Managing Denitrification in Tile-Drained Agricultural Watersheds

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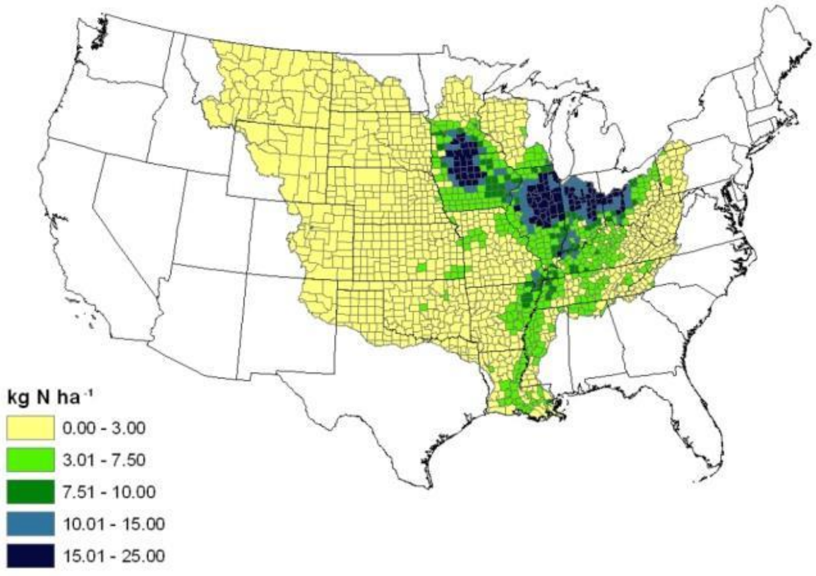
What I will cover

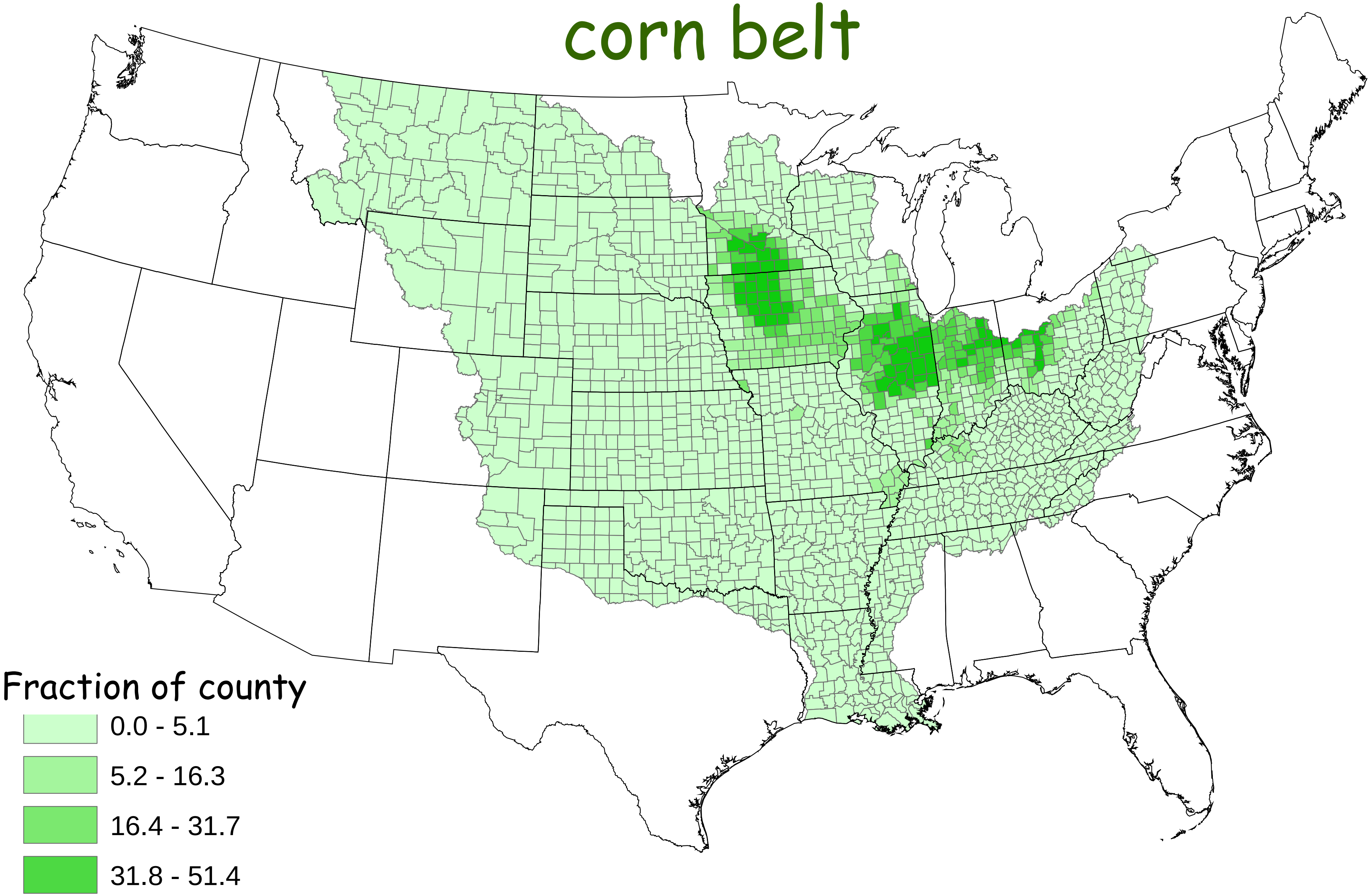
- background
  - tile drainage and the nitrate problem
- tools we have available
  - drainage water management
  - constructed wetlands
  - bioreactors
  - saturated riparian buffers
- limitations
  - landscape
  - social acceptance
  - dollars

Background

- tile drainage losses of nitrate from the corn belt are a major cause of Gulf of Mexico hypoxia
- also can lead to local water quality problems
- what can we do to reduce losses?



