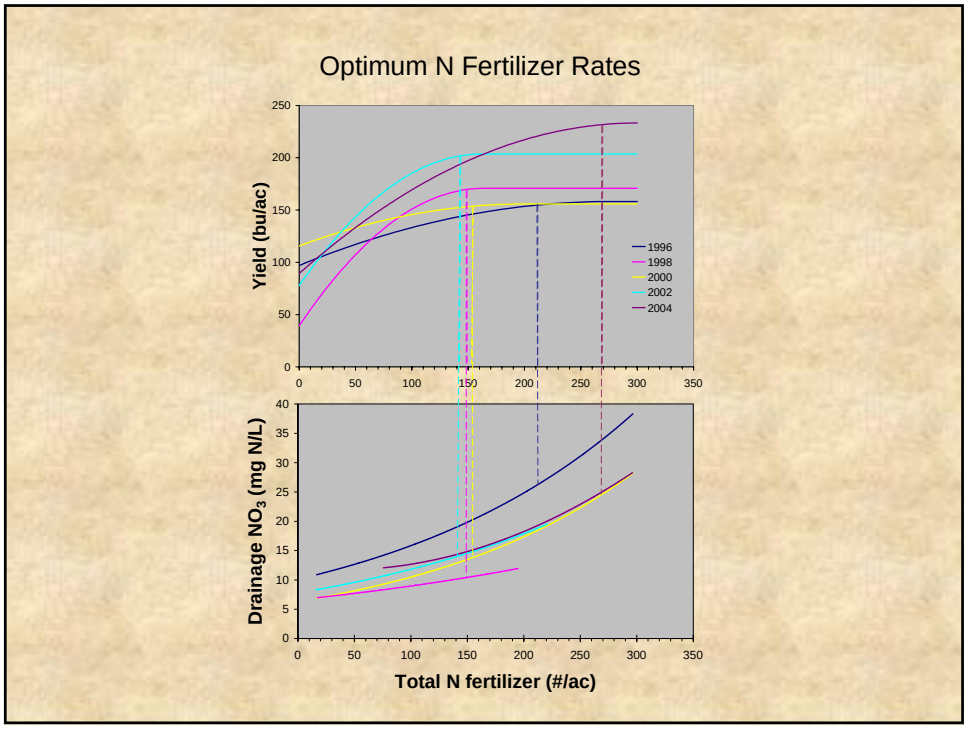


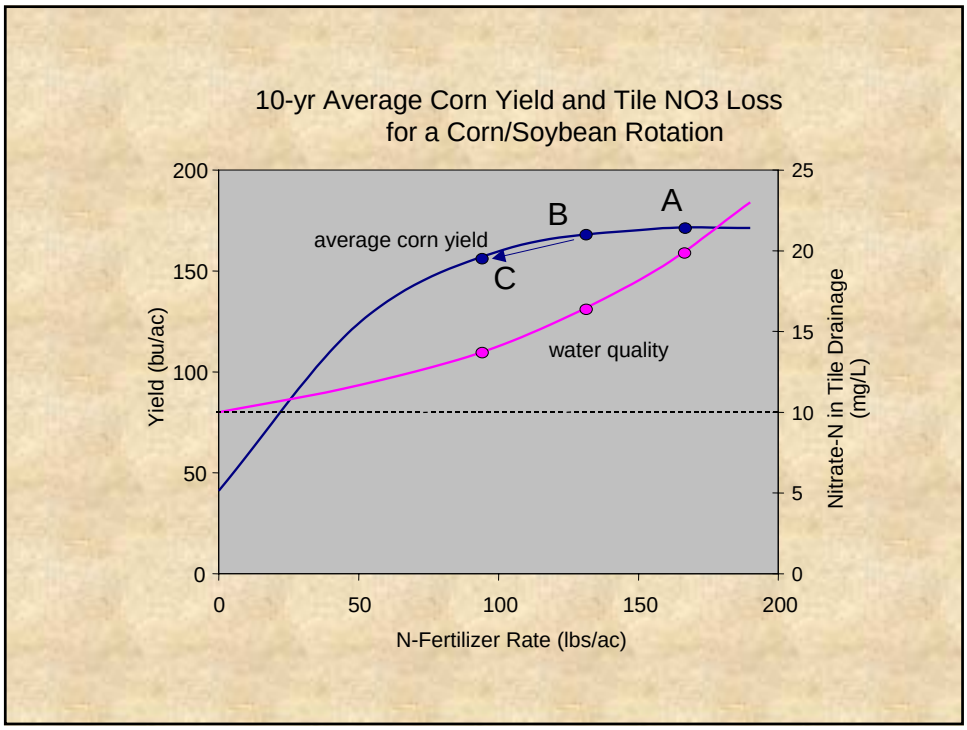
Suggested Solutions:

- Reduce N-fertilizer rates


10-yr Average Corn Yield and Tile NO_3 Loss
for a Corn/Soybean Rotation
average corn yield
water quality
Yield (bu/ac)
Nitrate-N in Tile Drainage (mg/L)
N-Fertilizer Rate (lbs/ac)
0
50
100
150
200
0
5
10
15
20
25

