Long-Duration, High-Frequency Monitoring of Nutrients and Sediments in an Agricultural Watershed

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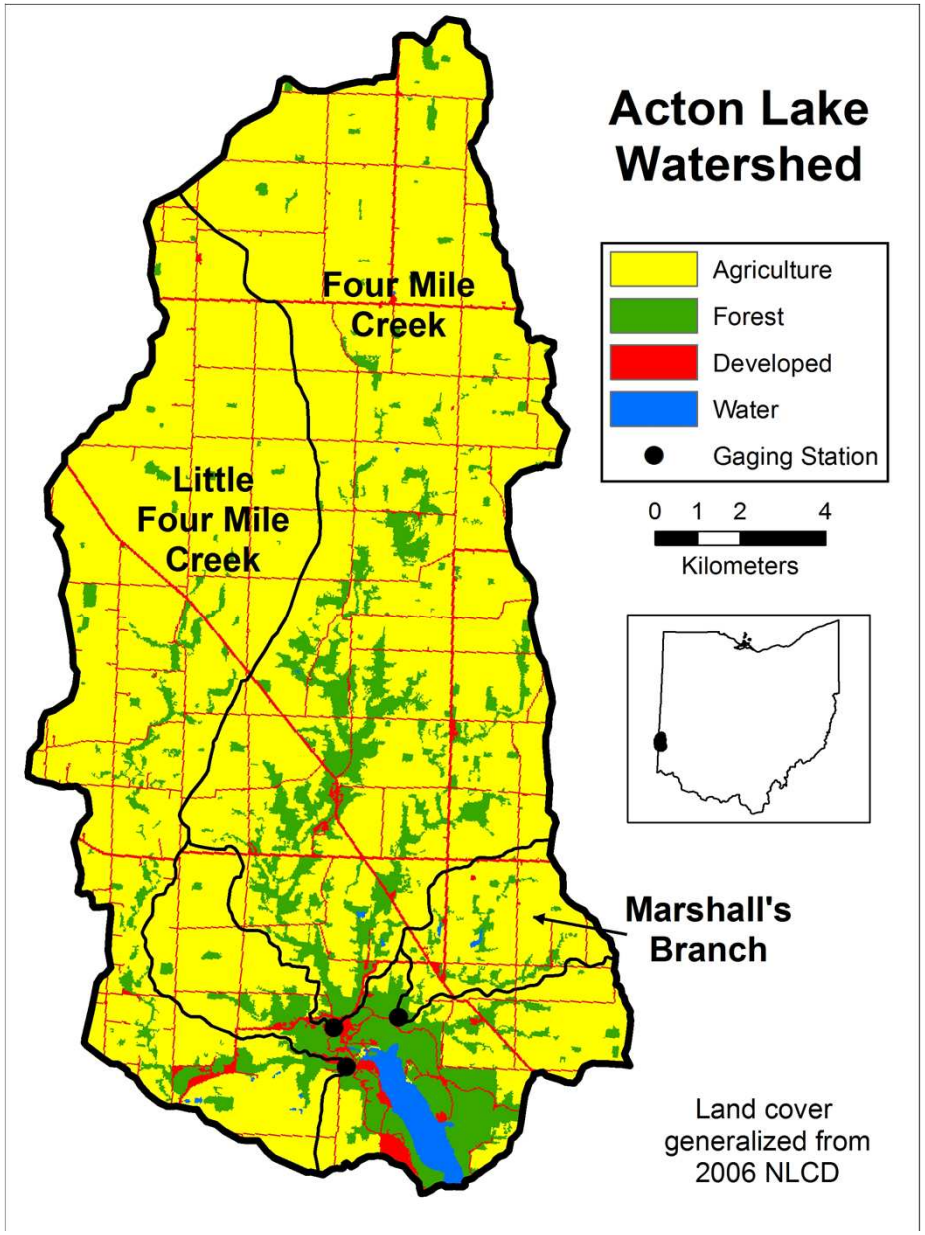
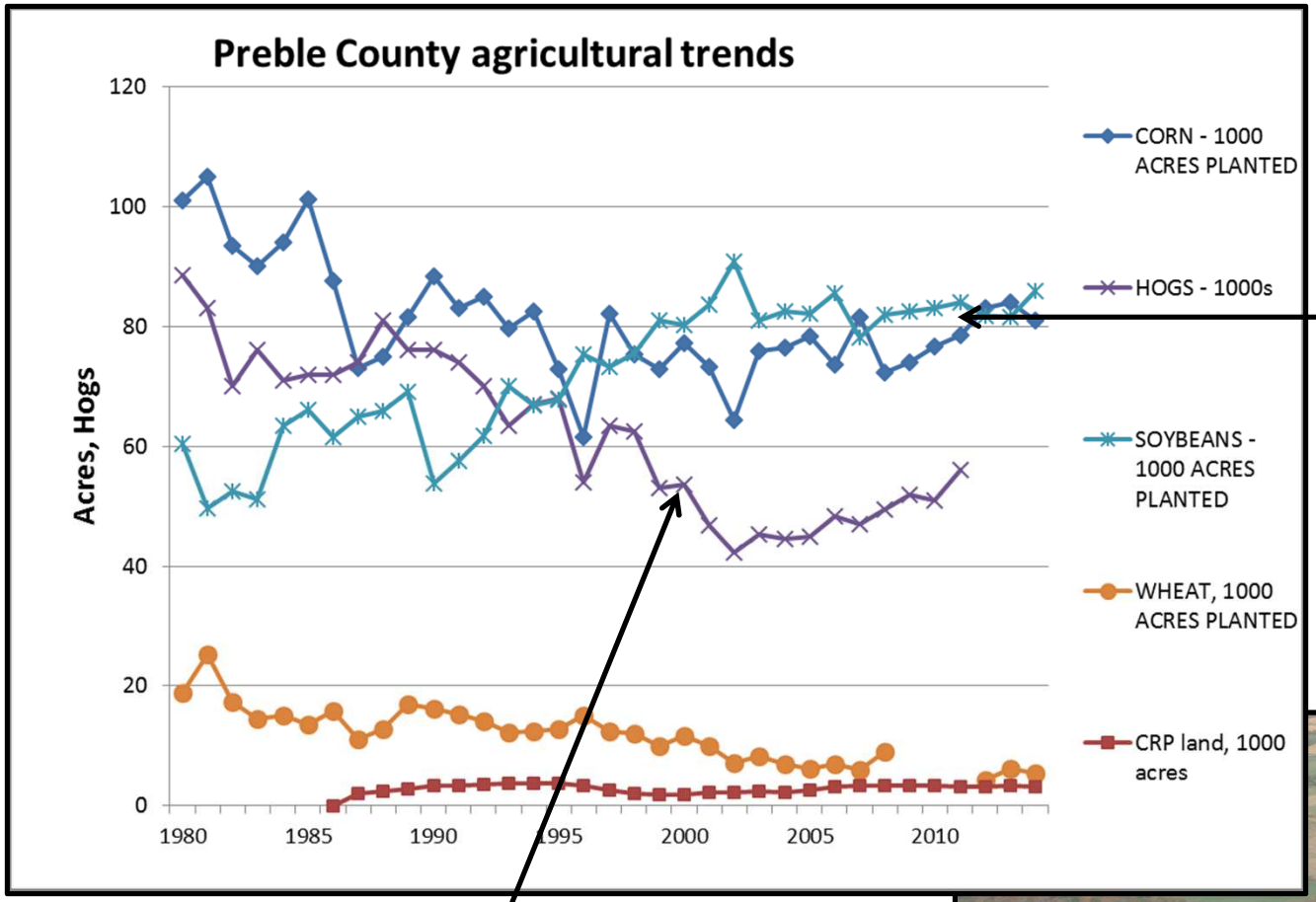
Monitoring program overview

