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IOWA STATE UNIVERSITY
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Phosphorus Loss Through Subsurface Tile Drainage

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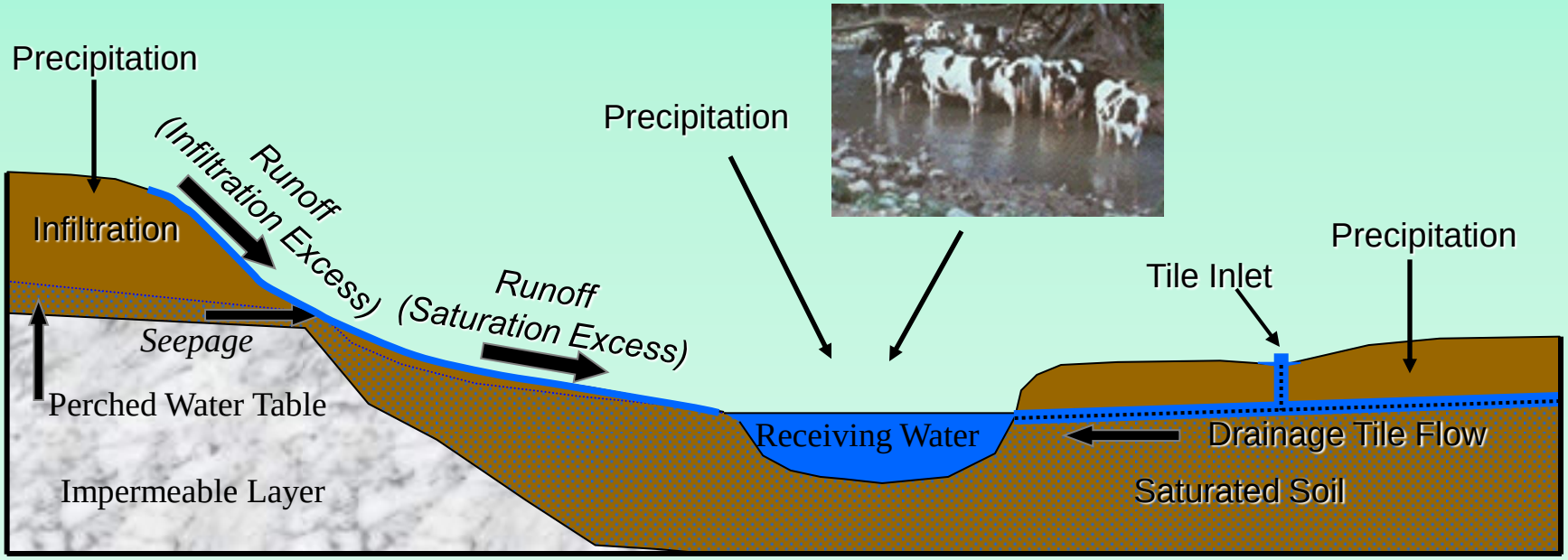
Nutrient Loss and Water Quality

- High P loss impairs water resources
- P has to be transported to groundwater or off fields to streams in order to impair water
- Deviations from agronomic BMPs can't be directly used to estimate risk of P loss
- Transported P forms:
  - Dissolved P: immediate, short-term impact
  - Sediment bound: delayed, long-term impact
  - Bioavailable P: A laboratory estimate of forms with "medium-term" impact

Pathways for P Loss

- Soil erosion:
  - gully
  - sheet and rill
  - stream bank
- **Surface runoff**:
  - infiltration excess
  - saturation excess
  - seepage
- **Subsurface drainage**:
  - tiles
  - coarse soil/subsoil



P Index Three Components

Soil Erosion
(Particulate P)

Source Factors
- soil P
- application method, timing, and rate

Surface Runoff
(Dissolved P)

Subsurface Drainage
(Dissolved P)

Soil and water conservation practices

Applied P, Soil-Test P, and P Loss

- Fertilizer or manure P application in excess of crop removal increases the soil P level and the risk of P loss with runoff or subsurface drainage
- The risk of P loss with surface runoff begin to increase significantly at soil-test P levels slightly higher then Optimum for crops
- Risk of P loss with tile drainage begin to increase significantly at levels 4-5 times higher than Optimum for crops

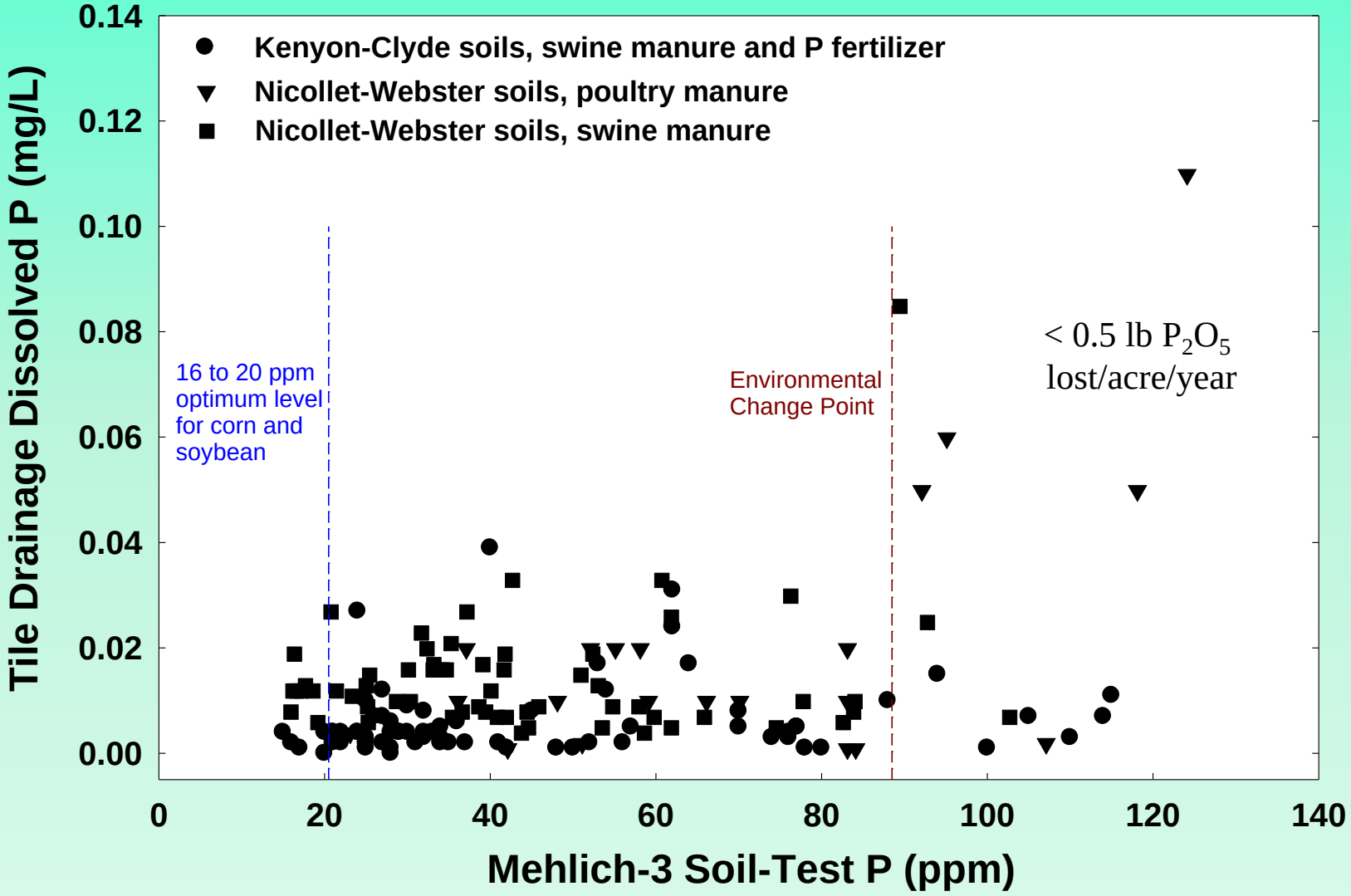
P Loss through Tile Drainage

- Vertical P flow is mediated by water infiltration, flow, P concentration and also the soil/subsoil properties and desorbable P concentration
- Subsurface tile drains collect P containing profile water and discharge to surface drains or streams
- Lateral water and P flow to tiles should be affected by the subsoil hydrological and chemical properties