Tile drainage is concentrated in the corn belt

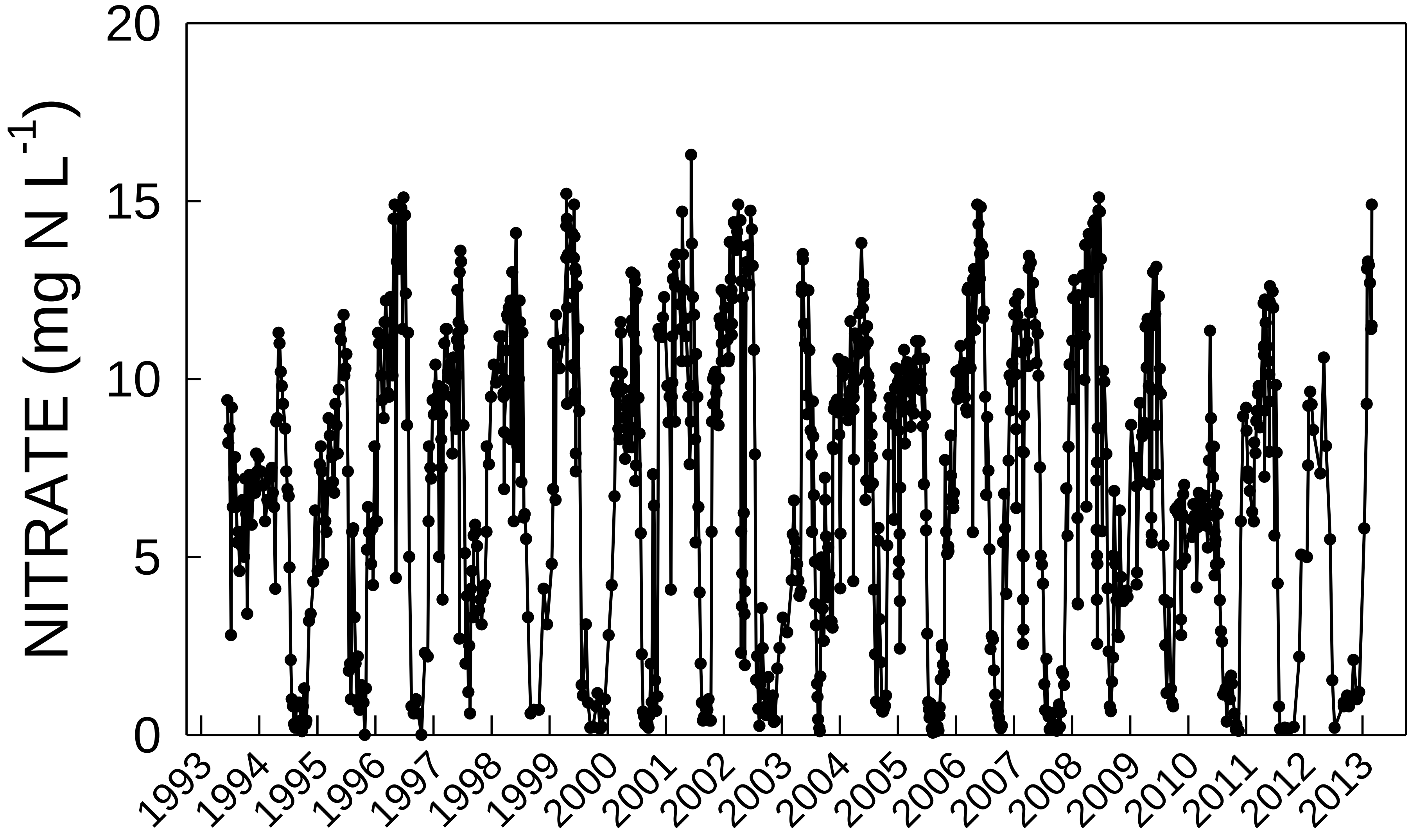


From David et al. (2010)