- Began in 1994; ongoing. 22+ years to date.
- Stations on three streams tributary to Acton Lake; drainage areas of 129, 87, and 12.1 km^2; representing 85% of area tributary to the lake.
- Focused on inputs of ammonium, nitrate, soluble reactive phosphorus and sediment to the lake; linked to studies of the Acton Lake ecosystem.
- Significant changes in water quality have been observed. Attribution is difficult but trends are linked to agricultural land management.

Study area

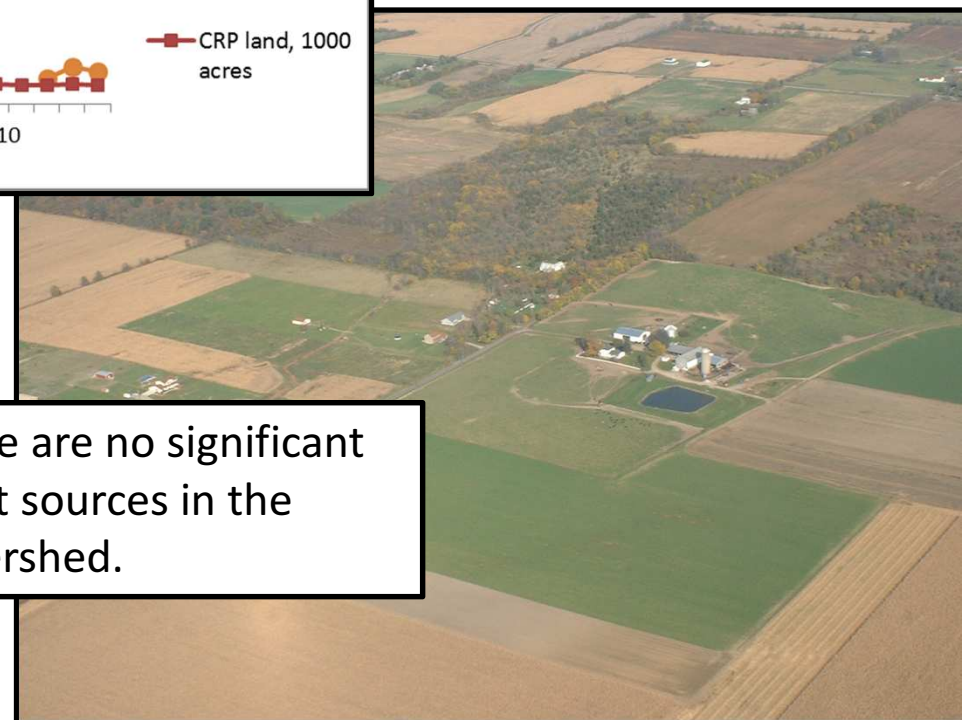


Land use/land cover Cropscape average 2000-2014	Percent of area
Corn and soybeans	70.9
Other row crops	0.9
Pasture and hay	8.5
Forest and forested wetlands	13.2
Developed (farmsteads, roads, recreation)	5.5
Open water and herbaceous wetlands	1.0



