Scientific and Technical Advisory Committee

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Nutrient Transport in Maryland Coastal Plain Watersheds: What We Know and What Next

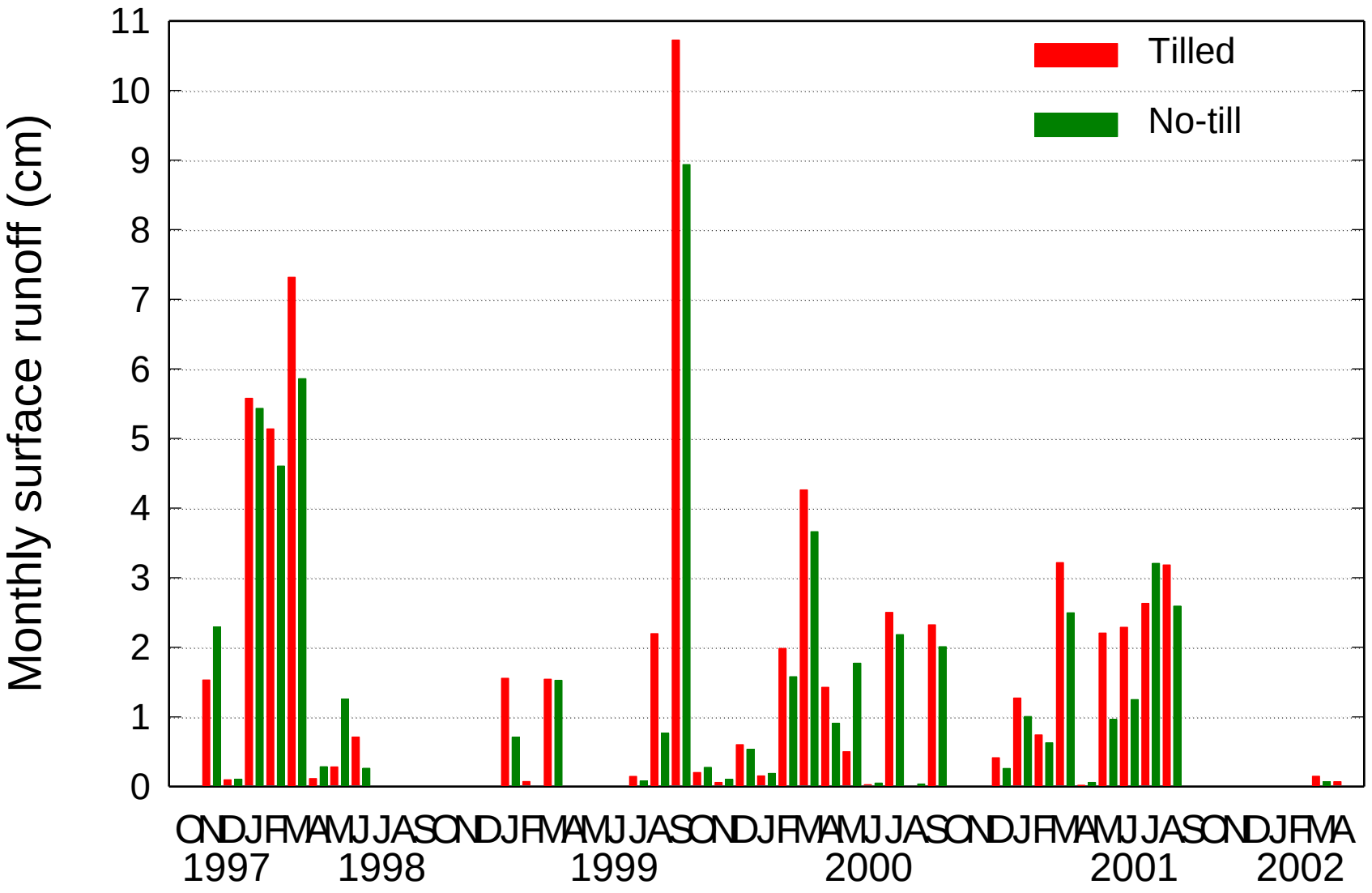
Ken Staver

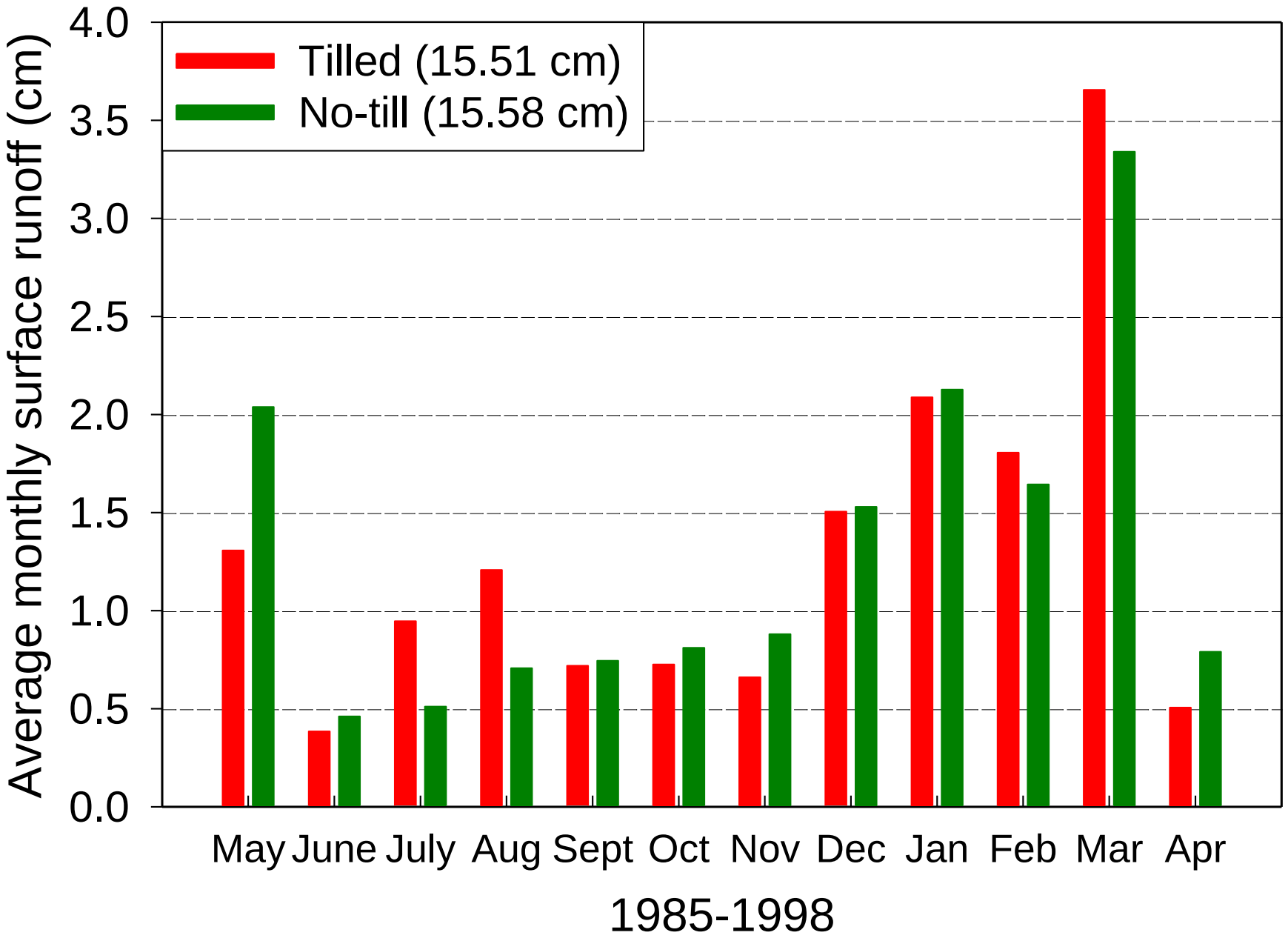
University of Maryland
College of Agriculture and Natural Resources
Wye Research and Education Center
Queenstown, Maryland

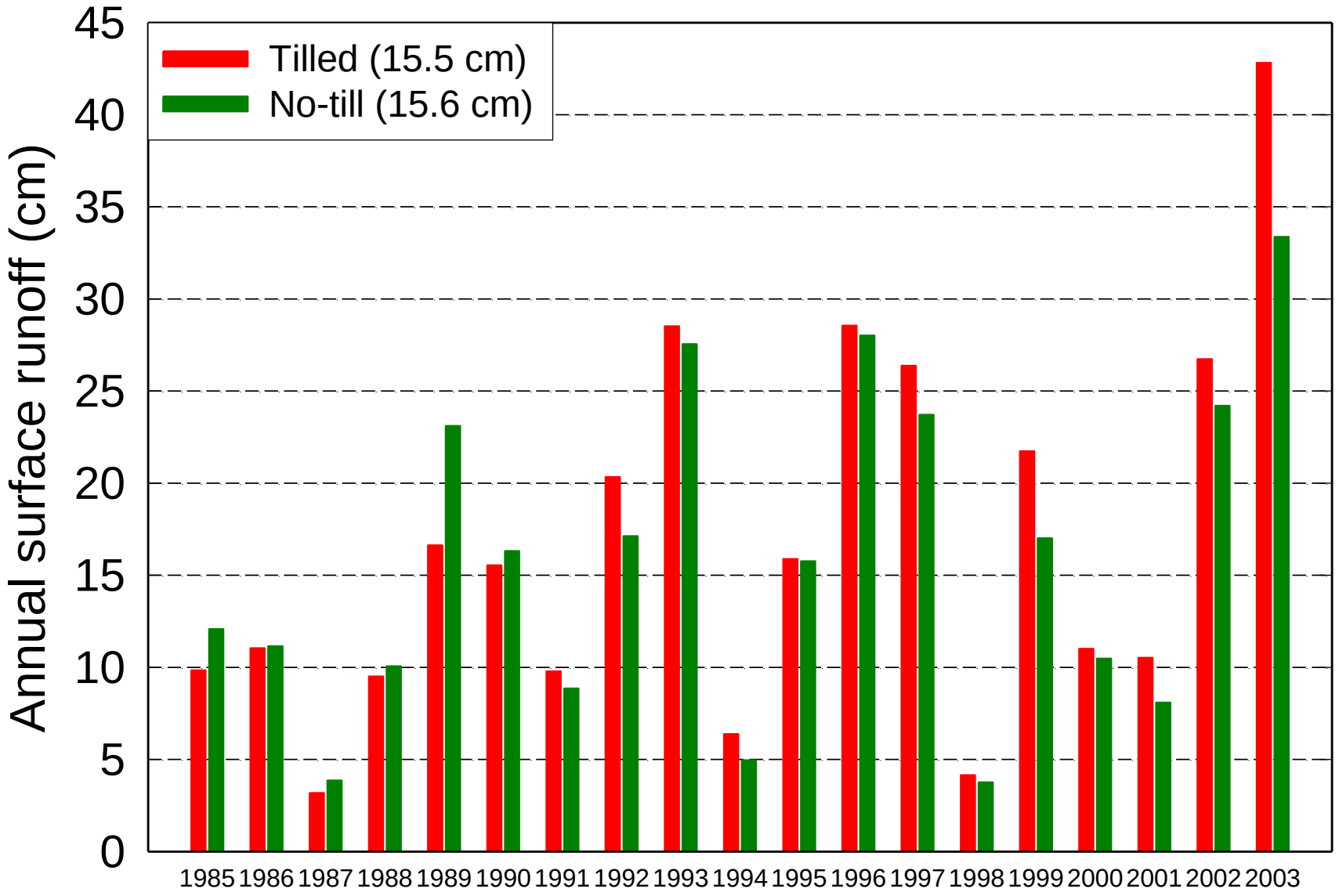
Watershed Management

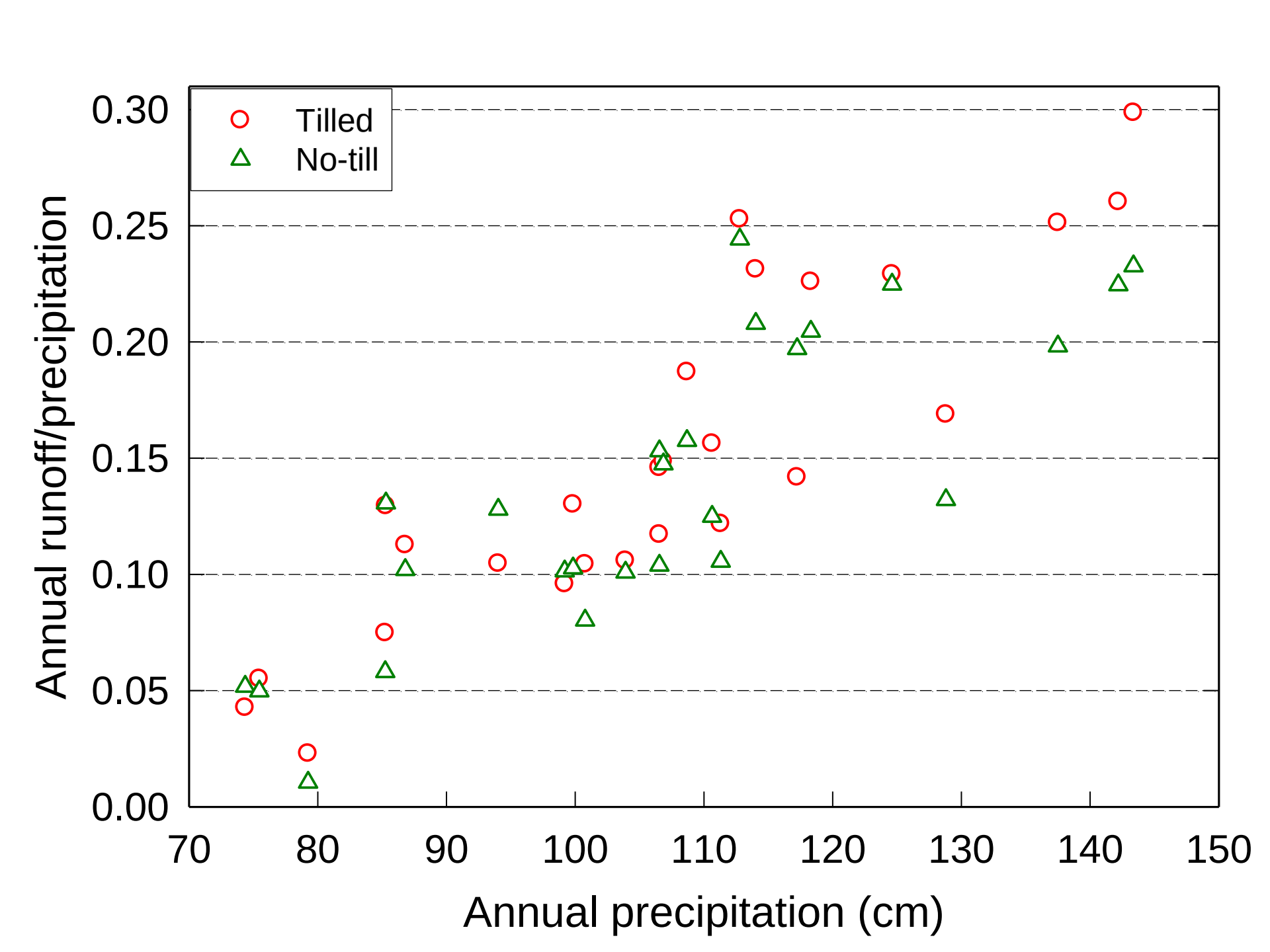
- 1985-97 continuous corn, CT/NT
- 1988-97 rye winter cover crops
- 1990 installed grass waterways
- 1994-97 No P applications
- 1998-2003 corn/wheat/dc soybean
- 1998-2003 CT/NT poultry litter
- 2004-07 surface/subsurface N
- 2008-09 NT/turbotill poultry litter

Surface runoff volume?


Monthly surface runoff (cm)
11
10
9
8
7
6
5
4
3
2
1
0
Tilled
No-till
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1997
1998
1999
2000
2001
2002


Tilled (15.51 cm)
No-till (15.58 cm)
Average monthly surface runoff (cm)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1985-1998


Tilled (15.5 cm)
No-till (15.6 cm)
Annual surface runoff (cm)
0
5
10
15
20
25
30
35
40
45
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


Tilled
No-till
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Annual runoff/precipitation
70
80
90
100
110
120
130
140
150
Annual precipitation (cm)

Basic Fact #1

Volume = precipitation – evaporation

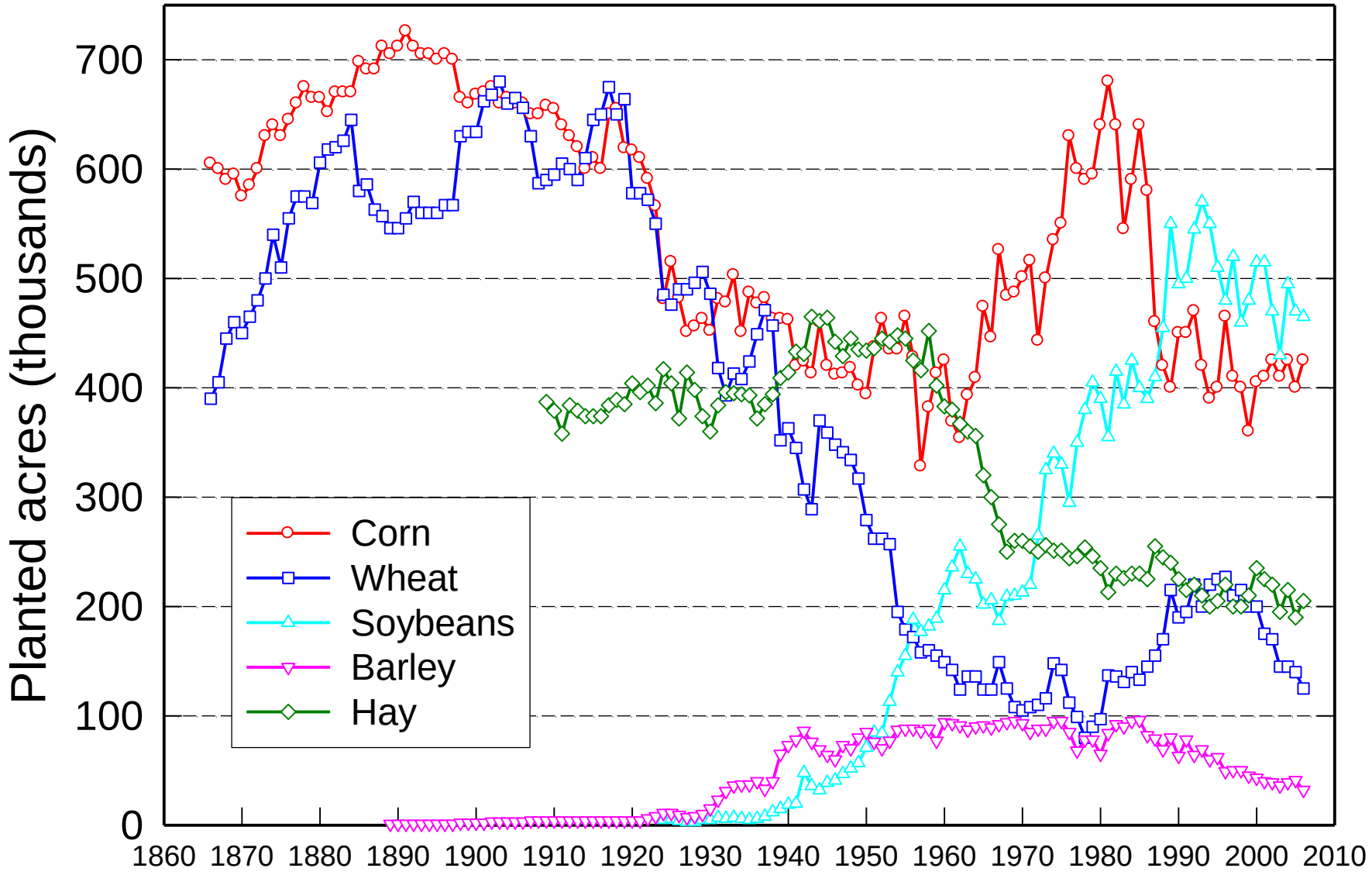
We have little ability to reduce the overall volume of water leaving crop fields although we do have some limited opportunities to affect how water leaves crop fields.