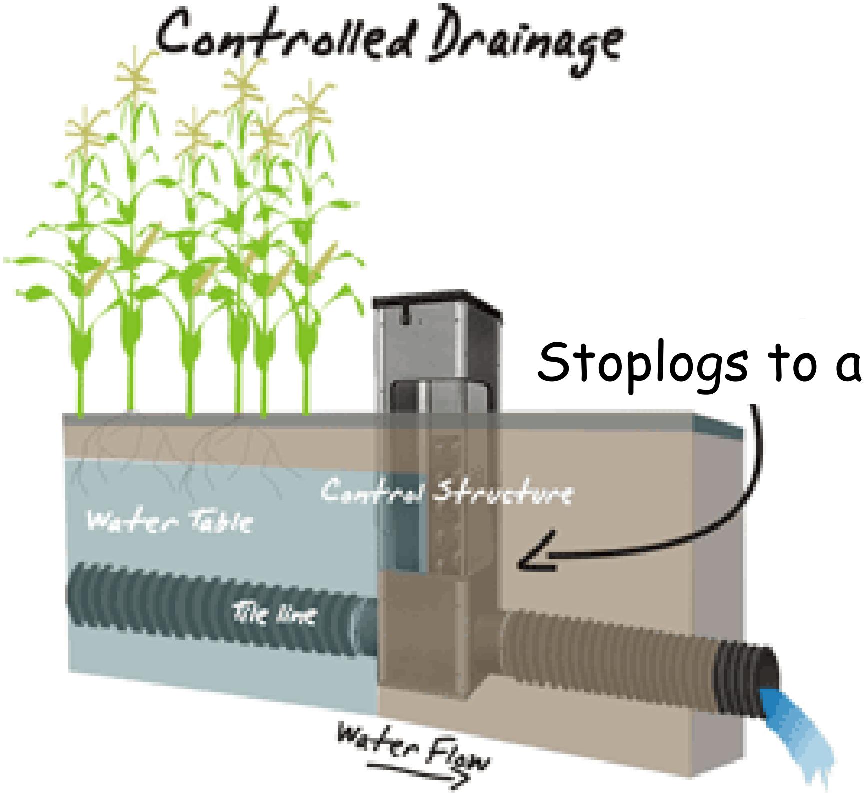
Patterned tile systems

Embarras River - Camargo

Embarras River



Drainage water management

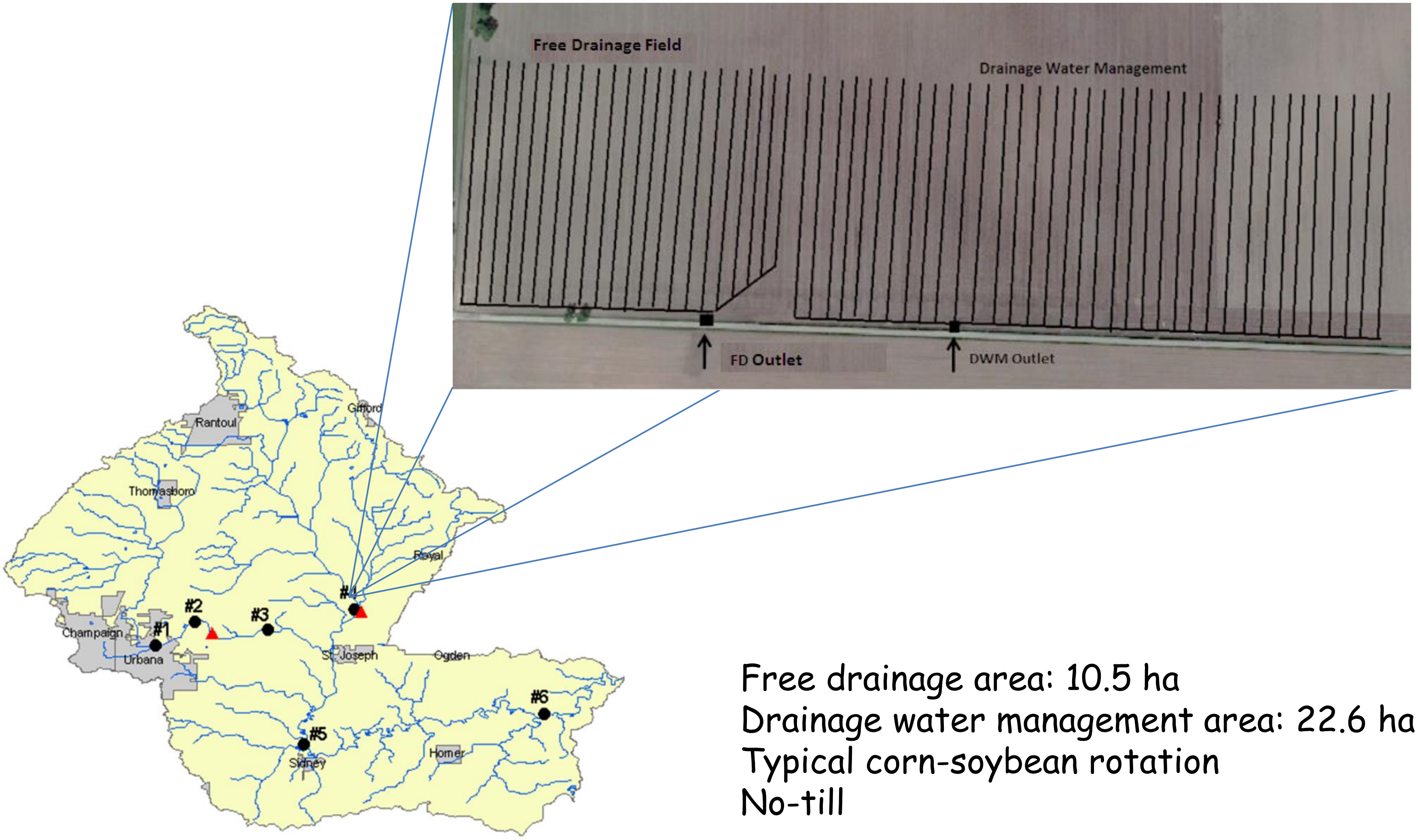


Stoplogs to adjust water level

This technique has been shown to be reduce water and nitrate coming out of a tile line, but where does the water go that is held back?

Salt Fork River Watershed

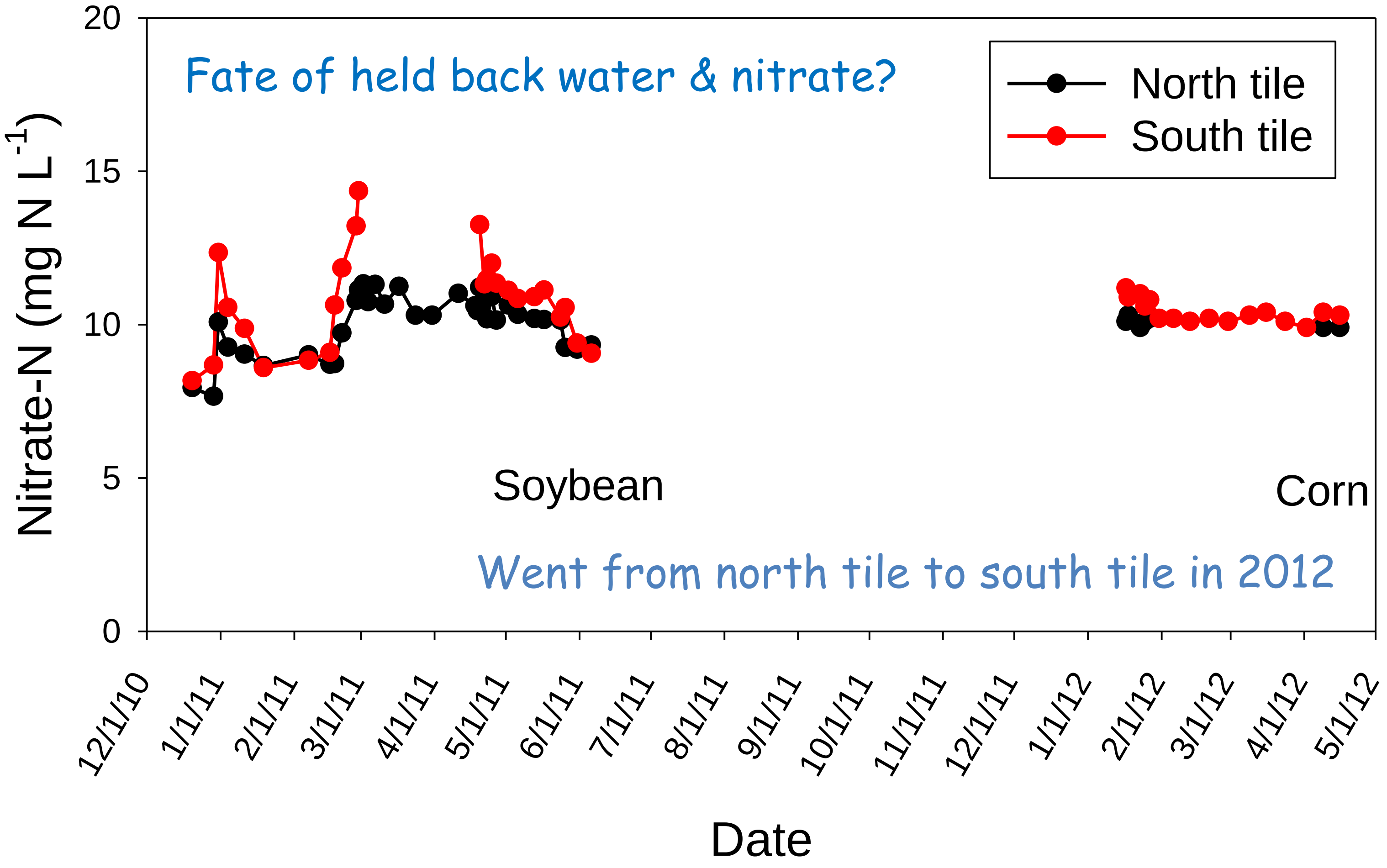
Paired field approach



Free drainage area: 10.5 ha
Drainage water management area: 22.6 ha
Typical corn-soybean rotation
No-till