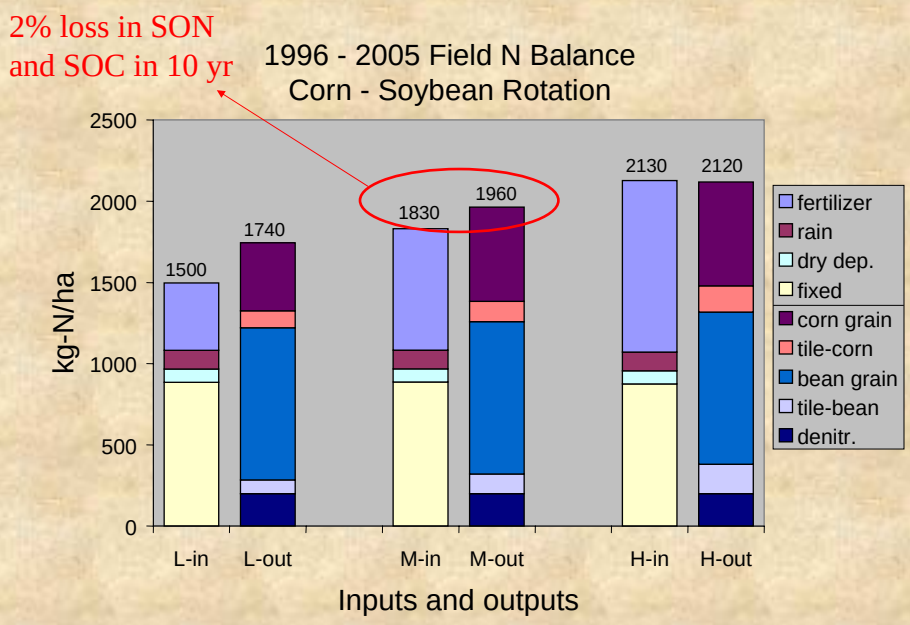

10-yr Average Corn Yield and Tile NO3 Loss
for a Corn/Soybean Rotation
average corn yield
water quality
A
B
C
Yield (bu/ac)
Nitrate-N in Tile Drainage (mg/L)
N-Fertilizer Rate (lbs/ac)
0
50
100
150
200
0
5
10
15
20
25


Optimum N Fertilizer Rates
Yield (bu/ac)
1996
1998
2000
2002
2004
Drainage NO_3 (mg N/L)
Total N fertilizer (#/ac)


10-yr Average Corn Yield and Tile NO3 Loss
for a Corn/Soybean Rotation
average corn yield
water quality
A
B
C
Yield (bu/ac)
Nitrate-N in Tile Drainage (mg/L)
N-Fertilizer Rate (lbs/ac)

Other Consequences of Deficit Fertilization

- Potential loss of soil organic C and N



Results from Other Studies

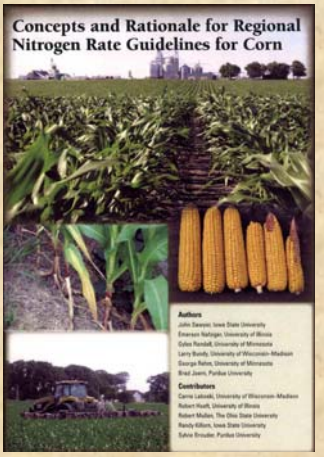
Ref.	Study	soil N change (kg/ha/yr)
Drinkwater et al., 1998	160 N, C-S	-33
Russell et al., 2005	0 N, CC	-18
	180 N, C-S	-21
Havlin et al., 1990	252 N, C-S	-12.5
Robinson et al., 1996	0 N, CC	-31
	200 N, CC	-17
Harper et al., 1989	0N, CS, no till	-15
Jaynes et al., unpub.	200 N, C-S	2
	200 N, C-S, cover crop	52
Karlen et al., 2004	160 N as swine manure, CC	46
	133 N as swine manure, C-S	-11

Suggested Solutions:

- ~~Reduce N-fertilizer rates~~
- Fine-tune N-fertilizer rates
  - Follow University recommendations