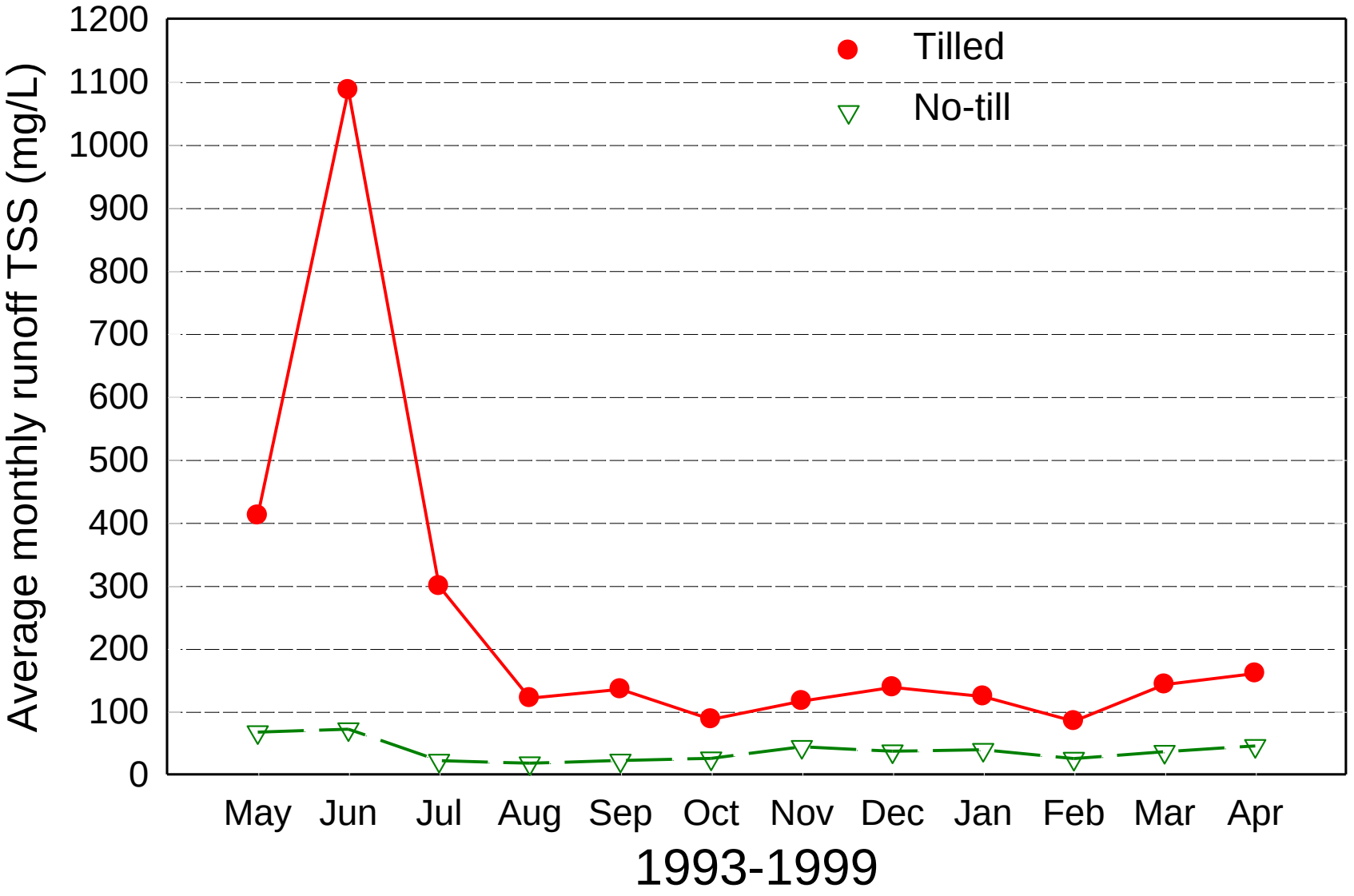
Basic Fact #2

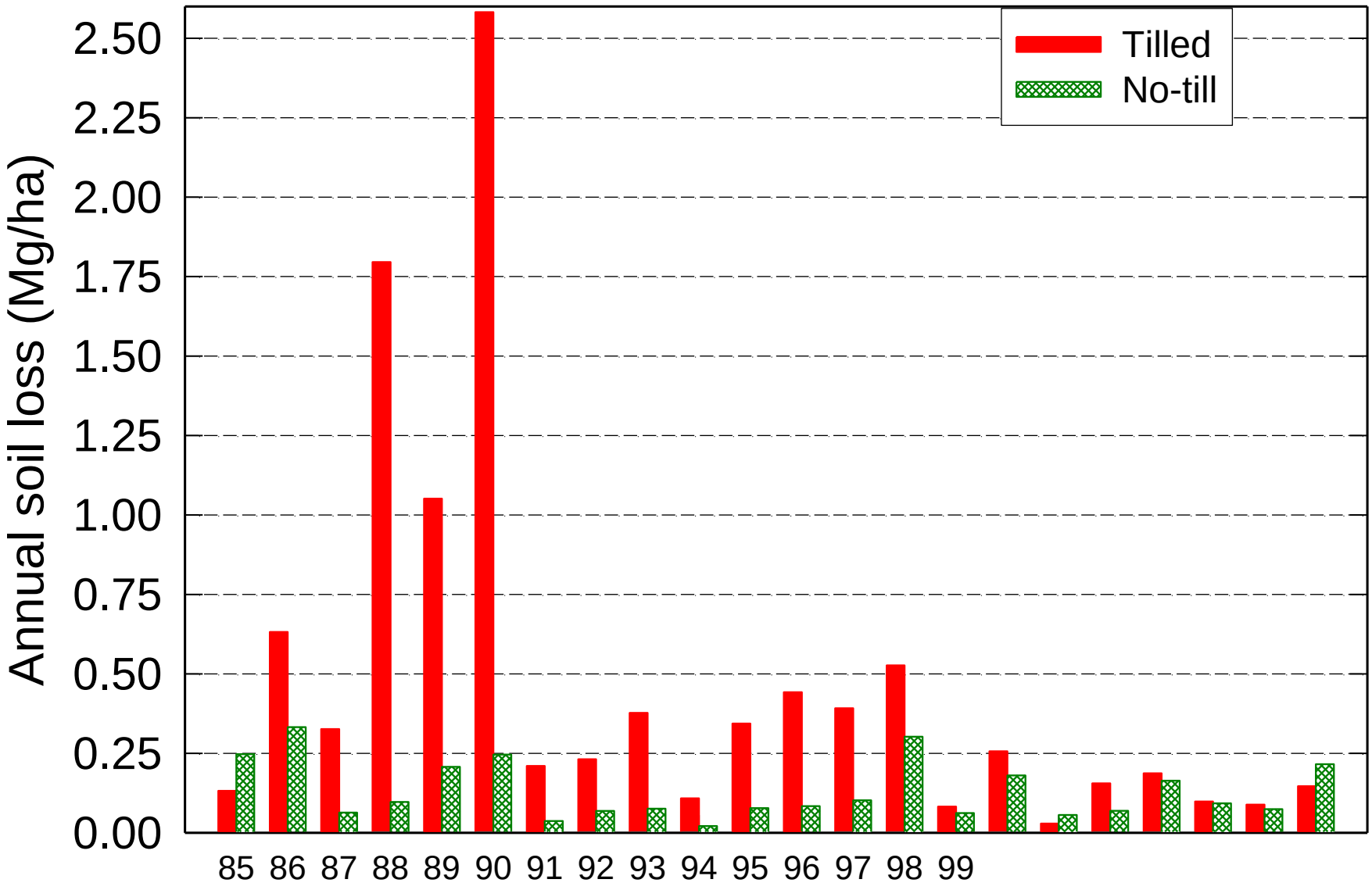
Nutrient losses occur when water leaving the crop field interacts with transportable forms of N and P.

Nutrient load = concentration x volume.

What about erosion?

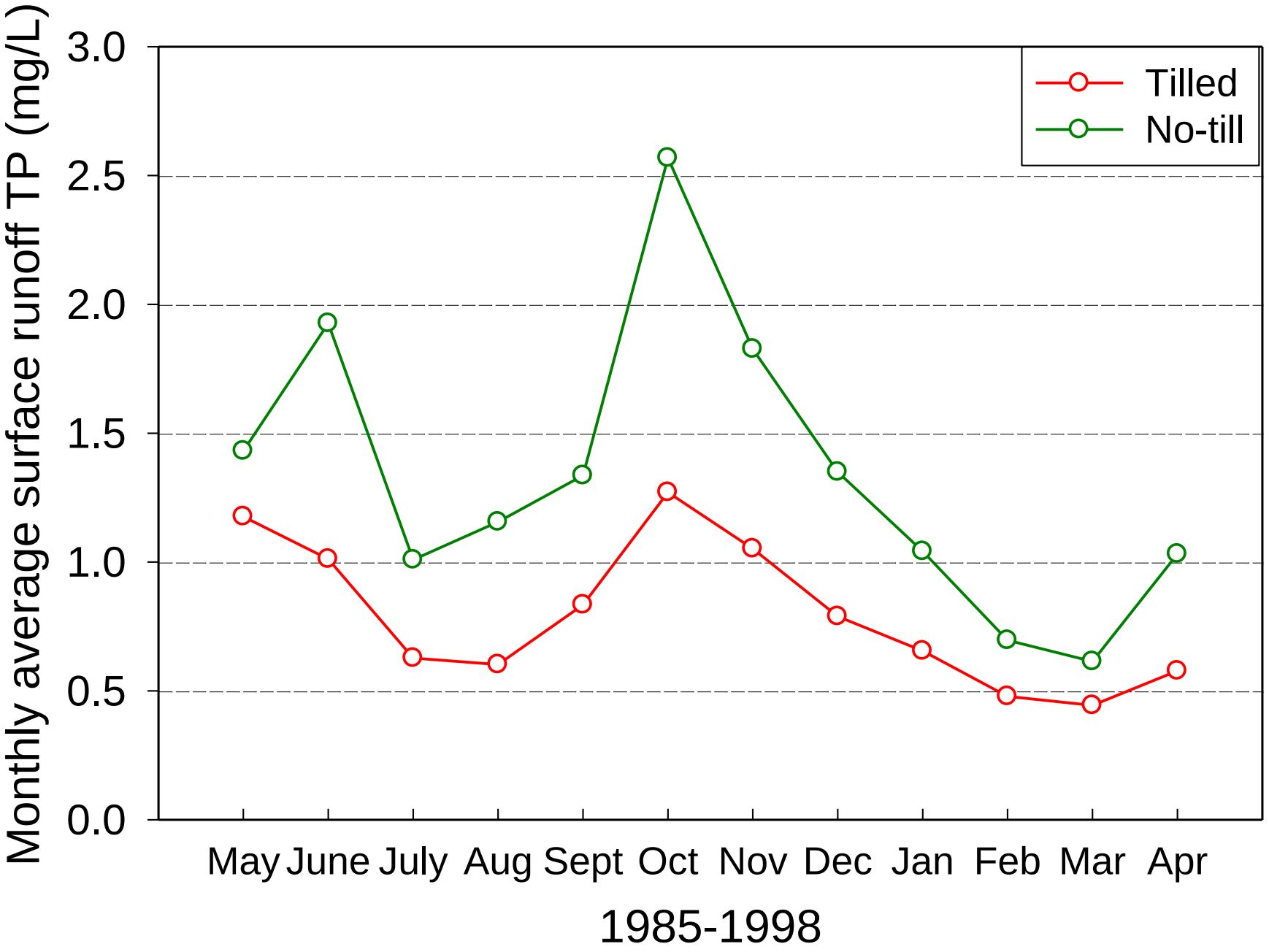

Planted acres (thousands)
700
600
500
400
300
200
100
0
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Corn
Wheat
Soybeans
Barley
Hay

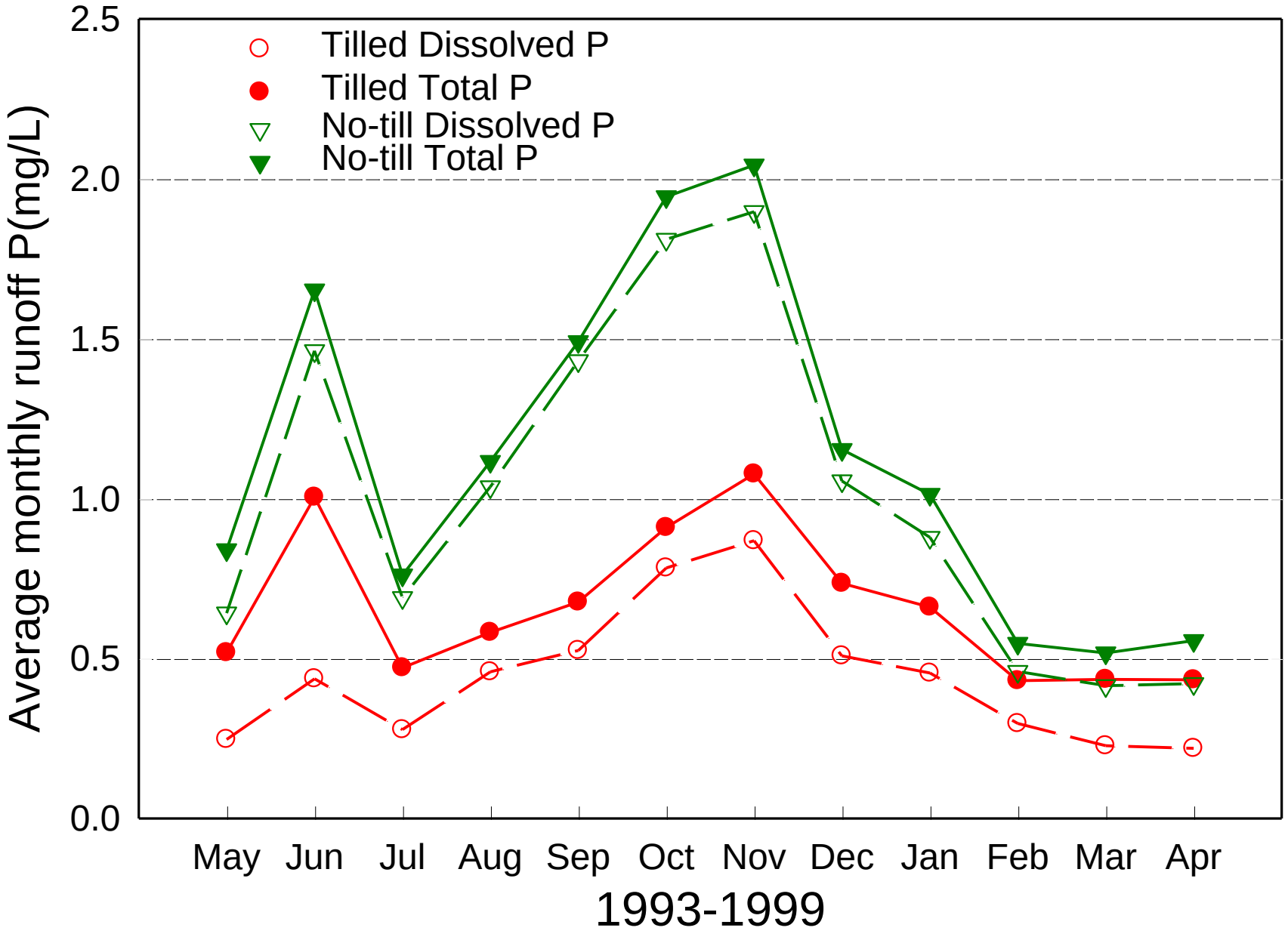

Average monthly runoff TSS (mg/L)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Tilled
No-till
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1993-1999

