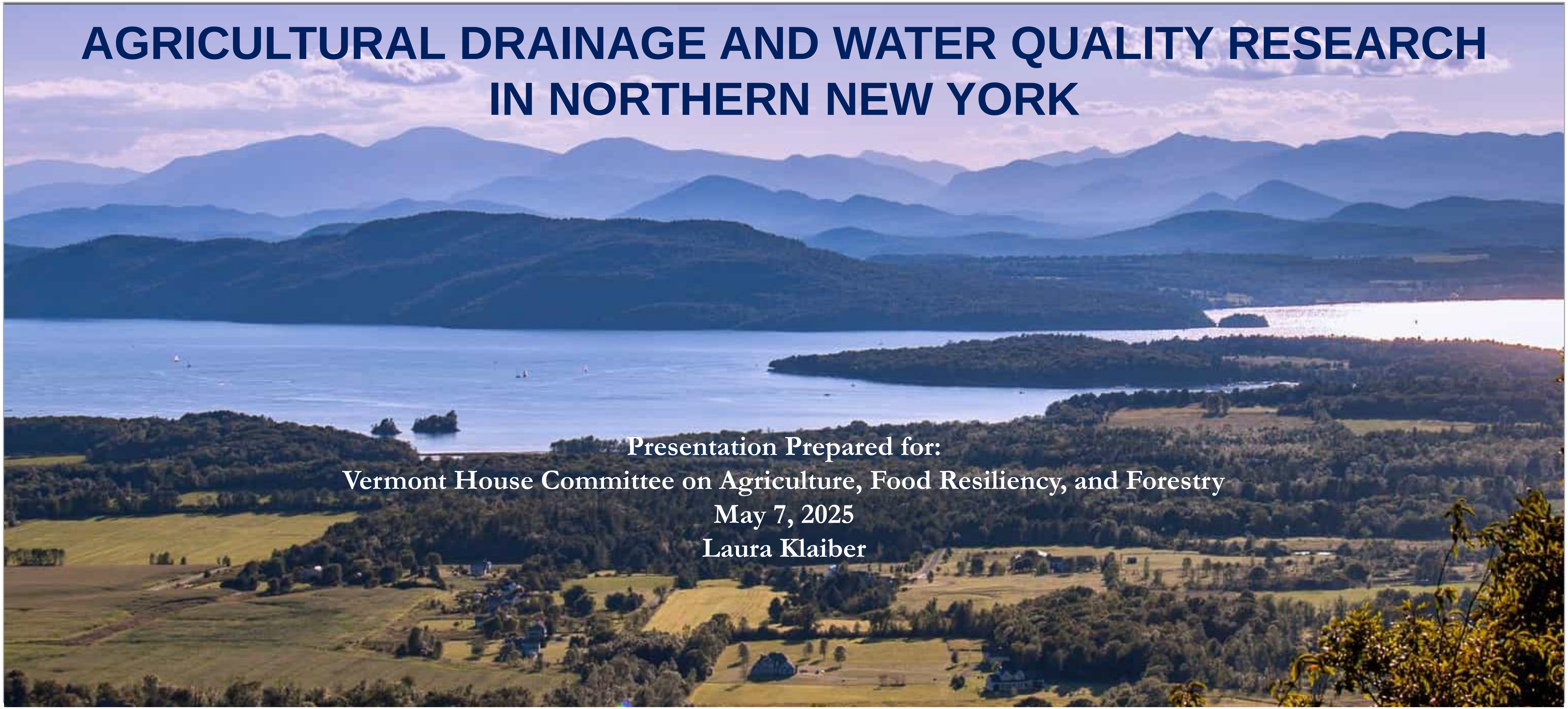


AGRICULTURAL DRAINAGE AND WATER QUALITY RESEARCH IN NORTHERN NEW YORK

Presentation Prepared for:
Vermont House Committee on Agriculture, Food Resiliency, and Forestry
May 7, 2025
Laura Klaiber

The William H. Miner Agricultural Research Institute
Chazy, NY

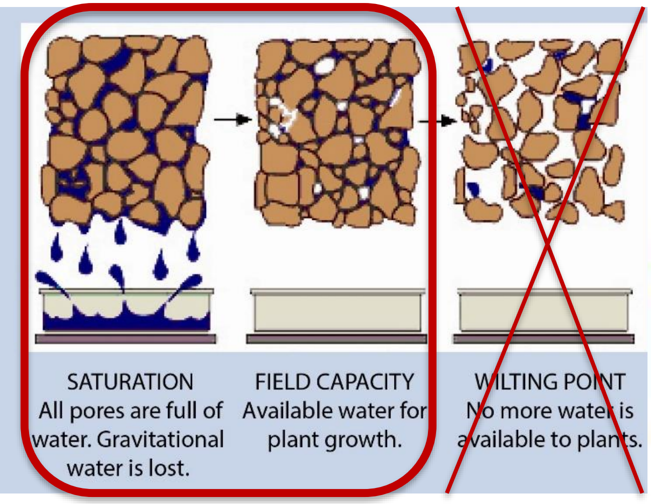
Miner Institute, Chazy, NY

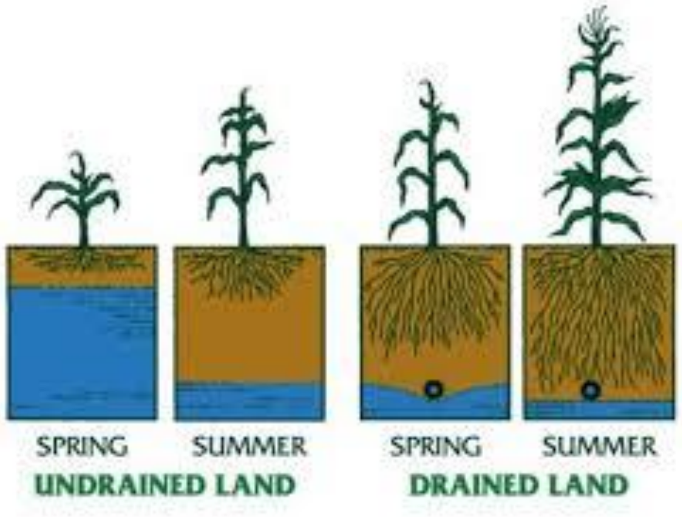
Miner Institute Dairy Farm

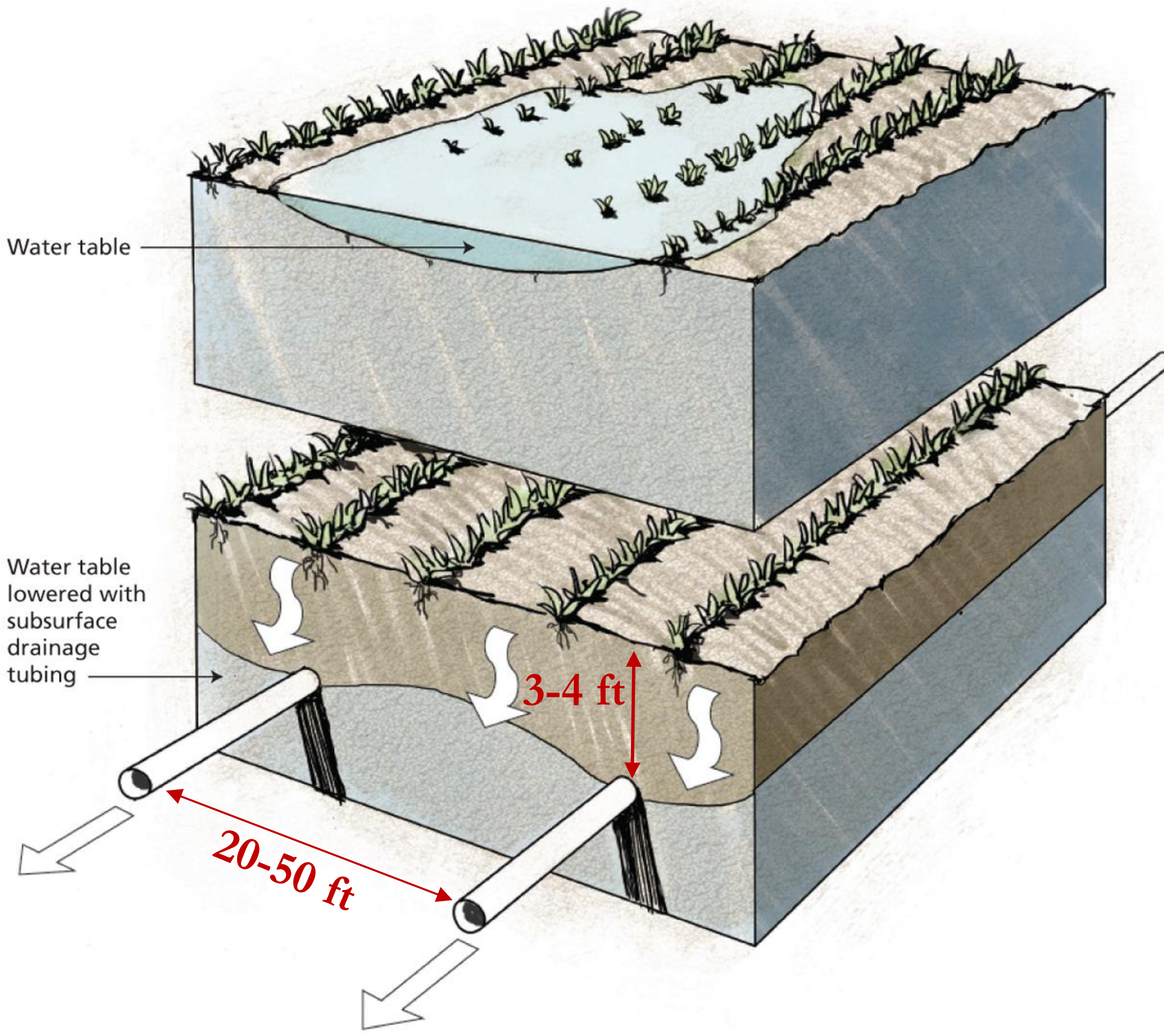
- 500 milking Holstein cows
- 1300 acres of cropland
  - alfalfa-grass/corn rotation

Why Install Tile Drainage?

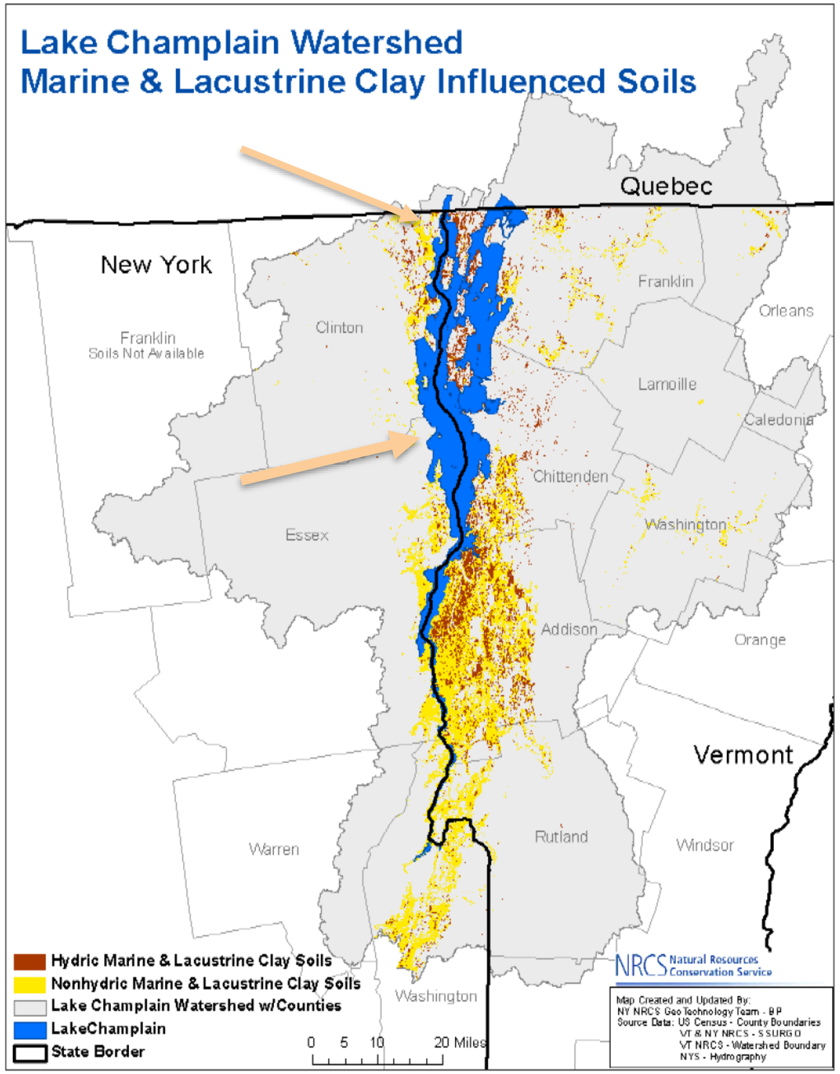
- **Drains *excess* water from poorly drained fields**
- Can improve soil health (↓compaction, ↑aeration)
- Reduces risk of surface runoff
- Lengthens growing season
  - ❖Higher crop yield *and* quality; reduces annual variation
  - ❖Reduces need for imported feeds (nutrients)
  - ❖Conservation Practices: “green manure” cover crops, double-cropping, timing of manure applications, etc.