Applied P, Soil-Test P, and P Loss

- Good fertilizer management to avoid STP buildup and bad application is easy
- But with manures things get complicated
  - Uncertain nutrient concentration
  - Difficult/expensive uniform application
  - Storage needs to apply only at the best times
  - N-based manure for corn may apply excess P
    - Poultry manure for corn of corn-soybean rotations or continuous corn
    - Any manure for continuous corn

Early Data: STP and Tile Drainage P Loss



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Mallarino, Haq, Klatt, Baker, Kanwar, Pedersen, & Pecinovsky. ISU

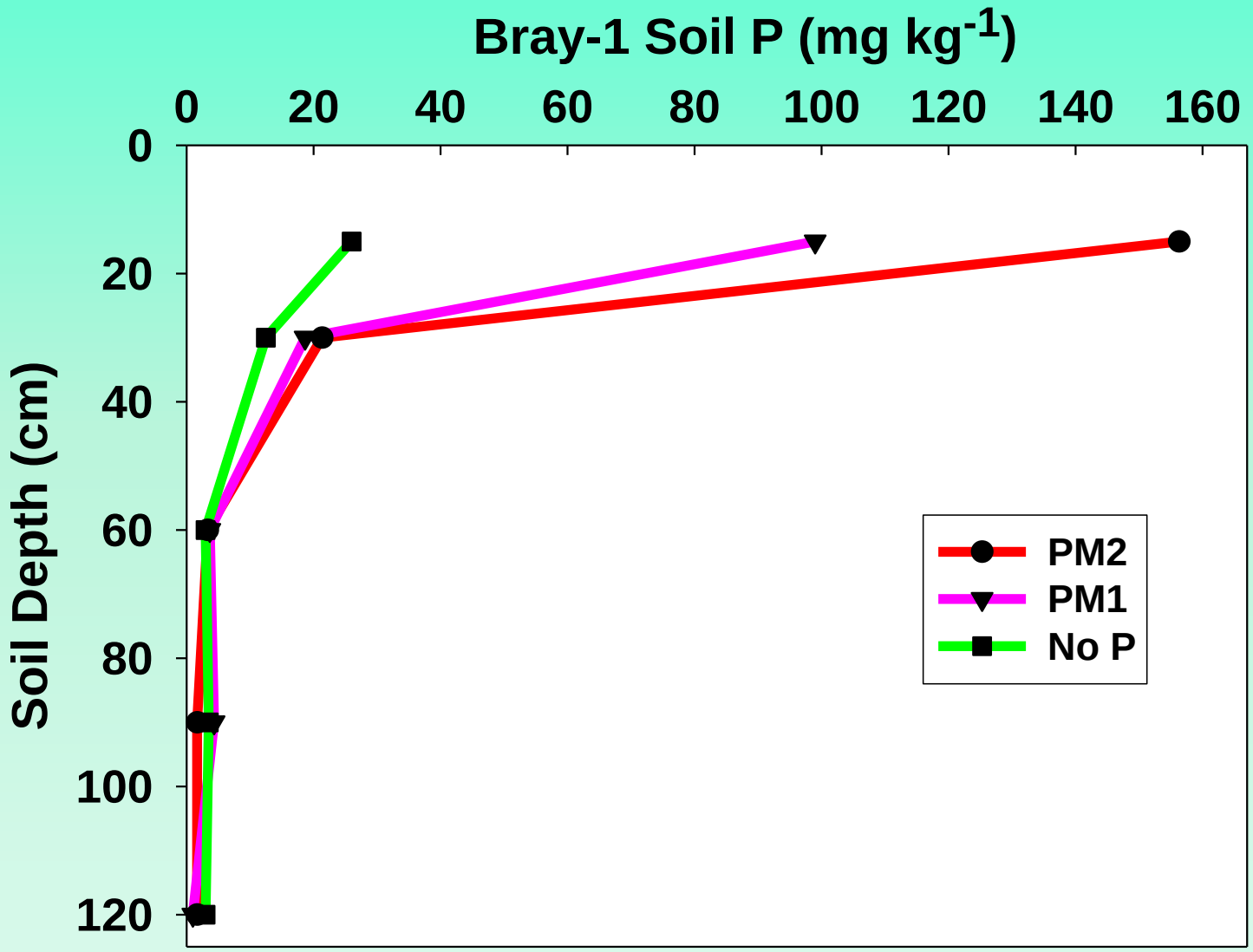
Three Long-Term Experiments

- Central Iowa, poultry manure rates, corn-soybean rotations
- Northeast Iowa, fertilizer or swine manure management, corn-soybean rotations or continuous corn
- Central Iowa, fertilizer or swine manure management, corn-soybean rotation, continuous corn, switchgass, corn harvest systems for bioenergy

Central Iowa Poultry Manure Site

- 9-year study (1999-2006)
- Nicollet/Webster loam soil, loam subsoil
- 1-acre plots, ½ corn and ½ soybean, tiles at 1.2 m depth collected the combined drainage from corn and soybean areas of each plot
- 3 treatments applied in spring only for corn
  - Inorganic N fertilizer (no P)
  - Low manure rate @ 150 lb N/acre (230 lb P_2O_5)
  - High manure rate @ 300 lb N/acre (410 lb P_2O_5)
  - Therefore, 115 or 205 lb P_2O_5/acre/CS plot/year

Management Effects on Profile Soil P



Subsurface Water Flow

TRT	1999	2000	2001	2002	2003	2004	2005	2006	Mean
	----------	----------	----------	----------	cm	----------	----------	----------	----------
PM2	15	1	4	6	5	13	7	12	8
PM1	12	1	3	5	5	11	5	10	7
No P	19	1	6	6	5	14	9	16	9
$LSD_{0.10}$	3	ns	ns	ns	ns	ns	ns	ns	1

Dissolved Reactive P Concentration

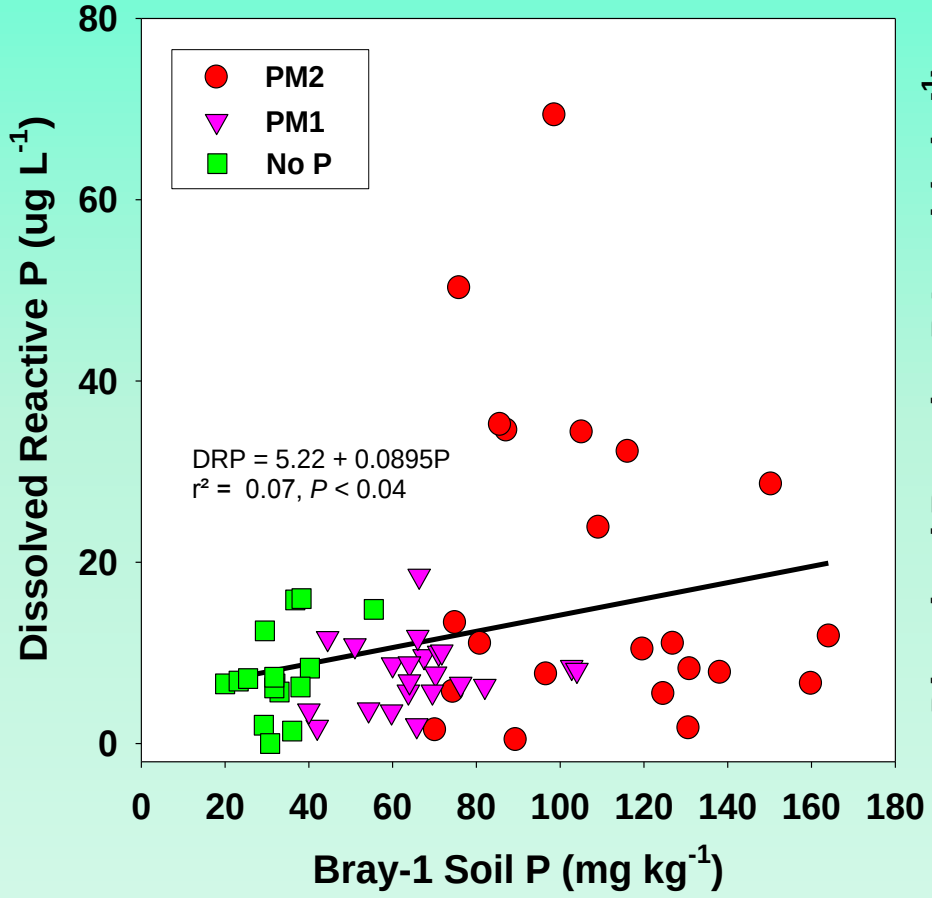
TRT	1999	2000	2001	2002	2003	2004	2005	2006	Mean
	----------	----------	----------	----------	μg P L^{-1}	----------	----------	----------	----------
PM2	27	24	17	23	28	17	8	9	19
PM1	10	10	2	10	6	10	9	7	8
No P	15	12	2	6	3	10	6	7	8
$LSD_{0.10}$	15	ns	ns	17	ns	ns	ns	ns	6