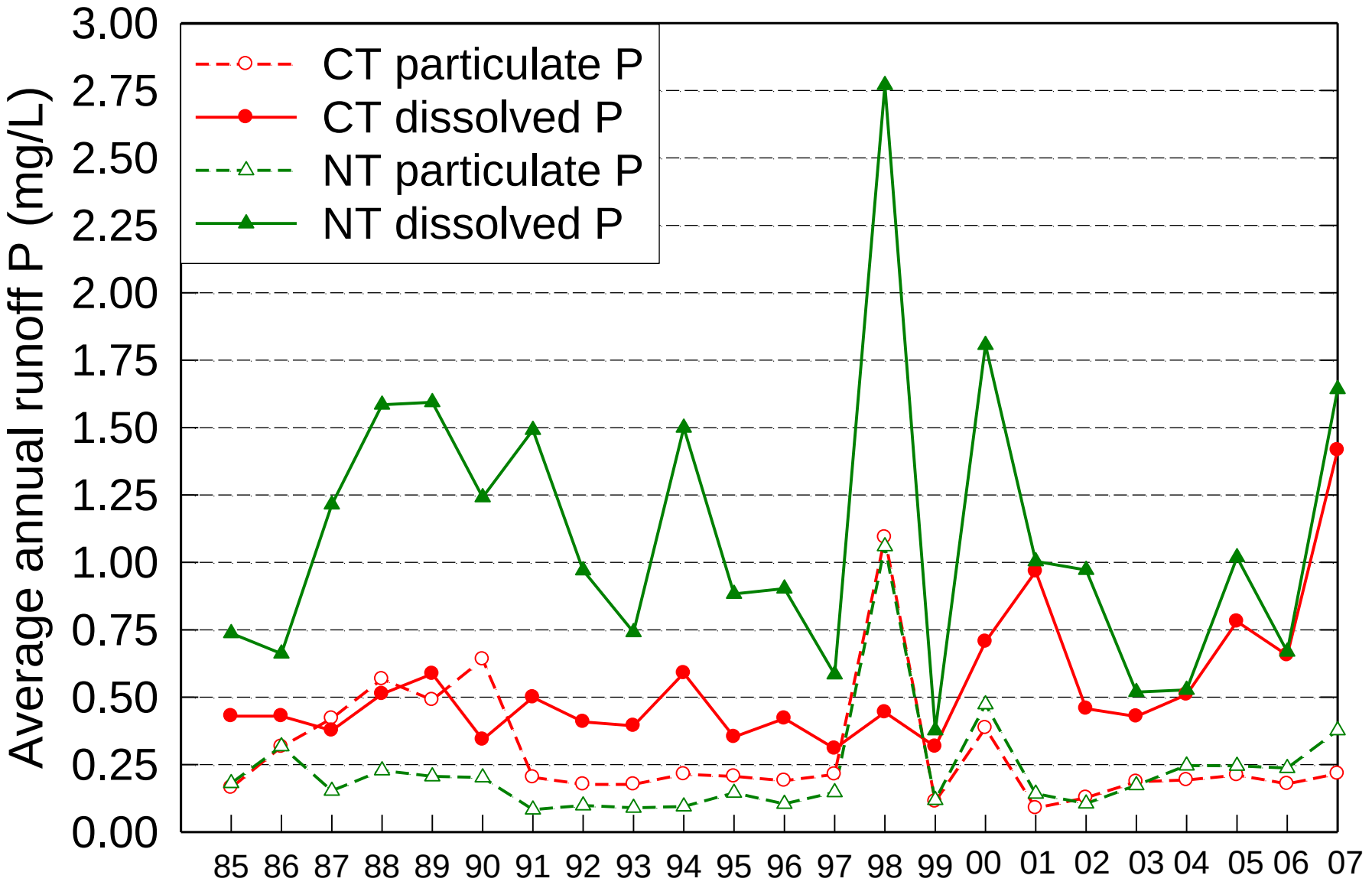

Annual soil loss (Mg/ha)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Tilled
No-till
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99

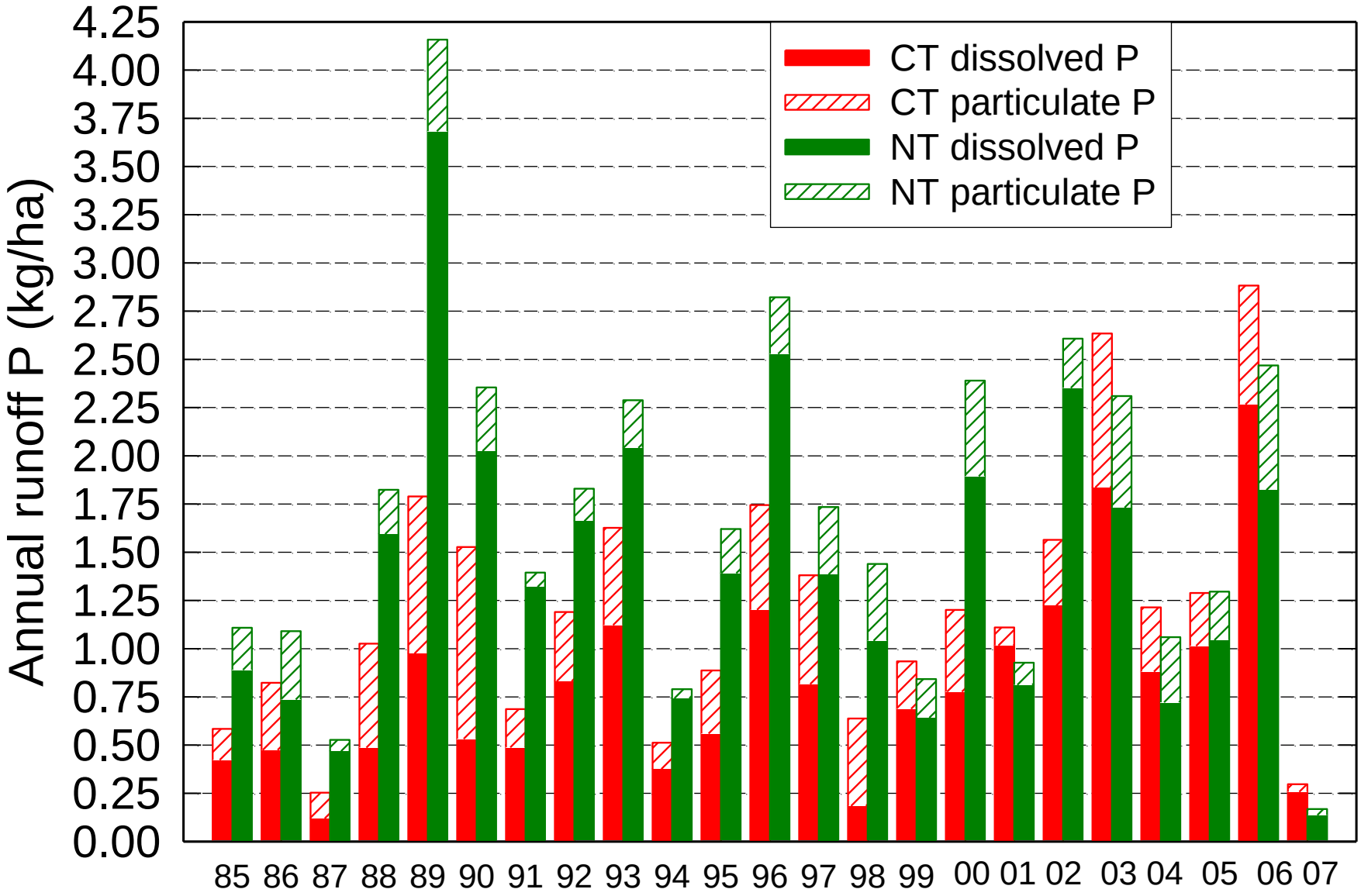
What about surface runoff N and P concentrations ?

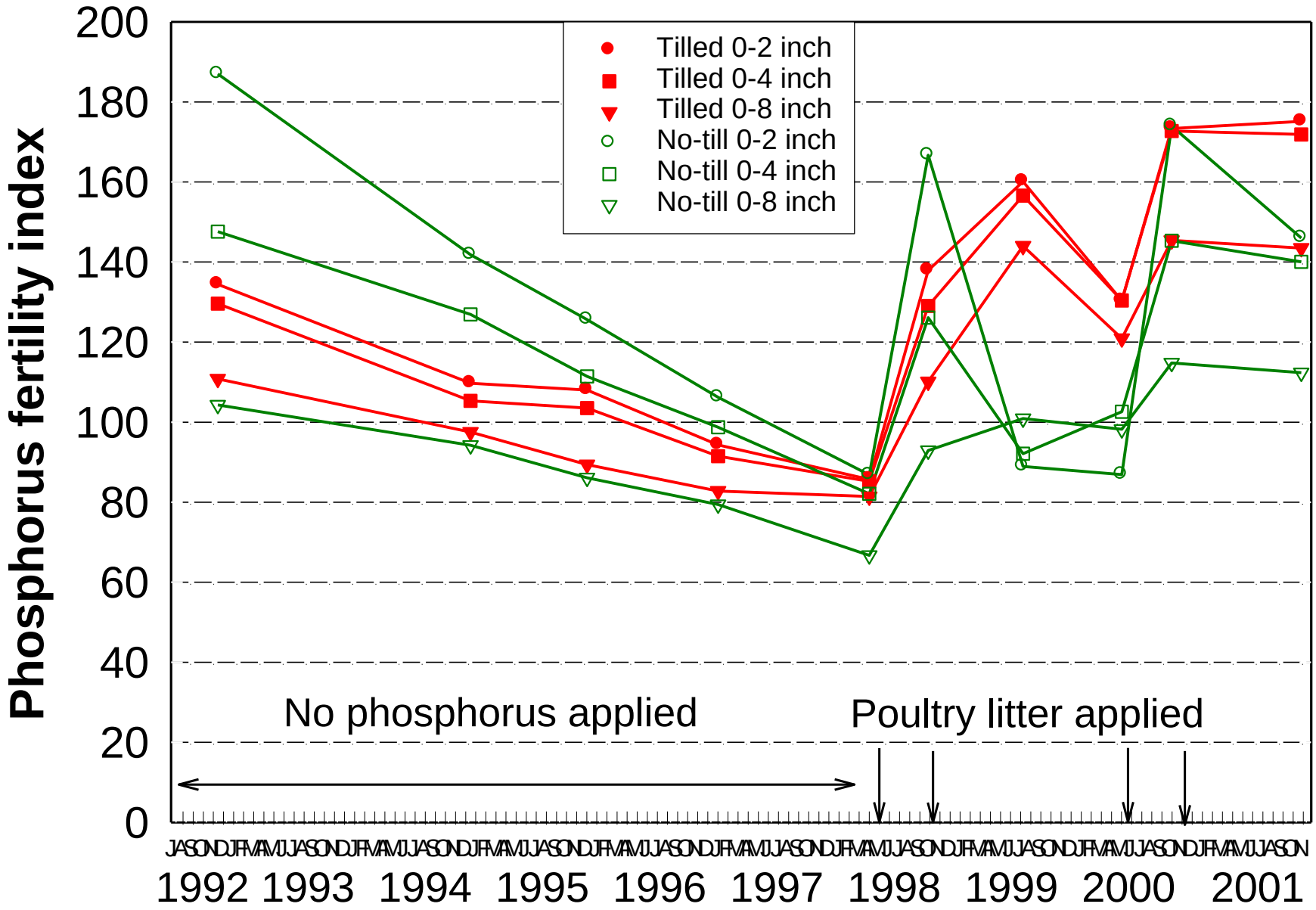
Unfortunately, erosion control did not translate into phosphorus control.

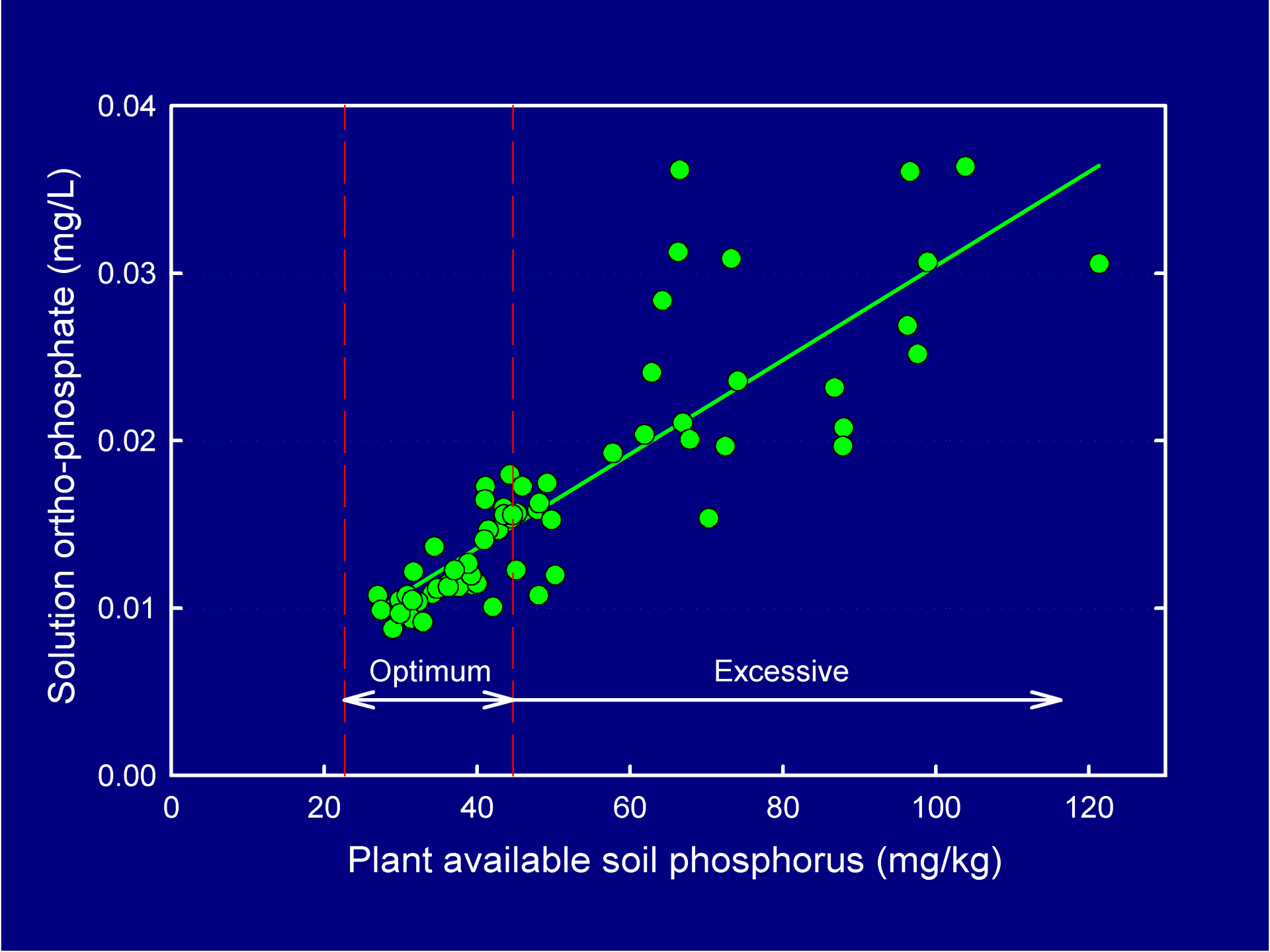

Monthly average surface runoff TP (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Tilled
No-till
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1985-1998

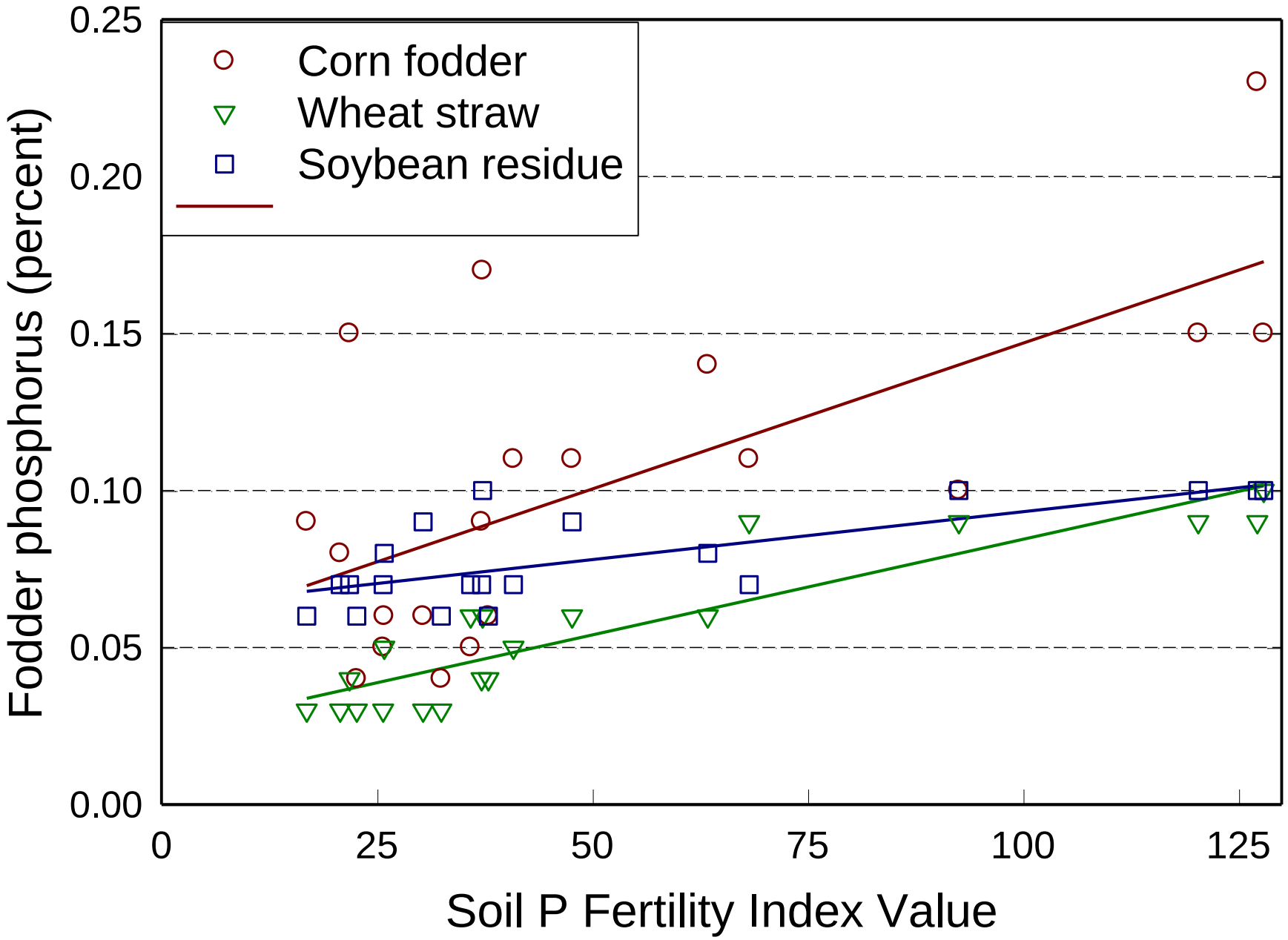

Tilled Dissolved P
Tilled Total P
No-till Dissolved P
No-till Total P
Average monthly runoff P(mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1993-1999