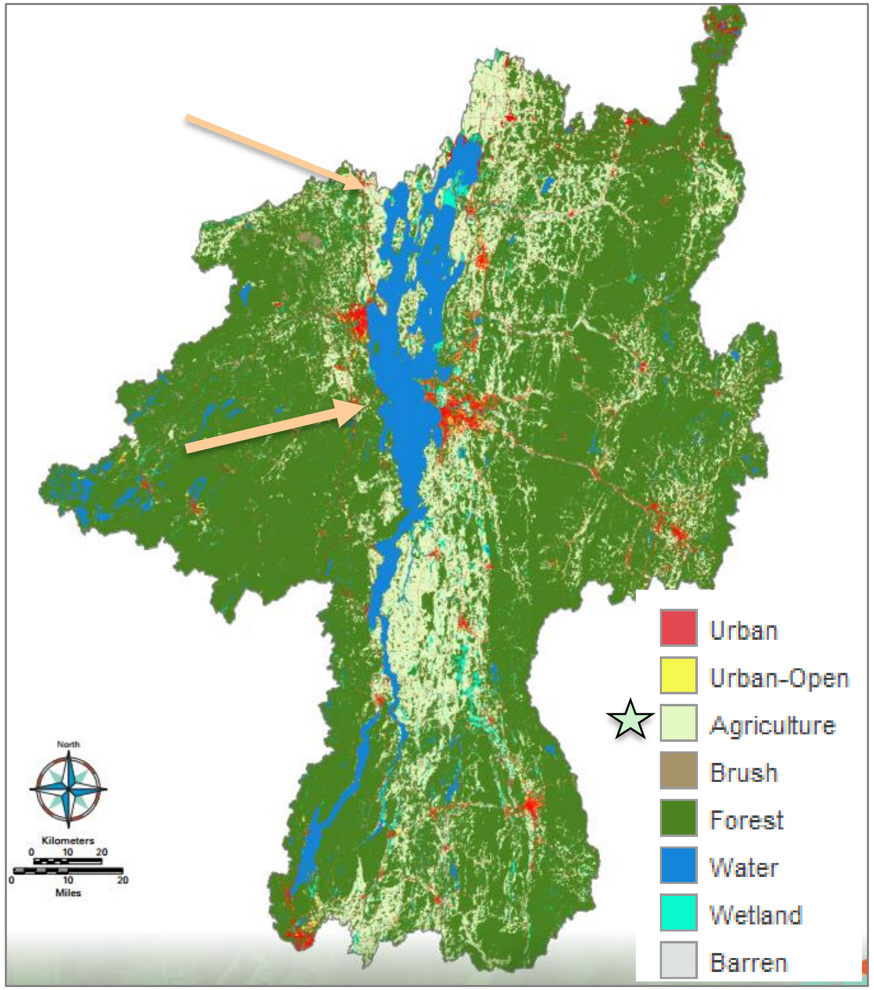






Agricultural Soils in the Lake Champlain Basin





https://atlas.lcbp.org/people-economy/land-cover/

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- Drains *excess* water from poorly drained fields
- Can improve soil health (↓compaction, ↑aeration)
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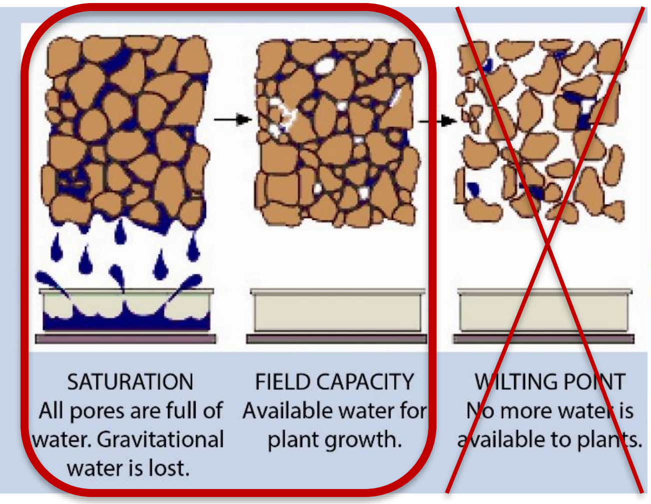
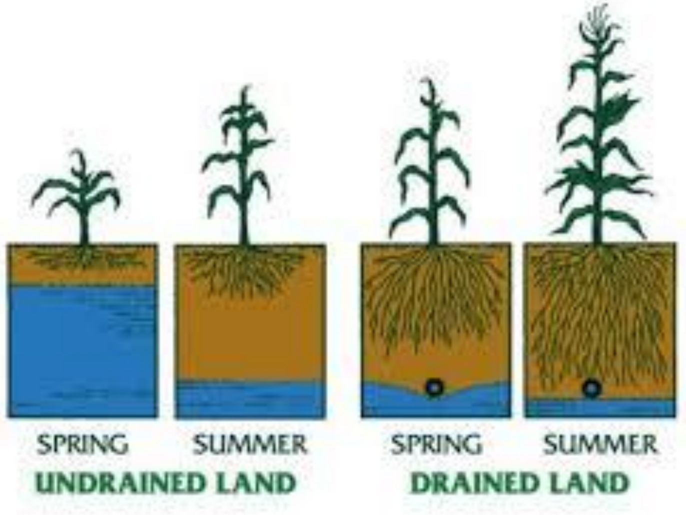
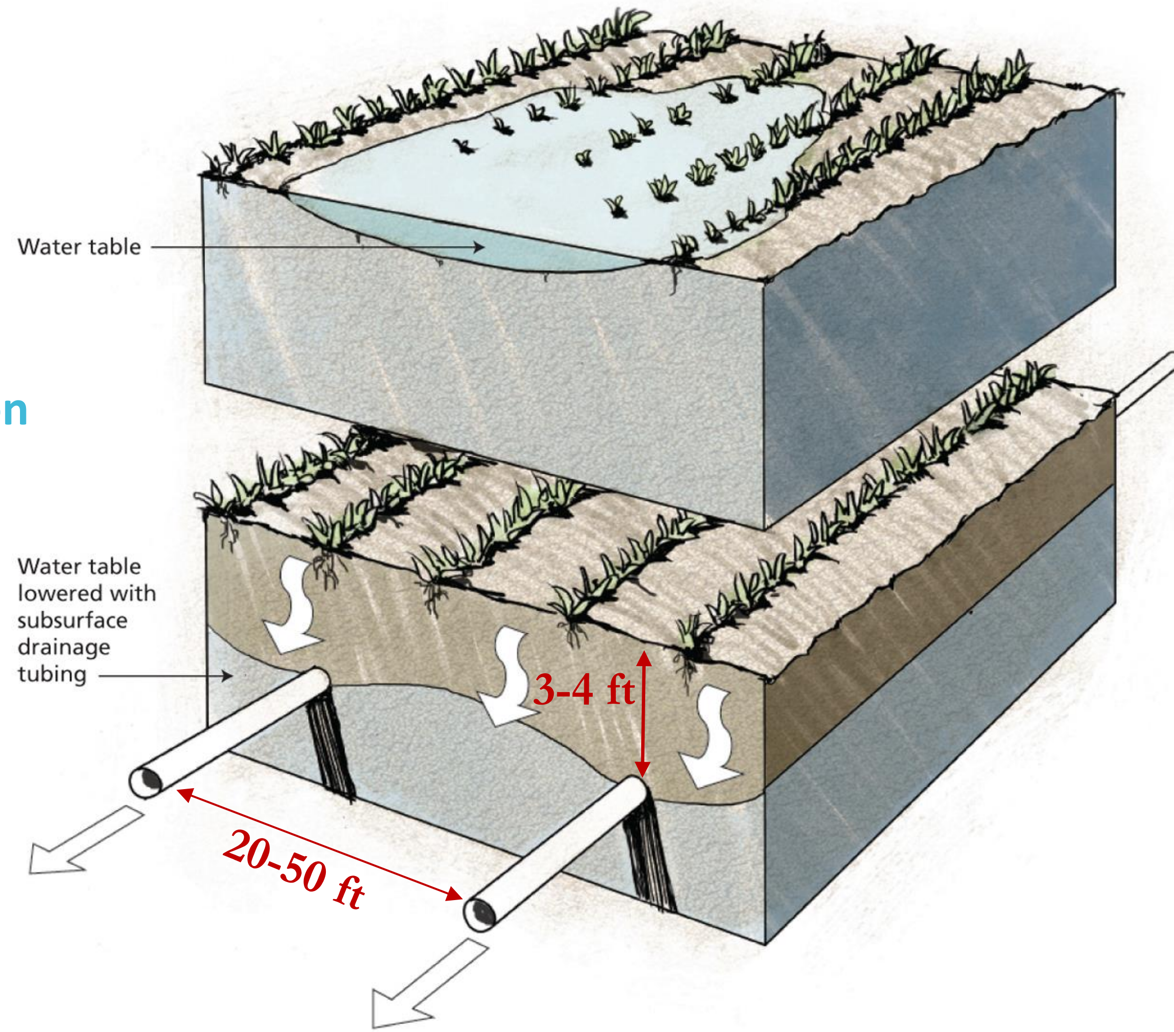
  - ❖ **Higher crop yield *and* quality; reduces annual variation**
  - ❖ Reduces need for imported feeds (nutrients)
  - ❖ Conservation Practices: "green manure" cover crops, double-cropping, timing of manure applications

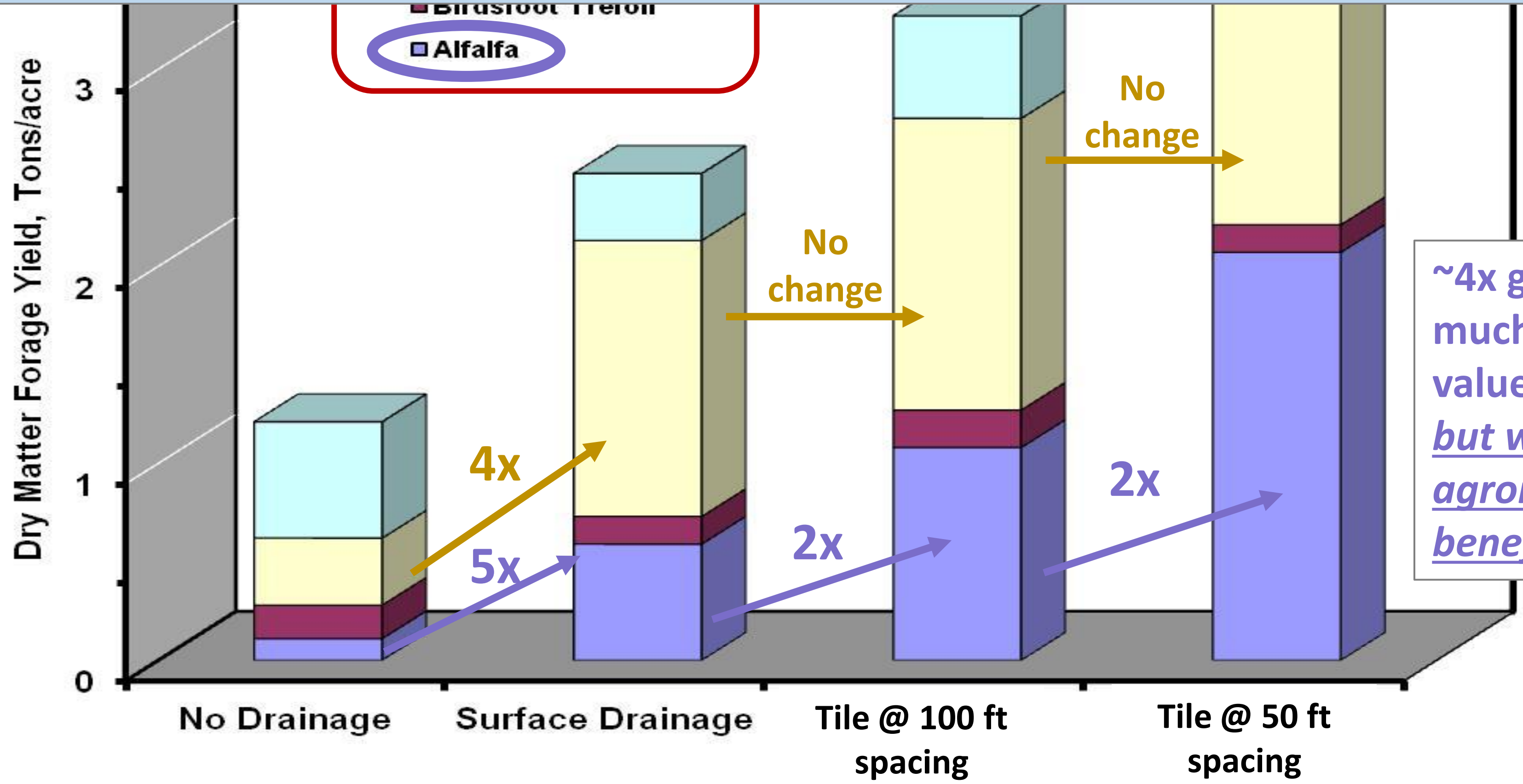






Yield benefits in NNY (4-yr average): Poorly drained silty clay soil

"These results indicate that you could feed a ration formulated using our approach that ranged between 10:90 and 90:10 alfalfa to corn silage and expect similar intake and milk production." -Grant et al., 2022

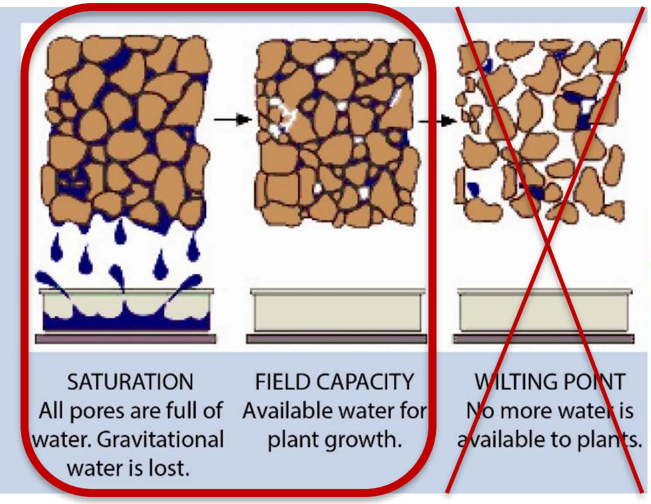


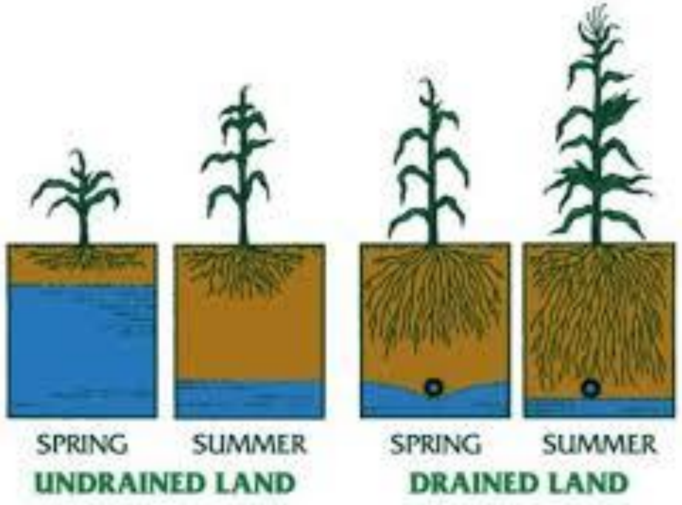
~4x greater yield overall, w/ much higher nutritional value, similar to corn silage, *__but with more agronomic/environmental benefits__*

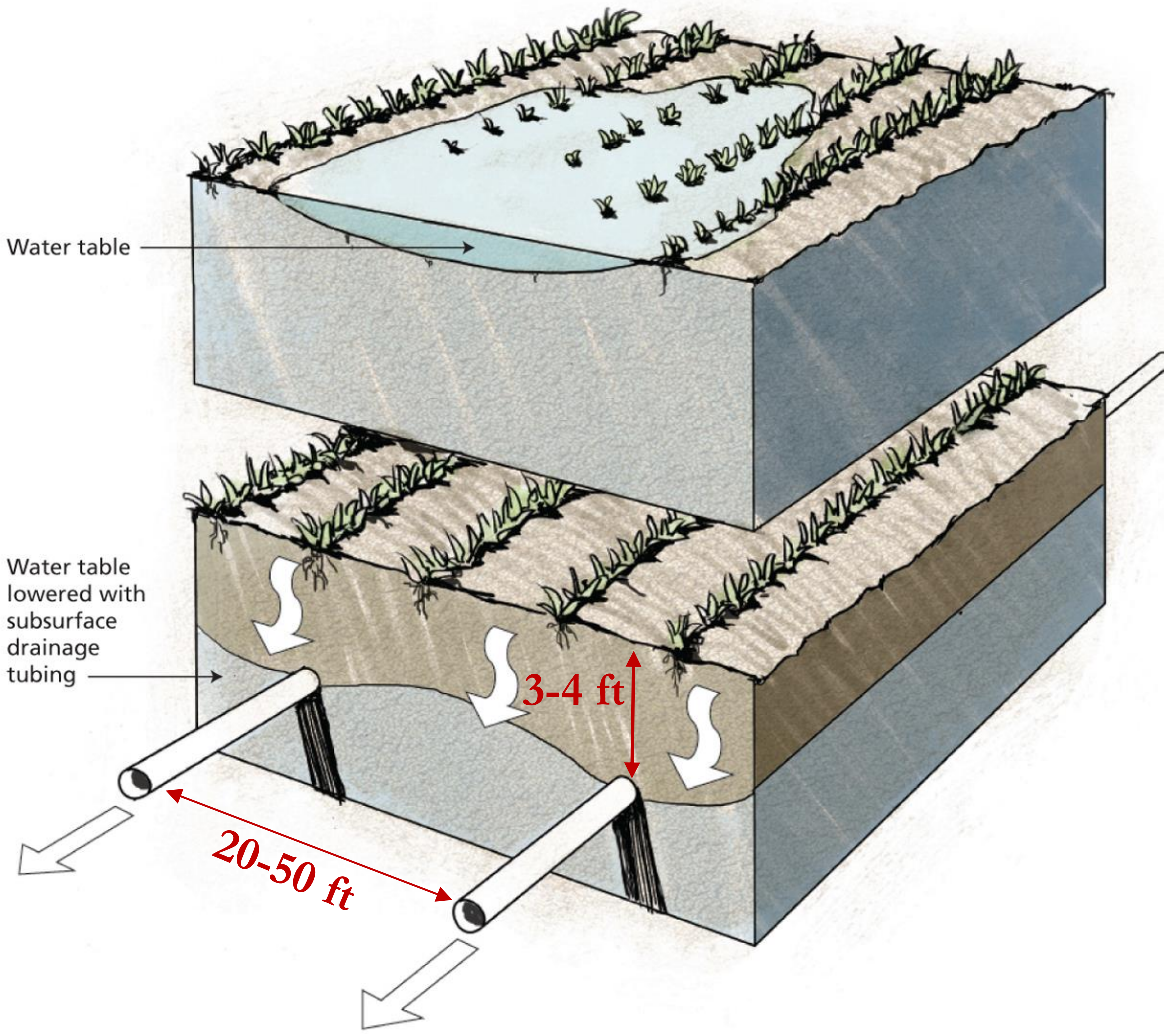
Geohring et al., 1985

Why Install Tile Drainage?