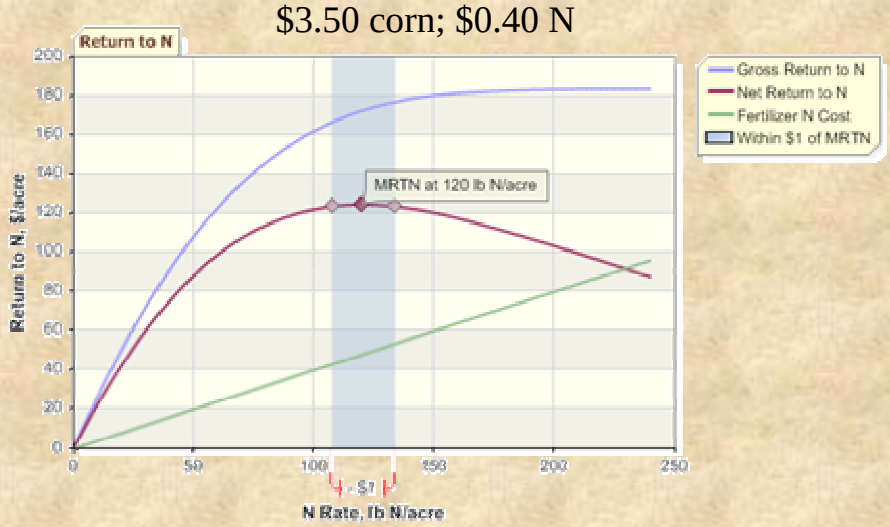
    EONR

    MRTN



PM 2015 April 2006

N recommendation, corn after soybean, Iowa
$3.50 corn; $0.40 N



Corn Nitrogen Rate Calculator, ISU Extension

Table 3. Most Profitable (Least Loss) Rotation and N Rate Using

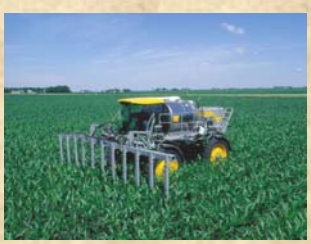
1985 – 2005 Average Yields		2000 – 2005 Average Yields	
N = $.20			
Corn Price	Rotation and N level	Corn Price	Rotation and N Level
< $1.70	CS 80	< $1.20	CS 80
$1.70 - $2.90	CS 160	$1.20 - $1.75	CS 160
$2.90 - $3.40	CS 240	$1.75 - $3.55	CS 240
$3.40 - $3.55	CCS 240	$3.55 - $4.00	CCS 240
> $3.55	CC 240	> $4.00	CC 240
N = $.30			
Corn Price	Rotation and N Level	Corn Price	Rotation and N Level
< $2.40	CS 80	< $1.70	CS 80
$2.40 - $3.45	CS 160	$1.70 - $2.55	CS 160
$3.45 - $3.85	CCS 160	$2.55 - $3.55	CS 240
> $3.85	CC 240	$3.55 - $4.15	CCS 160
		$4.15 - $5.25	CC 160
		> $5.25	CC240
N = $.40			
Corn Price	Rotation and N Level	Corn Price	Rotation and N Level
< $3.05	CS 80	<$2.10	CS 80
$3.05 - $3.60	CS 160	$2.10 - $3.30	CS 160
$3.60 - $4.10	CCS 160	$3.30 - $3.50	CS 240
> $4.10	CC 240	$3.50 - $4.30	CCS 160
		> $4.30	CC 160

Duffy, Where will the Corn Come From? ISU Extension, 2006

Suggested Solutions:

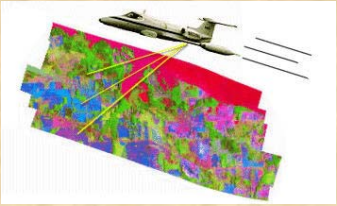
- ~~Reduce N-fertilizer rates~~
- Fine-tune N-fertilizer rates
  - Follow University recommendations
  - Adaptive rates and synchronized timing

Soil sampling

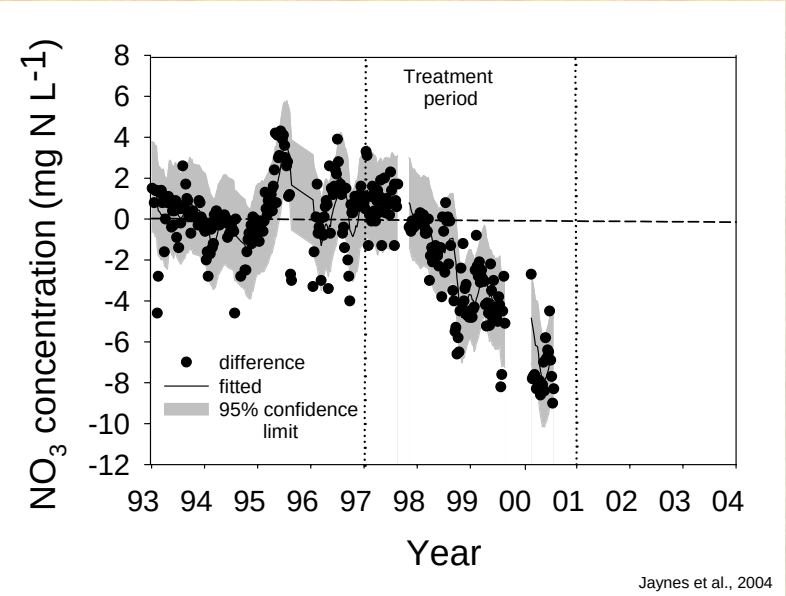


On board sensors

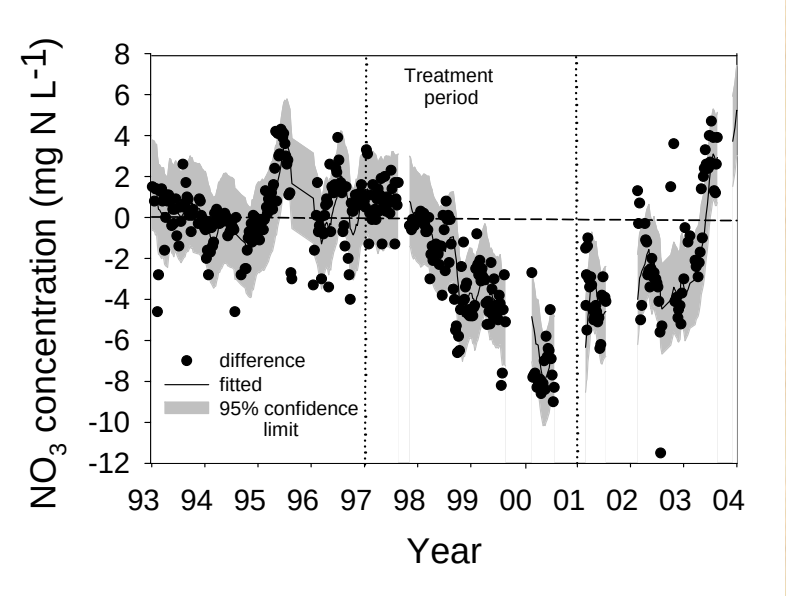
Remote sensing



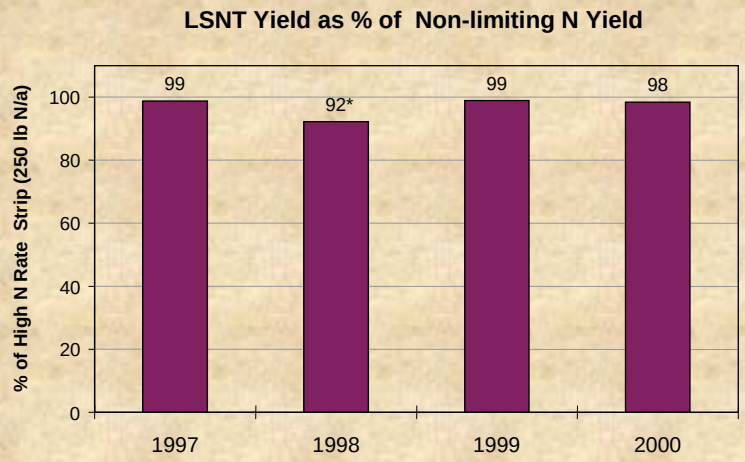
Reduction in [NO_3] for LSNT vs. fall anhydrous