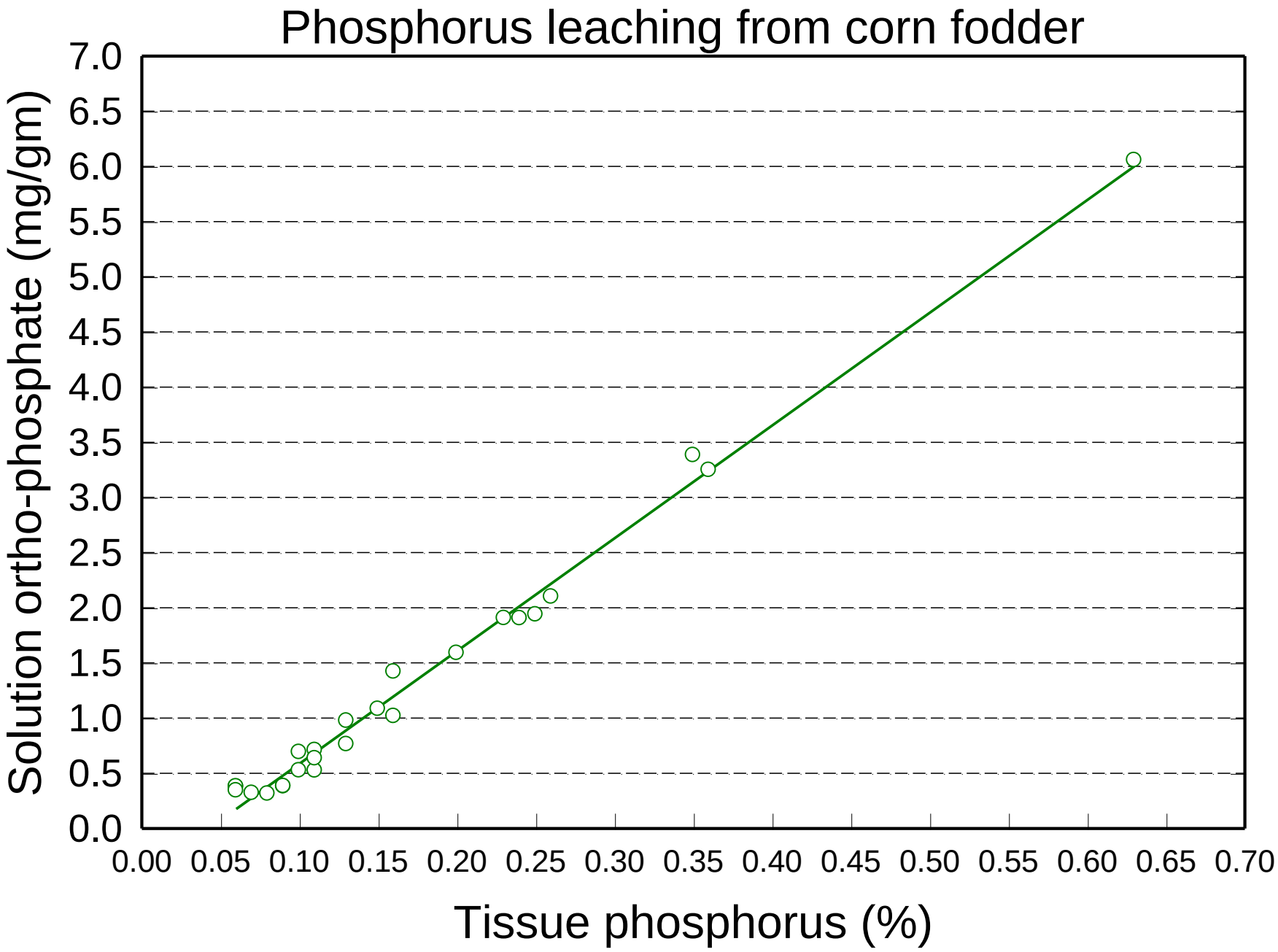

Average annual runoff P (mg/L)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
CT particulate P
CT dissolved P
NT particulate P
NT dissolved P
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07


Annual runoff P (kg/ha)
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
CT dissolved P
CT particulate P
NT dissolved P
NT particulate P
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07


Phosphorus fertility index
200
180
160
140
120
100
80
60
40
20
0
Tilled 0-2 inch
Tilled 0-4 inch
Tilled 0-8 inch
No-till 0-2 inch
No-till 0-4 inch
No-till 0-8 inch
No phosphorus applied
Poultry litter applied
JASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASON
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001


0.04
0.03
0.02
0.01
0.00
Solution ortho-phosphate (mg/L)
0
20
40
60
80
100
120
Plant available soil phosphorus (mg/kg)
Optimum
Excessive


Corn fodder
Wheat straw
Soybean residue
Fodder phosphorus (percent)
0.25
0.20
0.15
0.10
0.05
0.00
0
25
50
75
100
125
Soil P Fertility Index Value


Phosphorus leaching from corn fodder
Solution ortho-phosphate (mg/gm)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70
Tissue phosphorus (%)

Sims et al. 2002 SSAJ

"We conclude that routine soil tests, such as Mehlich 3, can be an effective interim approach to guide environmentally based P recommendations for fertilizers, manures, biosolids and other P sources… Higher risks are clearly associated with M3-P values that are above the concentrations needed for economically optimum crop yields. "

Watershed Management

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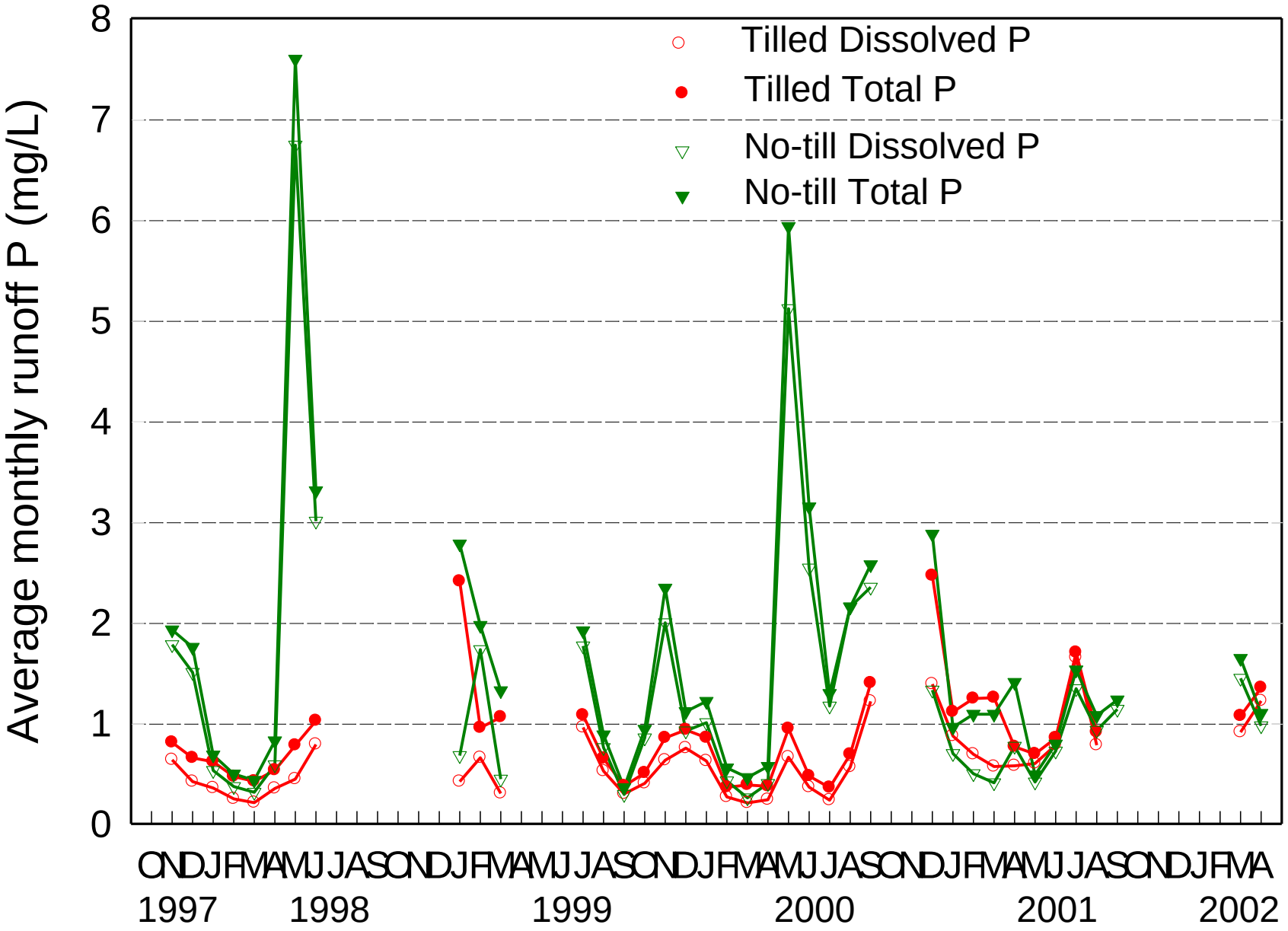
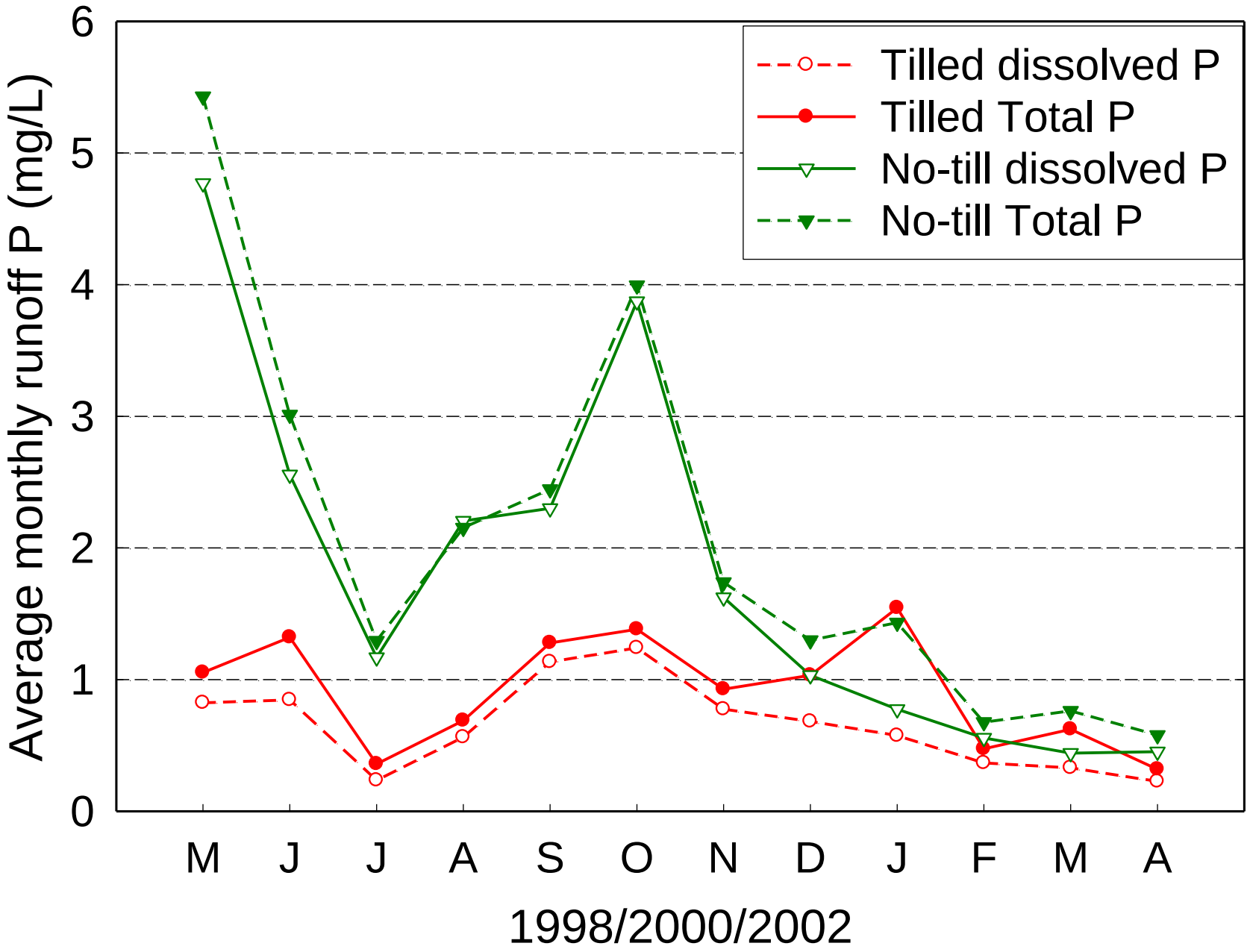
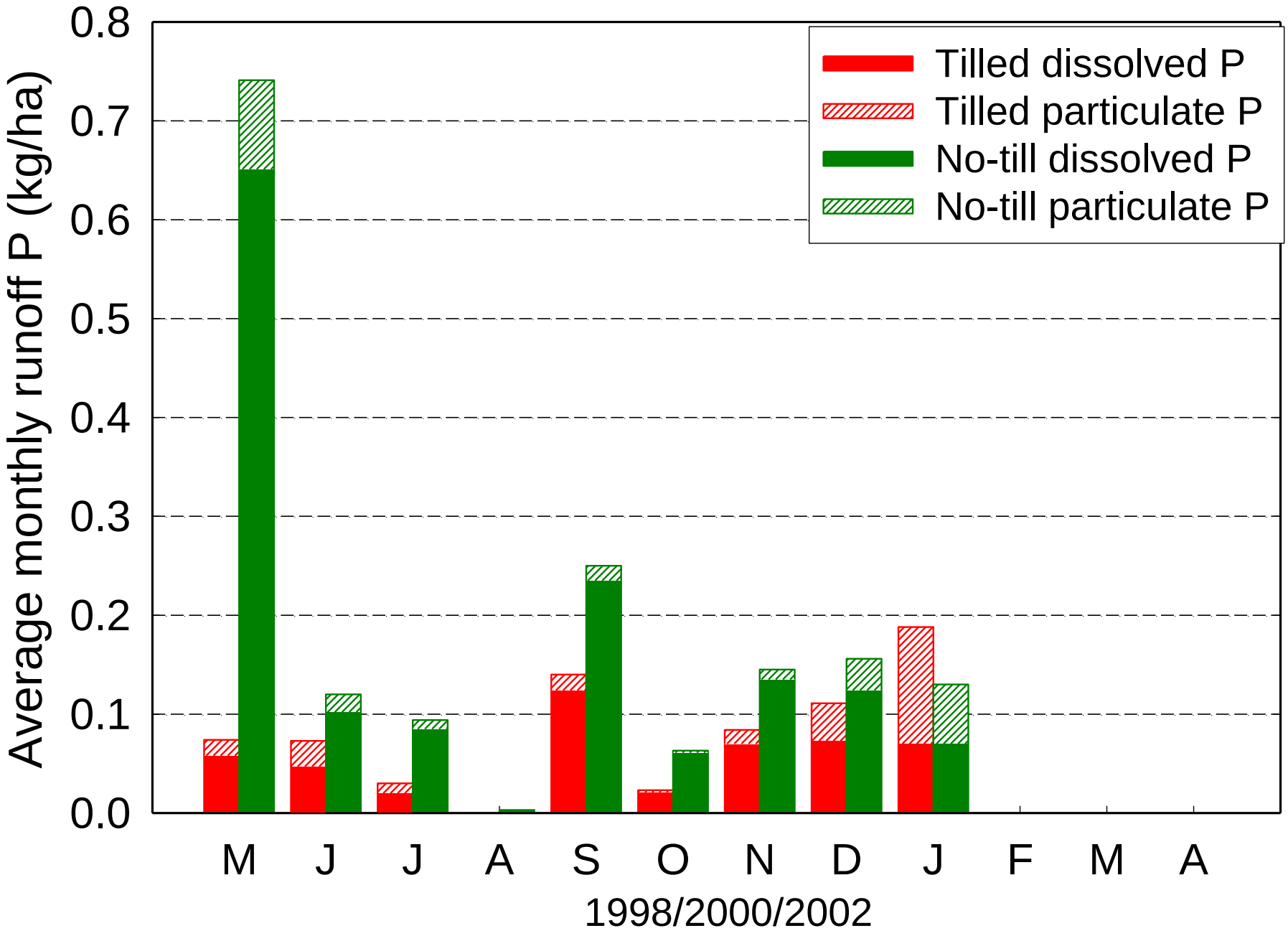
- 2004-07 surface/subsurface N
- 2008-09 NT/turbotill poultry litter


Average monthly runoff P (mg/L)
0
1
2
3
4
5
6
7
8
Tilled Dissolved P
Tilled Total P
No-till Dissolved P
No-till Total P
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1997
1998
1999
2000
2001
2002


Average monthly runoff P (mg/L)
0
1
2
3
4
5
6
M
J
J
A
S
O
N
D
J
F
M
A
1998/2000/2002
Tilled dissolved P
Tilled Total P
No-till dissolved P
No-till Total P


Average monthly runoff P (kg/ha)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
M
J
J
A
S
O
N
D
J
F
M
A
1998/2000/2002
Tilled dissolved P
Tilled particulate P
No-till dissolved P
No-till particulate P

How P applications are managed is crucial to controlling P losses in surface runoff, independent of soil P levels.

The same principles apply for surface runoff N transport.