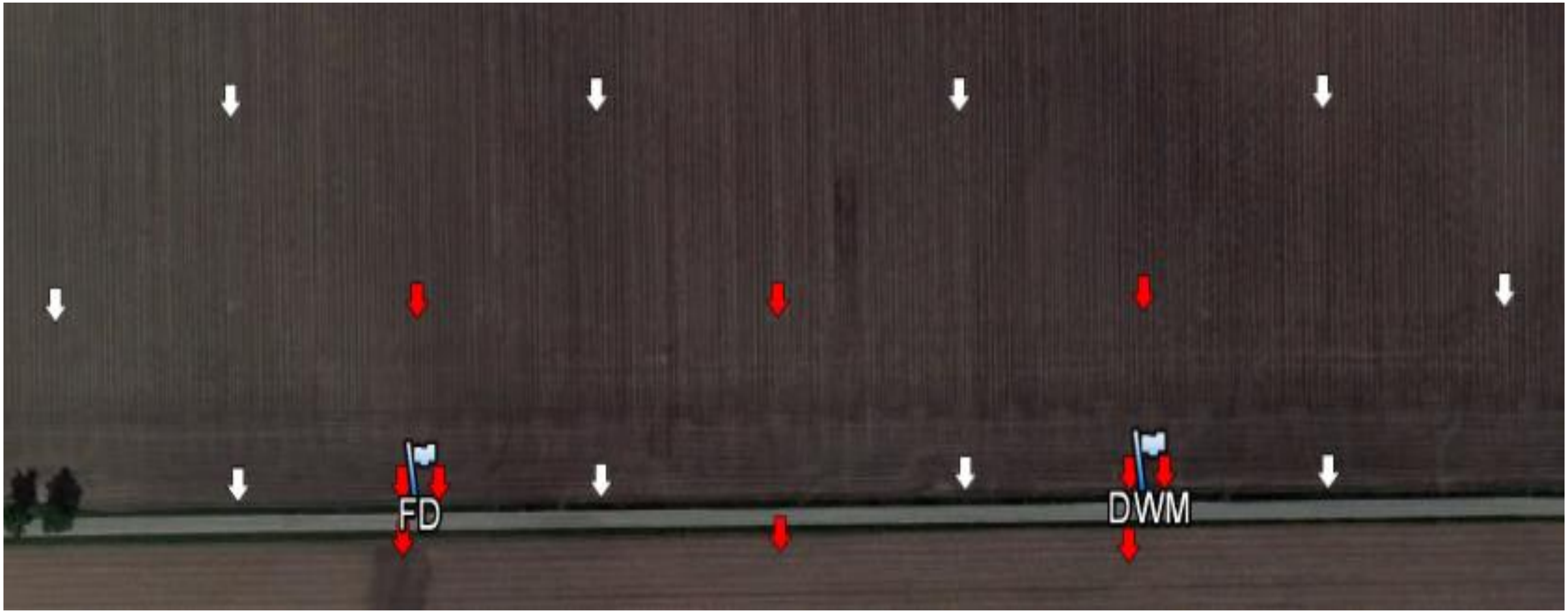
Well locations in 2012

Drainage Water Management



Flow control dates: 28 Feb. through 19 April 2011; 27 Jan. through 5 April 2012

2013 Well Locations



Since January 2013 close both tiles, or one then the other

Skaggs et al. (2012) summary

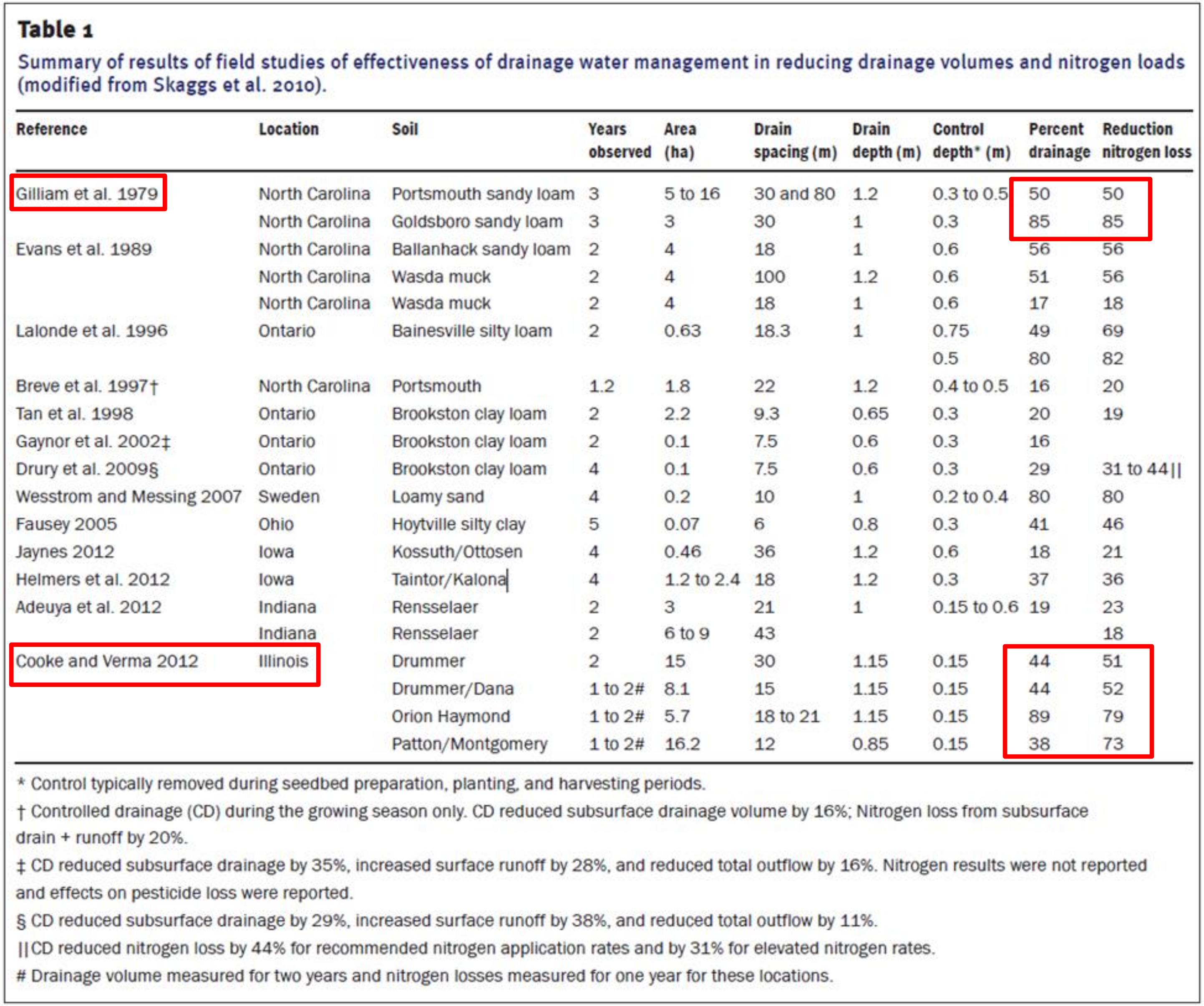


Table 1

Summary of results of field studies of effectiveness of drainage water management in reducing drainage volumes and nitrogen loads (modified from Skaggs et al. 2010).

Reference	Location	Soil	Years observed	Area (ha)	Drain spacing (m)	Drain depth (m)	Control depth* (m)	Percent drainage	Reduction nitrogen loss
Gilliam et al. 1979	North Carolina	Portsmouth sandy loam	3	5 to 16	30 and 80	1.2	0.3 to 0.5	50	50
	North Carolina	Goldsboro sandy loam	3	3	30	1	0.3	85	85
Evans et al. 1989	North Carolina	Ballanhack sandy loam	2	4	18	1	0.6	56	56
	North Carolina	Wasda muck	2	4	100	1.2	0.6	51	56
	North Carolina	Wasda muck	2	4	18	1	0.6	17	18
Lalonde et al. 1996	Ontario	Bainesville silty loam	2	0.63	18.3	1	0.75	49	69
							0.5	80	82
Breve et al. 1997†	North Carolina	Portsmouth	1.2	1.8	22	1.2	0.4 to 0.5	16	20
Tan et al. 1998	Ontario	Brookston clay loam	2	2.2	9.3	0.65	0.3	20	19
Gaynor et al. 2002‡	Ontario	Brookston clay loam	2	0.1	7.5	0.6	0.3	16	
Drury et al. 2009§	Ontario	Brookston clay loam	4	0.1	7.5	0.6	0.3	29	31 to 44||
Wesstrom and Messing 2007	Sweden	Loamy sand	4	0.2	10	1	0.2 to 0.4	80	80
Fausey 2005	Ohio	Hoytville silty clay	5	0.07	6	0.8	0.3	41	46
Jaynes 2012	Iowa	Kossuth/Ottosen	4	0.46	36	1.2	0.6	18	21
Helmers et al. 2012	Iowa	Taintor/Kalona	4	1.2 to 2.4	18	1.2	0.3	37	36
Adeuya et al. 2012	Indiana	Rensselaer	2	3	21	1	0.15 to 0.6	19	23
	Indiana	Rensselaer	2	6 to 9	43				18
Cooke and Verma 2012	Illinois	Drummer	2	15	30	1.15	0.15	44	51
		Drummer/Dana	1 to 2#	8.1	15	1.15	0.15	44	52
		Orion Haymond	1 to 2#	5.7	18 to 21	1.15	0.15	89	79
		Patton/Montgomery	1 to 2#	16.2	12	0.85	0.15	38	73

* Control typically removed during seedbed preparation, planting, and harvesting periods.