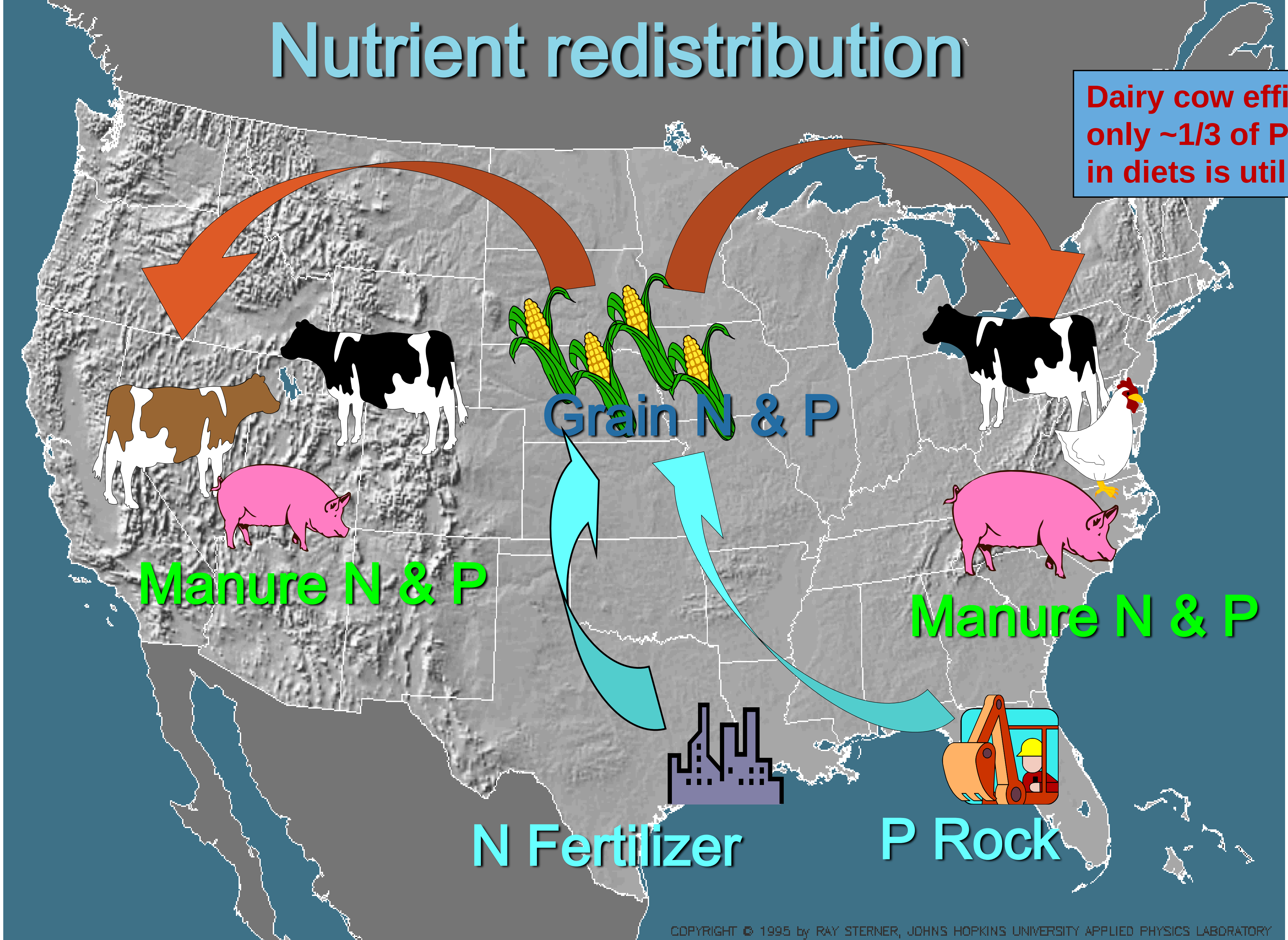
- Drains *excess* water from poorly drained fields
- Can improve soil health (↓compaction,↑aeration)
- Reduces risk of surface runoff
- Lengthens growing season
  - ❖Higher crop yield *and* quality; reduces annual variation
  - ❖**Reduces need for imported feeds (nutrients)**
  - ❖Conservation Practices: **"green manure" cover crops**, **double cropping**, timing of manure applications

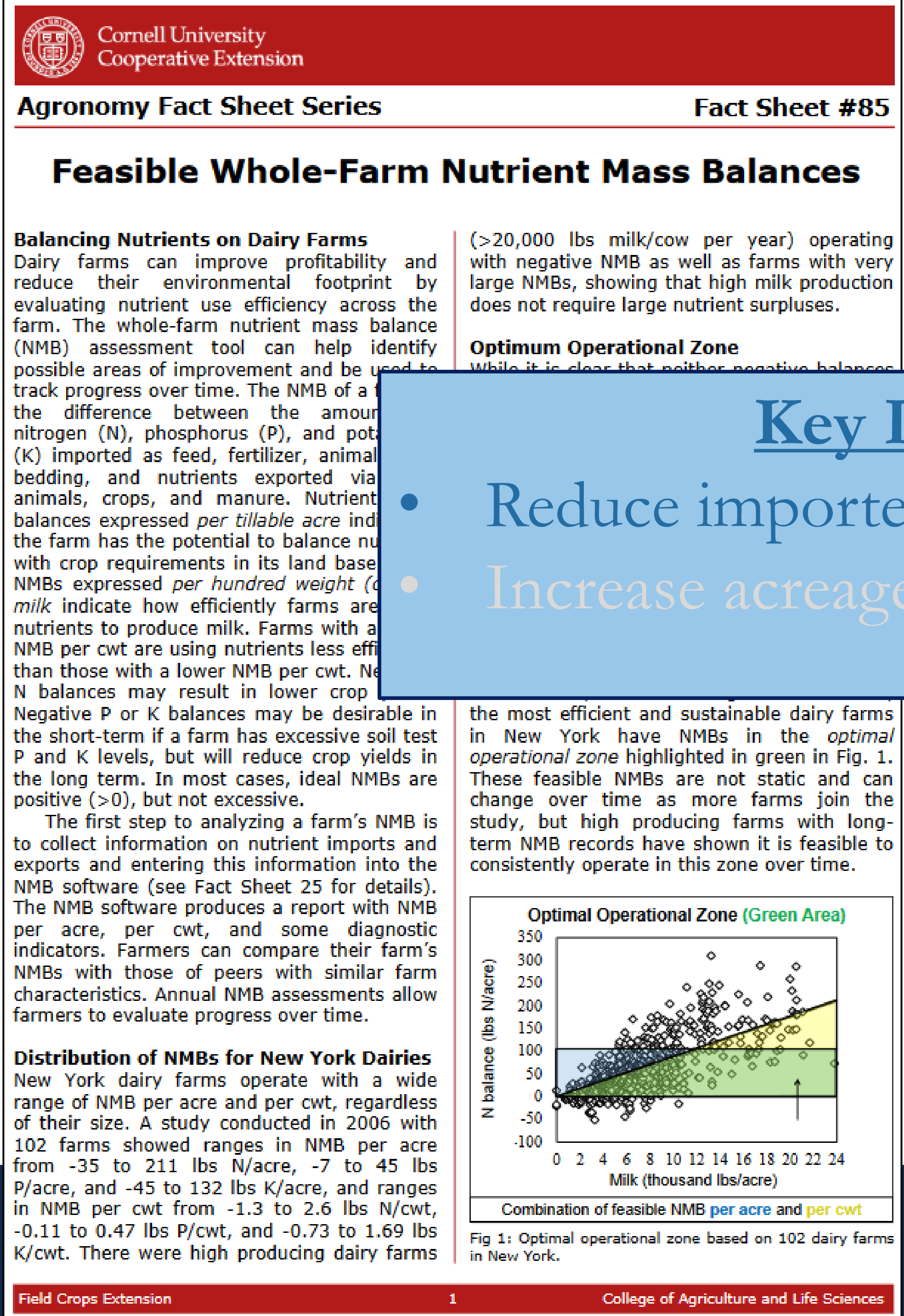






Nutrient redistribution




Cornell University
Cooperative Extension

Agronomy Fact Sheet Series — Fact Sheet #85

Feasible Whole-Farm Nutrient Mass Balances

Balancing Nutrients on Dairy Farms
Dairy farms can improve profitability and reduce their environmental footprint by evaluating nutrient use efficiency across the farm. The whole-farm nutrient mass balance (NMB) assessment tool can help identify possible areas of improvement and be used to track progress over time. The NMB of a f
the difference between the amour
nitrogen (N), phosphorus (P), and pot
(K) imported as feed, fertilizer, animal
bedding, and nutrients exported via
animals, crops, and manure. Nutrient
balances expressed *per tillable acre* indi
the farm has the potential to balance nu
with crop requirements in its land base
NMBs expressed *per hundred weight (c*
milk indicate how efficiently farms are
nutrients to produce milk. Farms with a
NMB per cwt are using nutrients less effi
than those with a lower NMB per cwt. Ne
N balances may result in lower crop
Negative P or K balances may be desirable in the short-term if a farm has excessive soil test P and K levels, but will reduce crop yields in the long term. In most cases, ideal NMBs are positive (>0), but not excessive.

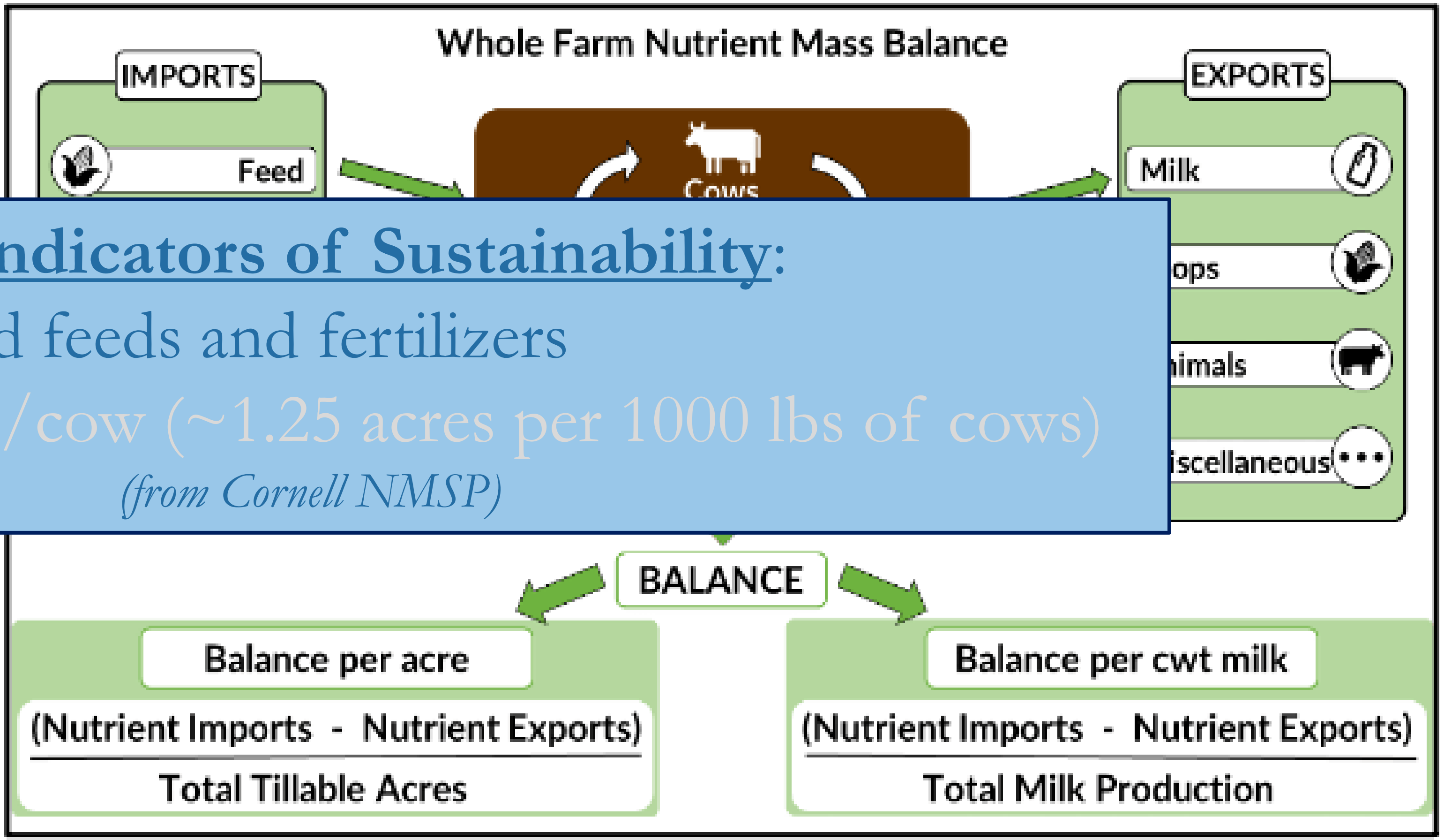
The first step to analyzing a farm's NMB is to collect information on nutrient imports and exports and entering this information into the NMB software (see Fact Sheet 25 for details). The NMB software produces a report with NMB per acre, per cwt, and some diagnostic indicators. Farmers can compare their farm's NMBs with those of peers with similar farm characteristics. Annual NMB assessments allow farmers to evaluate progress over time.

Distribution of NMBs for New York Dairies
New York dairy farms operate with a wide range of NMB per acre and per cwt, regardless of their size. A study conducted in 2006 with 102 farms showed ranges in NMB per acre from -35 to 211 lbs N/acre, -7 to 45 lbs P/acre, and -45 to 132 lbs K/acre, and ranges in NMB per cwt from -1.3 to 2.6 lbs N/cwt, -0.11 to 0.47 lbs P/cwt, and -0.73 to 1.69 lbs K/cwt. There were high producing dairy farms (>20,000 lbs milk/cow per year) operating with negative NMB as well as farms with very large NMBs, showing that high milk production does not require large nutrient surpluses.

Optimum Operational Zone
While it is clear that neither negative balances

the most efficient and sustainable dairy farms in New York have NMBs in the *optimal operational zone* highlighted in green in Fig. 1. These feasible NMBs are not static and can change over time as more farms join the study, but high producing farms with long-term NMB records have shown it is feasible to consistently operate in this zone over time.

Fig 1: Optimal operational zone based on 102 dairy farms in New York.



Key Indicators of Sustainability:

- Reduce imported feeds and fertilizers
- Increase acreage/cow (~1.25 acres per 1000 lbs of cows)

(from Cornell NMSP)

http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html

Key Agricultural Nutrients

- Phosphorus (P) is limiting nutrient in freshwater systems
  - ❖ Soil solution P necessary for plant growth is 0.2 - 0.3 mg/L
  - ❖ P levels **very low** in lakes: **> 0.02 mg/L** – accelerated eutrophication, harmful algal blooms
  - ❖ P is relatively immobile (low solubility, binds to soil, no gaseous phase)
  - ❖ Losses from: soil erosion, insufficient nutrient management strategies
  - ❖ *Legacy P*: Build-up of P over years/decades; field soils & lake sediments
- Nitrogen (N) is limiting nutrient in saltwater systems
  - ❖ Very mobile; leaching and atmospheric losses
  - ❖ Inorganic N is soluble, highly mobile (NO_3 leaching)
  - ❖ *Saturated soils -> denitrification, GHG emissions (N_2O)*
  - ❖ Losses from: interaction of weather and soils; amount, method, & timing of manure/fertilizer applications. Does not readily accumulate as P does.