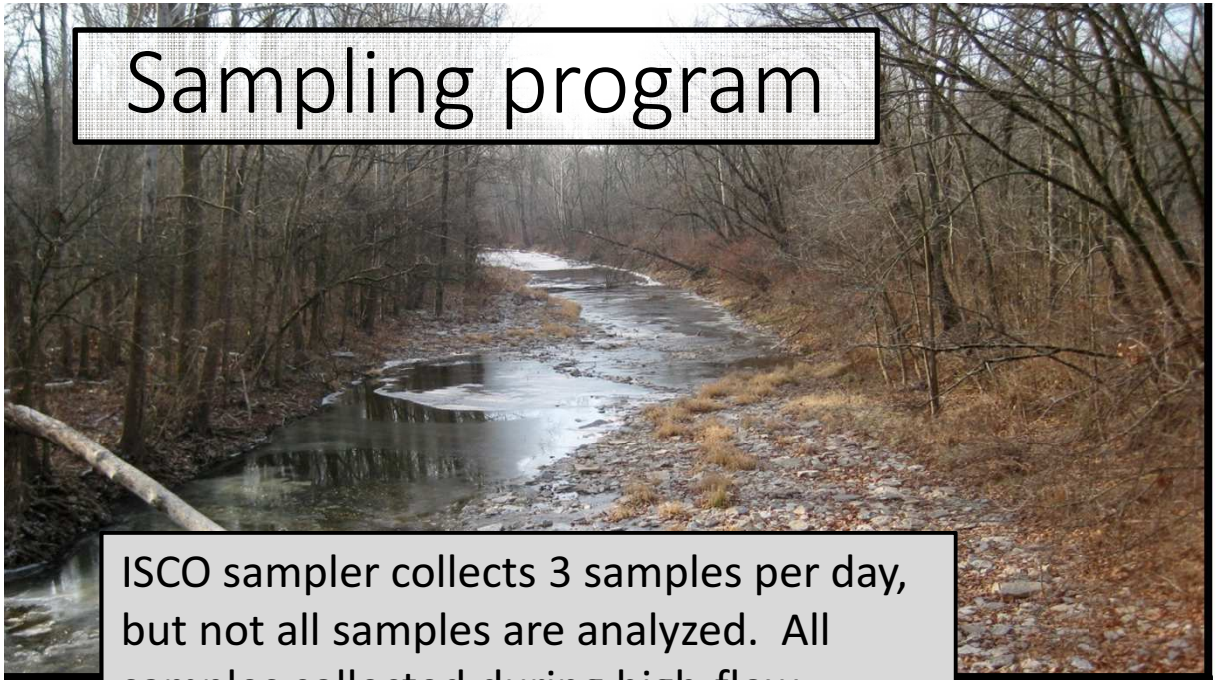
Convergence of row crop production around corn and soybeans in 2-year rotation cycle

Decline in hog population until about 2000; modest increase since then. Concentration of hog production in a small number of facilities



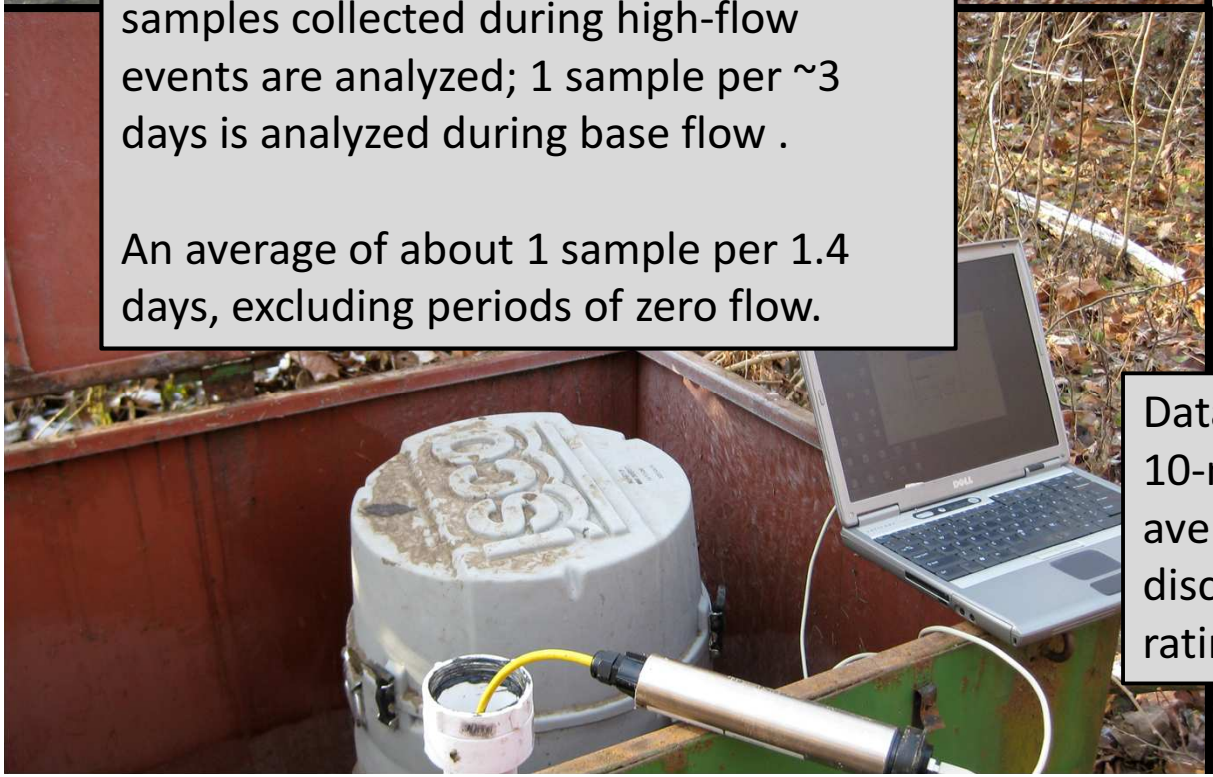
There are no significant point sources in the watershed.