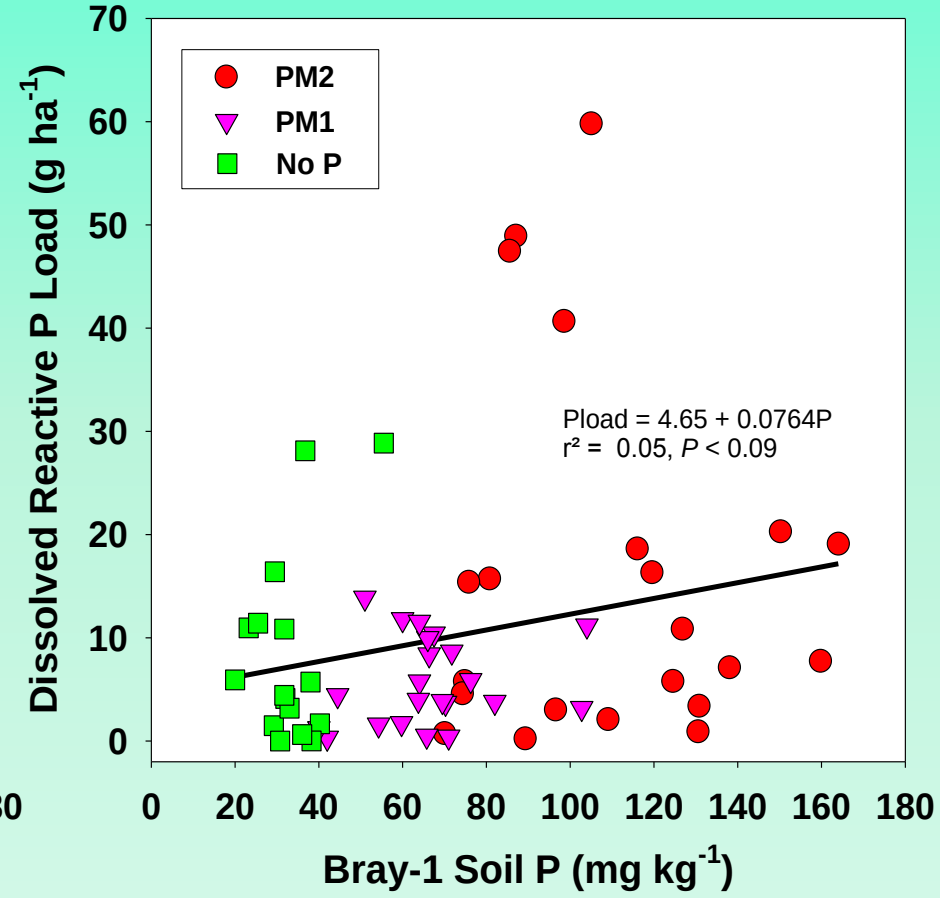
Dissolved Reactive P Loss

TRT	1999	2000	2001	2002	2003	2004	2005	2006	Mean
	---------- g P ha^{-1} ----------								
PM2	42	2	5	14	16	23	6	11	15
PM1	12	1	1	5	3	10	4	7	5
No P	28	1	1	4	2	14	6	11	8
$LSD_{0.10}$	26	ns	ns	ns	ns	ns	ns	ns	5

Correlation with Soil-Test P

Annual means or sums by treatment





Poultry Site Conclusions

- Soil-test P buildup was significant even for the N-based low manure rate, due to the usually low poultry manure N:P ratio
- Subsoil P was increased to a 30-cm depth
- Only the high manure rate increased P loss over the no-P control, and only on average across all years
  - The P loss was very small, ranged from just 2 to 42 g P/ha over time; on average15 g P/ha

Northeast Iowa Experimental Site

- 11-year study (2000- 2010)
- Site in Northeast Iowa:
  - 0.4-ha plots, 1 to 4% slope
  - Kenyon/Floyd/Readlyn (Aquic/Typic Hapludolls)
  - Loam to clay loam subsoil
  - Tiles at 1.2 m depth, 28.5 m spacing
  - Three replications
- Four nutrient/tillage management systems for continuous corn or corn-soybean rotations