Challenge: Identify complementary practices to maximize retention of P and N in order to maximize efficiency of farm manure nutrients (and other beneficial properties)

Nutrient Management

Dairy farms – constant need to manage nutrients from manure

Excellent source of nutrients and other benefits for plant growth

Nutrient management is a system that optimizes the use of these nutrients for crop growth and minimizes losses to the surrounding environment

- ❖ <u>"4 R's": Right amount, right form, right place, right time</u>

Value of Manure – Not just N-P-K

Northern New York Agricultural Development Program
2022 Project Report

On-Farm Evaluation of the Value of Manure as a Nutrient Resource

Project Leader
- Quirine M. Ketterings, Ph.D., Cornell Nutrient Management Spear Program (NMSP), 323 Morrison Hall, Department of Animal Science, Cornell University

Collaborators
- Crop Consultants and Nutrient Management Planners: Mike Contessa and Eric Beaver, Champlain Valley Agronomics, Peru, NY
- Cornell Cooperative Extension Field Crops and Soils Specialists: Kitty O'Neil, Mike Hunter
- Miner Institute: Forage Agronomist Allen Wilder, Nutrient Management Researcher Laura Klaiber
- Cornell University: Juan Carlos Ramos, Kirsten Workman (PRO-DAIRY), Olivia Godber, Manuel Marcaida

Cooperating Producer
- Northern New York dairy farm

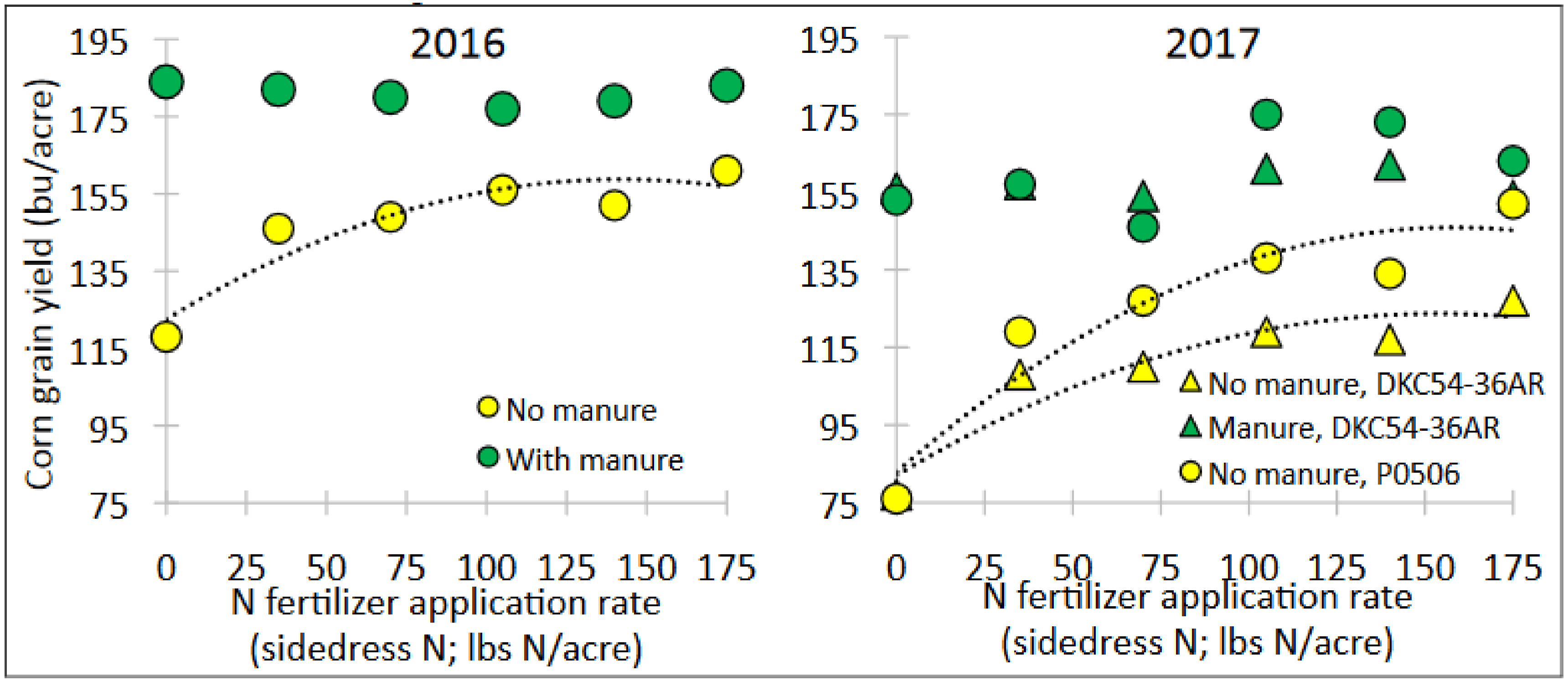


Figure 1. Corn grain yields as impacted by mid-season manure application, fertilizer sidedress N rate and variety. Yield data obtained with a yield monitor. Conditions were extremely dry in 2016 and wet in 2017.

https://nnyagdev.org/wp-content/uploads/2023/03/NNYADP2022ManureReportFINAL.pdf

Quantifying Water Quality: "Concentration" vs. "Load"

Concentration (ex. mg P/L) = mass in a standard volume (1 L)

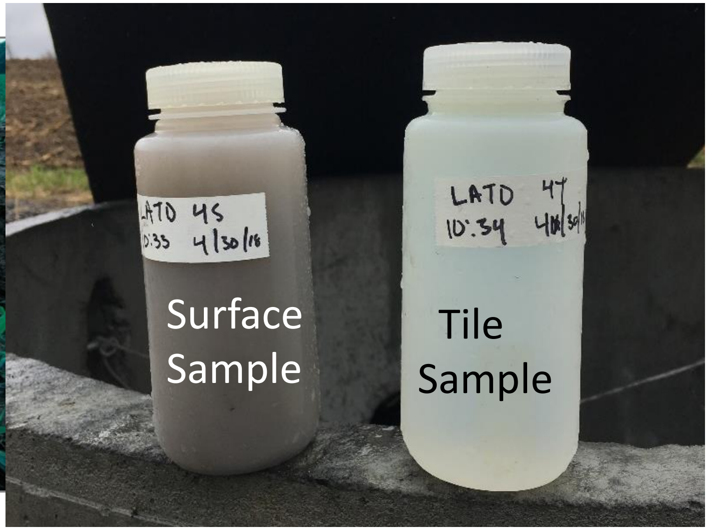
Load (aka Mass, lb) = Concentration x Actual Volume

$$2\,\frac{\text{mg P}}{\text{L}} \times 500{,}000\text{ L} = 1{,}000{,}000\text{ mg P} \times \frac{1\text{ lb}}{453{,}592\text{ mg}} = 2.18\text{ lb P}$$

Then divide load by the number of acres to standardize = lb/acre

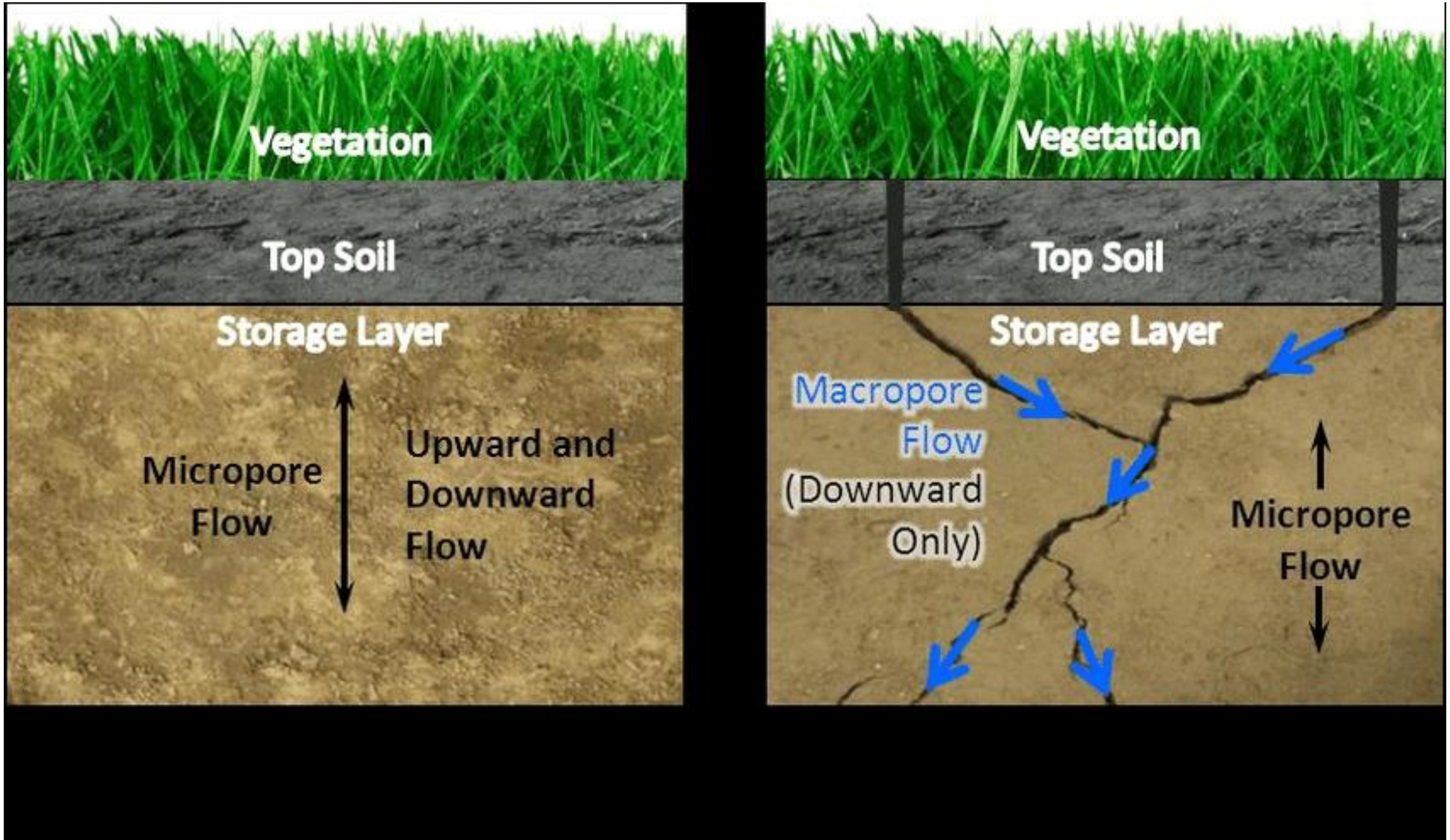
Field Drainage and Water Quality

- Results mixed – site (soil type, slope, fertility), climate, and management dependent
  - High organic matter = good soil quality/soil structure = erosion resistance
  - Residue/crop cover on soil surface = raindrop interception = no surface crusting = erosion resistance
  - Good soil structure = maximize runoff infiltration into soil = less surface runoff = less erosion
  - No-till: Better soil structure = resistance to erosion and higher infiltration rate, more macropores
- Tile drainage water – lower concentrations of P and sediment than surface runoff; but higher flow volumes (Gilliam et al., 1999)
- Total P export from tiles (mineral soils) – 0.35 lbs/acre to 1.4 lbs/acre (King et al., 2015)
- Nitrogen export (leaching) increased from tiled fields (more mineralization & transport)
- Denitrification rates decrease (plant available N → gaseous N forms, often GHG)



Risk Assessment and Management: Preferential Flow Pathways & Contact Time

Tradeoffs between enhancing drainage rates and soil contact time



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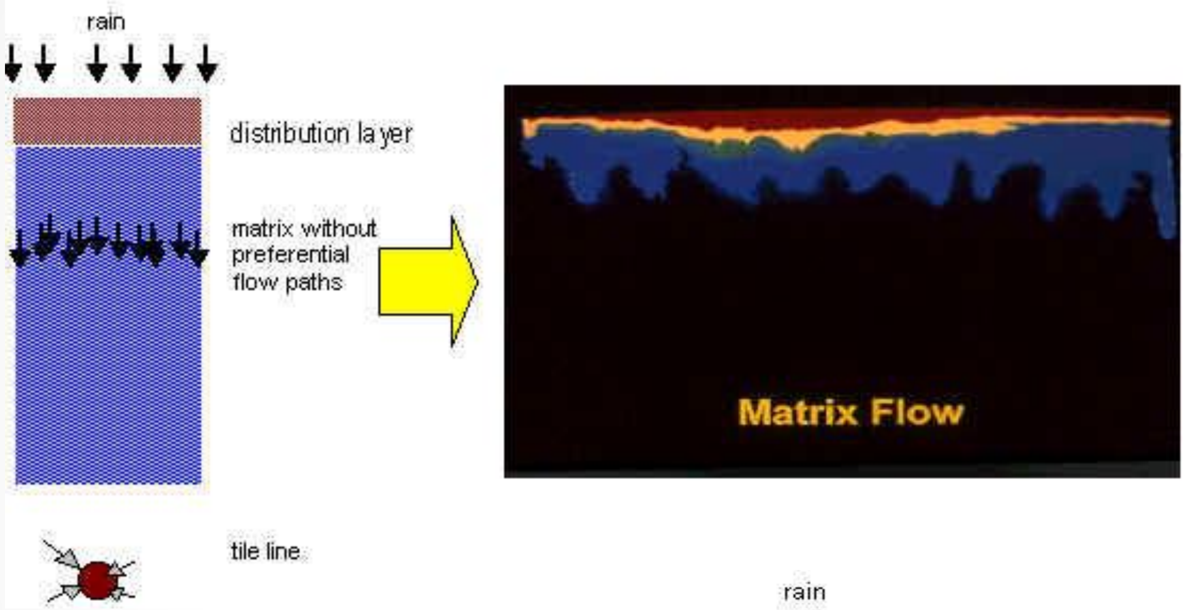
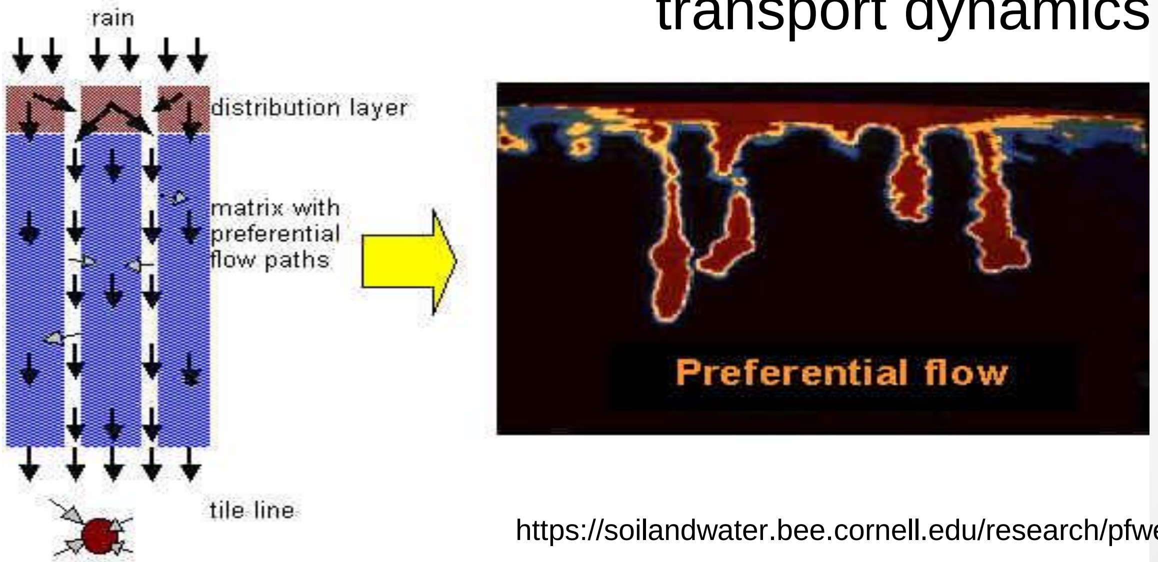


Macropores

- Earthworm burrows
- Root channels
- Shrink/swell (dry/wet) soils (type and amount of ***clay***)
- Disrupted by tillage
- Tradeoffs between drainage efficiency and nutrient transport dynamics