Reduction in [NO_3] for LSNT vs. fall anhydrous



Additional Risk to Farmers



N Application Timing and Rate

Adjusted rate, split in-season vs. fall

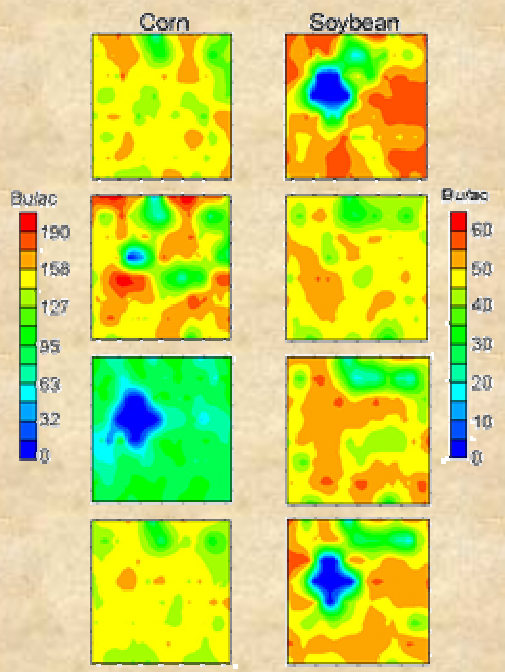
- N loss reduction: -25 to 70%
- Expected long-term reduction: 30%

Adjusted rate, split in-season vs. spring pre-plant

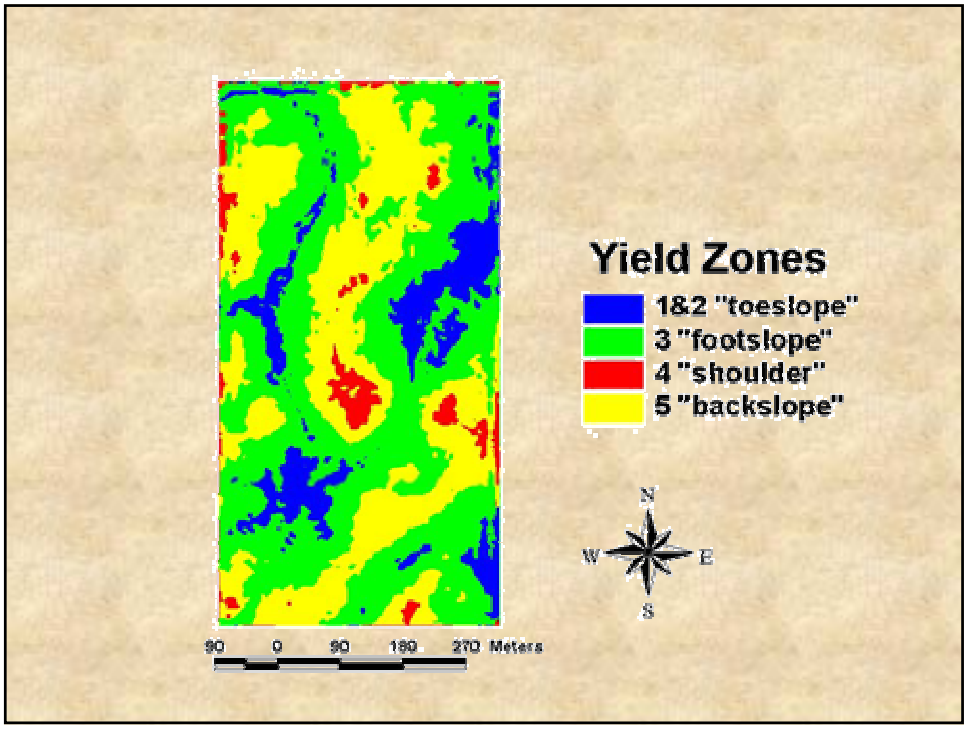
- N loss reduction: -50 to 70% reduction
- Expected long-term reduction: 15%

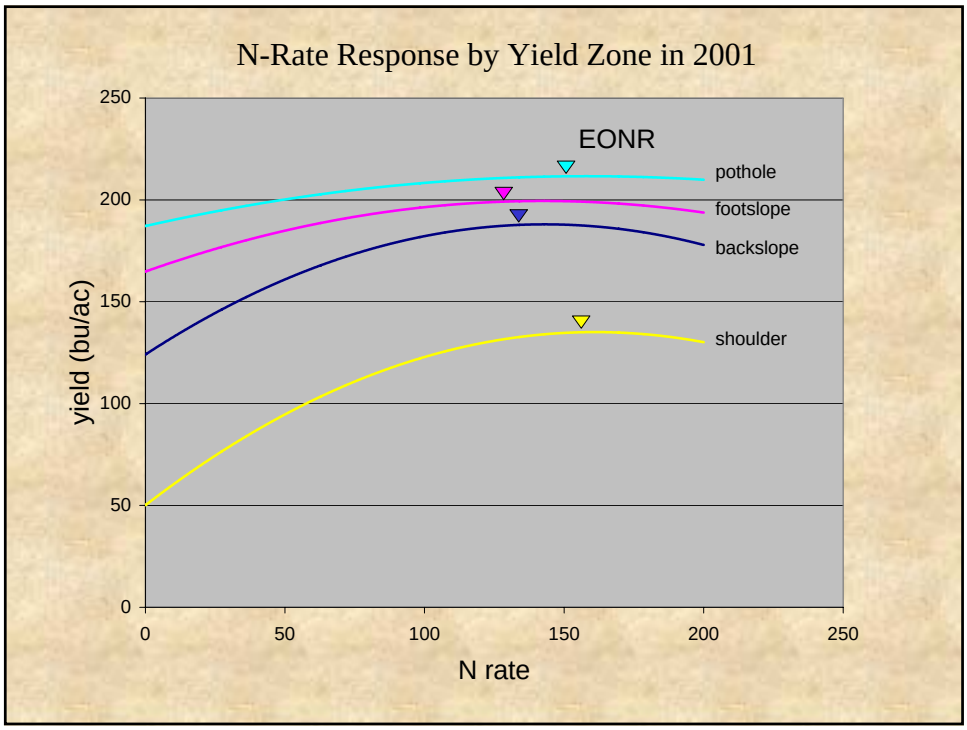
Suggested Solutions:

- ~~Reduce N-fertilizer rates~~
- Fine-tune N-fertilizer rates
  - Follow University Recommendations
  - Adaptive rates and synchronized timing
  - Precision agriculture (spatially variable inputs)

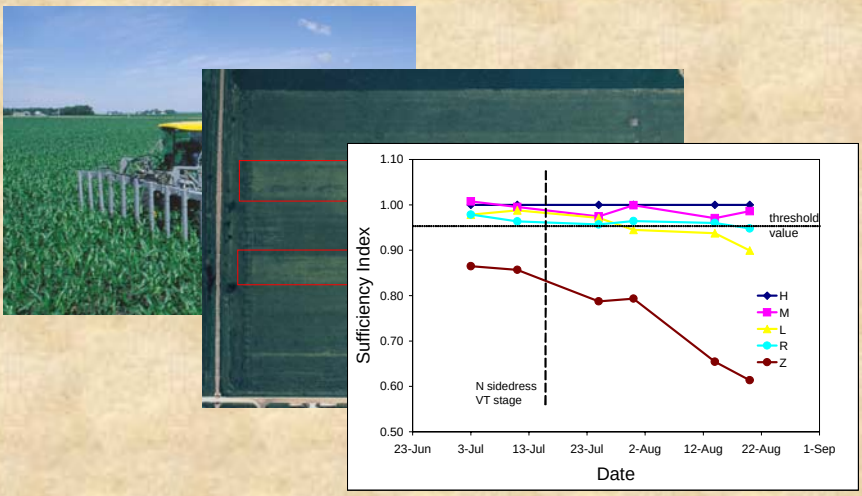


Yield varies over space and among years

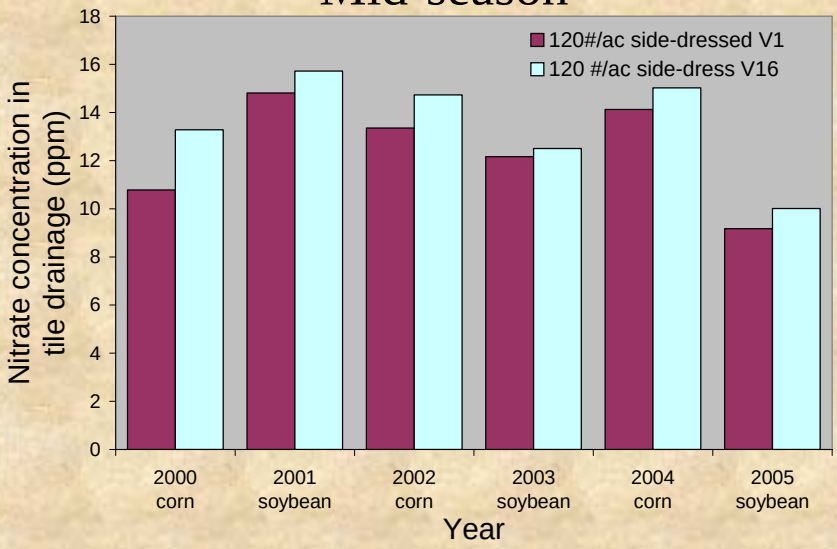

Yield Zones
1&2 "toeslope"
3 "footslope"
4 "shoulder"
5 "backslope"
N
W
E
S
90
0
90
180
270 Meters


N-Rate Response by Yield Zone in 2001
EONR
pothole
footslope
backslope
shoulder
yield (bu/ac)
N rate
0
50
100
150
200
250

Remote Sensing Guided N Rates



Delaying N Application Until Mid-season



Suggested Solutions:

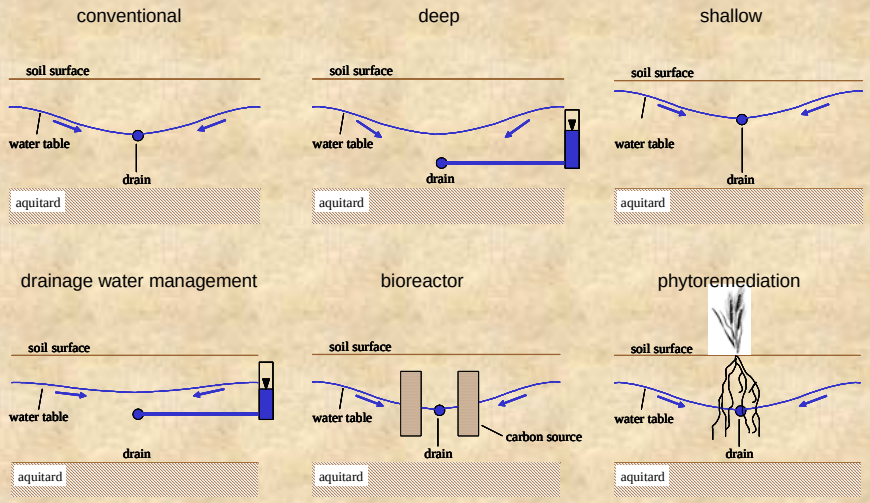
- ~~Reduce N-fertilizer rates~~
- Fine-tune N-fertilizer rates
  - Follow University Recommendations
  - Adaptive rates and synchronized timing
- Modify tile design and management