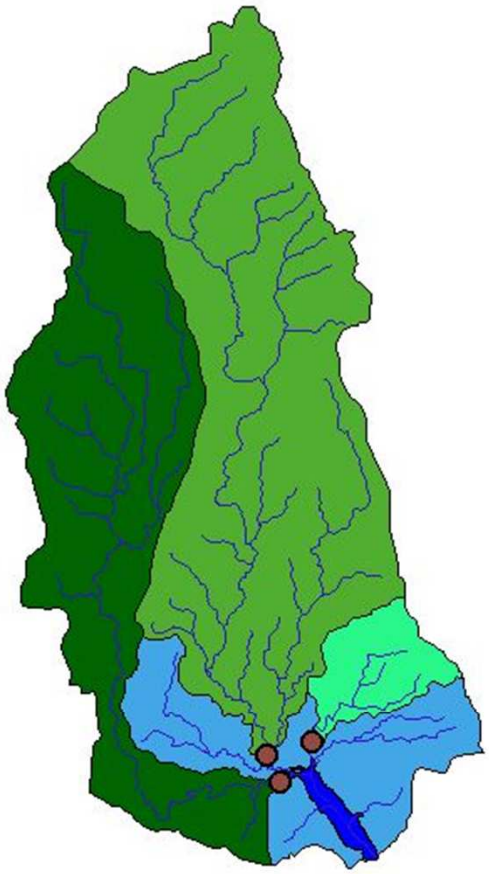
Sampling program

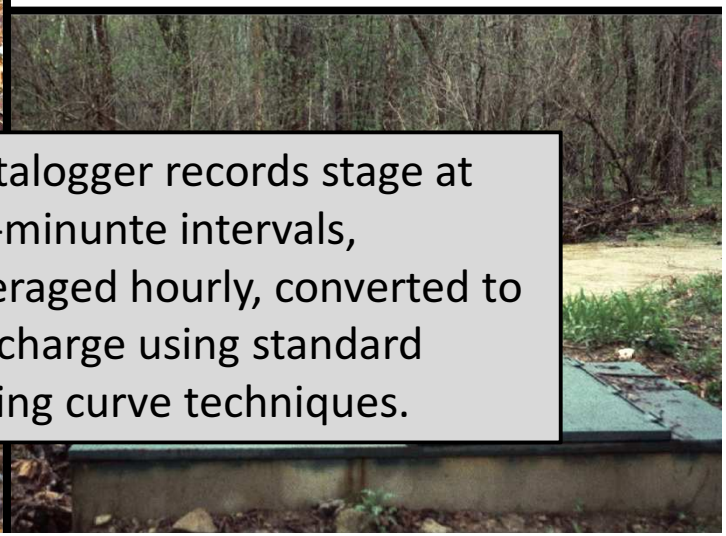


ISCO sampler collects 3 samples per day, but not all samples are analyzed. All samples collected during high-flow events are analyzed; 1 sample per ~3 days is analyzed during base flow .

An average of about 1 sample per 1.4 days, excluding periods of zero flow.

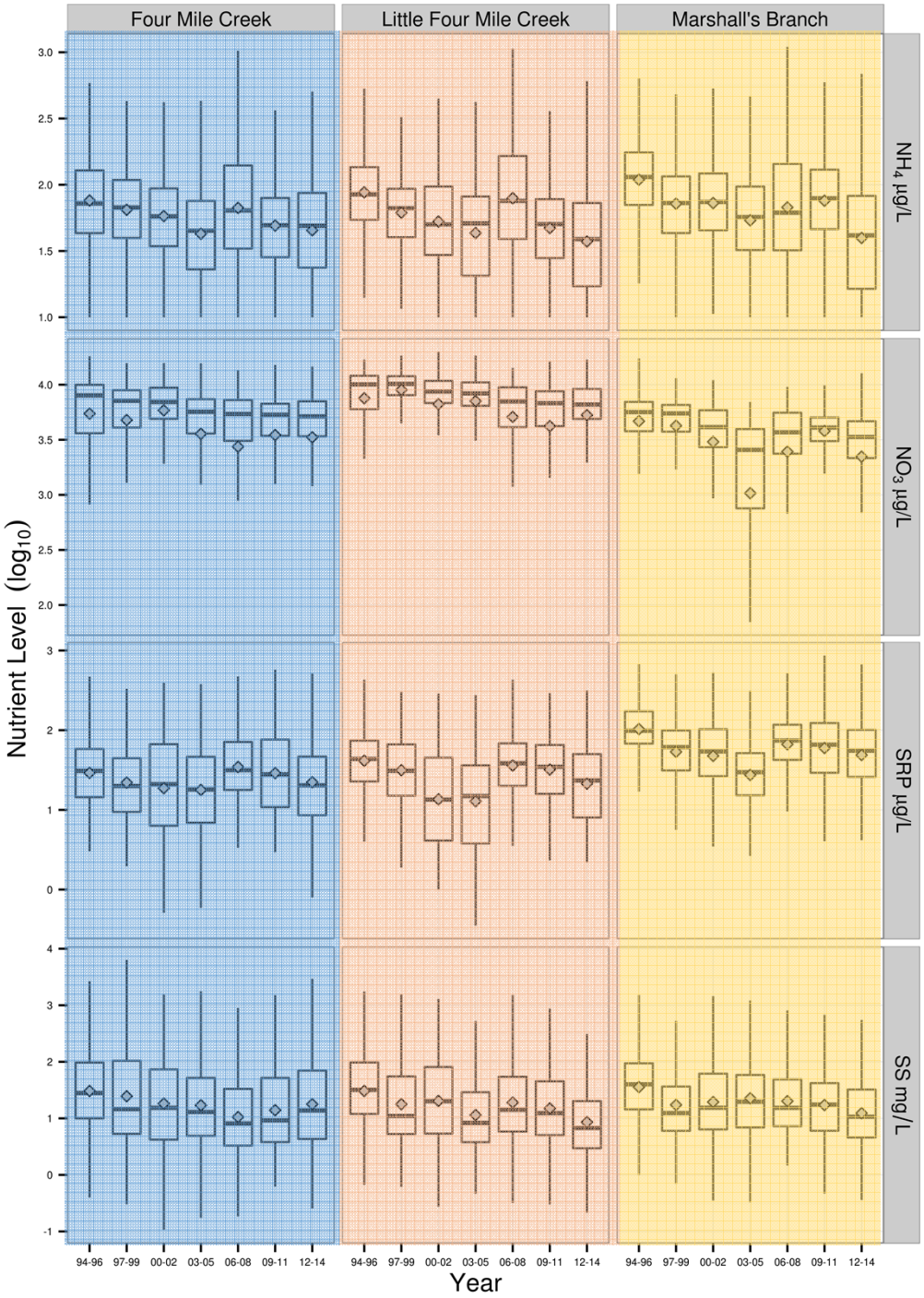






Datalogger records stage at 10-minunte intervals, averaged hourly, converted to discharge using standard rating curve techniques.