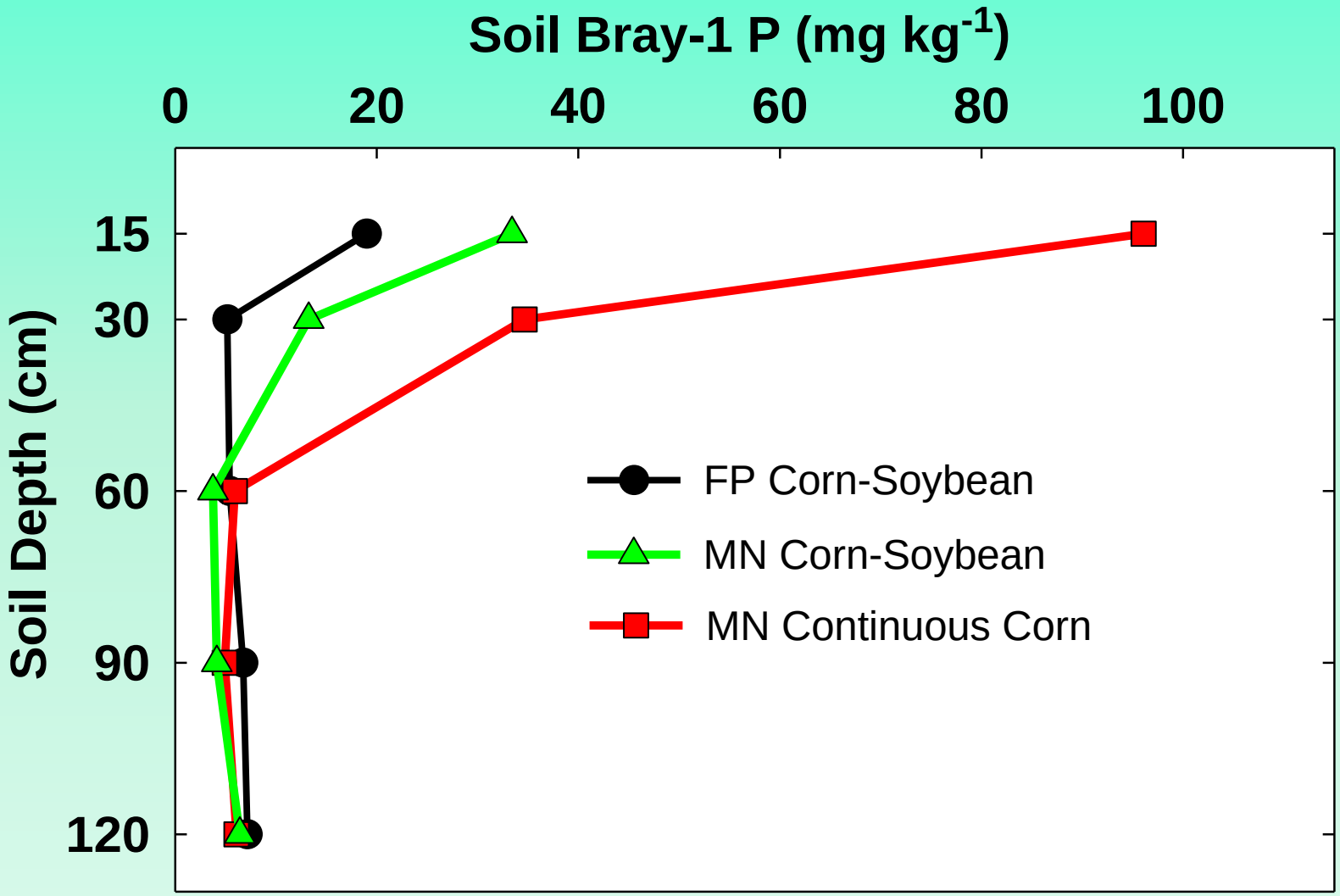
Management Systems

Code	System	Crop	Tillage	Target N Rate	Actual P Rate
				----- kg ha^{-1} -----	
FPCST	Fertilizer	Corn	Chisel/Disk	168	50
		Soybean	Disk	none	none
MNCST	Manure†	Corn	Chisel/Disk	168	45
		Soybean	Disk	none	none
MNCSNT	Manure†	Corn	No-till	168	43
		Soybean	No-till	none	none
MNCCT	Manure†	CS-CC‡	Chisel/Disk	200	73

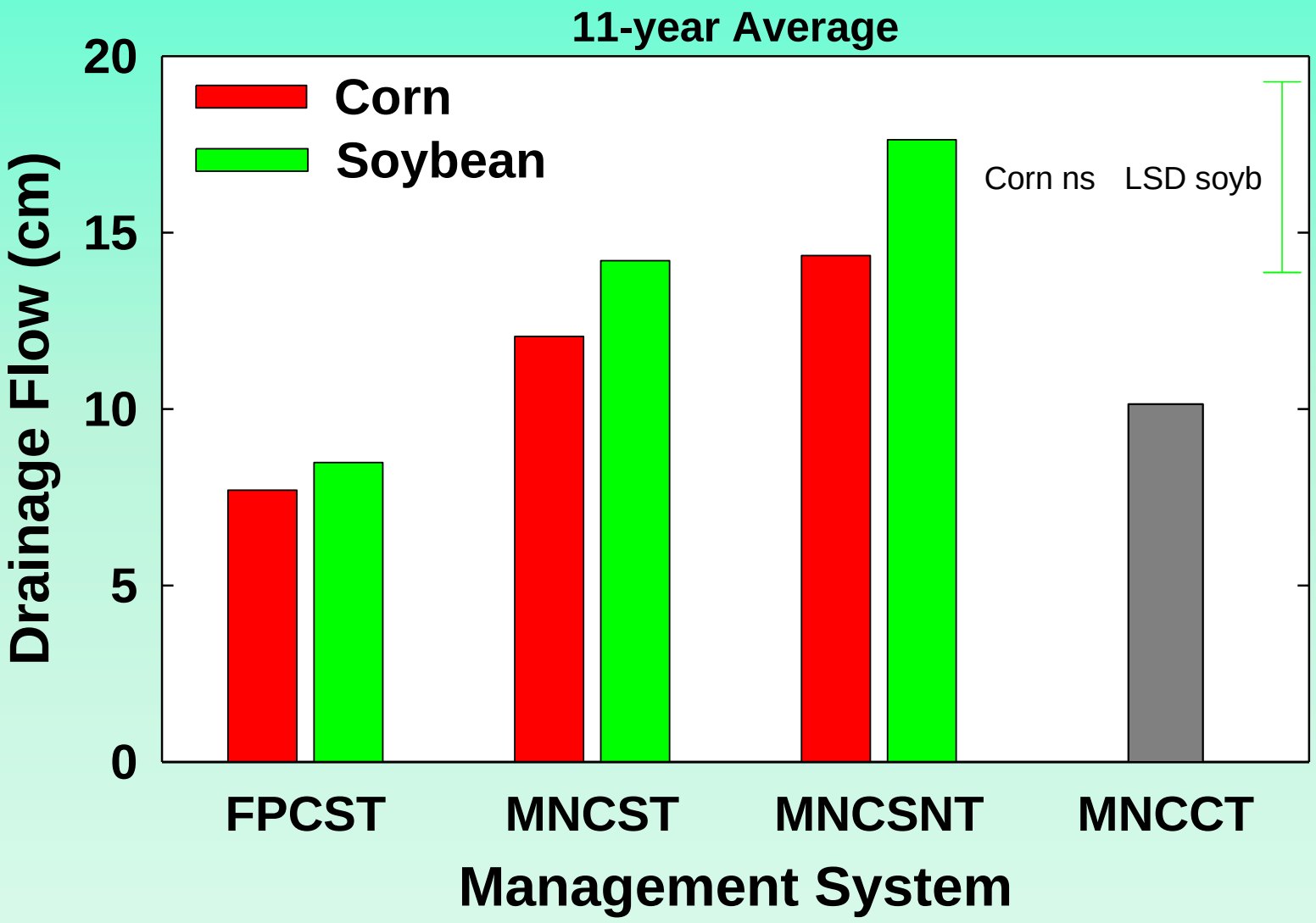
† The manure always was injected.

‡ Manure to corn and soybean until 2006, continuous corn since then.