† Controlled drainage (CD) during the growing season only. CD reduced subsurface drainage volume by 16%; Nitrogen loss from subsurface drain + runoff by 20%.

‡ CD reduced subsurface drainage by 35%, increased surface runoff by 28%, and reduced total outflow by 16%. Nitrogen results were not reported and effects on pesticide loss were reported.

§ CD reduced subsurface drainage by 29%, increased surface runoff by 38%, and reduced total outflow by 11%.

|| CD reduced nitrogen loss by 44% for recommended nitrogen application rates and by 31% for elevated nitrogen rates.

Drainage volume measured for two years and nitrogen losses measured for one year for these locations.

Constructed wetlands

- intercept tile line or water flow path with small constructed wetland (0.5 to several ha)
  - bulldoze berm
- water is retained for hours to days
- allows for nitrate removal by denitrification
- usually along side of ditch or stream
- extensive literature and experience with sewage treatment
  - less for agricultural drainage waters
  - Kadlec, R.H. 2012. Constructed marshes for nitrate removal. Critical Reviews in Environmental Science and Technology 42:934-1005.

Tile wetland

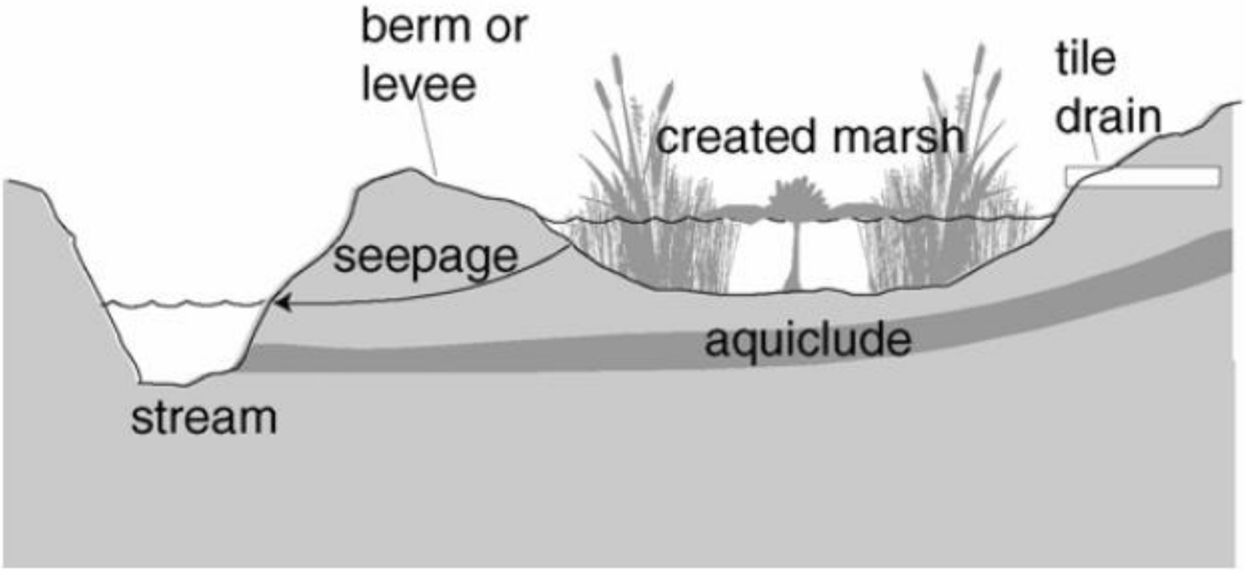
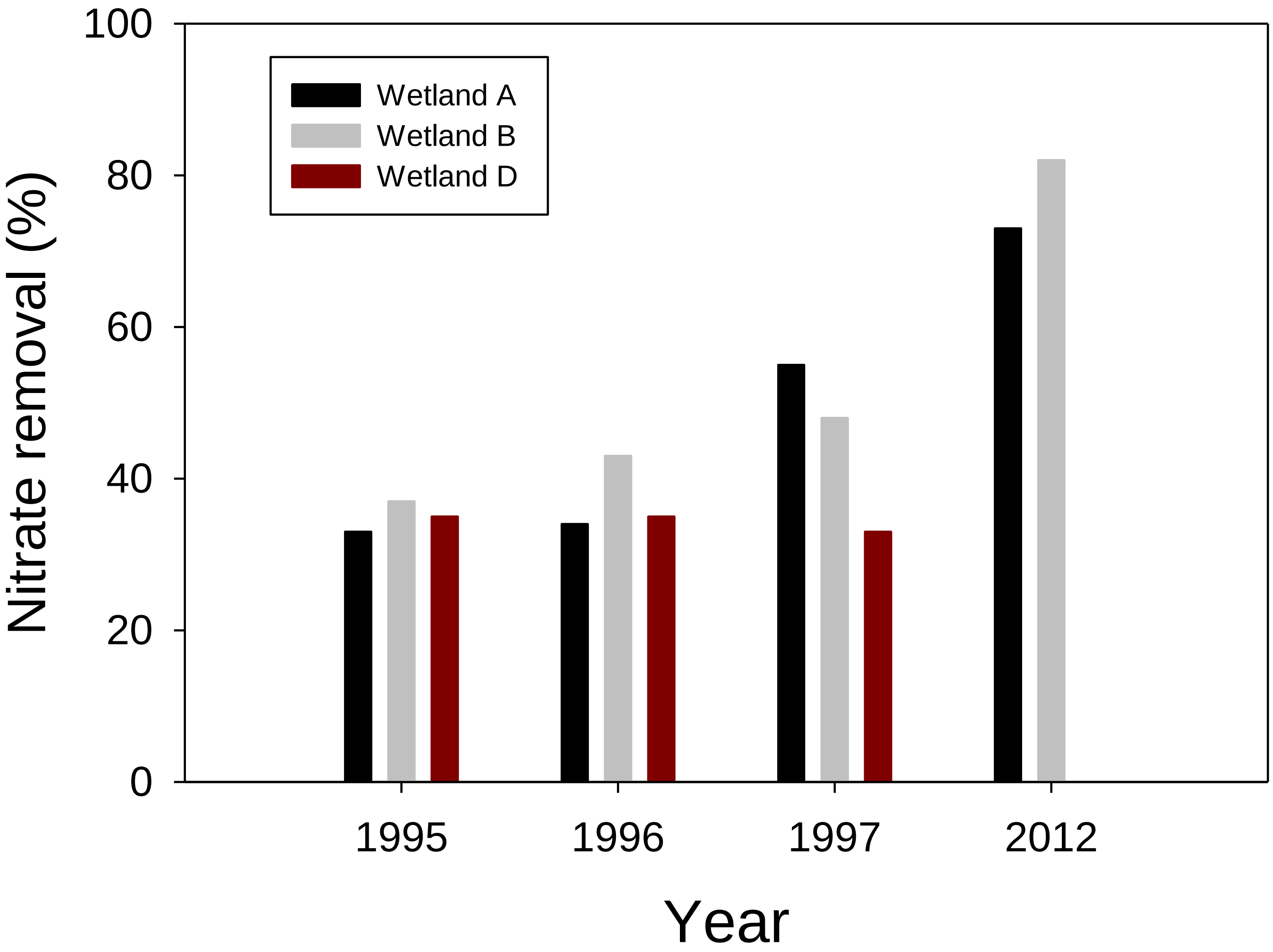


Fig. 5. Conceptual diagram of farm runoff wetland.