Constituent	Stream	N	Mean
NH_4 (ug/l)	Four Mile	5138	86
	Little Four Mile	4666	90
	Marshalls Branch	4958	103
NO_3 (ug/l)	Four Mile	5277	5843
	Little Four Mile	4874	7897
	Marshalls Branch	5162	4158
SRP (ug/l)	Four Mile	5381	50
	Little Four Mile	4853	49
	Marshalls Branch	5199	92
SS (mg/l)	Four Mile	5324	90
	Little Four Mile	4948	67
	Marshalls Branch	5181	70



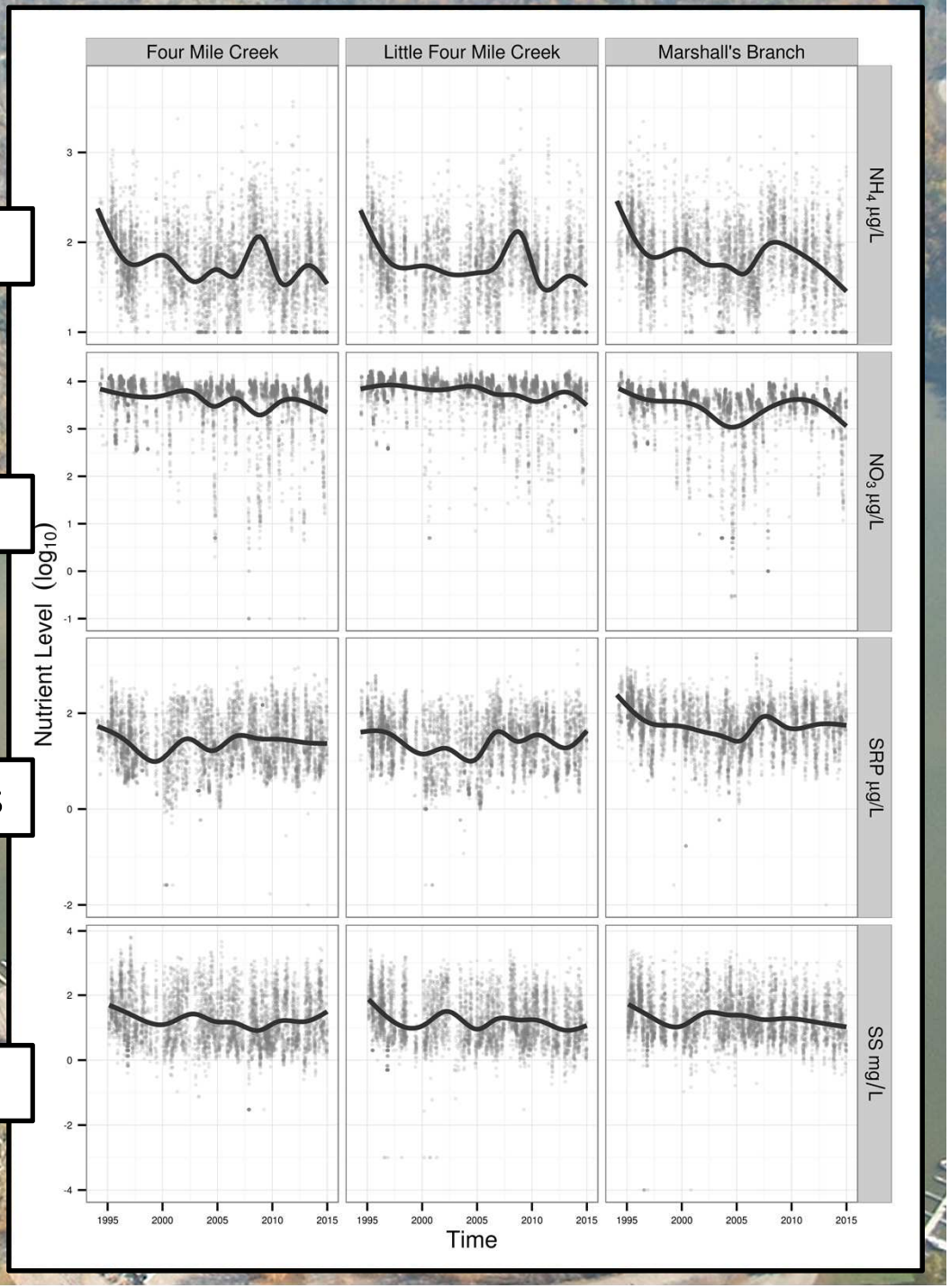
All samples

Ammonium

Nitrate

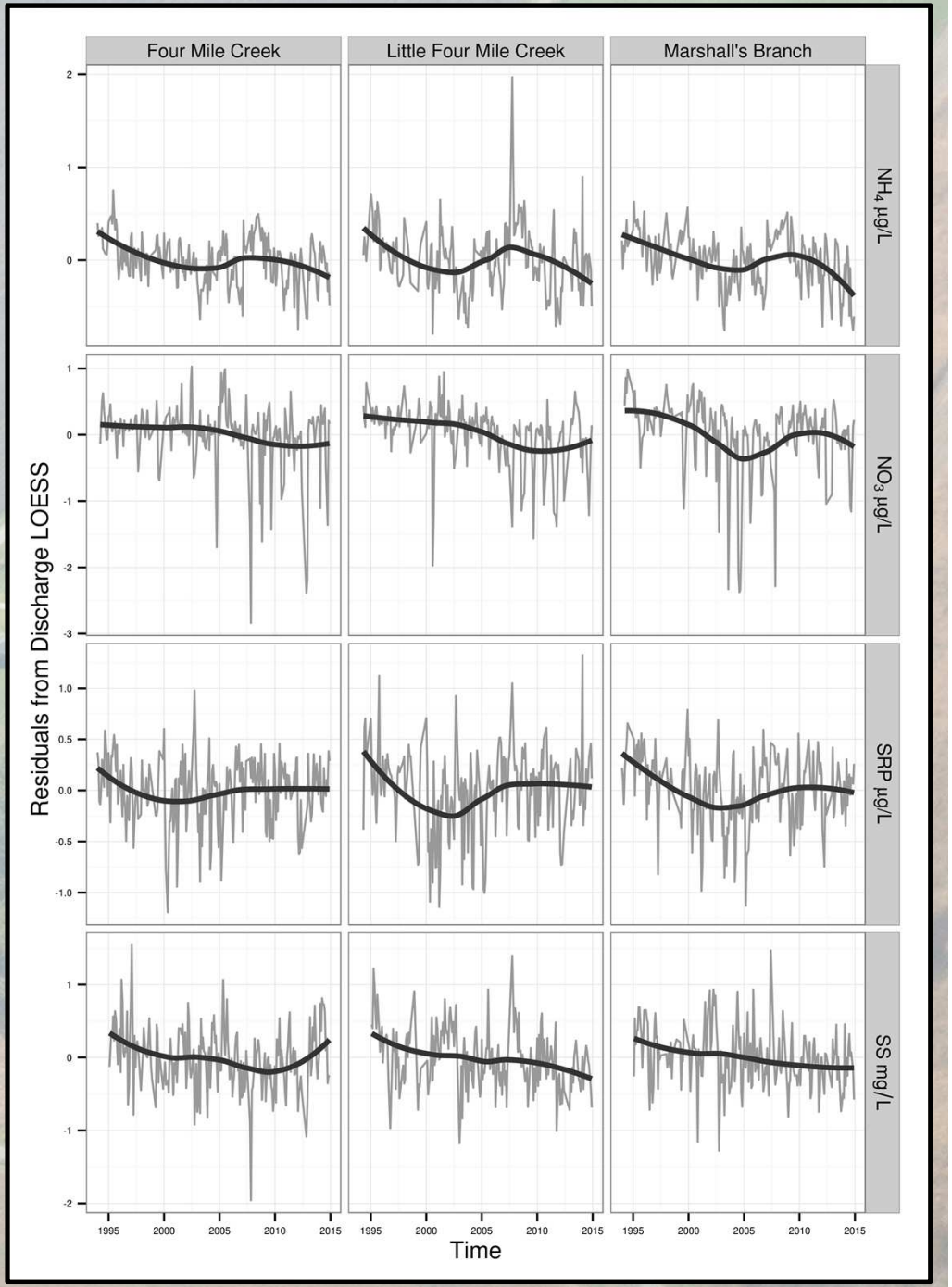
Soluble reactive phosphorus

Sediment



Monthly concentrations adjusted for flow, seasonality, and autocorrelation

Log_{10}-transformed monthly average concentrations were regressed against time with covariate discharge, a sinal/cosinal adjustment of seasonality and an autoregressive moving average (ARMA) model handling any temporal autocorrelation. Shown with LOESS smoothing.



Comparison of two analysis periods

Significant decline 1994-2006

Significant decline 1994-2014

Significant decline both periods

Constituent	Stream	Percent change per year		Weighted average percent change per year	
		1994-2006	1994-2014	1994-2006	1994-2014
NH_4	**FM**	**-8.08**	**-3.54**	-8.35	-3.39
	LF	**-8.86**	-2.87		
	MB	**-7.91**	**-4.95**		
NO_3	**FM**	-0.63	**-4.79**	-1.82	-5.30
	LF	-2.19	**-6.26**		
	MB	**-11.57**	**-4.69**		
SRP	**FM**	**-4.21**	-0.41	-5.48	-1.15
	LF	-6.46	-1.97		
	MB	**-12.31**	-3.63		
SS	FM	-6.44	-2.72	-6.67	-3.90
	LF	**-8.12**	**-5.83**		
	MB	-0.32	**-4.19**		

What is driving these changes?