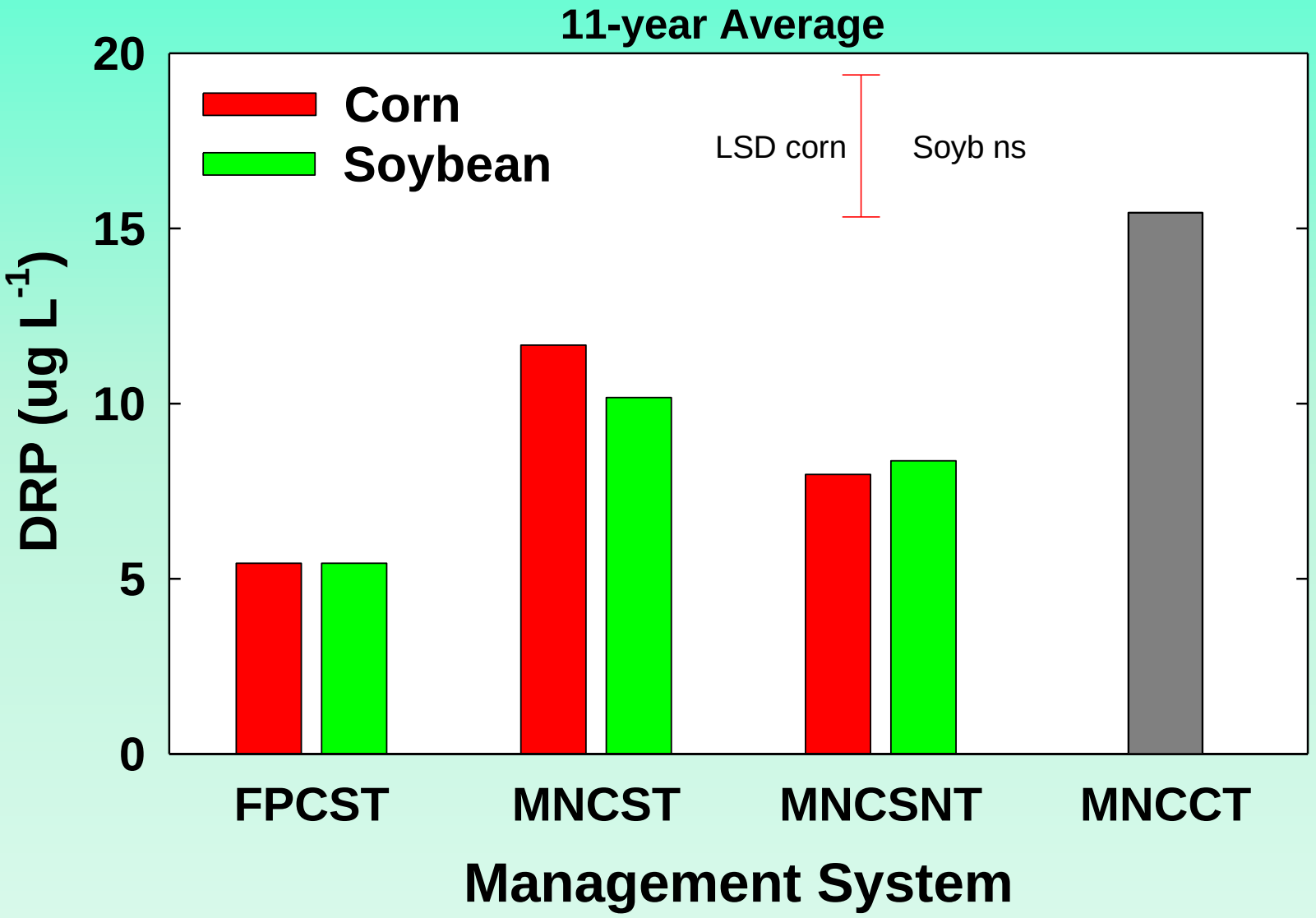
Management Effects on Profile Soil P



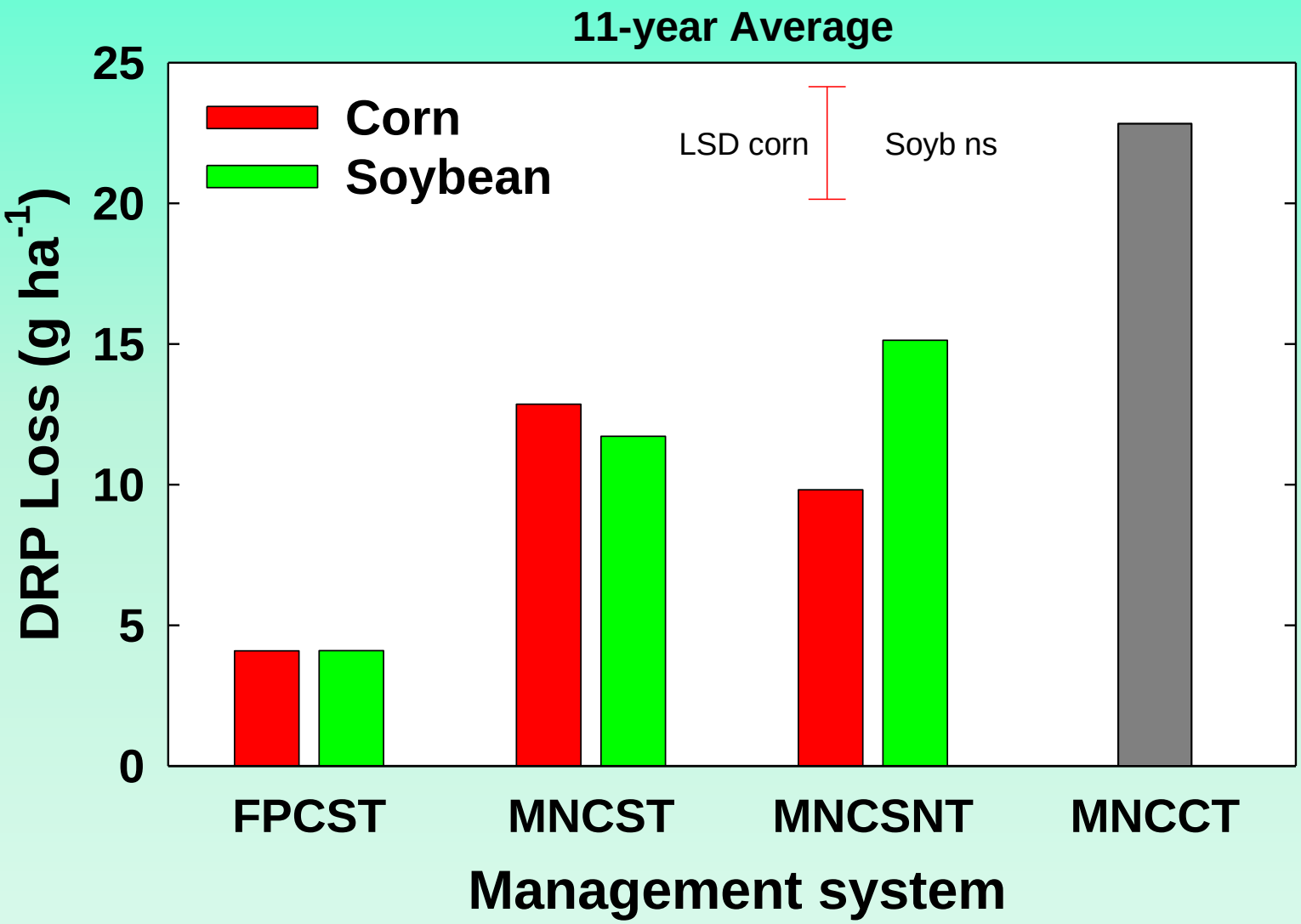
Subsurface Water Flow



Dissolved Reactive P Concentration

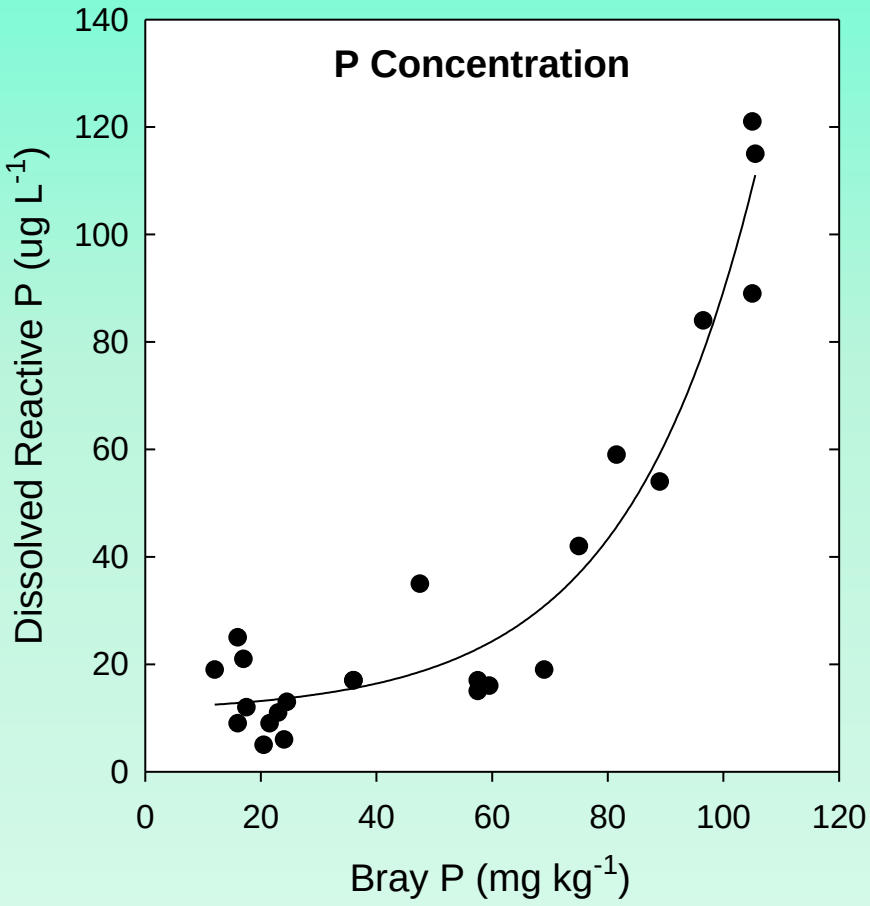


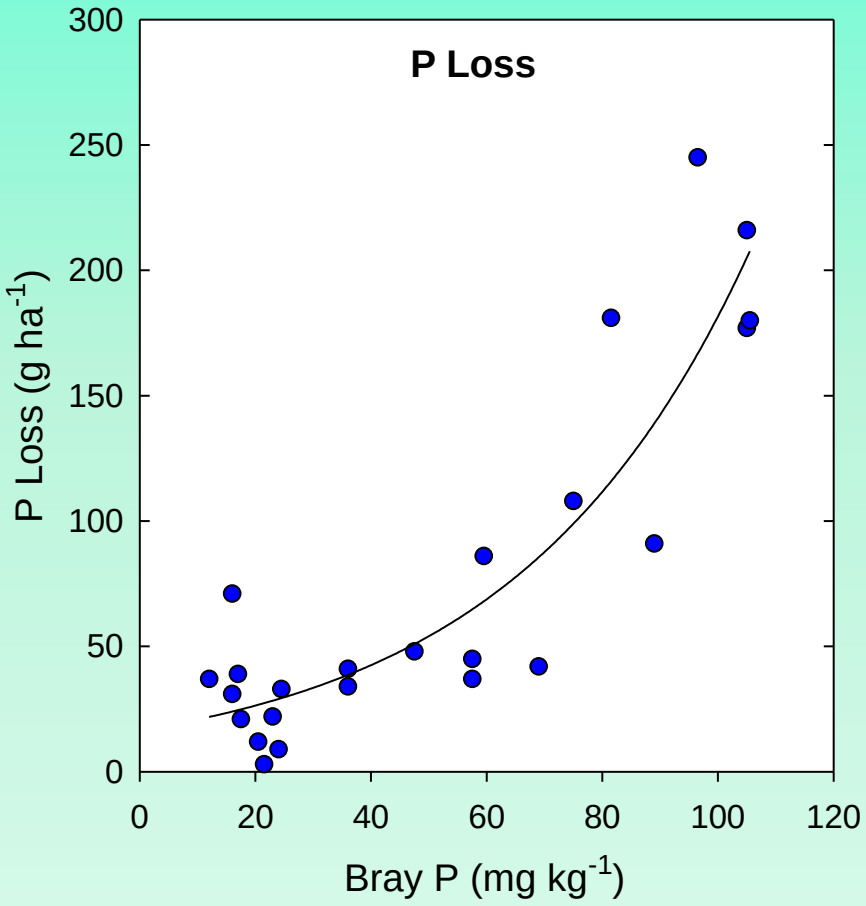
Dissolved Reactive P Loss



Correlation with Soil-Test P

Significant trend only in 2008, data by plot, a year of exceptionally high flow and P loss



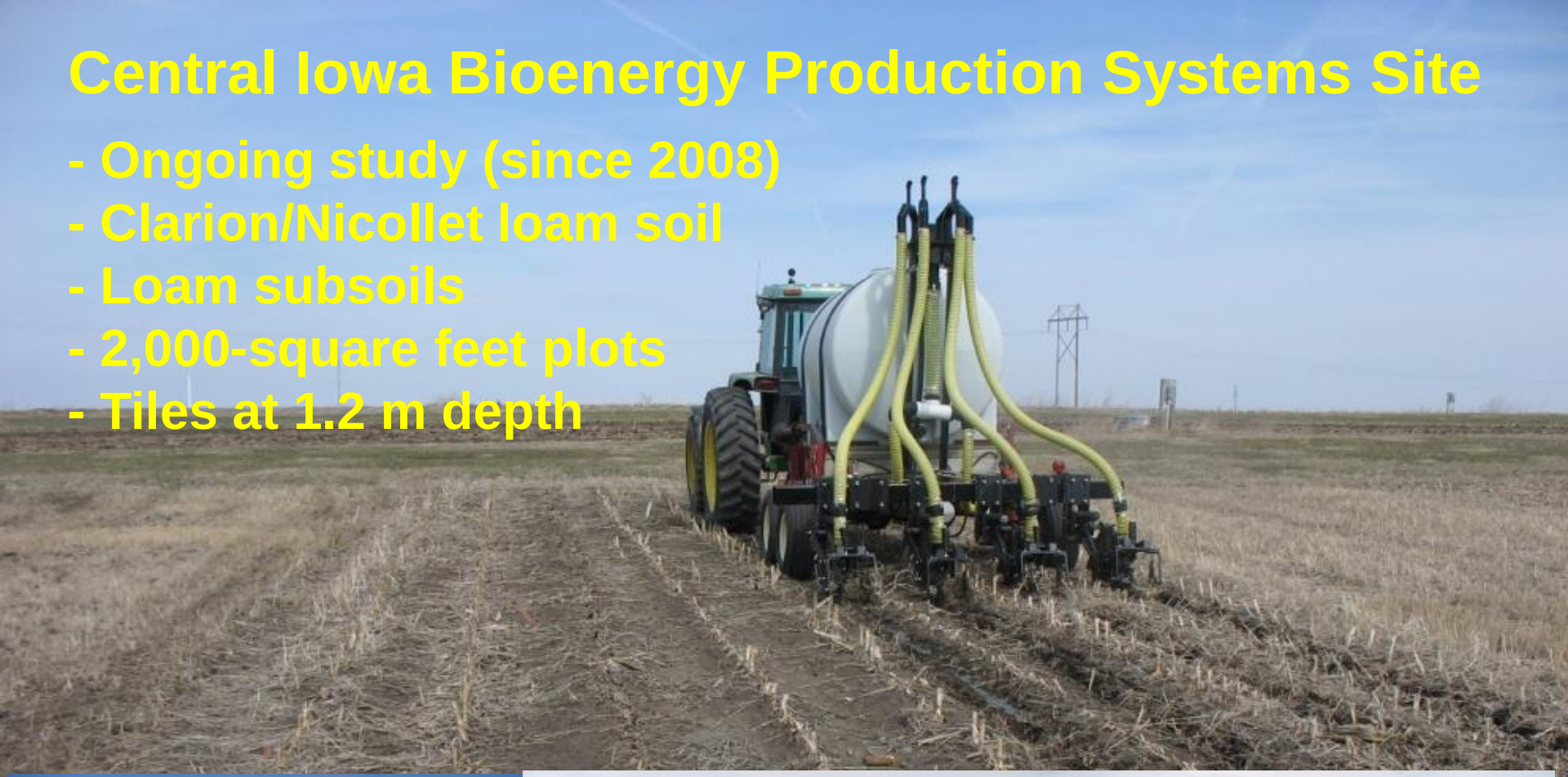


Northeast Site Conclusions

- STP buildup was large for N-based swine manure applied to continuous corn, but small for corn-soybean rotations
- Subsoil P was increased to a 30-cm depth
- P loss was highest for manure applied every year (23 g P/ha), intermediate and similar for corn-soybean rotation managed with no-till or tillage (12 g P/ha), and lowest for the fertilizer system designed to maintain an Optimum STP (4 g P/ha)

Central Iowa Bioenergy Production Systems Site

- Ongoing study (since 2008)
- Clarion/Nicollet loam soil
- Loam subsoils
- 2,000-square feet plots
- Tiles at 1.2 m depth