Improved Tile Drainage Design

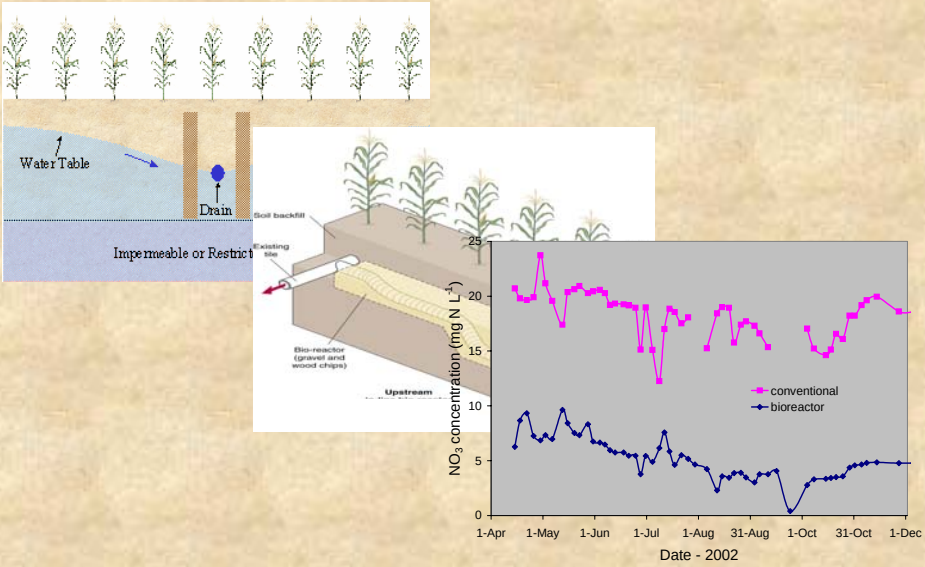
Decrease drainage of water (and N)
or
Increase denitrification:

$$4NO_3^- + CH_20 \xrightarrow[\text{heterotrophs}]{\text{facultative}} 2N_2(g) + 5HCO_3^- + H^+ + 2H_2O$$

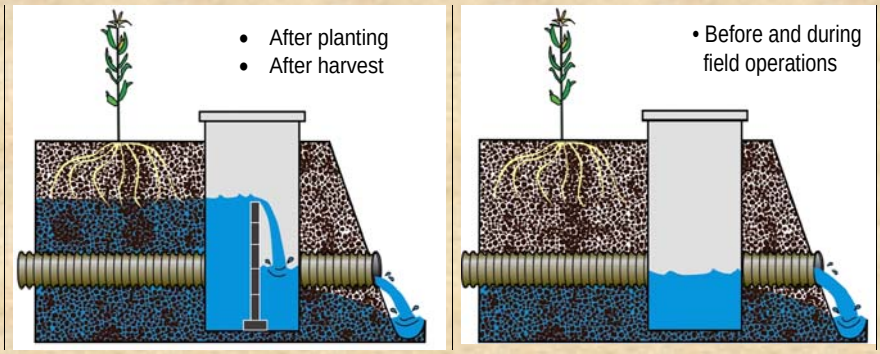
Alternative designs for reducing nitrate leaching from tiles