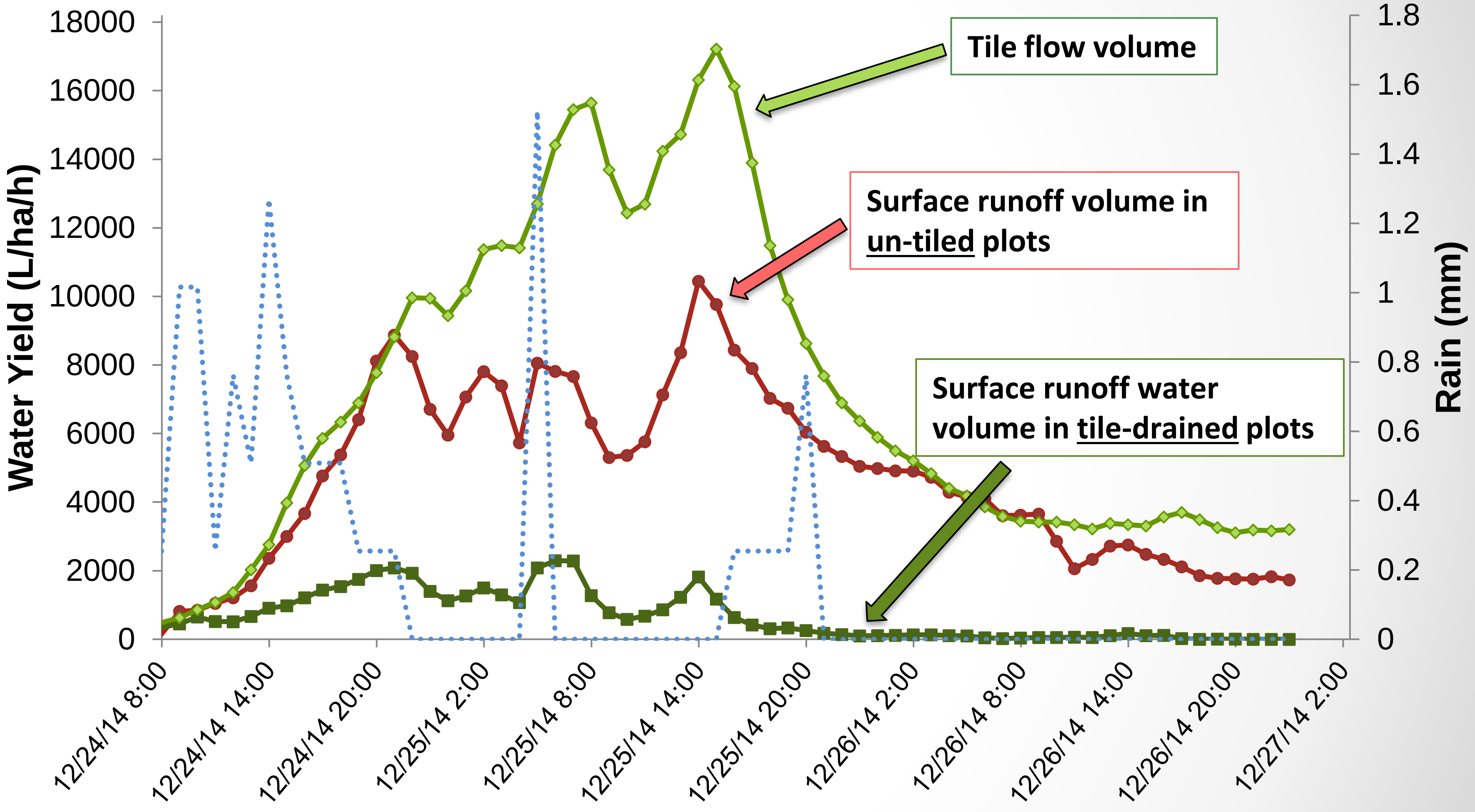
https://soilandwater.bee.cornell.edu/research/pfweb/educators/intro/why.htm

Tile vs. No tile Plots: Snowmelt Runoff Event

- 0.25-acre research corn plots in Chazy, NY
- 2 tile-drained, 2 un-tiled
- Surface runoff sampled from all, tile flows sampled in drained plots
- Hourly samples
- Manure applied 1 month prior, not incorporated

- 86% decrease in surface runoff in tiled plots

- 67% more total flow from tiled plots (tile was 91% of flow)



Klaiber et al., 2016

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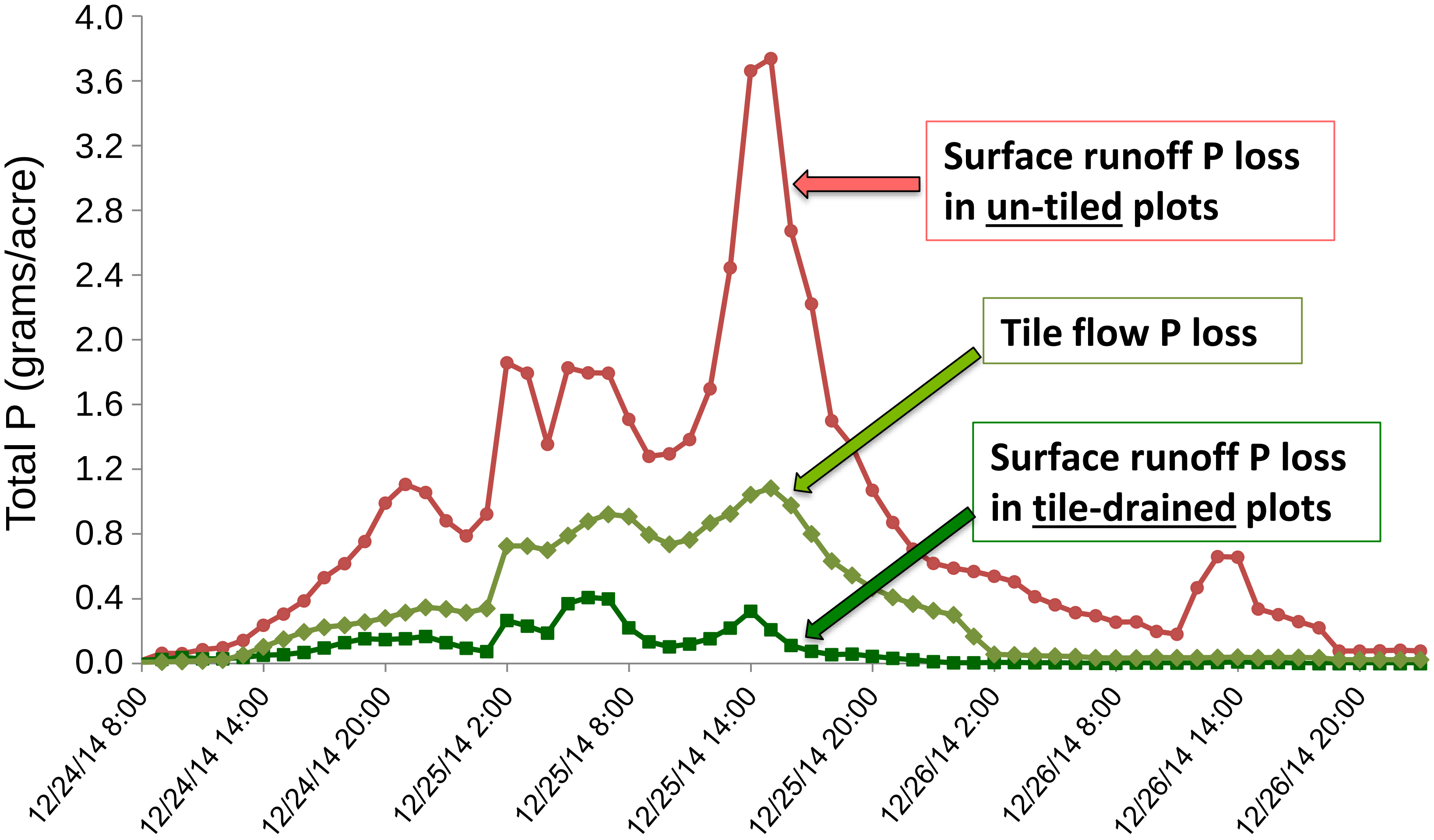
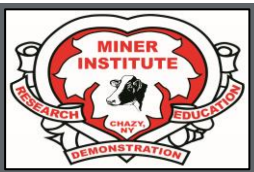
- Manure applied 1 month prior

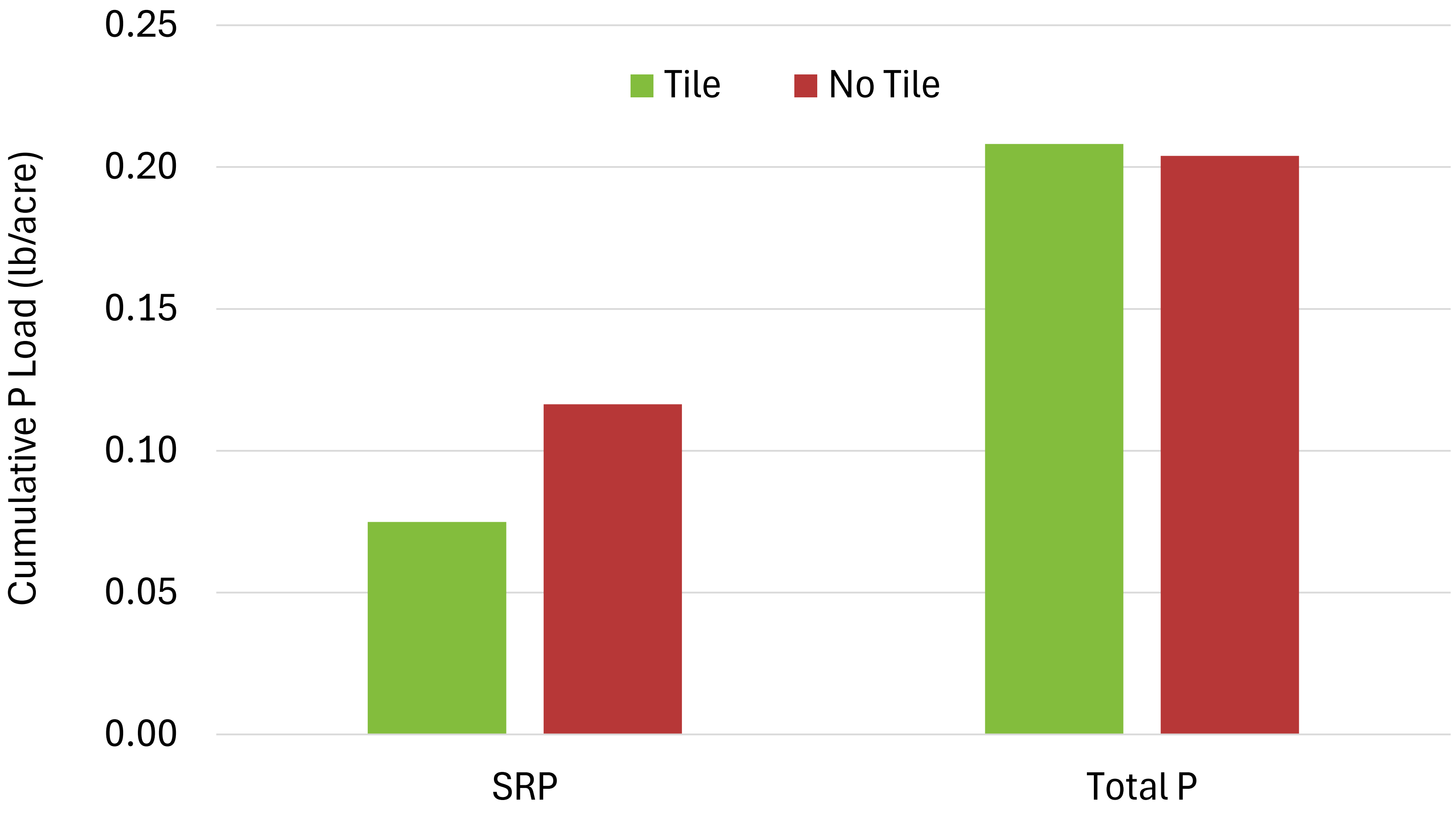
- 86% decrease in surface runoff in tiled plots
- 67% more total flow from tiled plots (tile was 91% of flow)
- Tiled plot loss = **0.06 lb/acre**
- Un-tiled plot loss = **0.12 lb/acre**



Klaiber et al., 2016



Cumulative P and TSS Loads (14 months): Tiled vs No Tile Plots (corn silage)



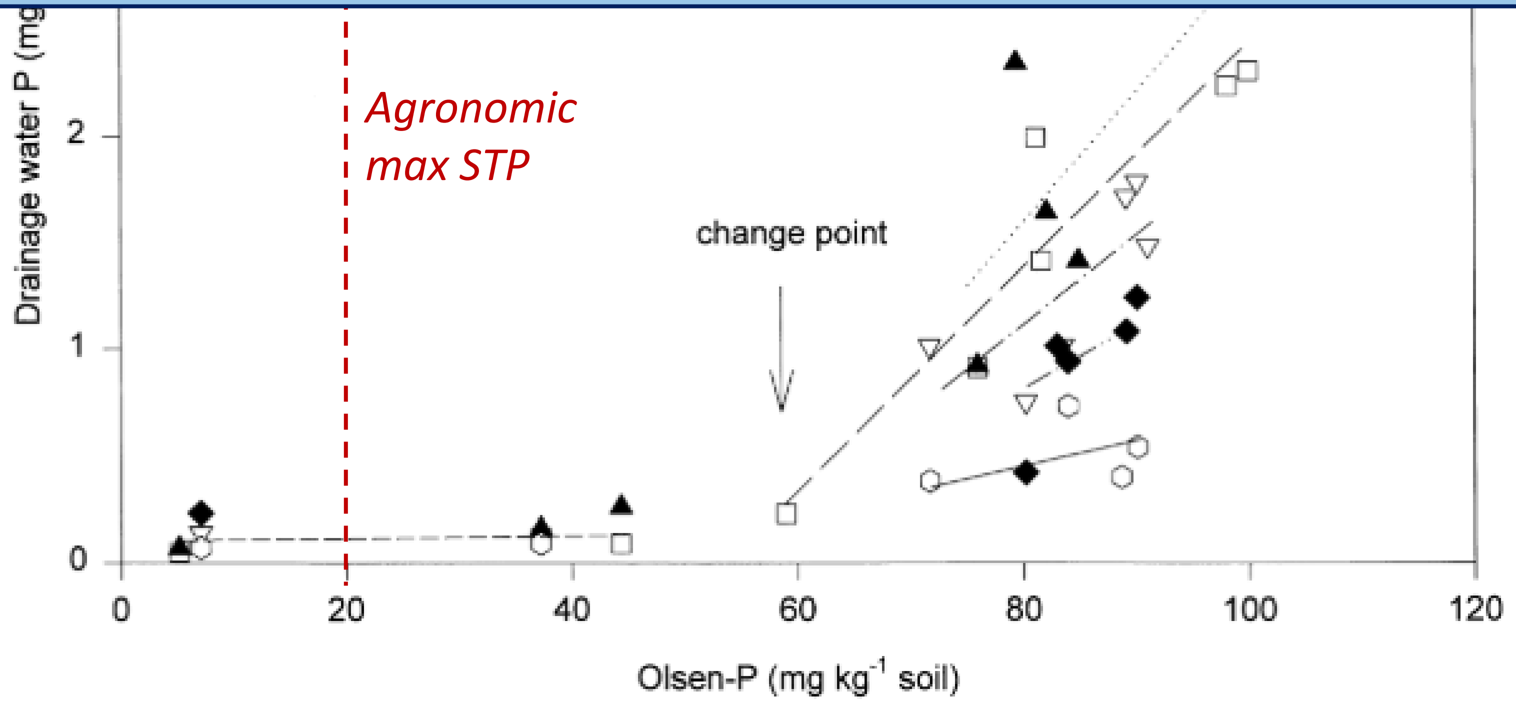
Klaiber et al., 2016

Risk Assessment and Management:

Key Indicators of Sustainability:

- Reduce imported feeds and fertilizers
- Increase acreage/cow (~1.25 acres per 1000 lbs) *OR* increase nutrient uptake by increasing crop yield/quality

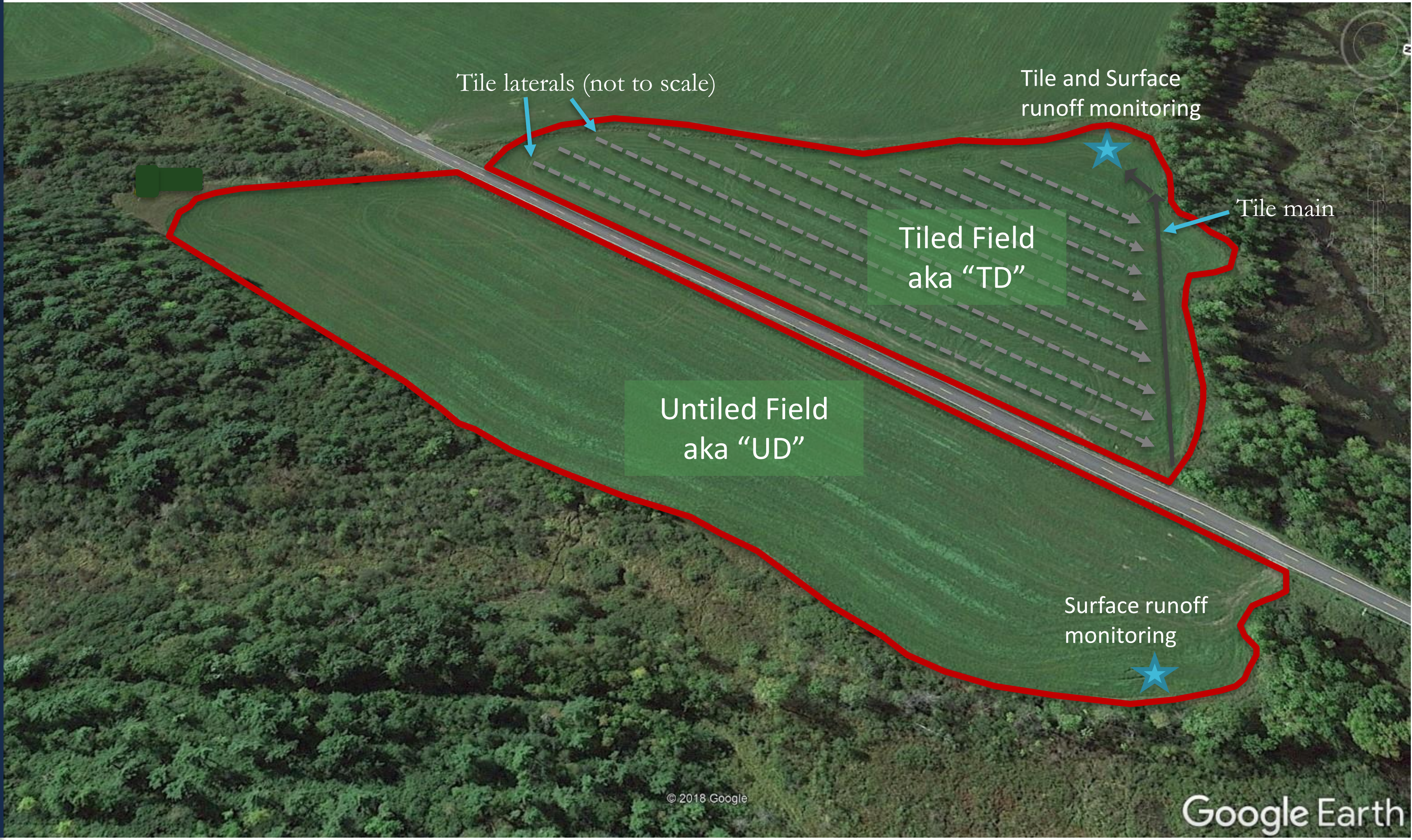
(from Cornell NMSP)