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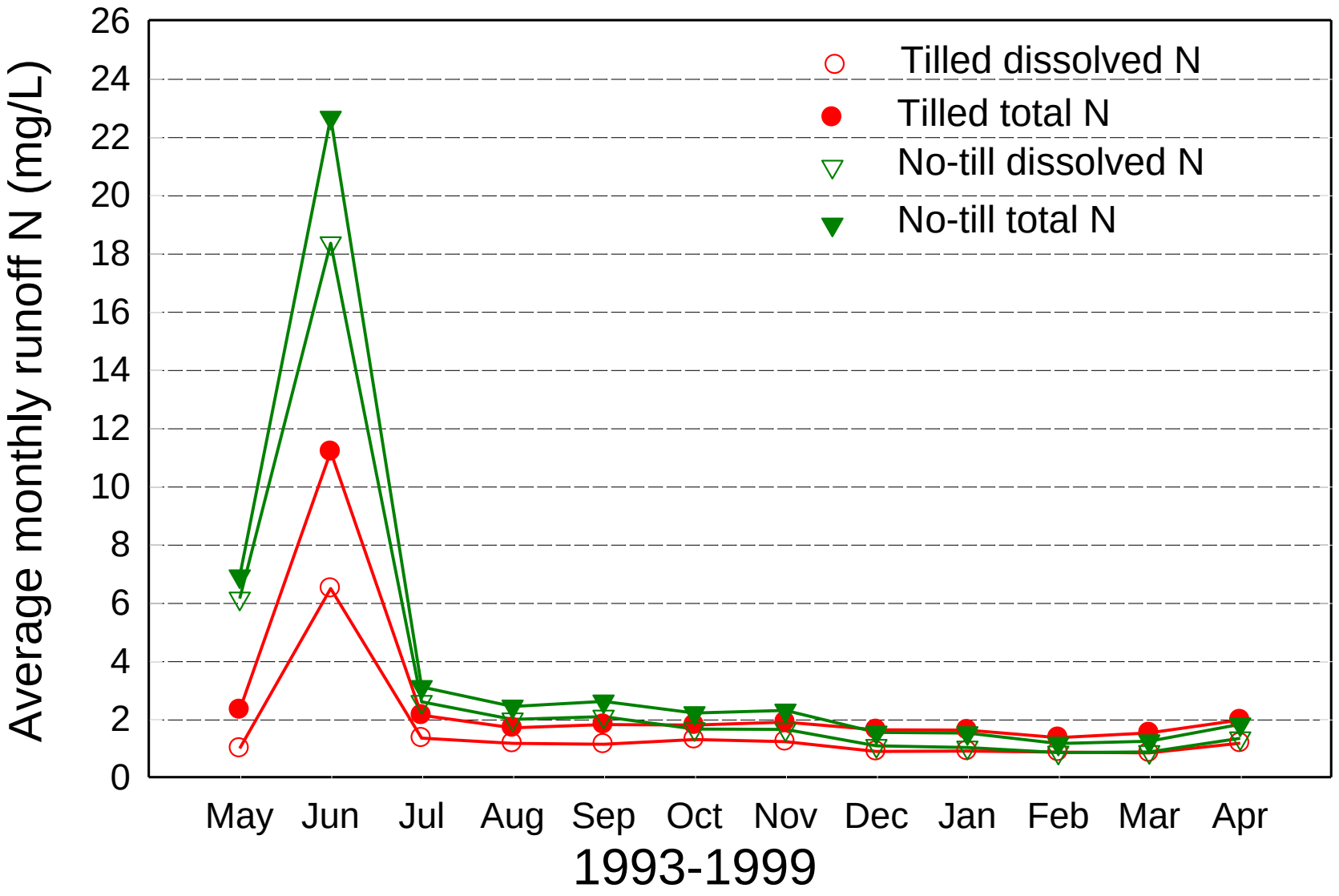
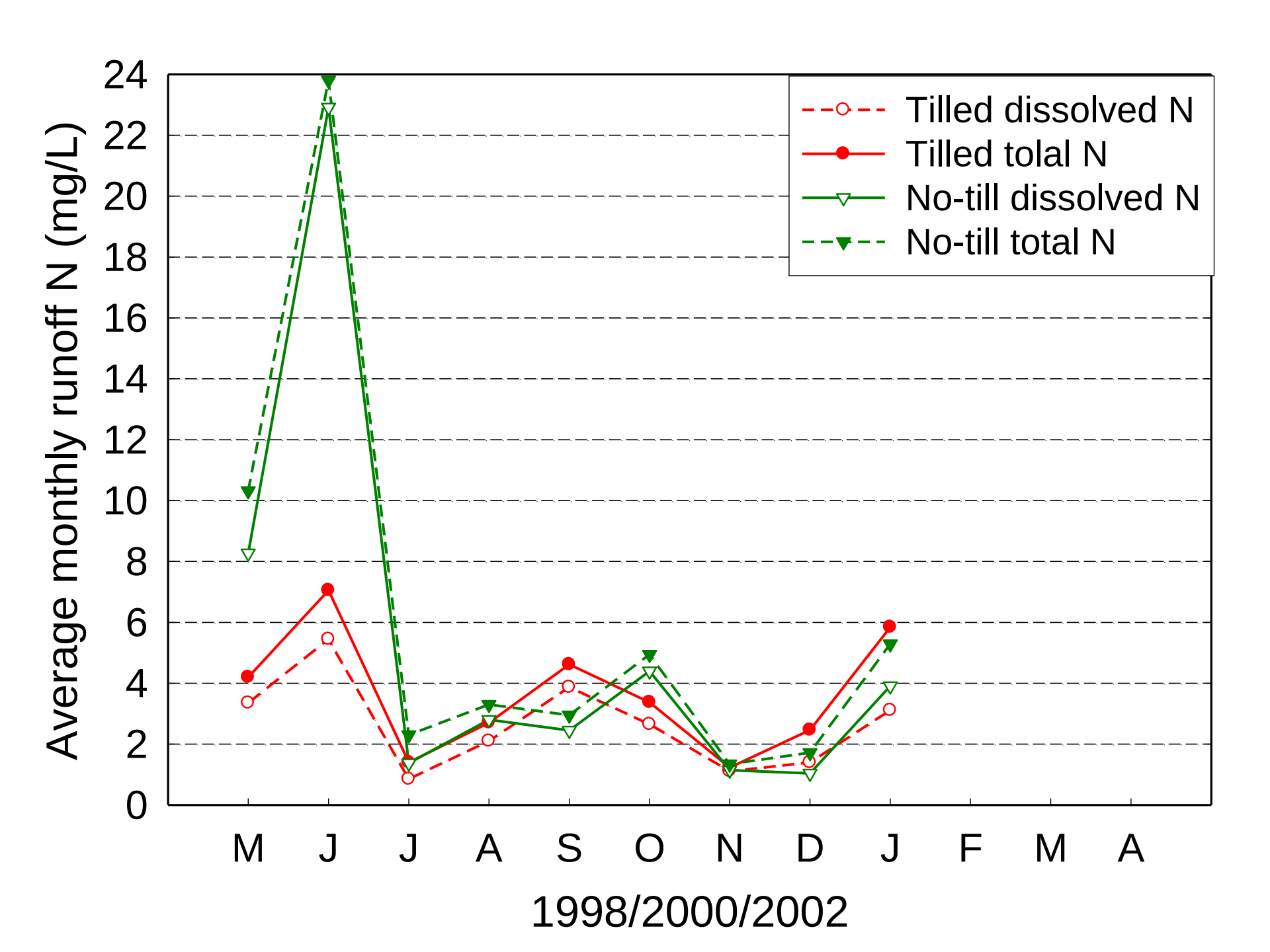
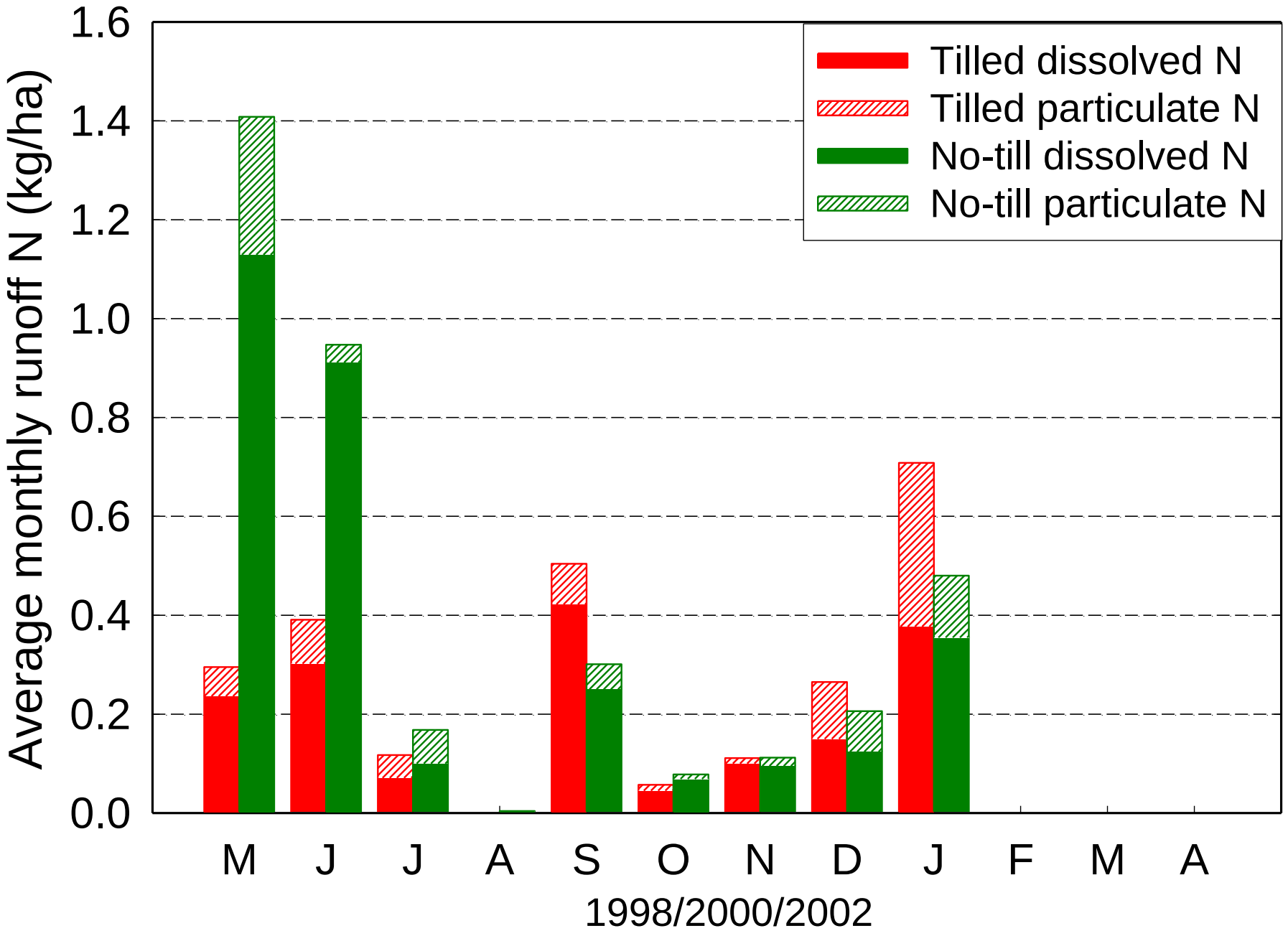
- 1998-2003 CT/NT poultry litter
- 2004-07 surface/subsurface N
- 2008-09 NT/turbotill poultry litter

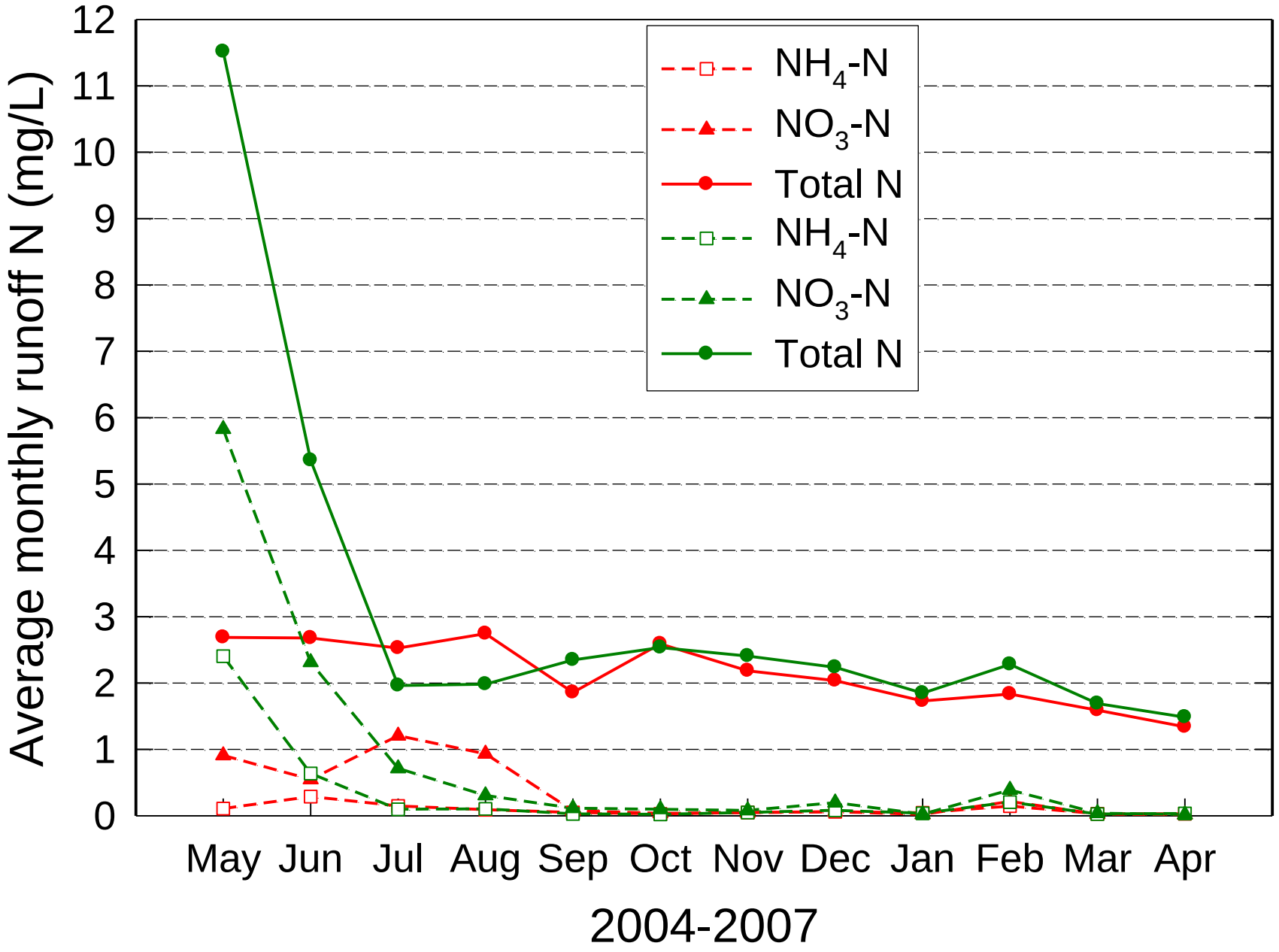

Average monthly runoff N (mg/L)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Tilled dissolved N
Tilled total N
No-till dissolved N
No-till total N
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1993-1999

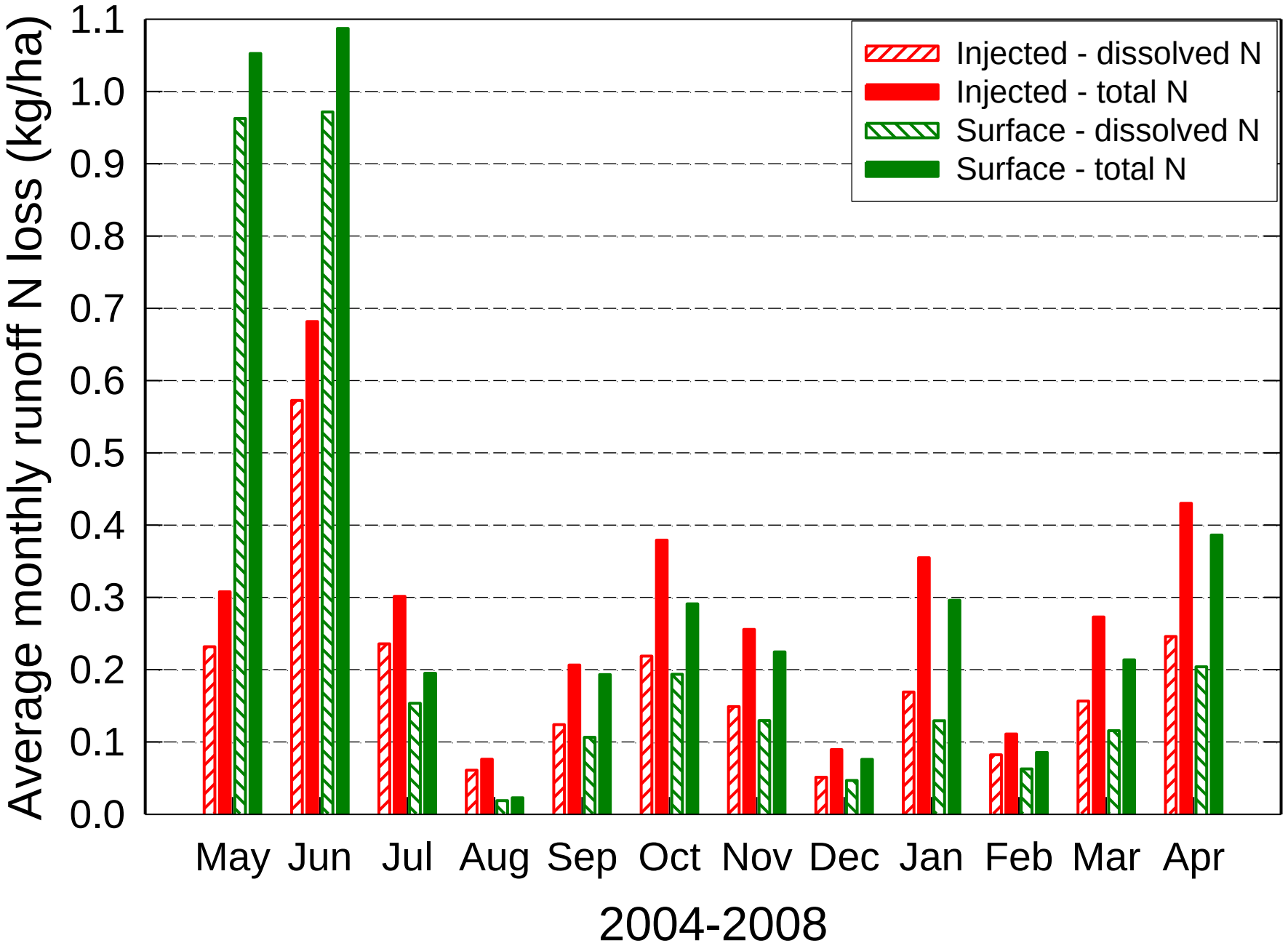

Average monthly runoff N (mg/L)
24
22
20
18
16
14
12
10
8
6
4
2
0
M
J
J
A
S
O
N
D
J
F
M
A
1998/2000/2002
Tilled dissolved N
Tilled tolal N
No-till dissolved N
No-till total N