Denitrification Wall - Results



Drainage water management

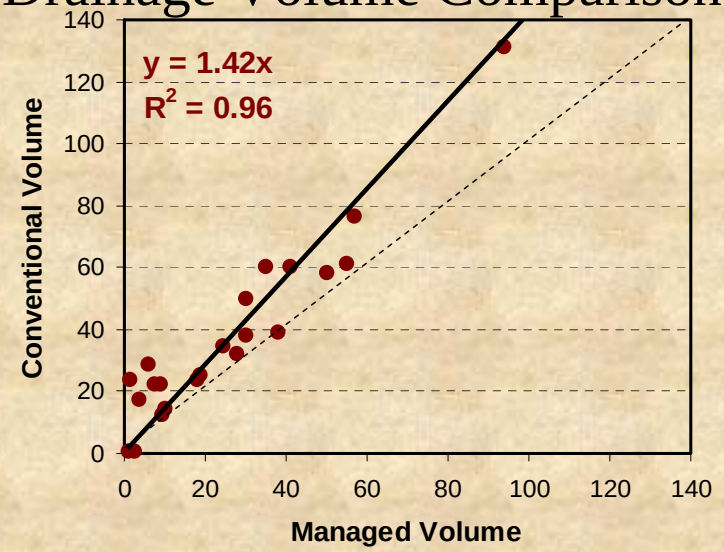


Structure closed to hold water back when drainage not needed

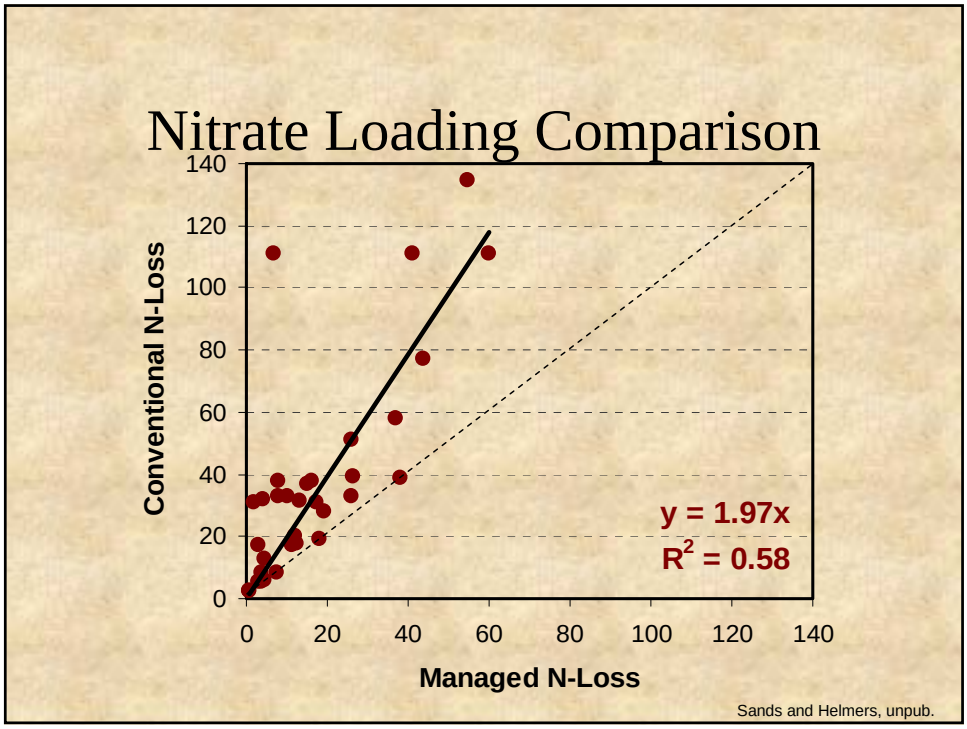
Structure opened for full drainage capacity

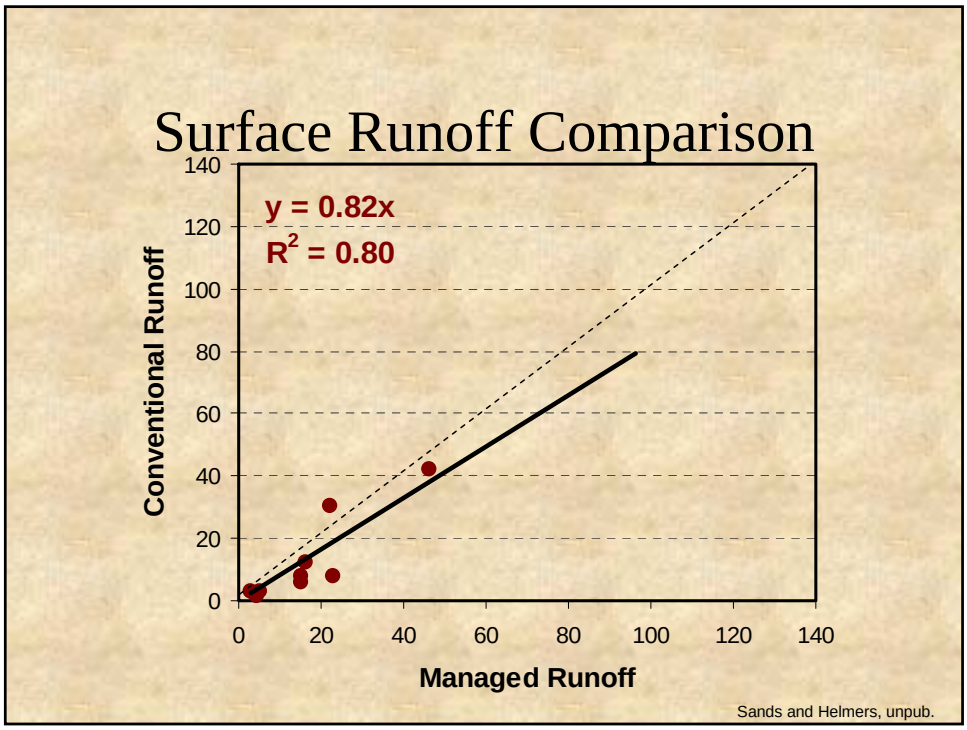
Graphic from J. Frankenberger

Drainage Volume Comparison

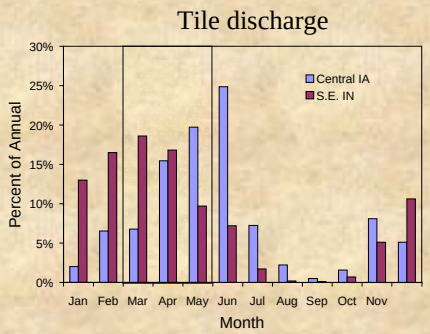


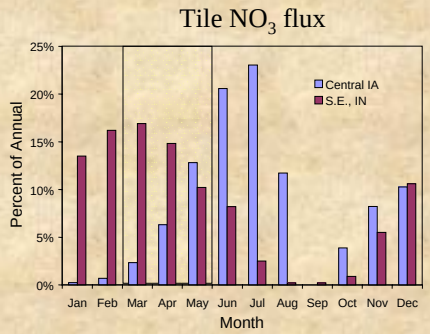
Sands and Helmers, unpub.


Nitrate Loading Comparison
Conventional N-Loss
Managed N-Loss
0
20
40
60
80
100
120
140
y = 1.97x
R2 = 0.58
Sands and Helmers, unpub.


Surface Runoff Comparison
Conventional Runoff
Managed Runoff
0
20
40
60
80
100
120
140
y = 0.82x
R2 = 0.80
Sands and Helmers, unpub.