Tiled vs. Untiled Corn Fields*, Essex County, NY

Experimental Site & Methods

- 6-acre corn silage fields
- Tonawanda silt loam – somewhat poorly drained
- 4.5 kg/ha soil test P (mod. Morgan)
- June 2016: Tile drainage installed in TD: 3 ft depth, 25 ft lateral spacing
- Spring manure and fertilizer applications w/ immediate incorporation
- Surface runoff (UD & TD) and tile drainage (TD only) gauged and sampled year-round, automated flow-proportional sampling
- Analyzed for dissolved reactive P (DRP), total P, nitrate, ammonium, total N, total suspended solids (TSS)



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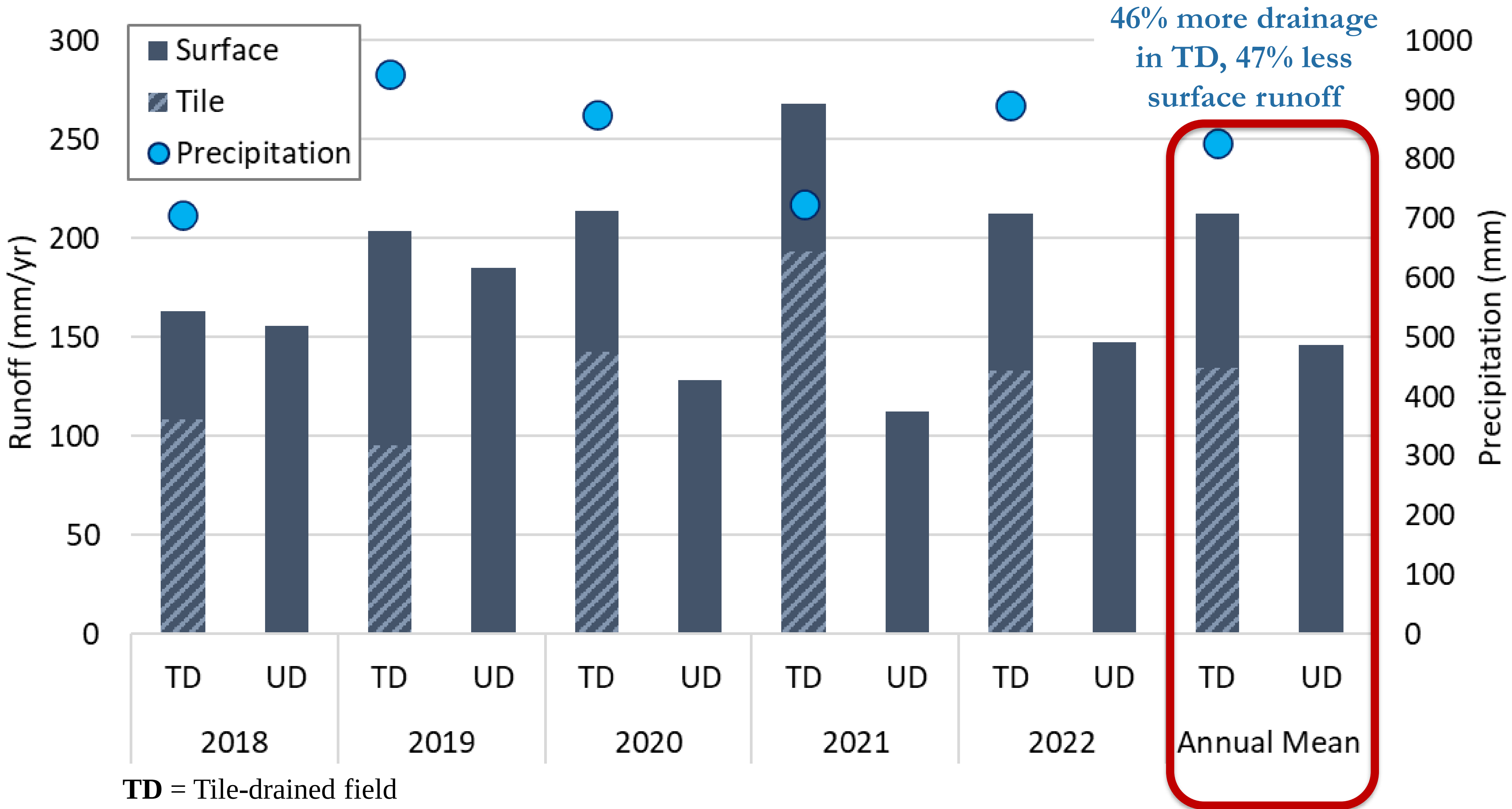
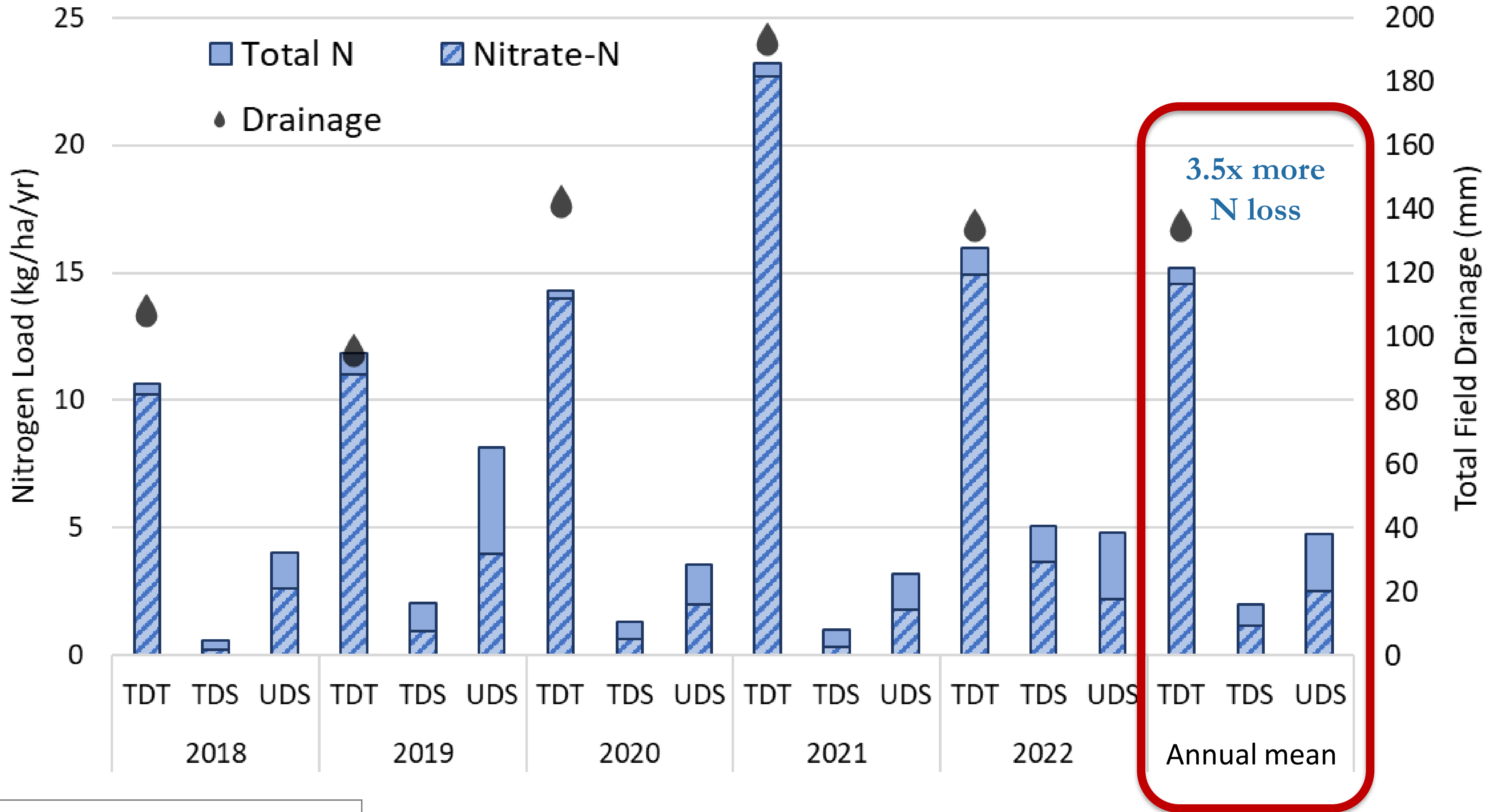


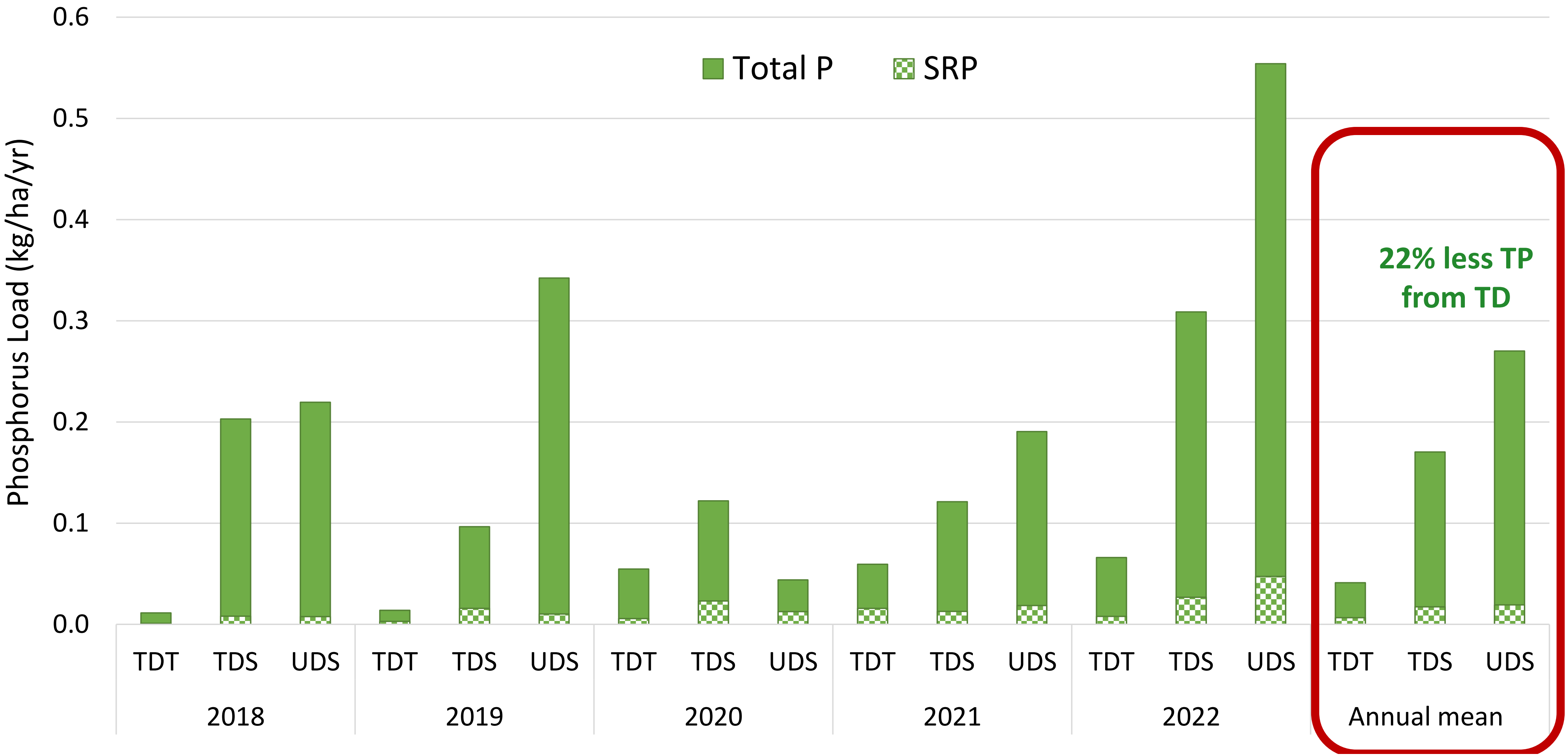
TD = Tile-drained field (tile+surface drainage)
UD = Undrained field (surface drainage only)

Klaiber et al., 2023
*Access full report at www.nnyagdev.org



TDT = TD tile drainage
TDS = TD surface drainage
UDS = UD surface drainage

Klaiber et al., 2023
*Access full report at www.nnyagdev.org



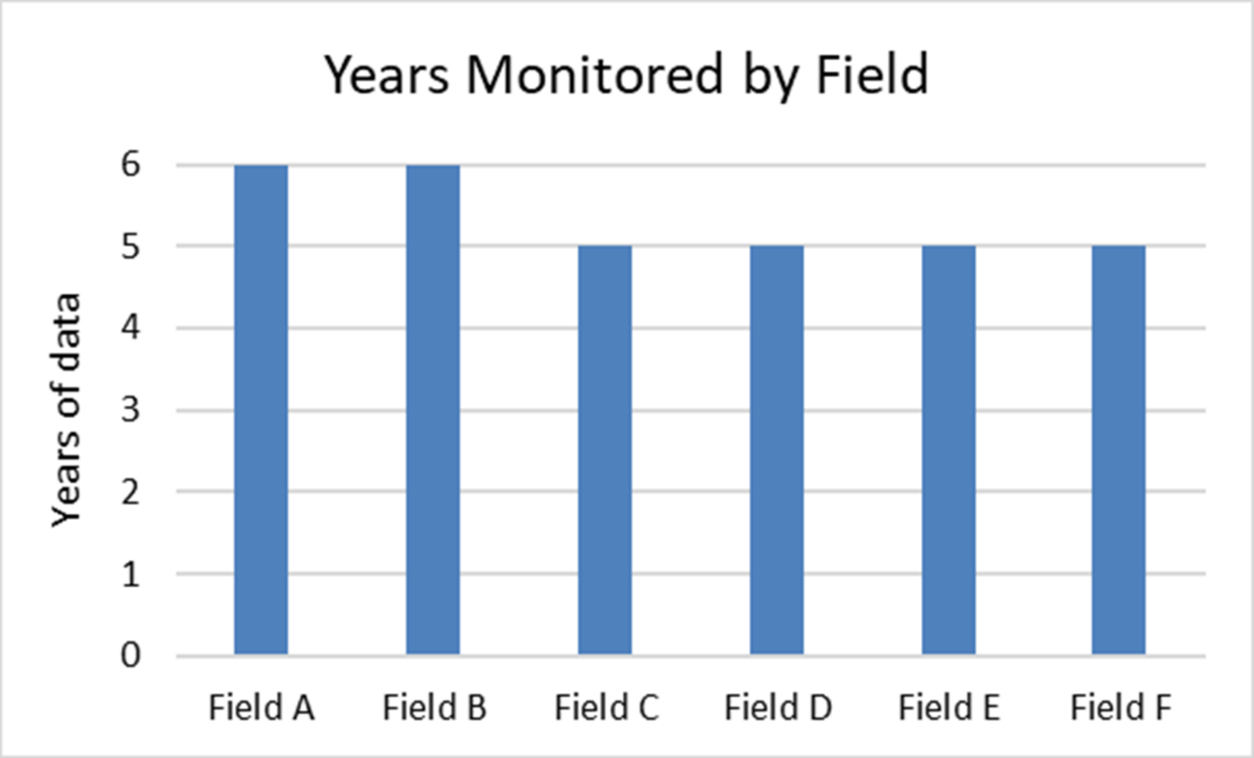
TDT = TD tile drainage
TDS = TD surface drainage
UDS = UD surface drainage