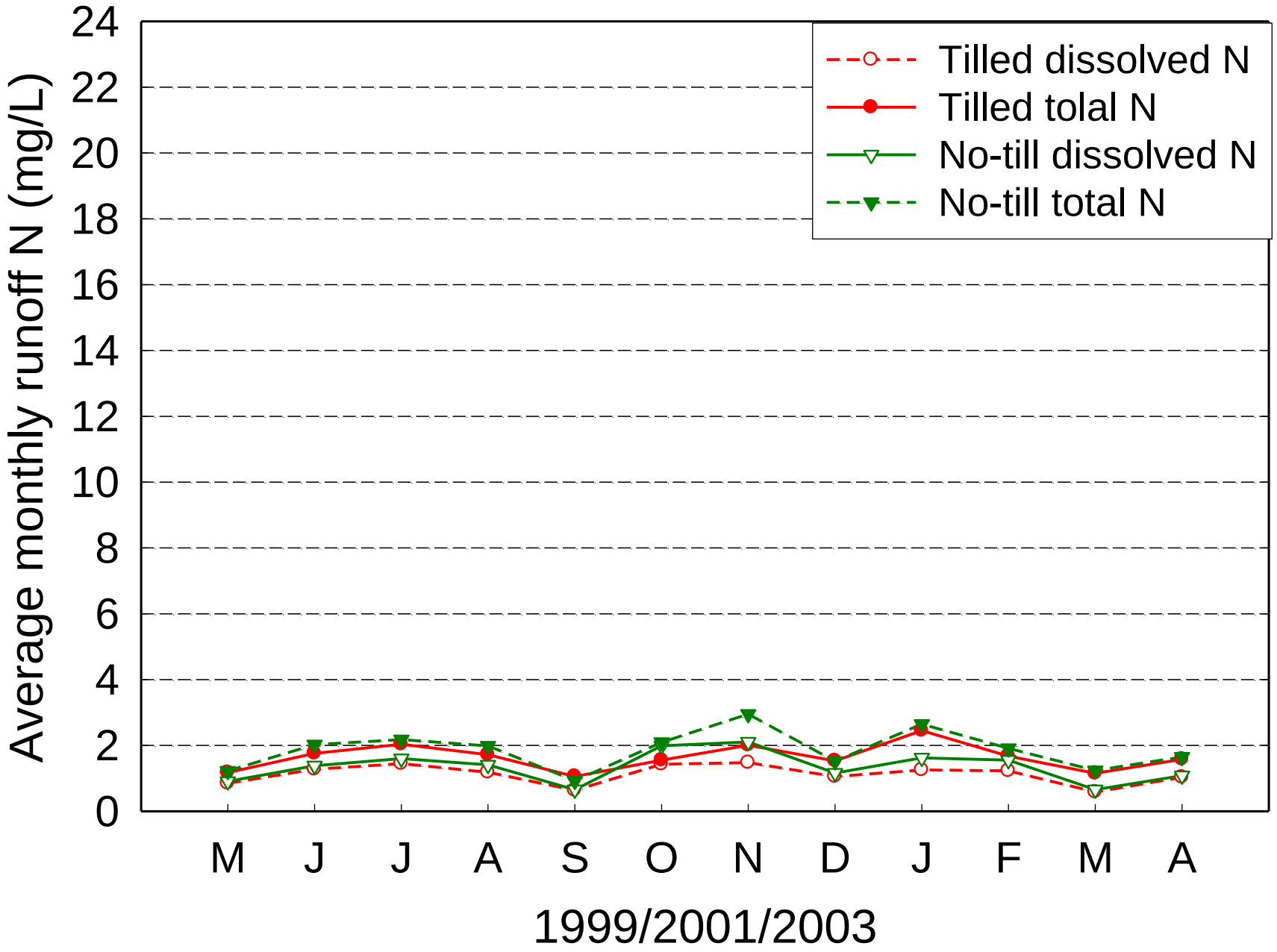

Average monthly runoff N (kg/ha)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Tilled dissolved N
Tilled particulate N
No-till dissolved N
No-till particulate N
M
J
J
A
S
O
N
D
J
F
M
A
1998/2000/2002

Placement objective

Minimize interaction of soluble N forms with surface runoff. Surface runoff N levels determined mostly by soluble N availability in the top 1” of soil.


Average monthly runoff N (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
2004-2007
NH4-N
NO3-N
Total N
NH4-N
NO3-N
Total N

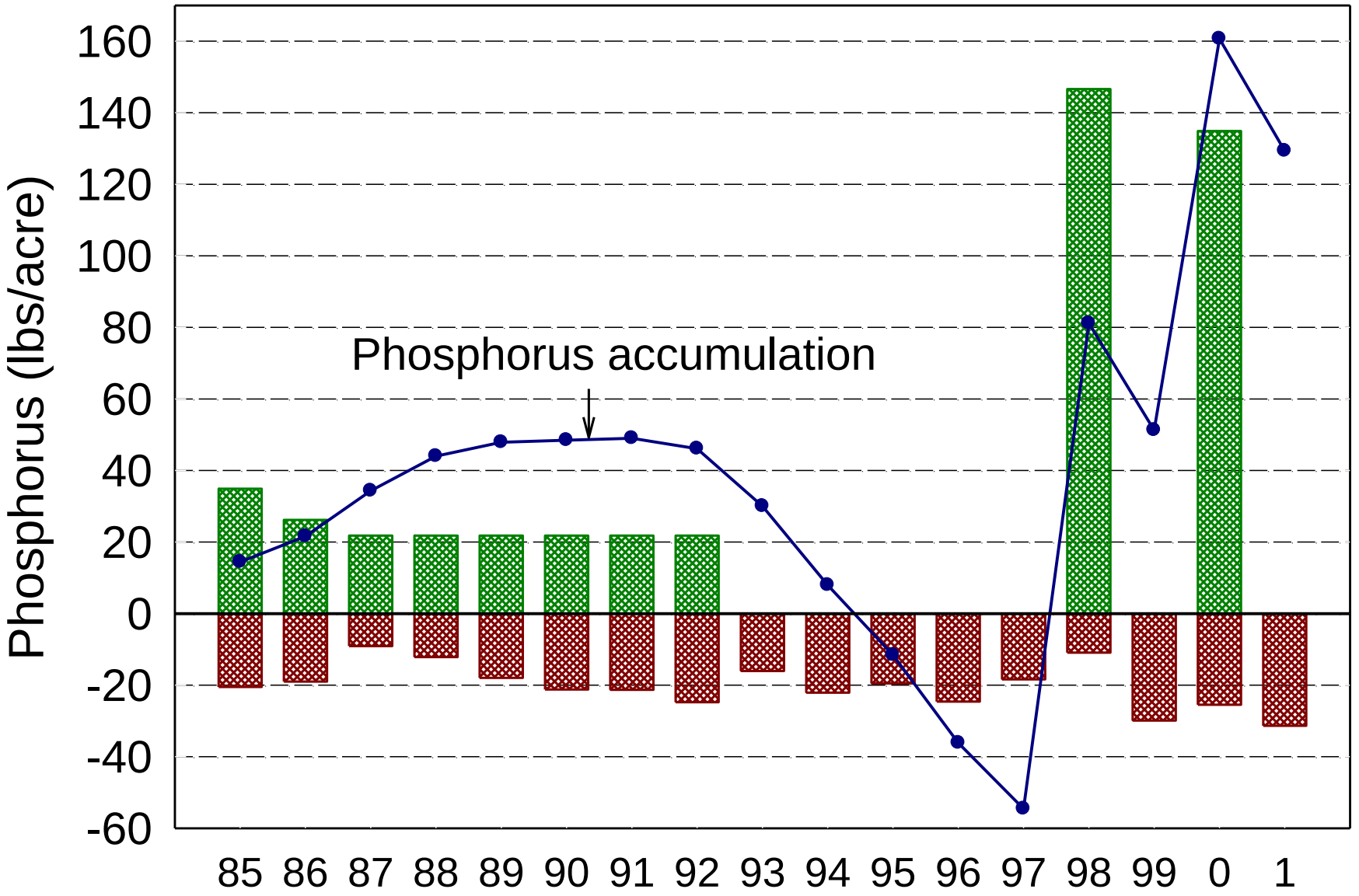

Average monthly runoff N loss (kg/ha)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Injected - dissolved N
Injected - total N
Surface - dissolved N
Surface - total N
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
2004-2008

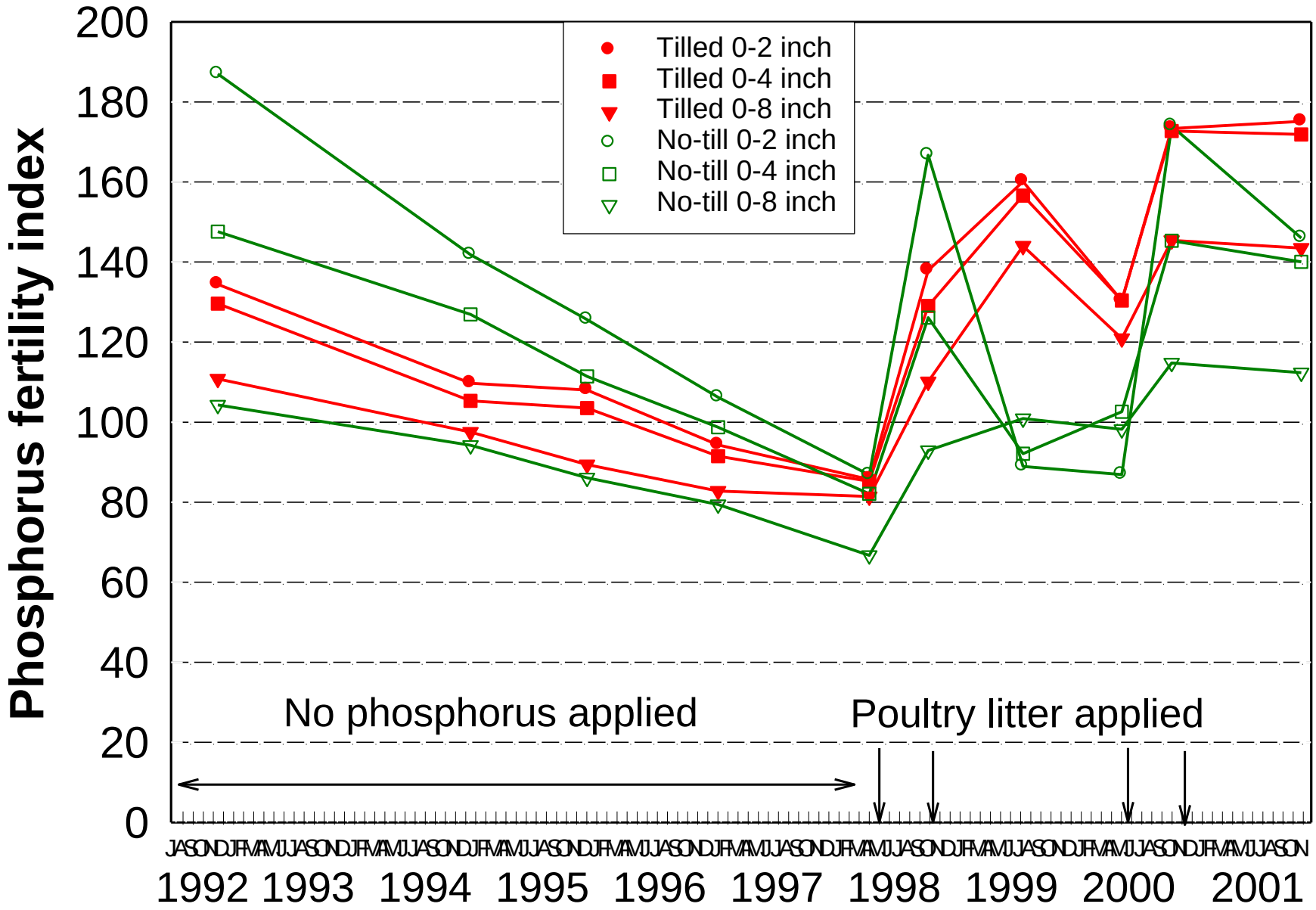

Average monthly runoff N (mg/L)
24
22
20
18
16
14
12
10
8
6
4
2
0
M
J
J
A
S
O
N
D
J
F
M
A
1999/2001/2003
Tilled dissolved N
Tilled tolal N
No-till dissolved N
No-till total N

What about the long-term issues with soil P?

Swink et al. 2009 JSWC

"From the 1980s on, soil test P levels of agricultural land in NY have steadily increased and, in the most recent assessment, 47 % test equal to or higher than the critical STP level… This increase is of concern because long-term accumulation of P insils can result in increased P runoff and leaching losses to surface and groundwater. "

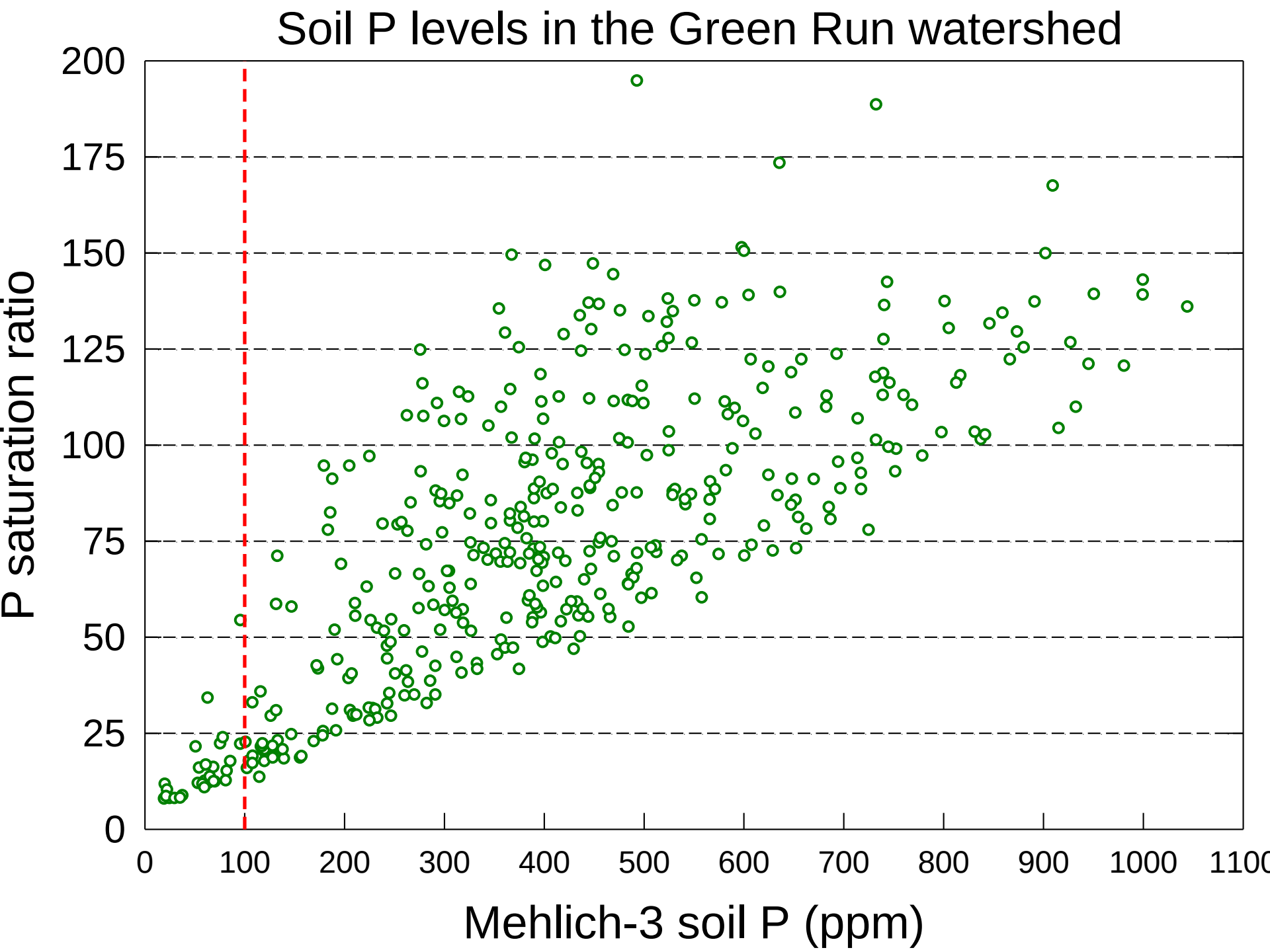

Phosphorus (lbs/acre)
160
140
120
100
80
60
40
20
0
-20
-40
-60
Phosphorus accumulation
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
0
1

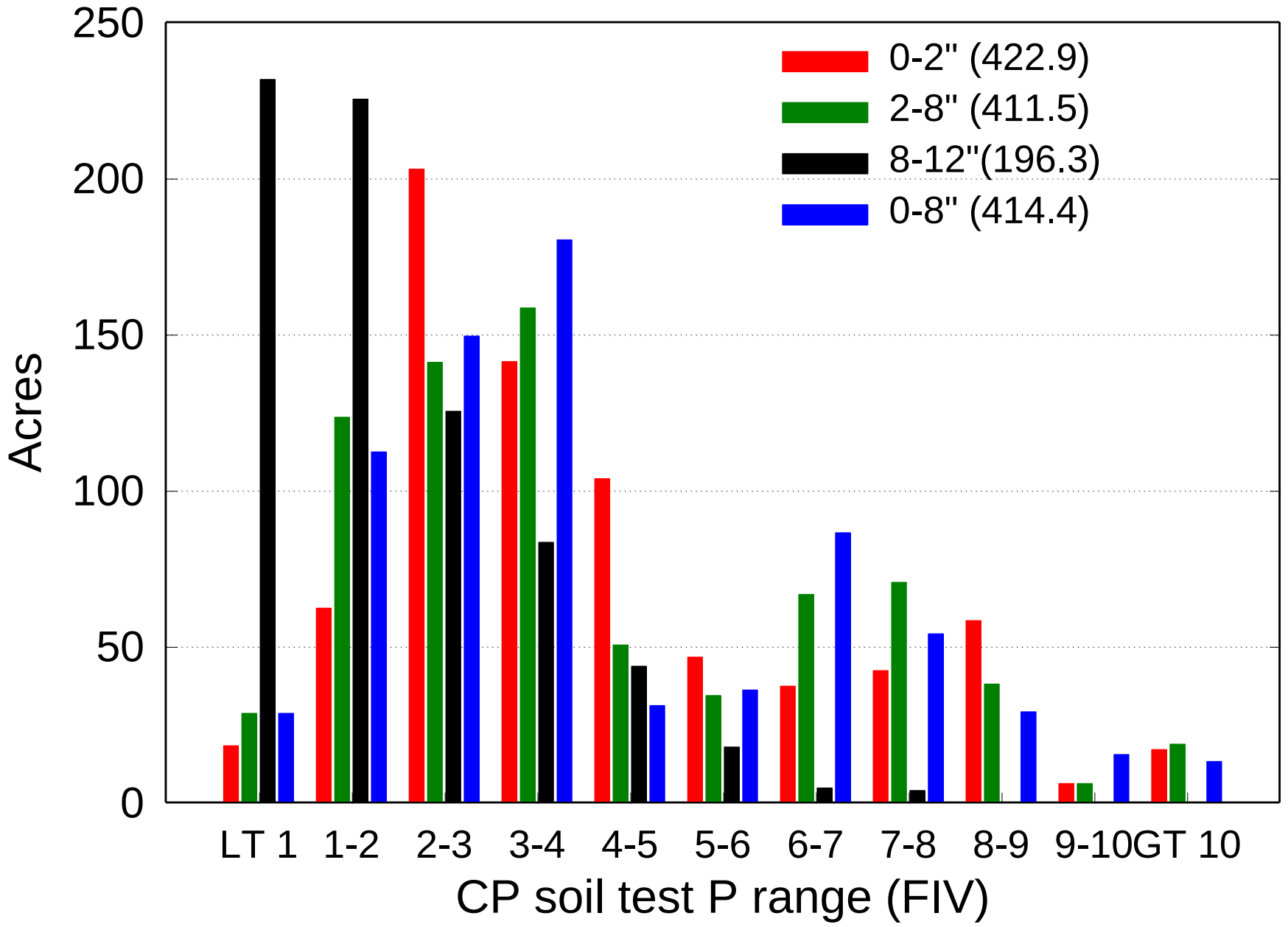

Phosphorus fertility index
200
180
160
140
120
100
80
60
40
20
0
Tilled 0-2 inch
Tilled 0-4 inch
Tilled 0-8 inch
No-till 0-2 inch
No-till 0-4 inch
No-till 0-8 inch
No phosphorus applied
Poultry litter applied
JASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASON
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001