- Conservation tillage

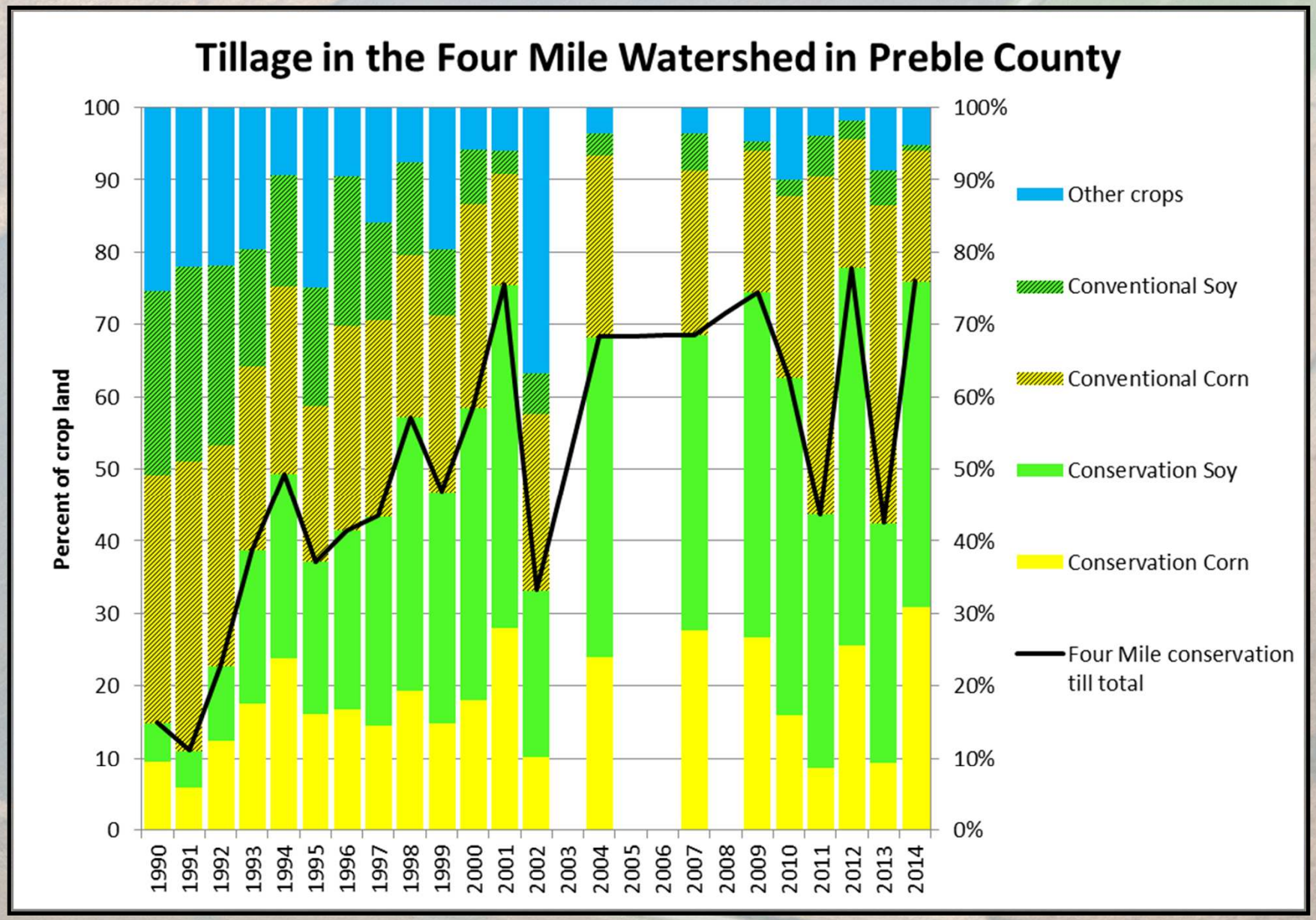
  Use of conservation tillage grew dramatically in the 1990s, but has leveled off since about 2000. Conservation tillage reduces soil erosion and associated nutrients, but has other impacts on soil that may affect forms and quantities of nutrient export.

- Nutrient management

  Improved fertilizer application technologies, including precision agriculture, facilitate increased fertilizer use efficiency.

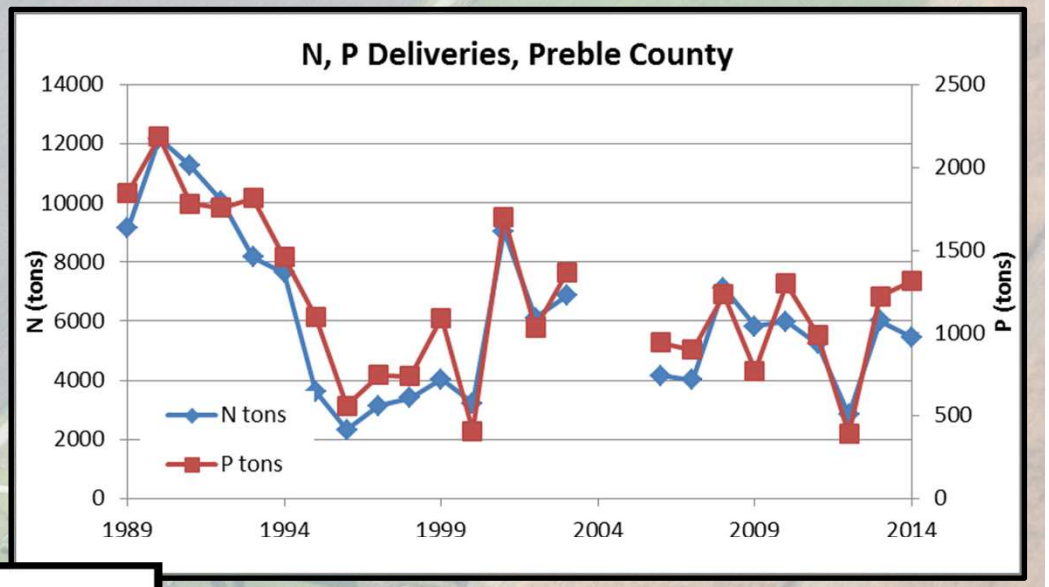
- Animal management

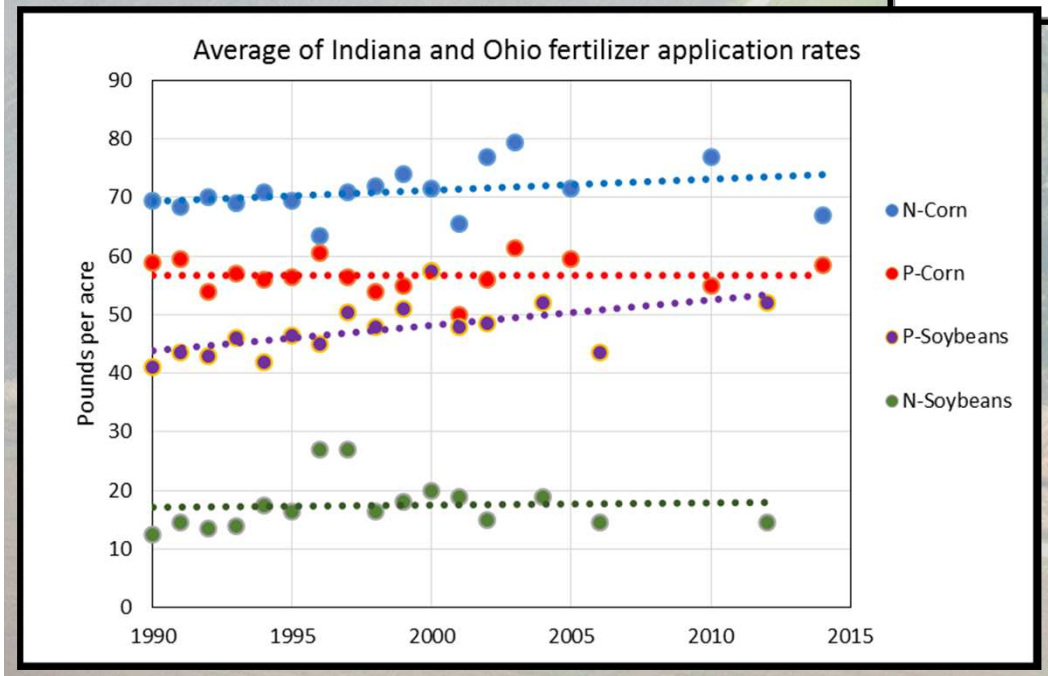
  Animal feeding has moved into a relatively small number of concentrated facilities in which manure can be intensively managed.