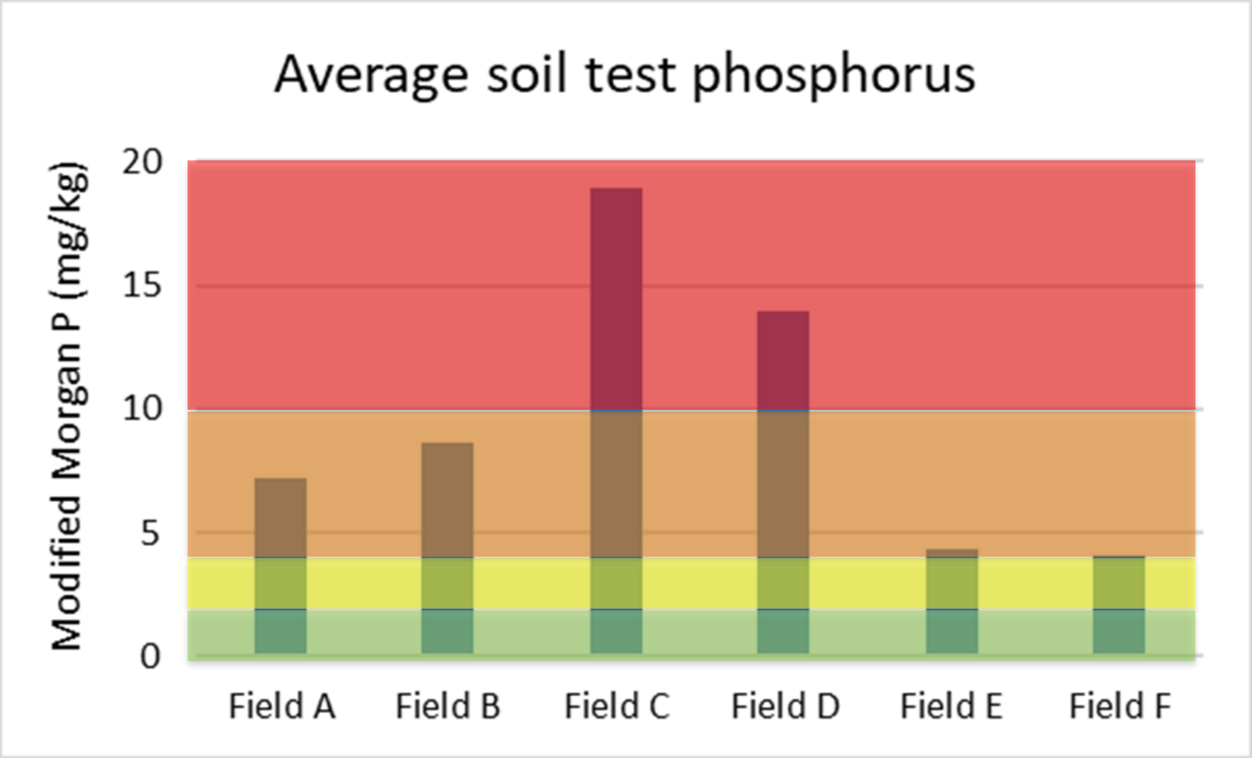
Klaiber et al., 2023
*Access full report at www.nnyagdev.org

Tiled vs Untiled Fields:
Annual Nutrient Partial Budgets

Year	Field	Total P inputs	Total N inputs	Corn Yield	P uptake	N uptake	P Loss	N Loss
		lb/acre	lb/acre	DM ton /acre	lb/acre	lb/acre	%	%
2018	TD	16.1	89.0	8.6	34.3	206.0	1.3	11.3
	UD	16.1	89.0	6.6	26.4	158.5	1.4	4.0
2019	TD	26.4	183.5	4.0	14.5	103.1	0.2	6.2
	UD	26.4	183.5	4.9	18.7	126.1	0.3	2.6
2020	TD	36.4	129.2	9.7	38.8	232.9	0.5	10.8
	UD	36.4	129.2	9.1	38.2	174.7	0.2	3.0
2021	TD	29.1	233.7	-	-	-	0.6	9.2
	UD	29.1	233.7	7.2	24.6	152.7	0.7	1.8
2022	TD	11.4	229.3	5.8	20.3	140.3	3.3	8.2
	UD	11.4	229.3	5.3	18.7	126.3	4.9	1.9

Tile Drained Research Fields 2016-2023

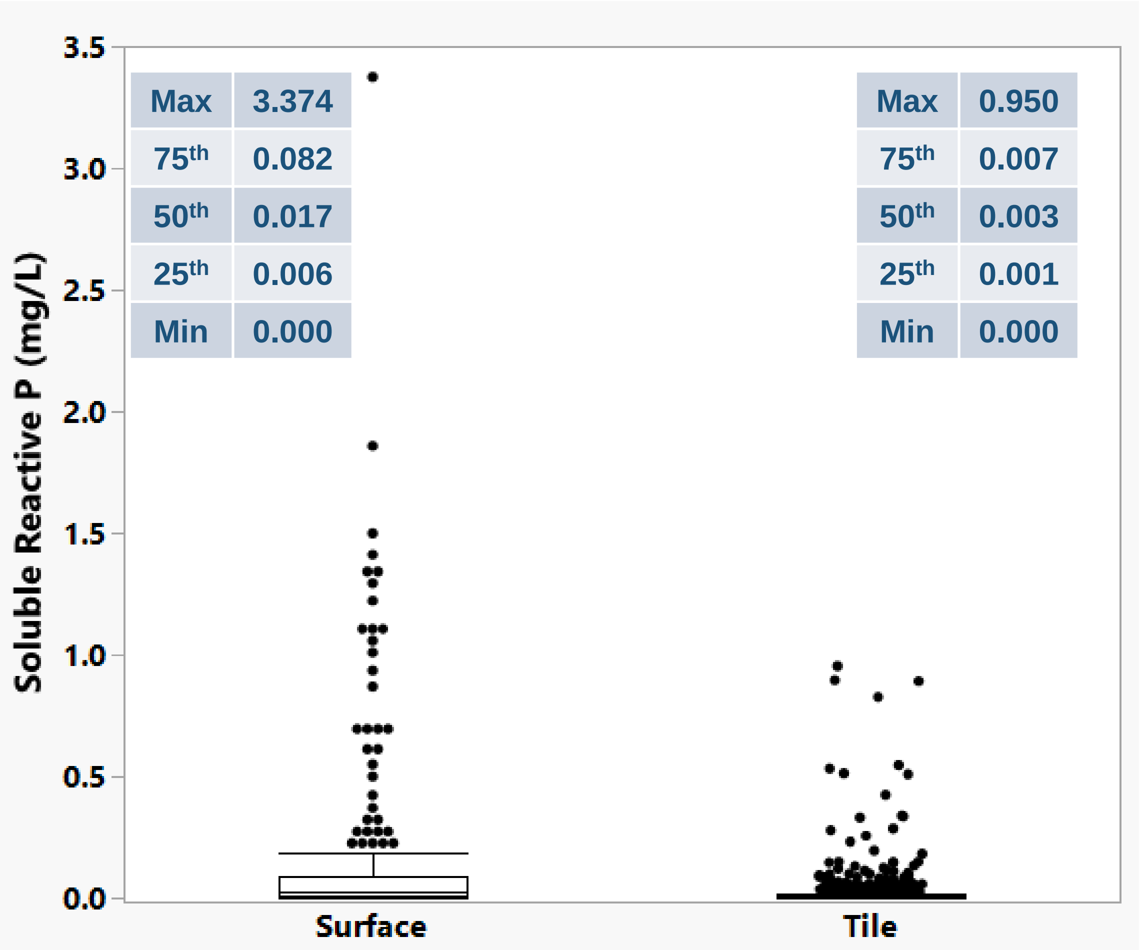


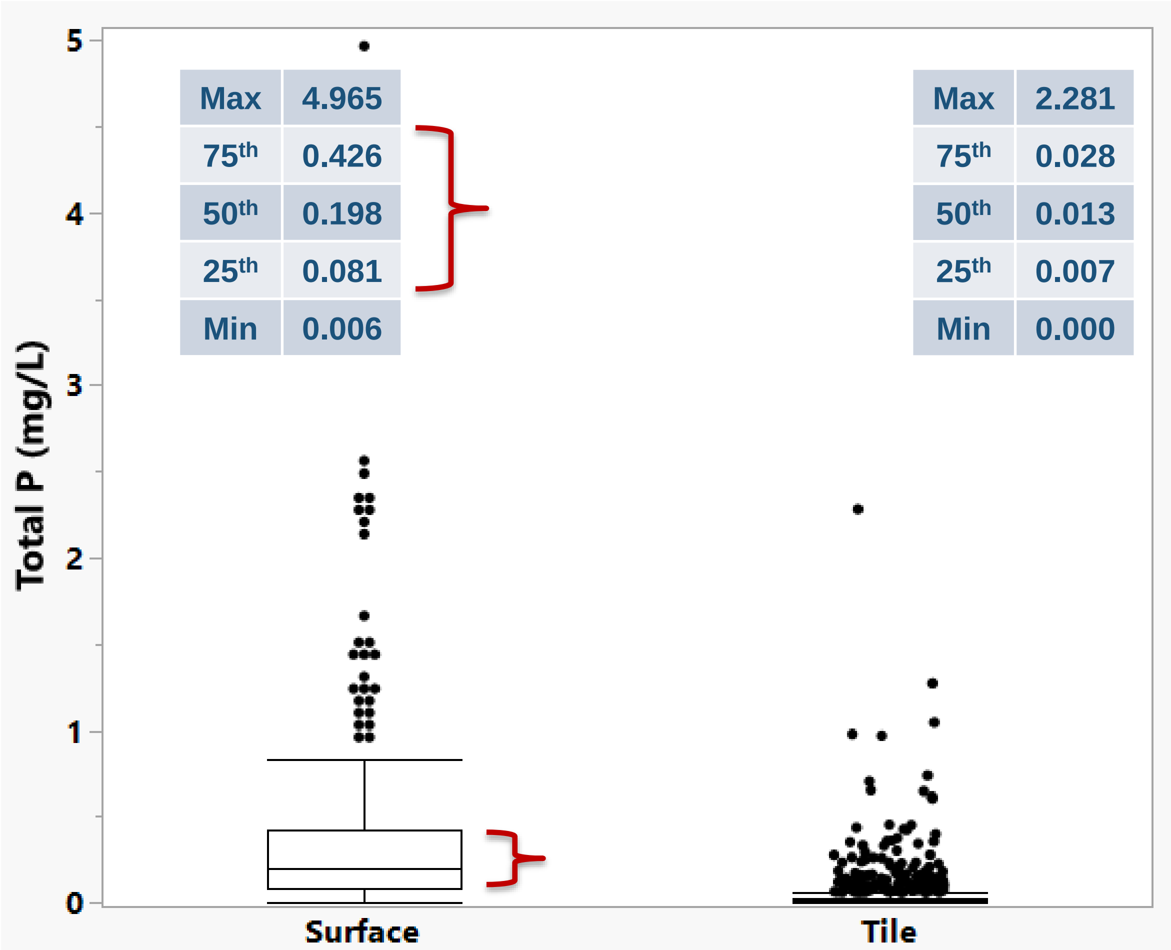


Sample Concentrations (event composite samples) 2016-2023

6 corn silage fields, annual manure applications, tillage

268 surface runoff samples & **1439** tile drainage samples





MINER INSTITUTE
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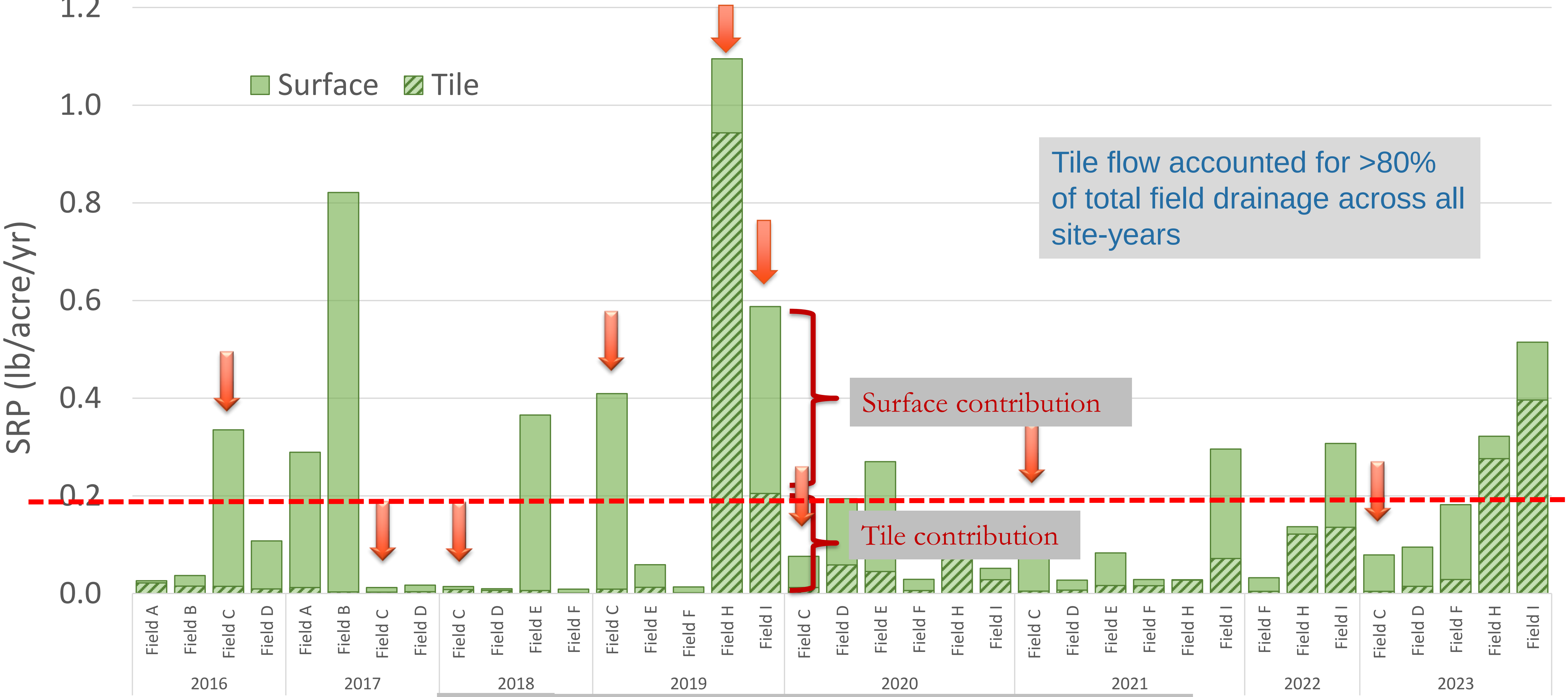
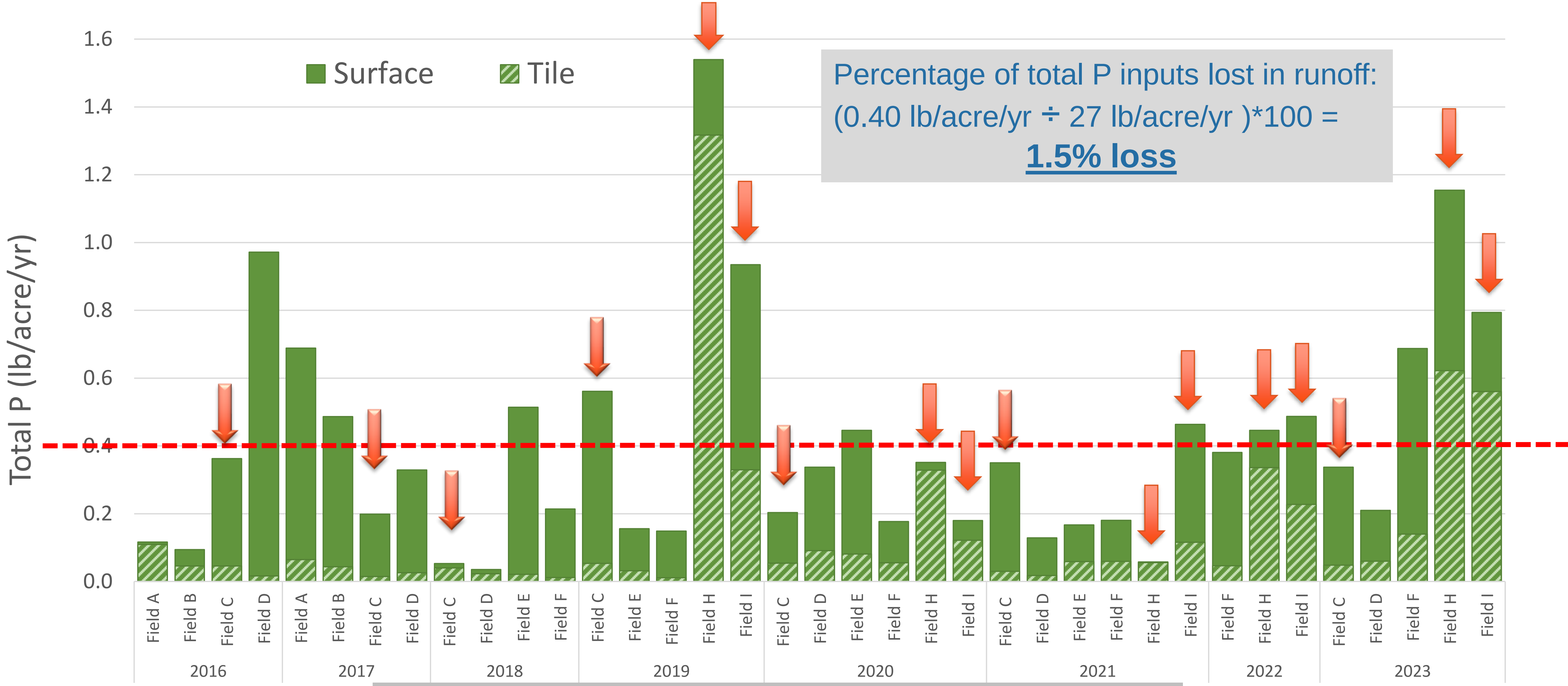
CHAZY, NY