From Mitsch and Day (2006)

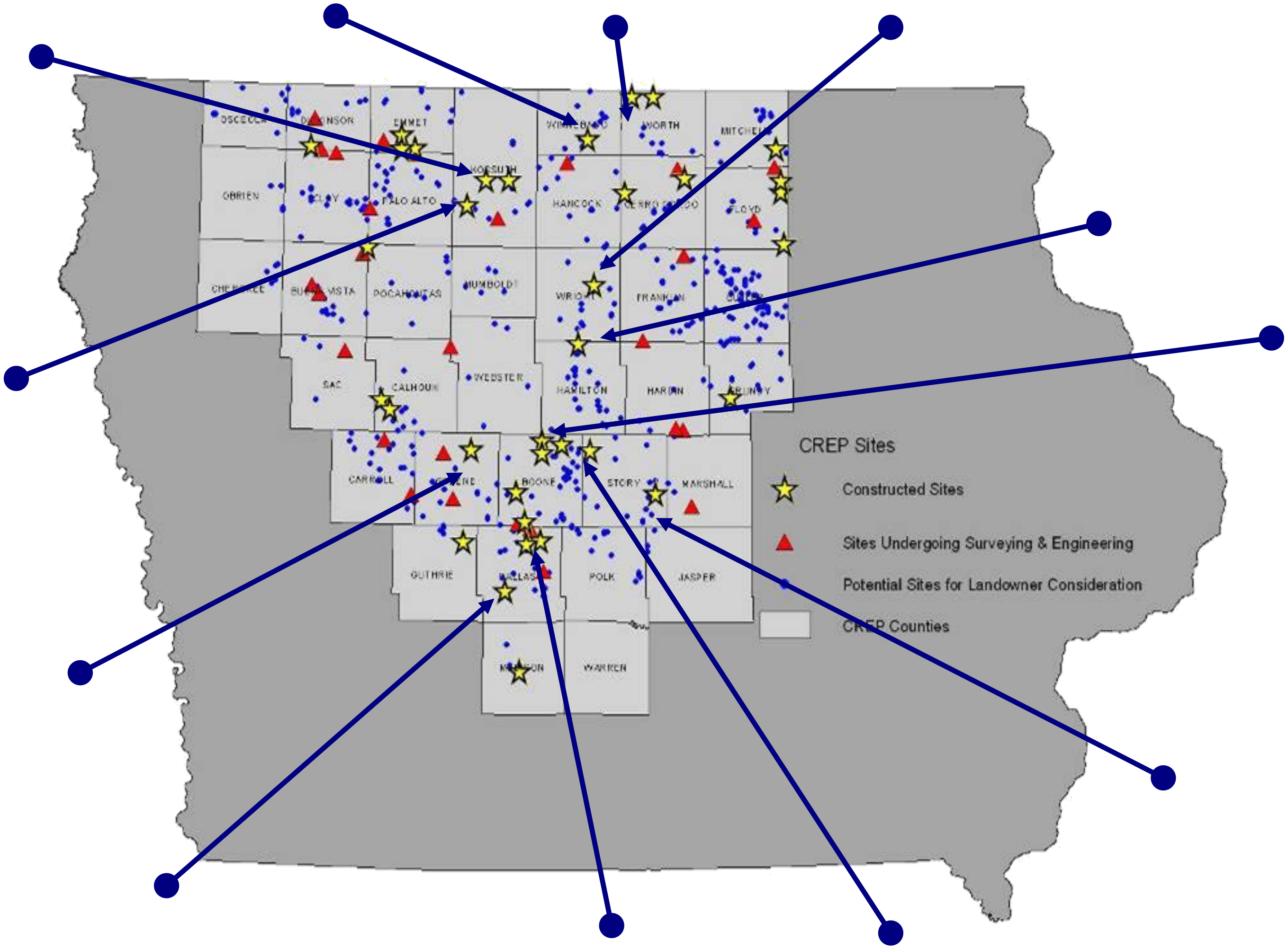
Illinois wetland nitrate removal



From Kovacic et al. (2000) and new results

Iowa Wetlands

- 1.5 to 7.3 ha (3.8 ha avg)
- depth 0.34 to 0.78 m
- 1 to 13 yrs old
- ratio of 0.34 to 5.3%
- tile inlets, plus surface runoff
- 44 to 93% rowcrop
- surrounded by buffers