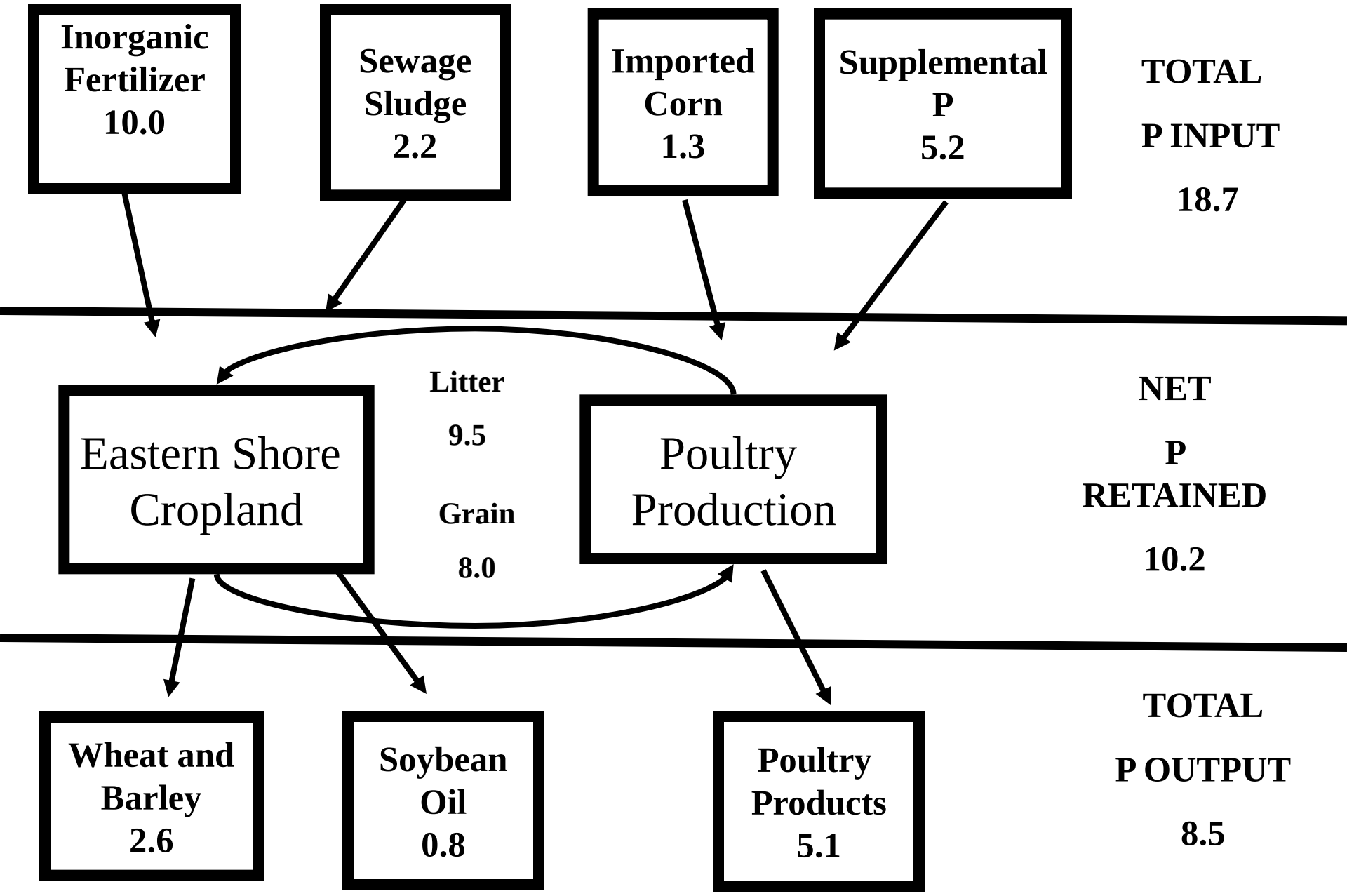
Pocomoke River Watershed

- 4 million lbs poultry litter P/year
- 100,000 acres cropland
- 40 lbs P/acre/year applied
- 20 lbs P/acre/year removed in harvested grain

Since the effort started to reduce nonpoint source nutrient loads in Maryland, the quantity of P stored in cropland in the Pocomoke River drainage basin increased by approximately 25 million pounds.

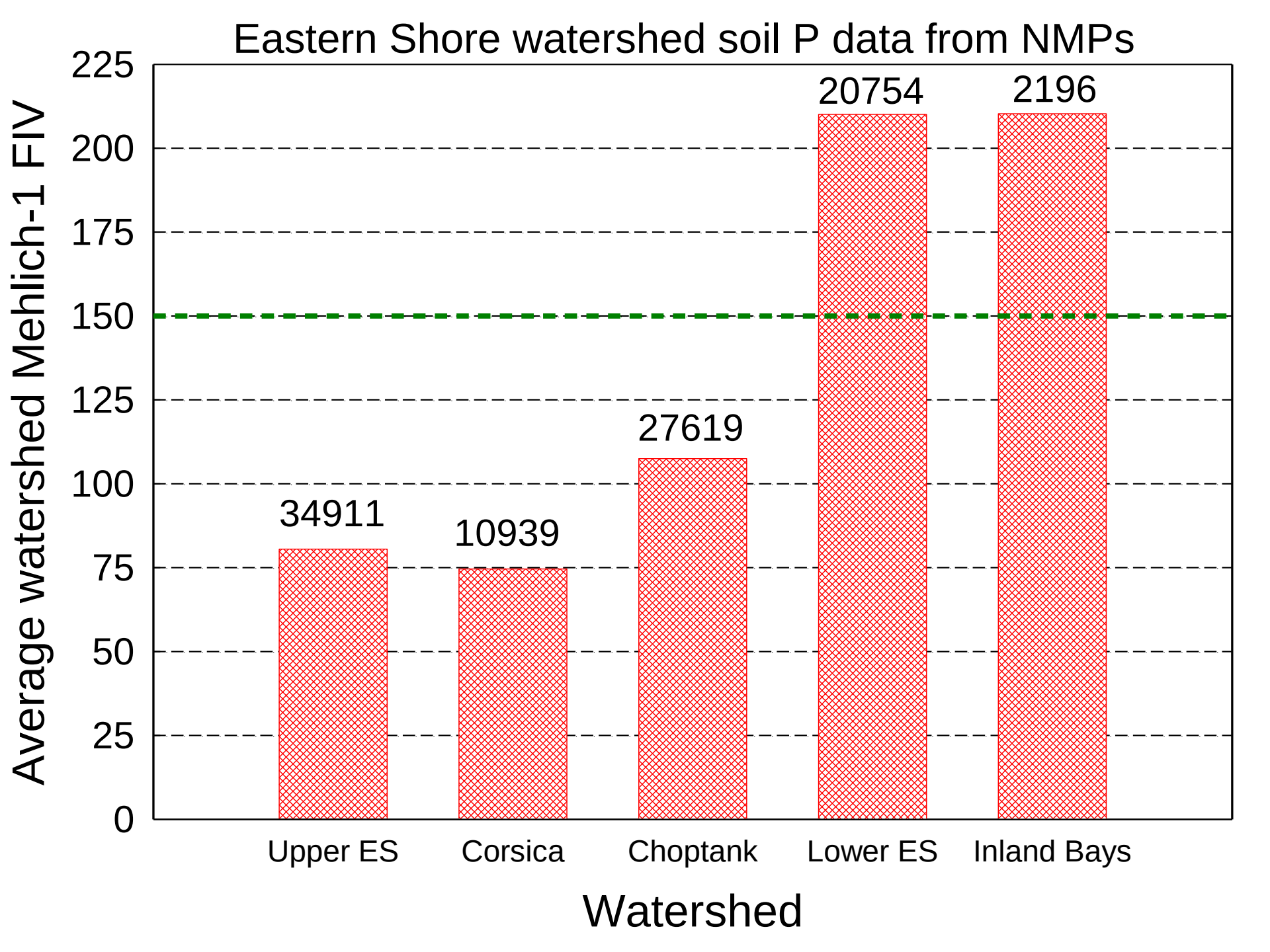

Soil P levels in the Green Run watershed
P saturation ratio
Mehlich-3 soil P (ppm)
0
25
50
75
100
125
150
175
200
0
100
200
300
400
500
600
700
800
900
1000
1100


250
200
150
100
50
0
Acres
0-2" (422.9)
2-8" (411.5)
8-12"(196.3)
0-8" (414.4)
LT 1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
GT 10
CP soil test P range (FIV)



millions of pounds P per year

Source: Kenneth Staver, Wye Research and Education Center


Eastern Shore watershed soil P data from NMPs
Average watershed Mehlich-1 FIV
225
200
175
150
125
100
75
50
25
0
34911
10939
27619
20754
2196
Upper ES
Corsica
Choptank
Lower ES
Inland Bays
Watershed

Agriculture and Phosphorus Management

The Chesapeake Bay

Edited by Andrew N. Sharpley

Concluding Remarks

"The overall long-term goal of efforts to reduce P losses from agriculture to surface waters should aim to balance off-farm inputs of P in feed and fertilizer with P outputs as produce, along with managing soils in ways that retain nutrients and applied P resources."

Research Bottom Line

1. Soil P concentrations and how we manage P applications are the major drivers for P losses that we can control.

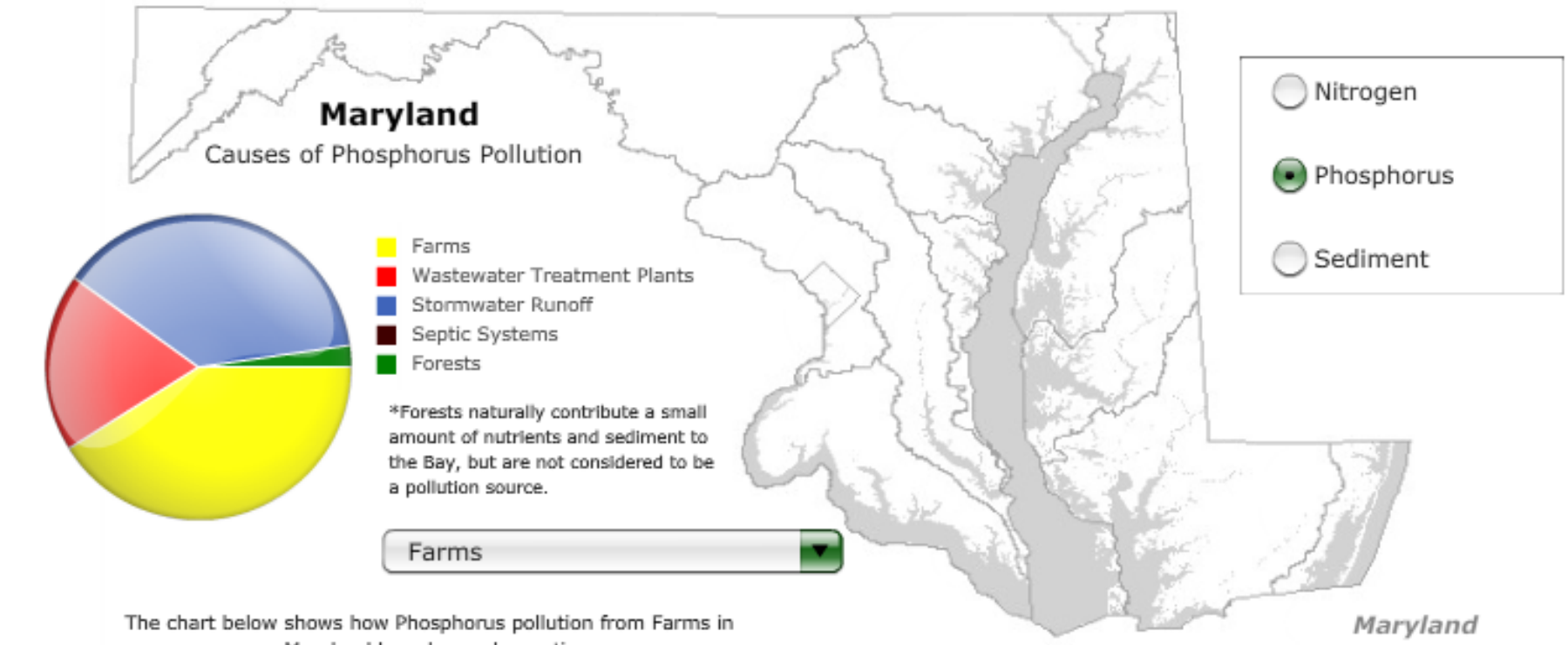
2. Changes in loads only come from changes in drivers. Need high quality pre- and post data sets. Baseline?

3. Small scale monitoring of runoff P losses impractical.

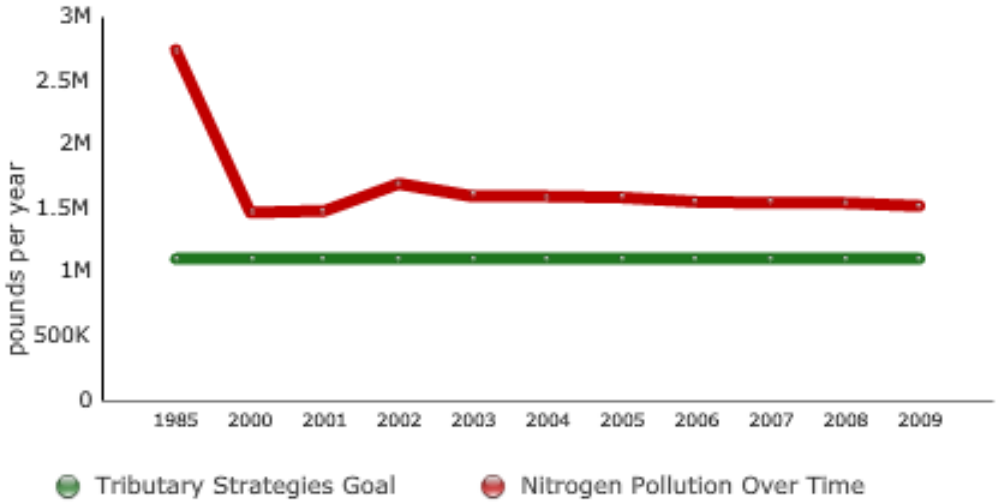
Are reduction strategies consistent with the science?

Unfortunately, so far the Bay watershed model has not considered soil P concentration or manure or inorganic fertilizer application methods.

Causes of the Problems



The chart below shows how Phosphorus pollution from Farms in Maryland has changed over time.



Phosphorus pollution fuels the growth of algae, creating dense, harmful algae blooms that rob the Chesapeake Bay's aquatic life of needed sunlight and oxygen. Phosphorus often attaches to soil and sediment particles on land, entering the Bay many years later when stream banks erode or rainwater washes it into streams, rivers and the Bay. Sources of phosphorus pollution include fertilizers from farmlands, lawns and golf courses; eroding soil & sediment from stream banks in urban and suburban neighborhoods; animal manure from farms; and wastewater from industrial facilities and sewage treatment plants.

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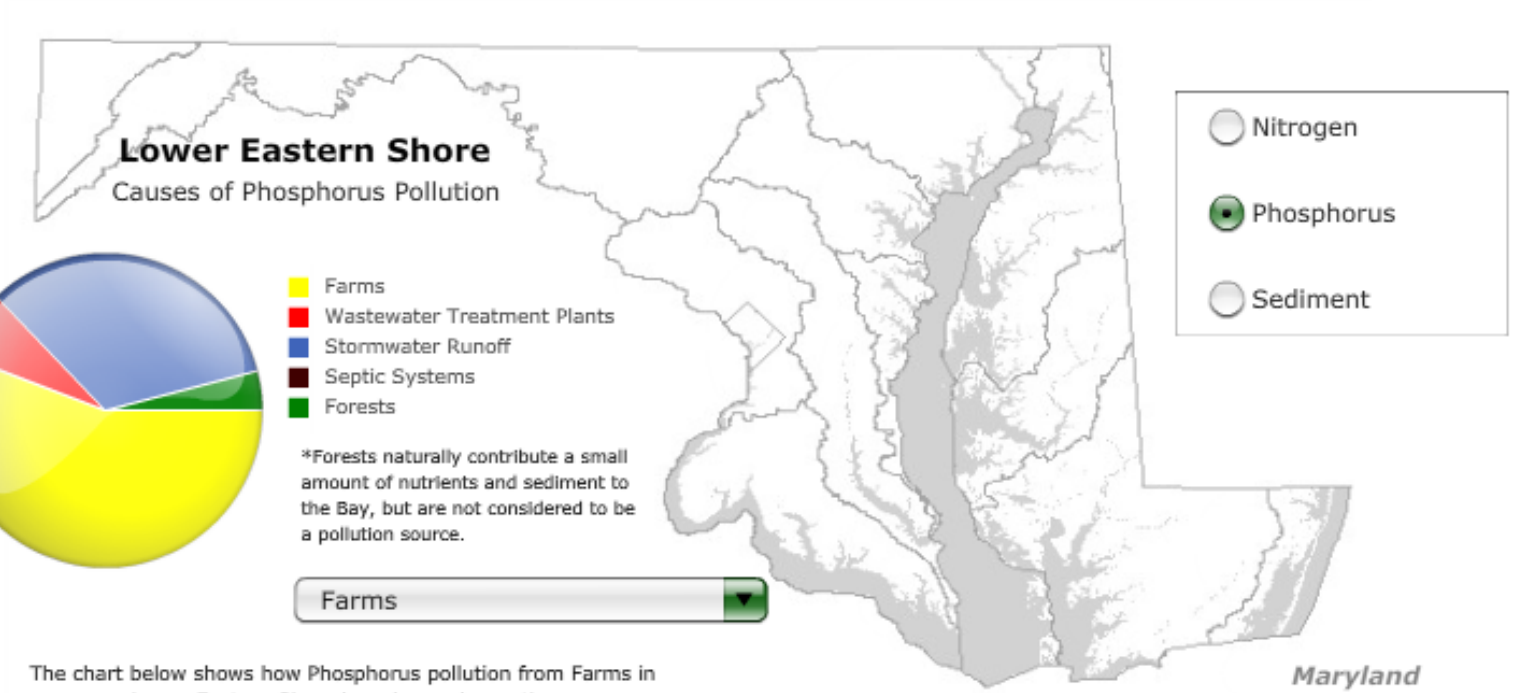
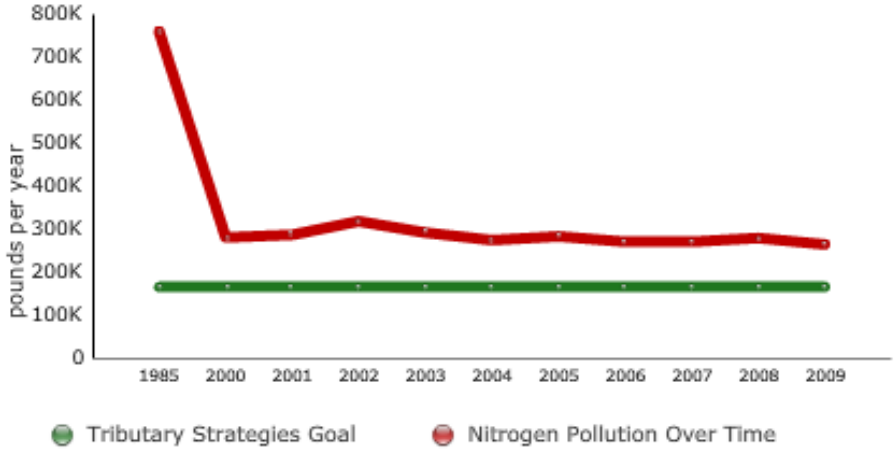


The chart below shows how Phosphorus pollution from Farms in Lower Eastern Shore has changed over time.