Tillage in the Four Mile Watershed in Preble County
Percent of crop land
100
90
80
70
60
50
40
30
20
10
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Other crops
Conventional Soy
Conventional Corn
Conservation Soy
Conservation Corn
Four Mile conservation till total

Are fertilizer application rates changing?

County level delivery data suggest a significant decline, but deliveries are not the same as applications.

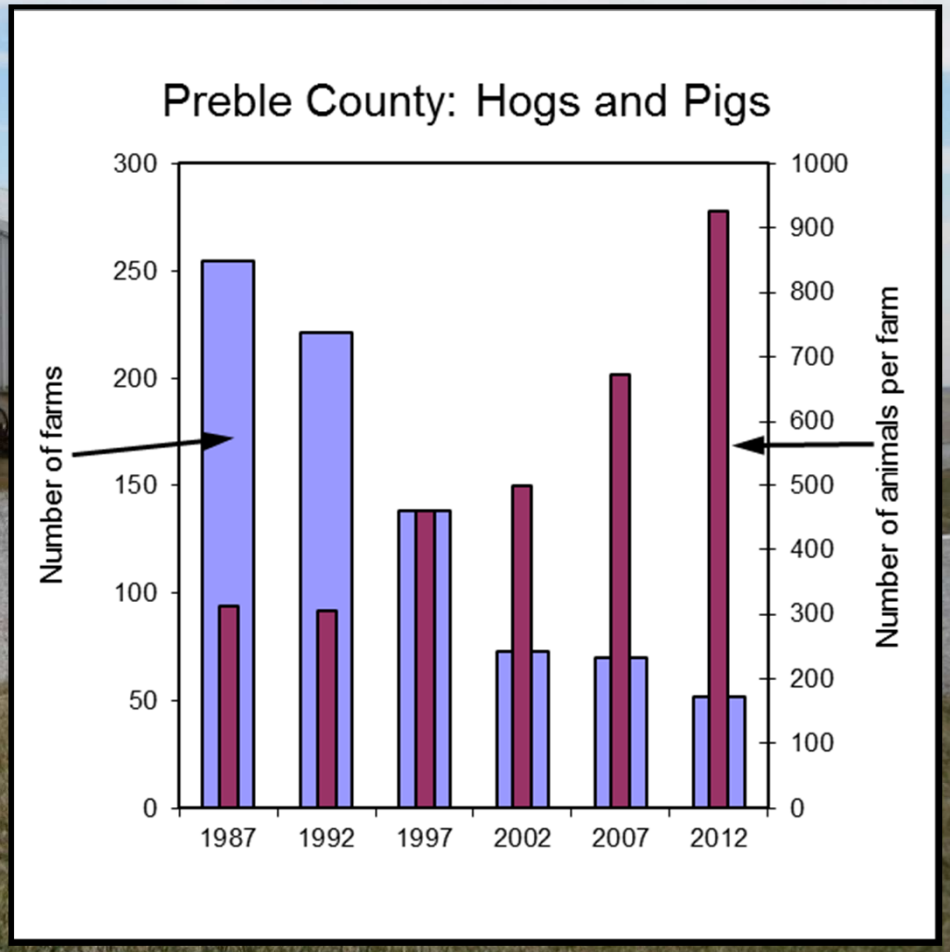




State level application rate data, from surveys, do not indicate a decline in applications.

Changing animal management

Feeding operations have changed dramatically, but nutrient quantities are relatively small in relation to chemical fertilizer applications, and it is not clear that manure management is having a significant effect on nutrient export to streams.



Summary/conclusions

- High-resolution, flow-dependent sampling programs allow detection of subtle changes in water quality.
- Declines in concentrations of NH_4, SRP, and SS observed for 1994-2006 appear to have slowed or ceased, while NO_3 has declined more recently.
- Water quality trends are driven by multiple factors; our study design does not allow identification of specific causes.
- Land use has not changed significantly, and it is reasonably certain that the observed improvement in water quality is a result of changing farm management practices.
- Past improvements in water quality may be limited by maximum in conservation tillage, or overshadowed by other factors such as soil phosphorus mobility or stream channel erosion.

Thanks!

- Tom Fisher and Emily Morris, Miami University
- National Science Foundation
- US Department of Agriculture
- Ohio DNR, Division of Parks
- Preble Soil & Water Conservation District
- Miami Resource Conservation and Development Council
- Miami University
- *Many* dedicated students

More information:

- http://www.cas.miamioh.edu/acton_ltreb/site.html
- Vanni, M.J., et al., 2001, *Biogeochemistry* 54:85-114
- Renwick, W.H., et al, 2008, *Journal of Environmental Quality* 13:1862-1874
- Vanni, M.J. et al, 2013, *Ecology* 94:978–978 (data paper)