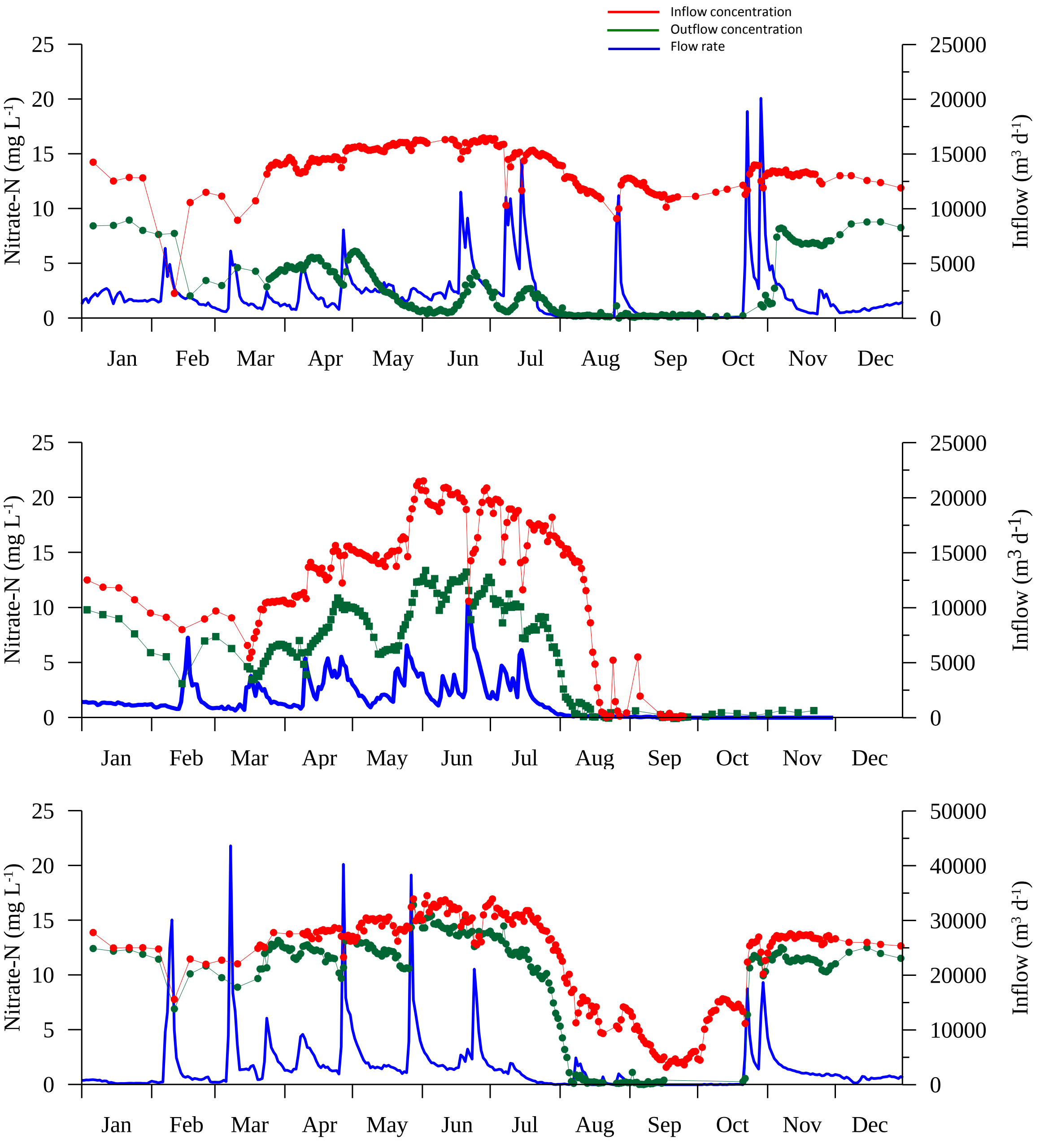


W.G. Crumpton, Iowa State University

Residence time

Longer

Shorter



Hydraulic Loading Rate

Lower

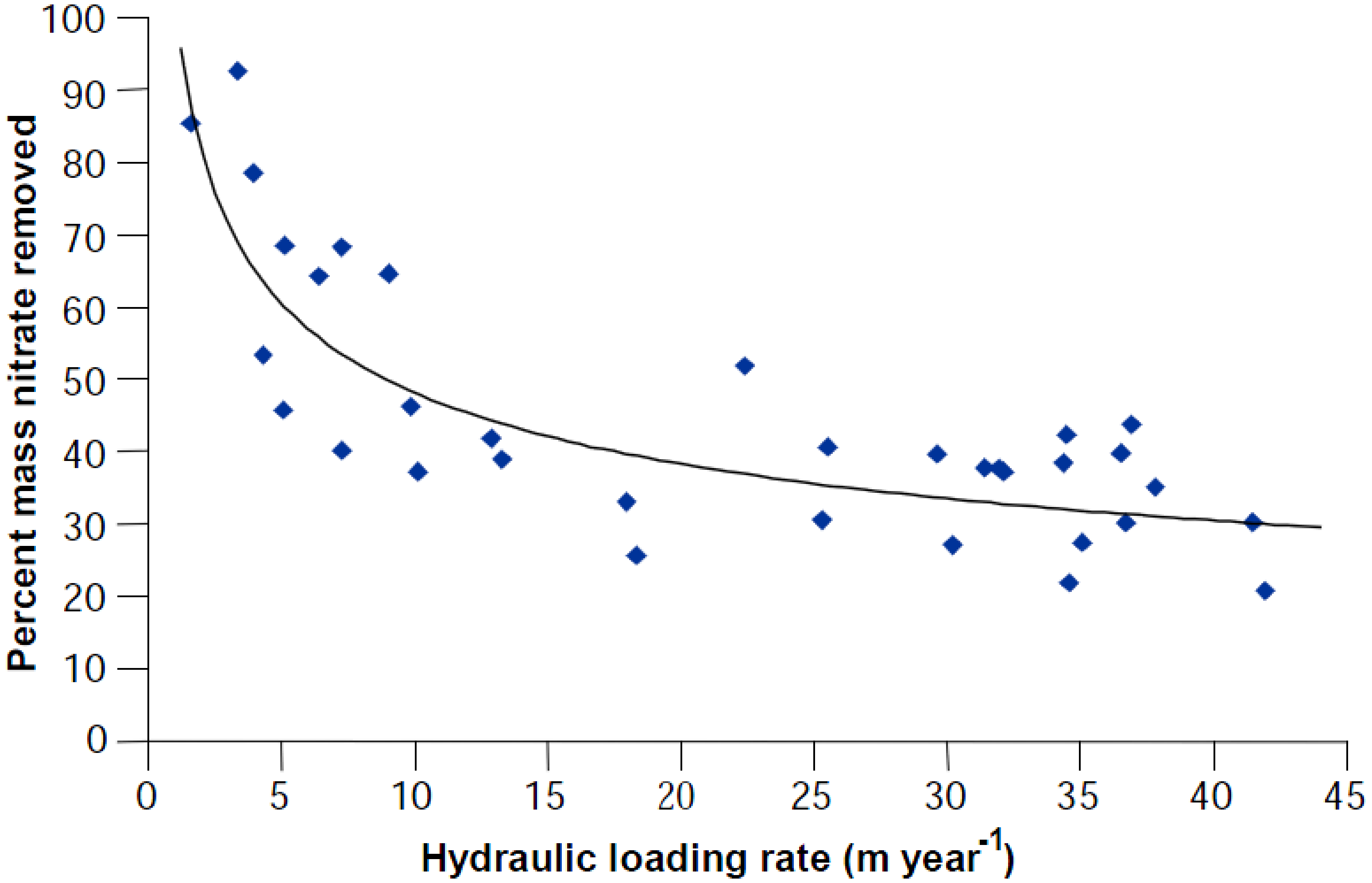
Greater

W.G. Crumpton, Iowa State University

What determines effectiveness?

- hydraulic loading
  - amount of water and nitrate
  - retention time
- nitrate concentration
- carbon
- temperature
- soils and vegetation
- microbial populations

Loading controls % removal



From Crumpton et al. (2008)