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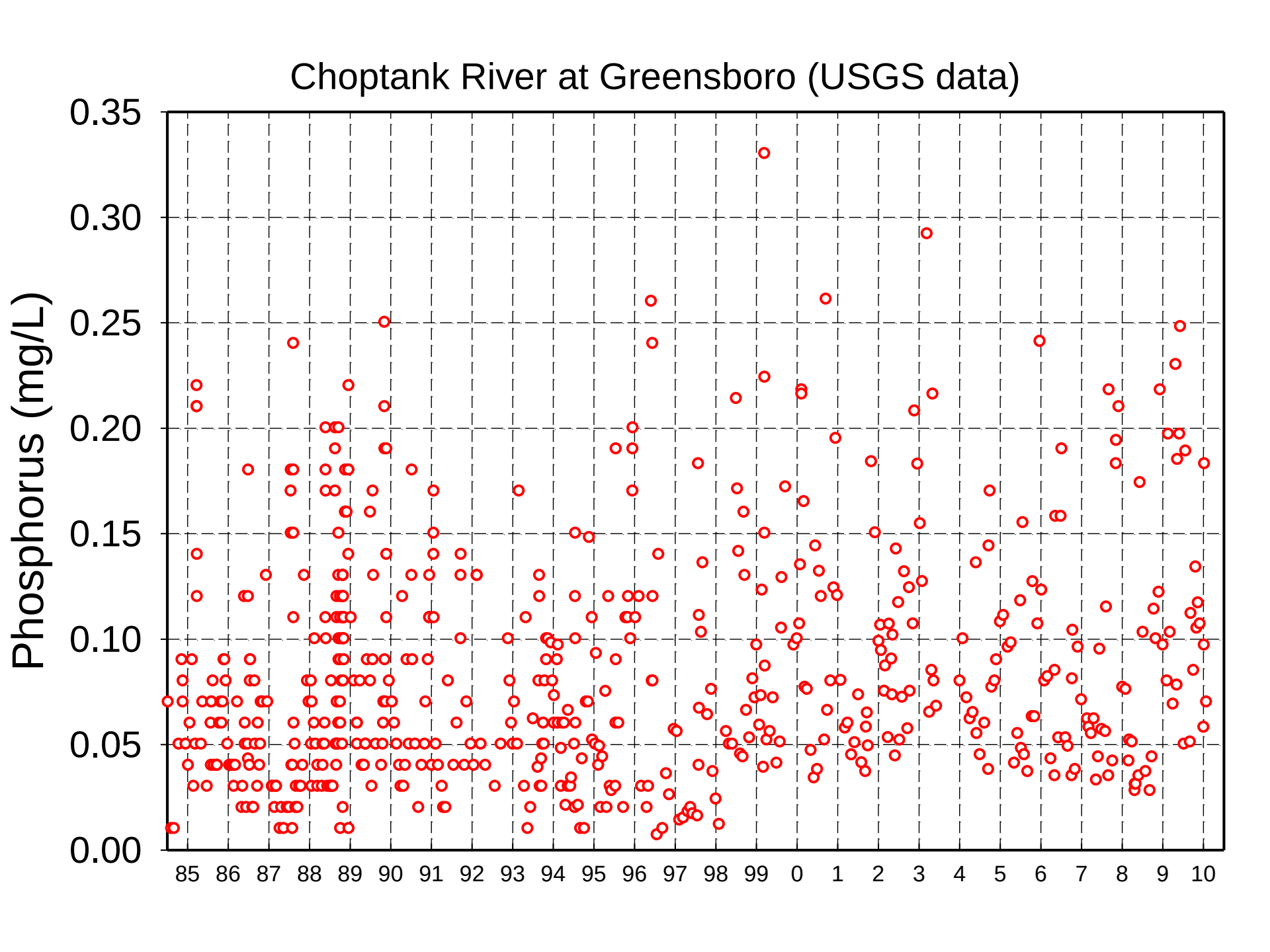
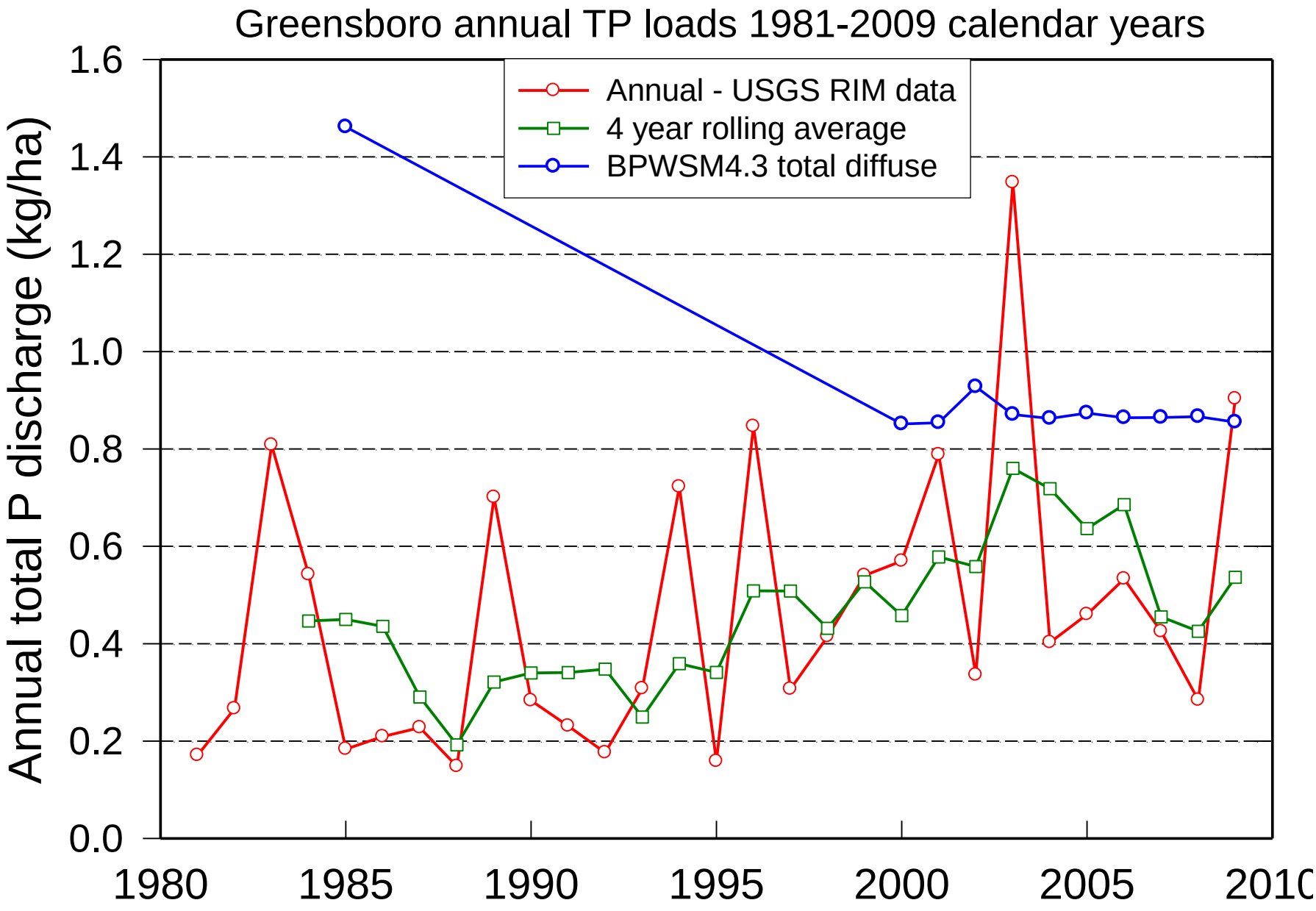
What about monitoring data?

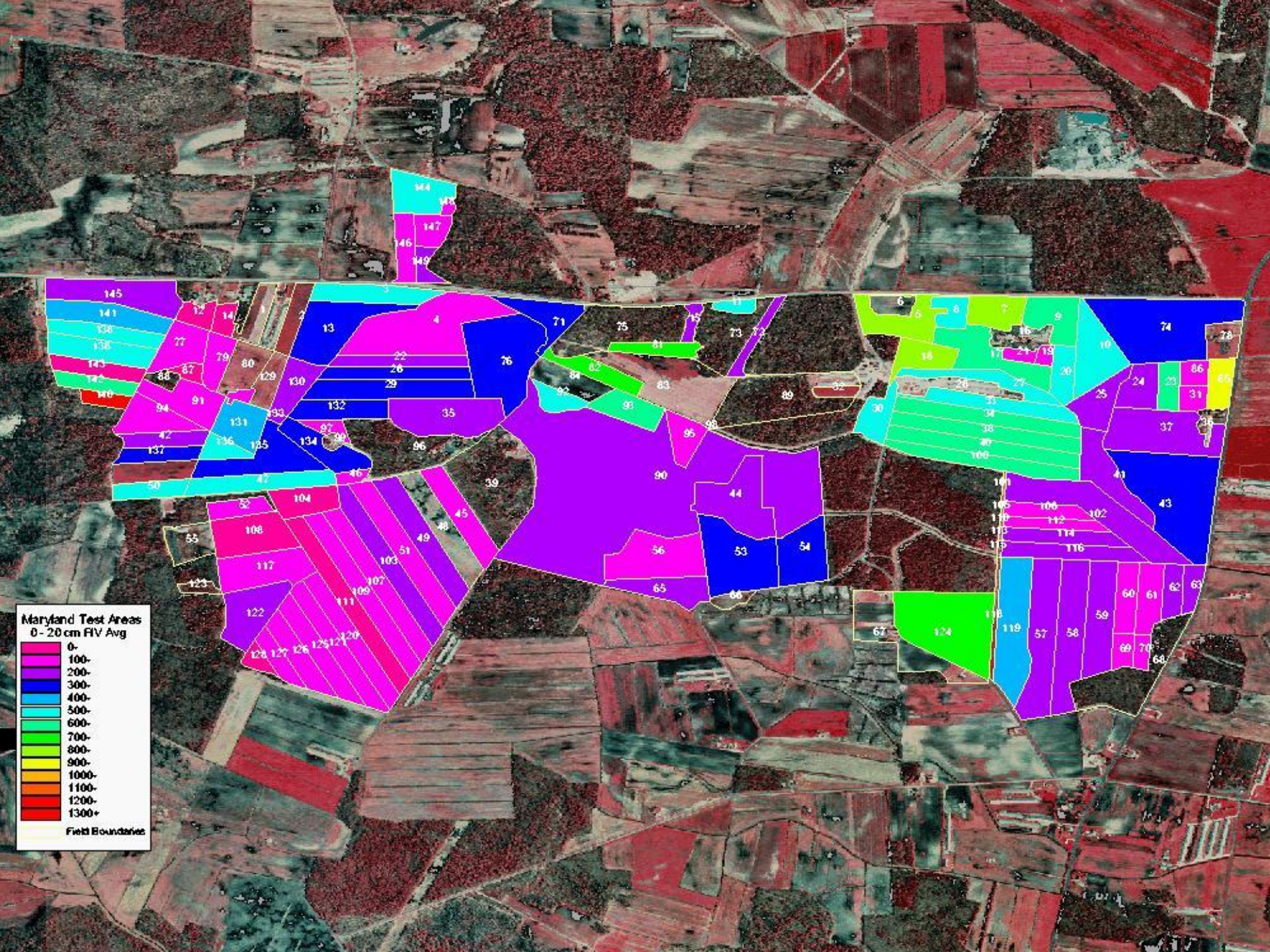
Unfortunately, P transport is primarily storm driven and highly variable. Accurately tracking loads requires rigorous and expensive monitoring strategies. Technology might help in the future.

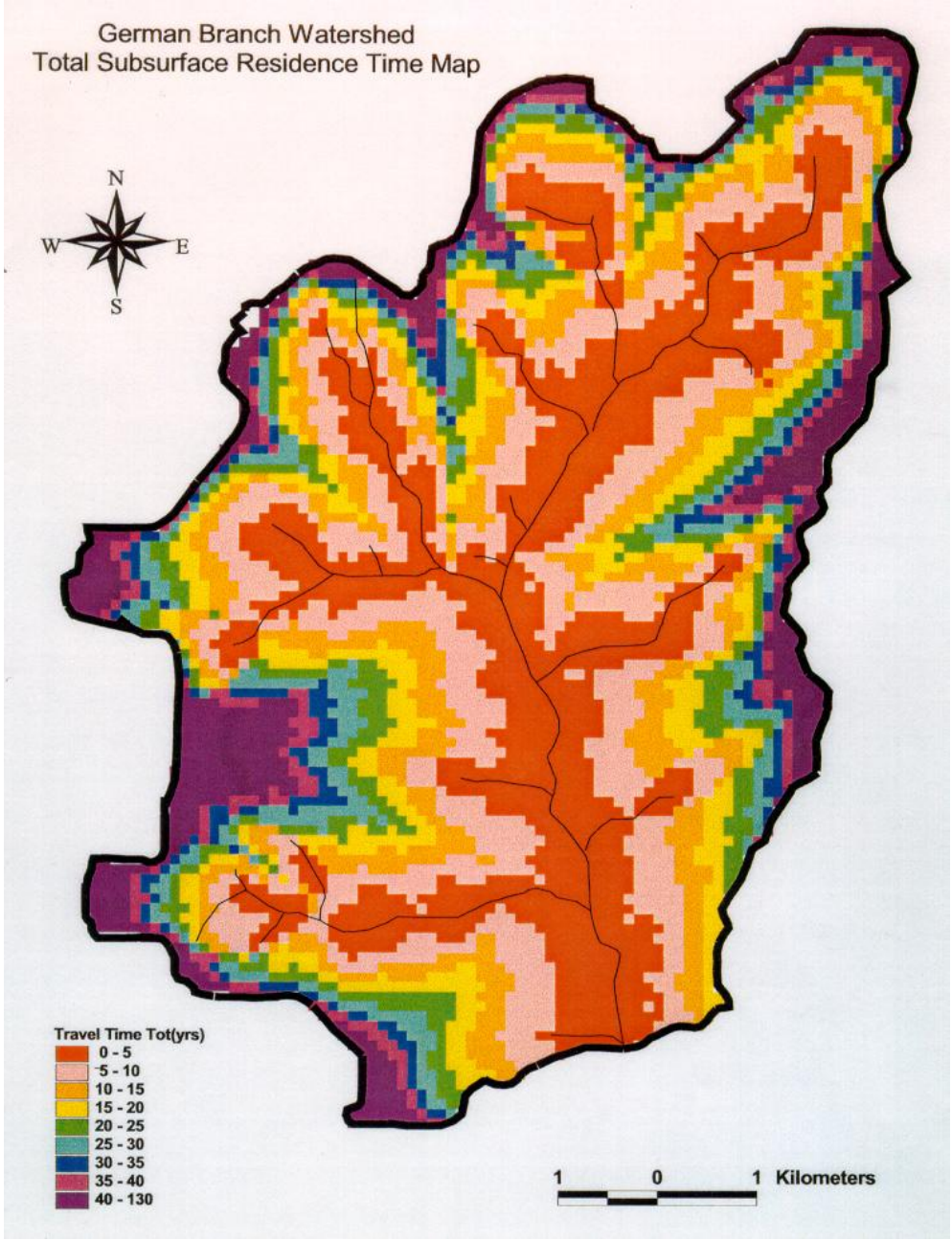

Choptank River at Greensboro (USGS data)
Phosphorus (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 0 1 2 3 4 5 6 7 8 9 10


Greensboro annual TP loads 1981-2009 calendar years
Annual total P discharge (kg/ha)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1980
1985
1990
1995
2000
2005
2010
Annual - USGS RIM data
4 year rolling average
BPWSM4.3 total diffuse

So what next?

- Must think long-term and start collecting critical data – soil P a must for models
- Subsurface apply inorganic P
- Incorporate organic wastes
- Aim for “Optimum” soil FIV-budgets
- GPS/GIS based tracking of watershed soil P levels – tells the budget story
- Buffers/ditch management


Maryland Test Areas
0 - 20 cm FIV Avg
0-
100-
200-
300-
400-
500-
600-
700-
800-
900-
1000-
1100-
1200-
1300+
Field Boundaries


German Branch Watershed
Total Subsurface Residence Time Map
N
W
E
S
Travel Time Tot(yrs)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 130
1
0
1
Kilometers