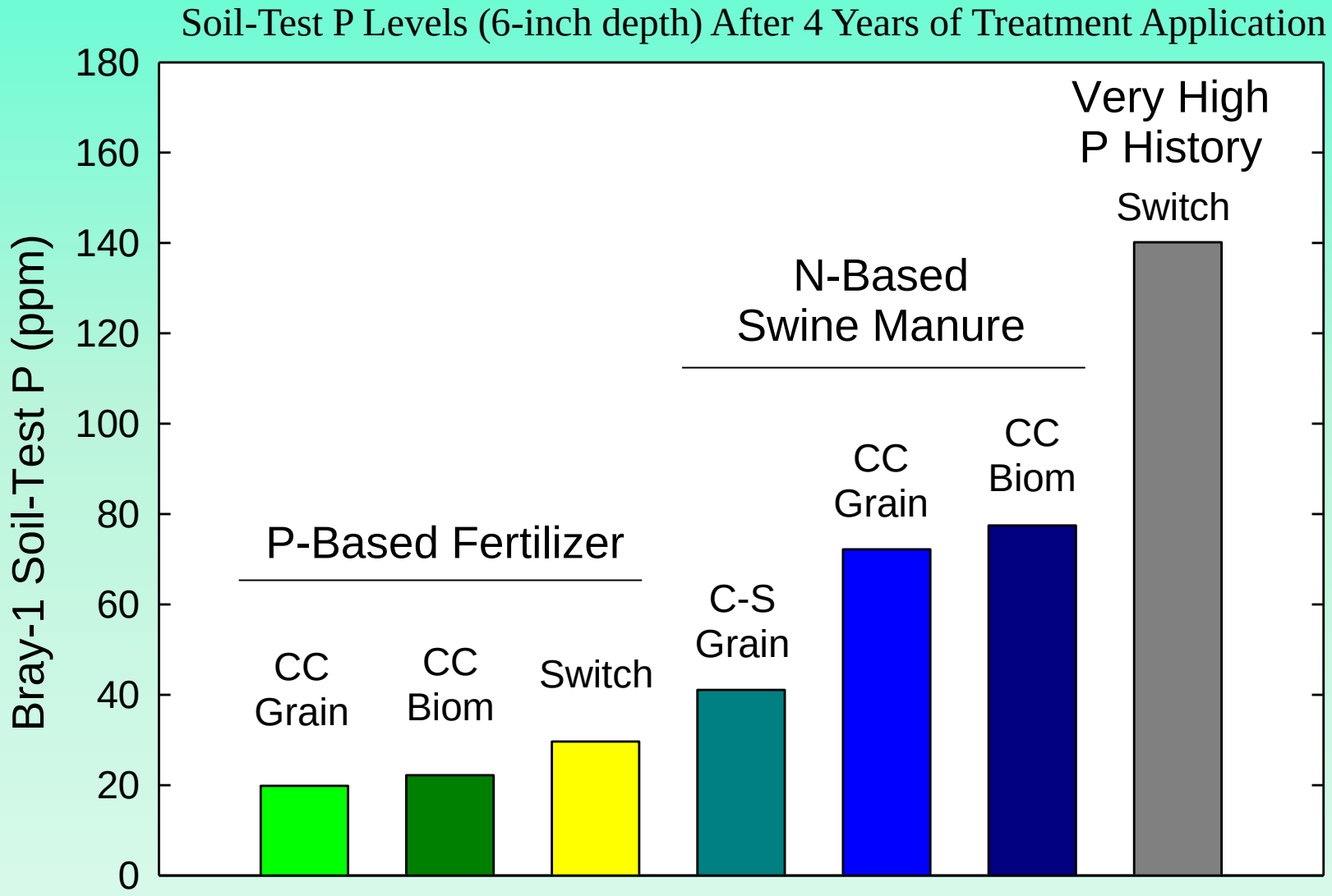


Management Systems

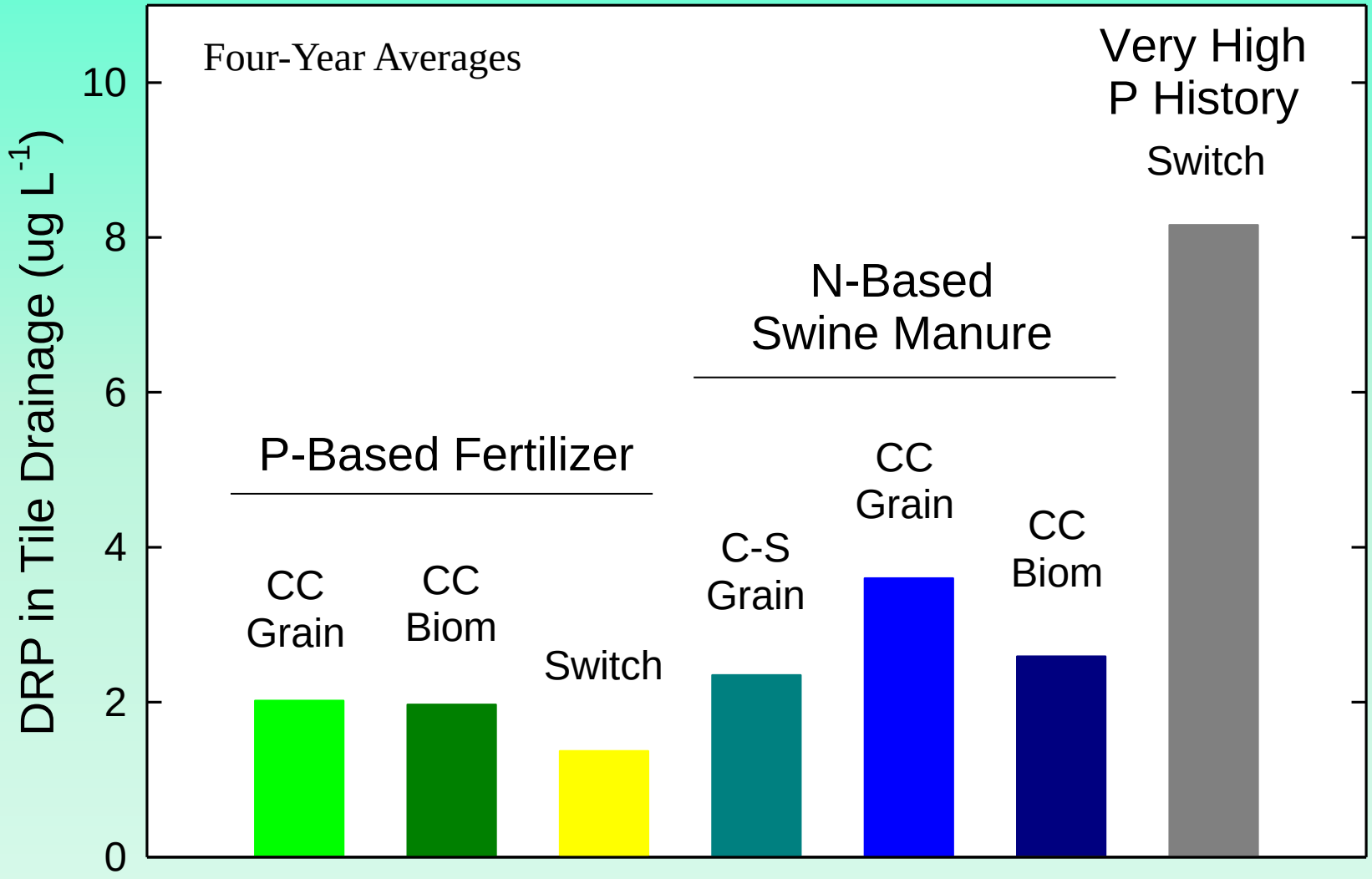
Treatment	Cropping System	Nutrient Management	Harvest Management
1	Continuous corn	Fertilizer N and P	Grain
2	Continuous corn	Fertilizer N and P	Grain + Baled Stover
3	Continuous corn	Fertilizer N and P	Total Biomass
4	Continuous corn	N-Based Swine Manure	Grain
5	Continuous corn	N-Based Swine Manure	Total Biomass
6	Corn/soybean	N-Based Swine Manure	Grain
7	Switchgrass	Fertilizer N and P	Total Biomass
8	Switchgrass	High manure history	Total Biomass

- Chisel-plow/Disk tillage for all row crops
- Fertilizer P to maintain an Optimum soil-test level
-150 lb N/acre for corn after soybean, and 200 lb N/acre for continuous corn
- Spring-applied treatments