Retention time and temperature

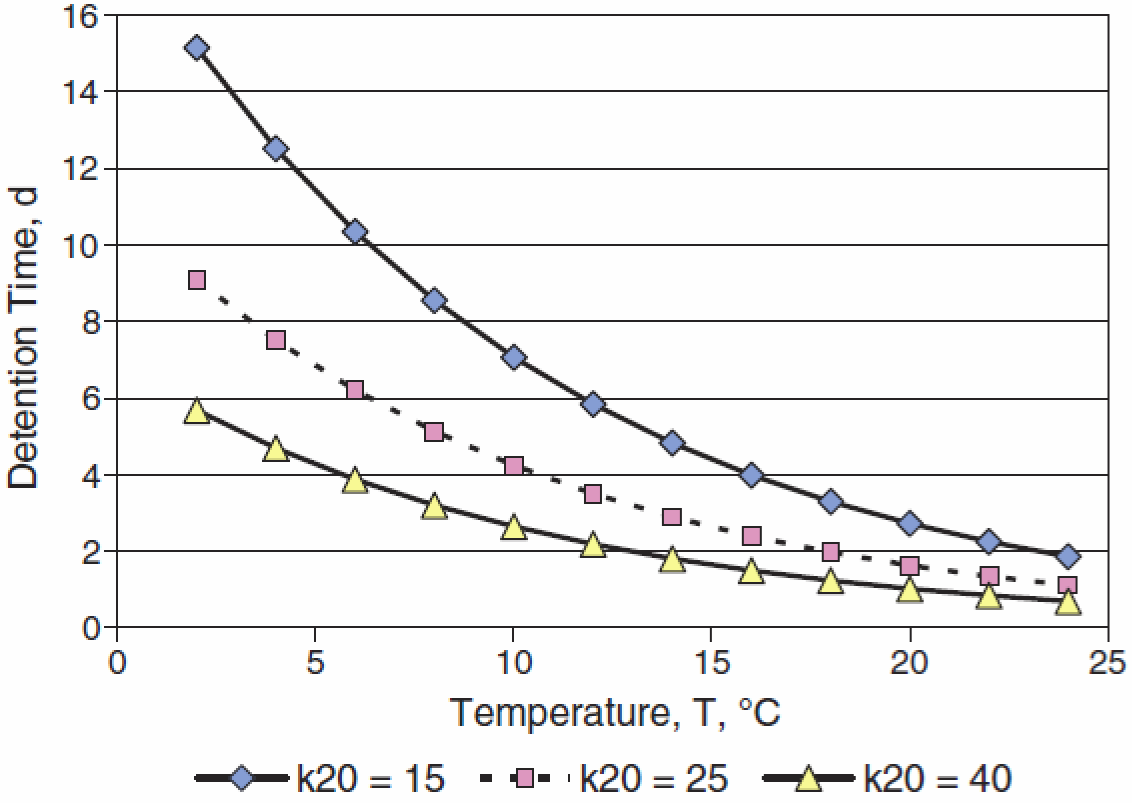


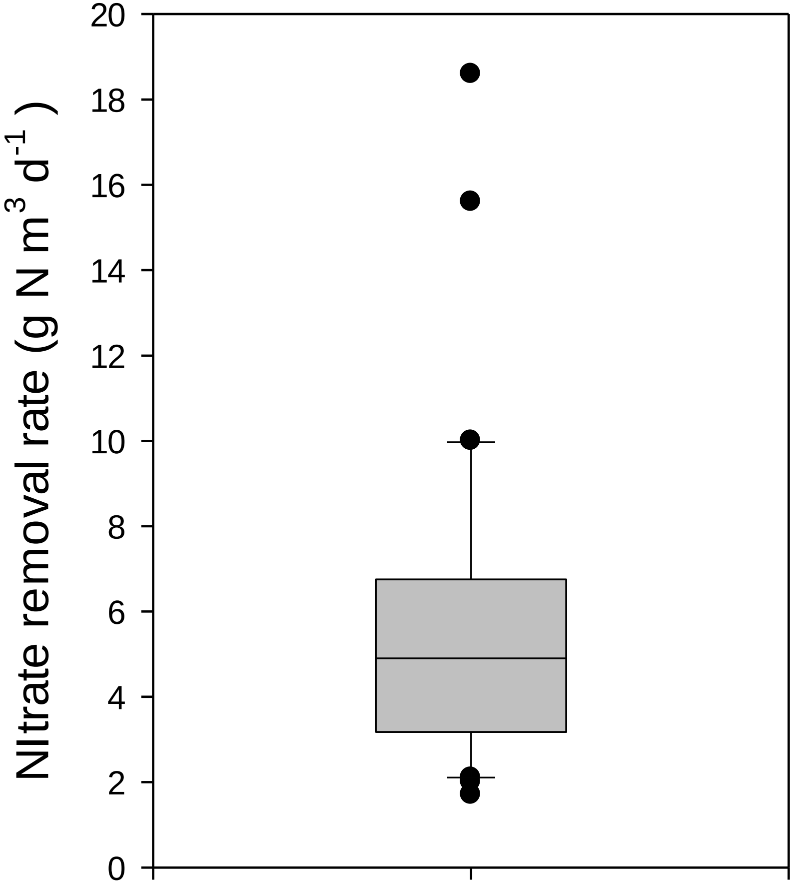
FIGURE 5. The effect of water temperature on the hydraulic loading, and corresponding detention time, required to accomplish 30% nitrate reduction. First-order NTIS areal model, with depth = 30 cm, N = 4 TIS, q = 1.1, and various k_{20} (m/year) (Color figure available online).

From Kadlec (2012)

Woodchip bioreactors

Rates of N removal

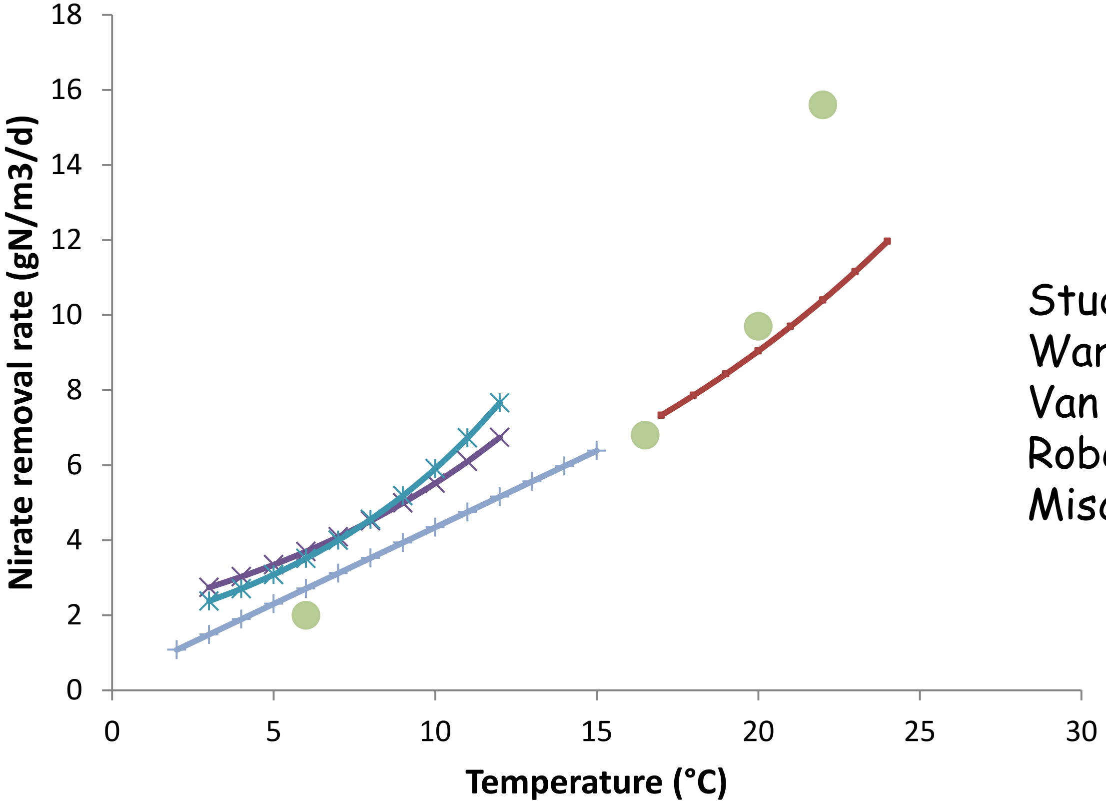
- geometric mean of 3.4 g m^{-3} d^{-1}
- range probably due to range of nitrate concentrations, ages carbon stocks, and temperature



Adapted from Schipper et al. (2010)

Temperature

Other factors non-limiting in field studies



Studies:
Warneke et al., 2011
Van Driel et al., 2006
Robertson and Merkley, 2009
Misc point studies

Roughly, as temperature increases by 10 °C rate increases 2 fold

Biophysical Limitations for Tile Management

- too flat for saturated riparian buffers
- grass buffers being removed along ditches
- many tile systems cannot retrofit control structures
  - outlets are too deep
  - multiple land owners
- dredge spoil along ditches
  - can't build a wetland

This area is so flat that…

- a town is called Flatville,
- and rows are long and straight

Conclusion- Role of denitrification

- still unknowns, especially drainage water management at watershed scale
- landscape limitations
- social limitations
- cost limitations
- certainly could be part of solution, but not major part