Annual SRP Losses: 2016-2023



Means: Tile = 0.06; Surface = 0.13; Total = 0.19 lb/acre/yr

Annual Total P Losses: 2016-2023



Means: Tile = 0.14; Surface = 0.26; Total = 0.40 lb/acre/yr

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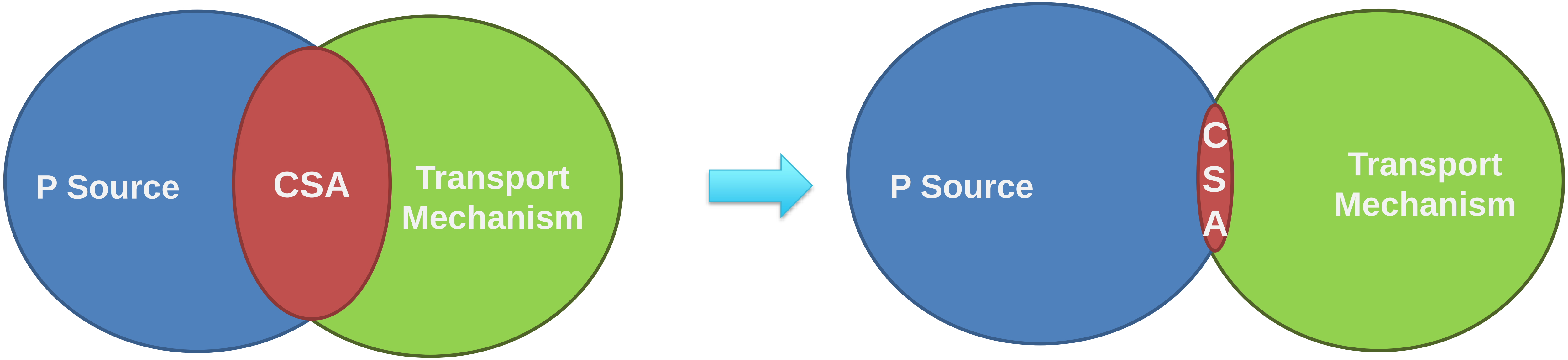
RESEARCH EDUCATION DEMONSTRATION
CHAZY, NY

Critical Source Areas (CSA)

- Nonpoint source pollution – challenging to identify contributing areas and control; varies across time and space
- Critical source areas
  - Where source and transport factors intersect
  - 80/20 rule (Sharpley et al., 2009)
- P Index: identify CSAs and influence management options for P application to limit risk of P loss in runoff



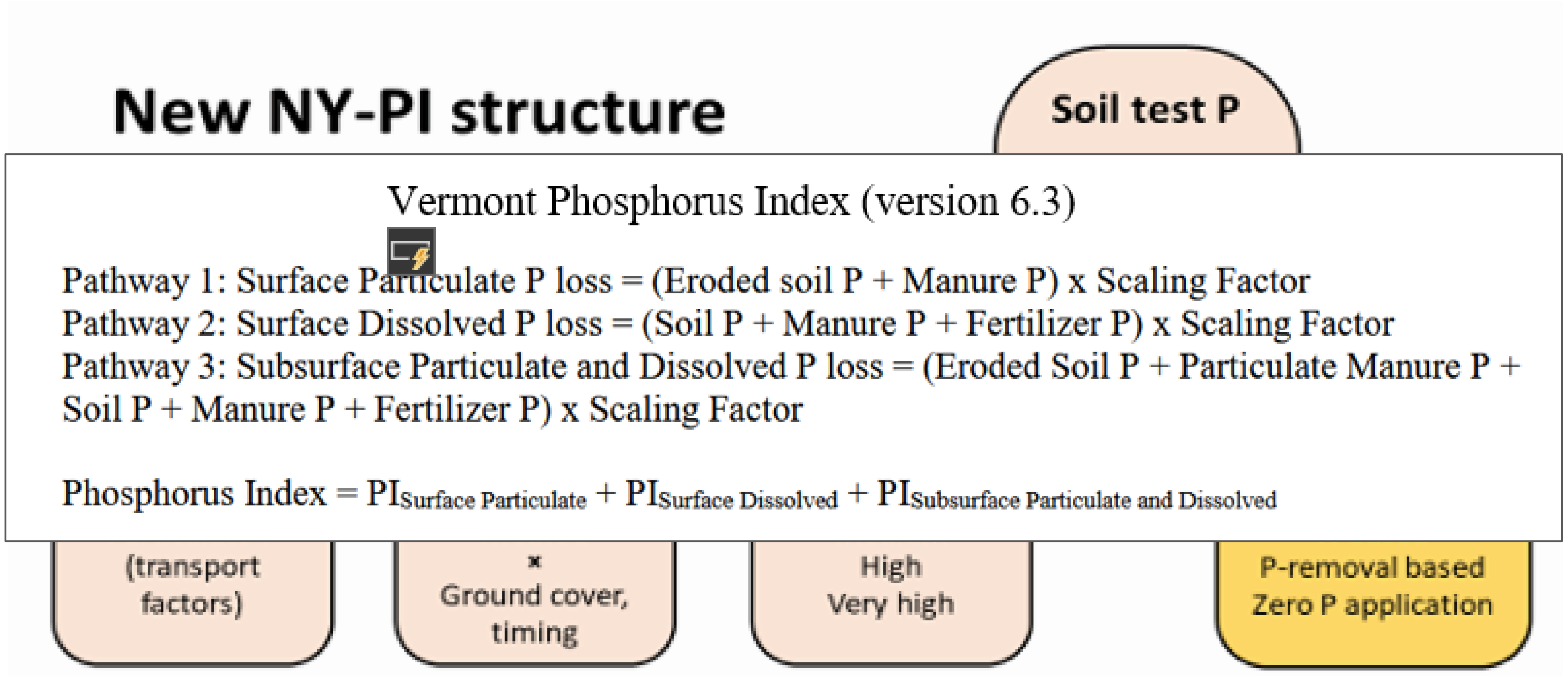
NY Phosphorus Index 2.0 Calculation (rev. 2020)

Transport Score Factors:

1. Flow distance to stream
2. Vegetated Buffer (only ≥ 35 ft)
3. Flooding frequency
4. Untreated concentrated flow
5. Hydrologic Soil Group (HSG)
6. Erosion (ton/acre)

BMP Score Factors:

1. Method of application (surface, incorporated, injected)
2. Application distance from down-gradient surface waters
3. Ground cover (bare, cover crop, growing sod/row crop)
4. Timing (in vs. out of growing season)



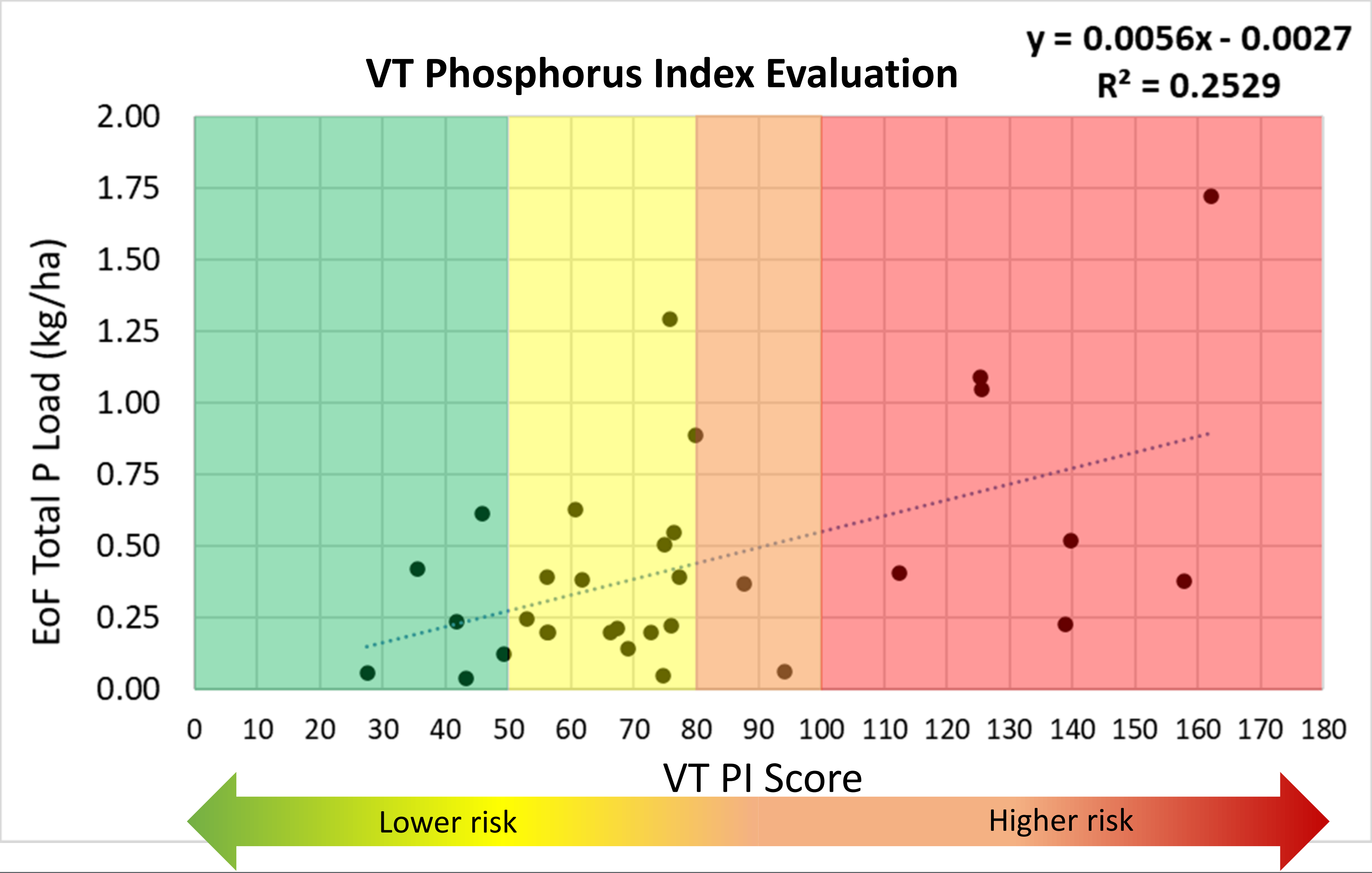
Vermont Phosphorus Index (version 6.3)

Pathway 1: Surface Particulate P loss = (Eroded soil P + Manure P) x Scaling Factor
Pathway 2: Surface Dissolved P loss = (Soil P + Manure P + Fertilizer P) x Scaling Factor
Pathway 3: Subsurface Particulate and Dissolved P loss = (Eroded Soil P + Particulate Manure P + Soil P + Manure P + Fertilizer P) x Scaling Factor

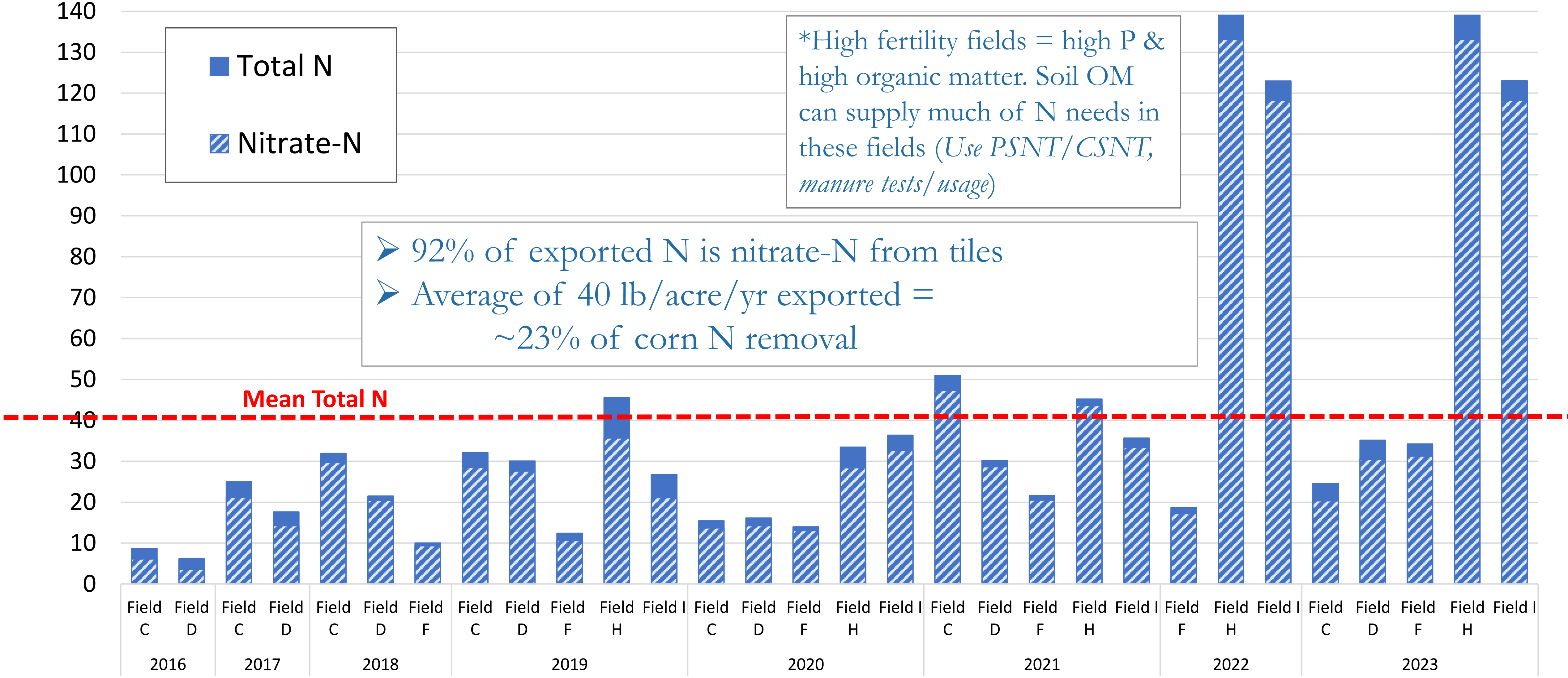
Phosphorus Index = $PI_{\text{Surface Particulate}} + PI_{\text{Surface Dissolved}} + PI_{\text{Subsurface Particulate and Dissolved}}$

Czymmek et al., 2021

Observed annual P loss by site-year



Annual Nitrogen Losses by Field: 2016-2023



Questions?

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