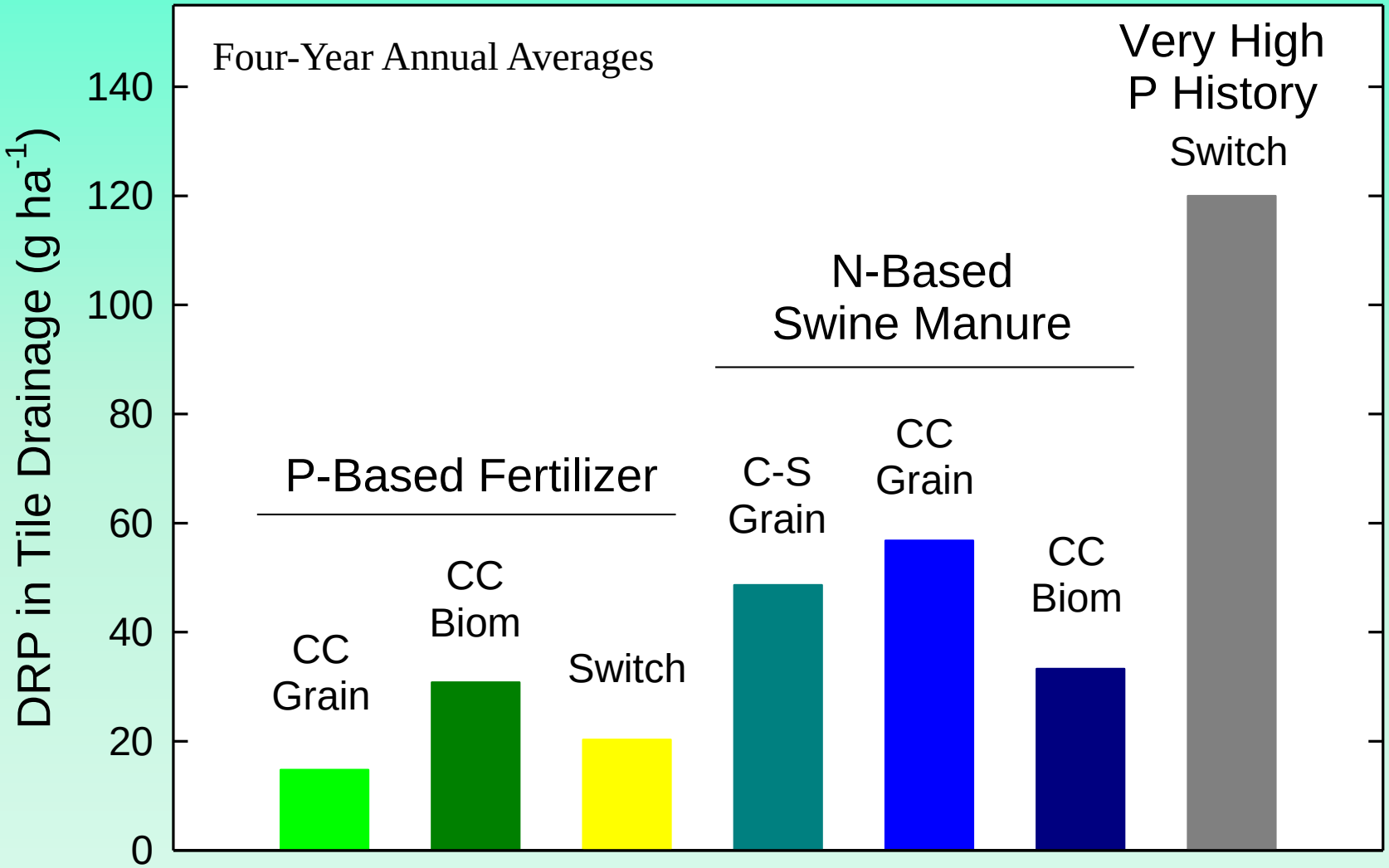
Management Effects on Soil P



Reactive P Concentration



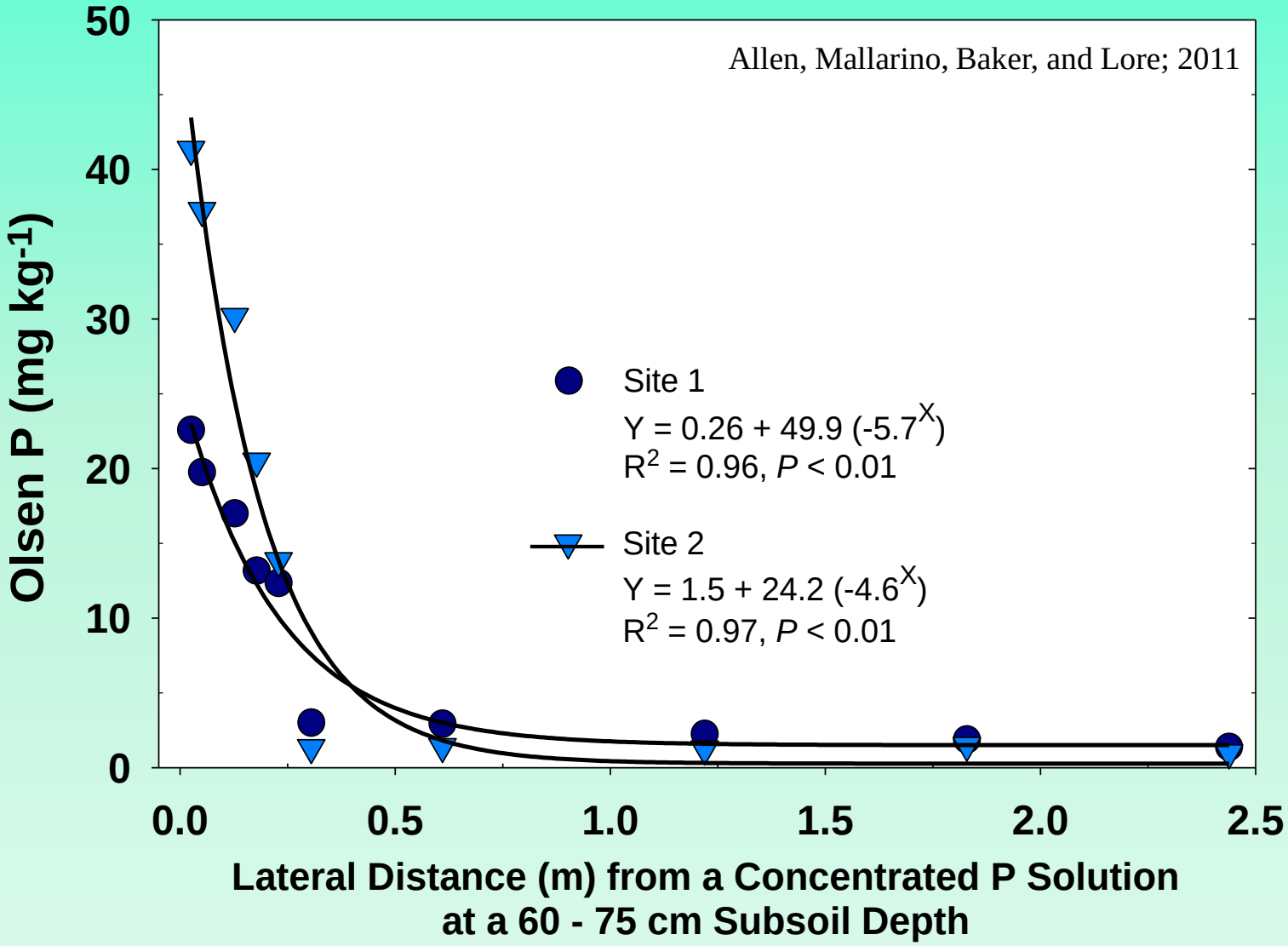
Reactive P Loss



P Loss through Tile Drainage

- P loss with tile drainage begins to increase significantly at STP levels 4-5 times higher than Optimum for crops, and much lower than loss with erosion or surface runoff
- Difficult to detect consistent management effects at lower STP levels
- Greater soil P buildup or higher rates may significantly increase P loss with drainage by preferential flow or reducing the subsoil P filtering capacity

Low P Subsoils Filter Soluble P



Index Component	Factors	Information
Gross Erosion	1	RUSLE erosion: 1 ton
Sediment Trap/SDR	0.10	DML: 1,000 feet
Buffer Factor	1	Buffer: None
Enrichment Factor	1.1	Tillage without Buffer
STP Erosion Factor	1.54	Bray 1-P: 200 ppm
Erosion	**0.17**	
Runoff Factor	0.21	RCN: 78
Precipitation Factor	7.4	Story County
STP Runoff Factor	1.05	Bray 1-P: 200 ppm
P Application Factor	0.02	100 lb P_2O_5/acre; 24 hr. incorp.
Runoff	**1.66**	
Flow Factor	0.1	Tile/Coarse Subsurface: Yes
Precipitation Factor	7.4	Story County
STP Drainage Factor	0.2	Bray 1-P: 200 ppm
Subsurface	**0.15**	
P-Index	**1.98** (borderline between Low and Medium)	

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