Annual pattern of drainage and NO_3 flux varies across the Cornbelt





Data from Kladivko and Jaynes

Drainage Management

Drainage Water Management vs. conventional

- N loss reduction: 0 to 75%
- Expected long term reduction: 25%

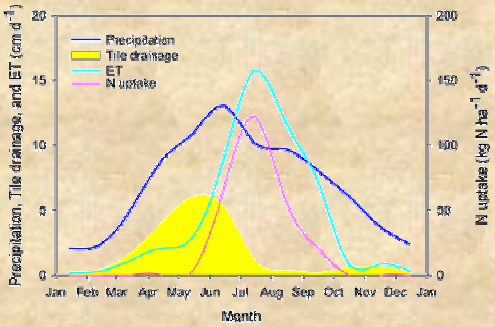
- Shallow vs. conventional drainage
- N loss reduction: 0 to 75%
- Expected long term reduction: 20%

Suggested Solutions:

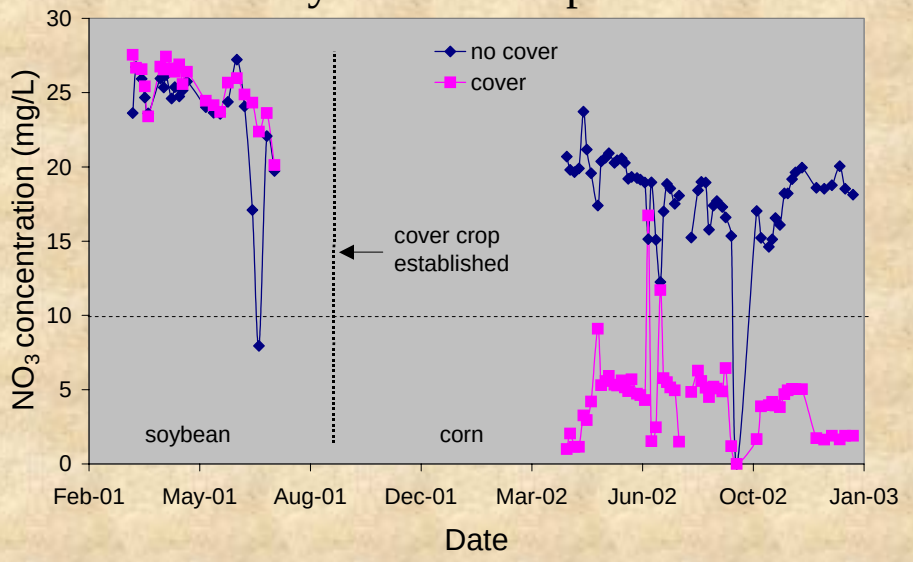
- ~~Reduce N-fertilizer rates~~
- Fine-tune N-fertilizer rates
  - Follow University Recommendations
  - Rate and timing
  - Precision Agriculture
- Modify tile design and management
- Cover crops and new crop rotations

Fall Cover "Catch" Crop

Row crop



Fall Rye Cover Crop - Results



Cover Crops and Perennials

Fall planted rye vs. no cover crop

- N loss reduction: -20 to 90%
- Expected long term reduction: 50%

Perennial vs. corn/soybean rotation

- N loss reduction: 20 to 90%
- Expected long term reduction: >50%

Table 1. Total nitrogen (TN) and total phosphorus (TP) potential nonpoint source (NPS) loss reductions estimated on a multiple year basis for conservation practices.

Conservation Practice	Percentage Impact on NPS Loss Reduction[1] TN	TP
Conservation Tillage		
Moderate vs. Intensive Tillage	+3%	+50%
No-Till vs. Intensive Tillage	+10%	+70%
No-Till vs. Moderate Tillage	+5%	+45%
Cover Crops	+50%[2]	+50%[2]
Diverse Cropping Systems	+50%	+50%
Drainage Management		
Controlled Drainage vs. Uncontrolled Drainage	+25%	-10%
Water Table Management vs. Uncontrolled Drainage	+30%	-10%
Shallow and/or Wide vs. Standard Tile Placement	+20%	-10%
In-Field Vegetative Buffers	+25%	+50%
Landscape Management	-10%	+50%
Nitrification and Urease Inhibitors	+10%	N/A[3]
Nitrogen Nutrient Application Techniques	+10%	N/A
Nitrogen Nutrient Timing and Rate Conservation Management		
Timing: Spring vs. Fall Application	+15%	N/A
Timing: Soil-Test Based Split In-Season vs. Fall	+30%	N/A
Timing: Soil-Test Based Split In-Season vs. Spring	+15%	N/A
Rate: Yield Goal or Crop Removal Based vs. Excessive	+35%	N/A
Rate: Soil-Test Based vs. Excessive	+60%	N/A
Rate: Soil-Test Based vs. Yield Goal or Crop Removal Based	+25%	N/A
Pasture/Grassland Management		
Livestock Exclusion from Streams vs. Constant Intensive Grazing	+30%	+75%
Rotational Grazing vs. Constant Intensive Grazing	+20%	+25%
Seasonal Grazing vs. Constant Intensive Grazing	+20%	+50%
Phosphorus Nutrient Application Techniques		
Deep Tillage Incorporation vs. Surface Broadcast	N/A	-15%
Shallow Tillage Incorporation vs. Surface Broadcast	N/A	-10%
Knife or Injection Incorporation vs. Surface Broadcast	N/A	+35%
Phosphorus Nutrient Timing and Rate Conservation Management		
Timing: Spring vs. Fall Application	N/A	+30%
Soil-Test P Rate Balanced to Crop Use vs. High and Excessive	N/A	+40%
Time to Runoff Event: 1-month vs. 1-day	N/A	+30%
Riparian Buffers	+40%	+45%
Wetlands	+30%	+20%

[1] Positive percentage number indicates reduced nutrient NPS pollution of surface waters; Negative percentage number indicates increased nutrient NPS pollution of surface waters.

[2] Estimate is based upon the conservation practice applied only to the most applicable systems for cover crops in Iowa, which the primary crops are harvested and removed in mid- to late-summer.

[3] N/A represents "not applicable."

Dinnes, Assessment of Practices …, 2004