Soil Fertility and Soil Health Testing: Is There a Connection

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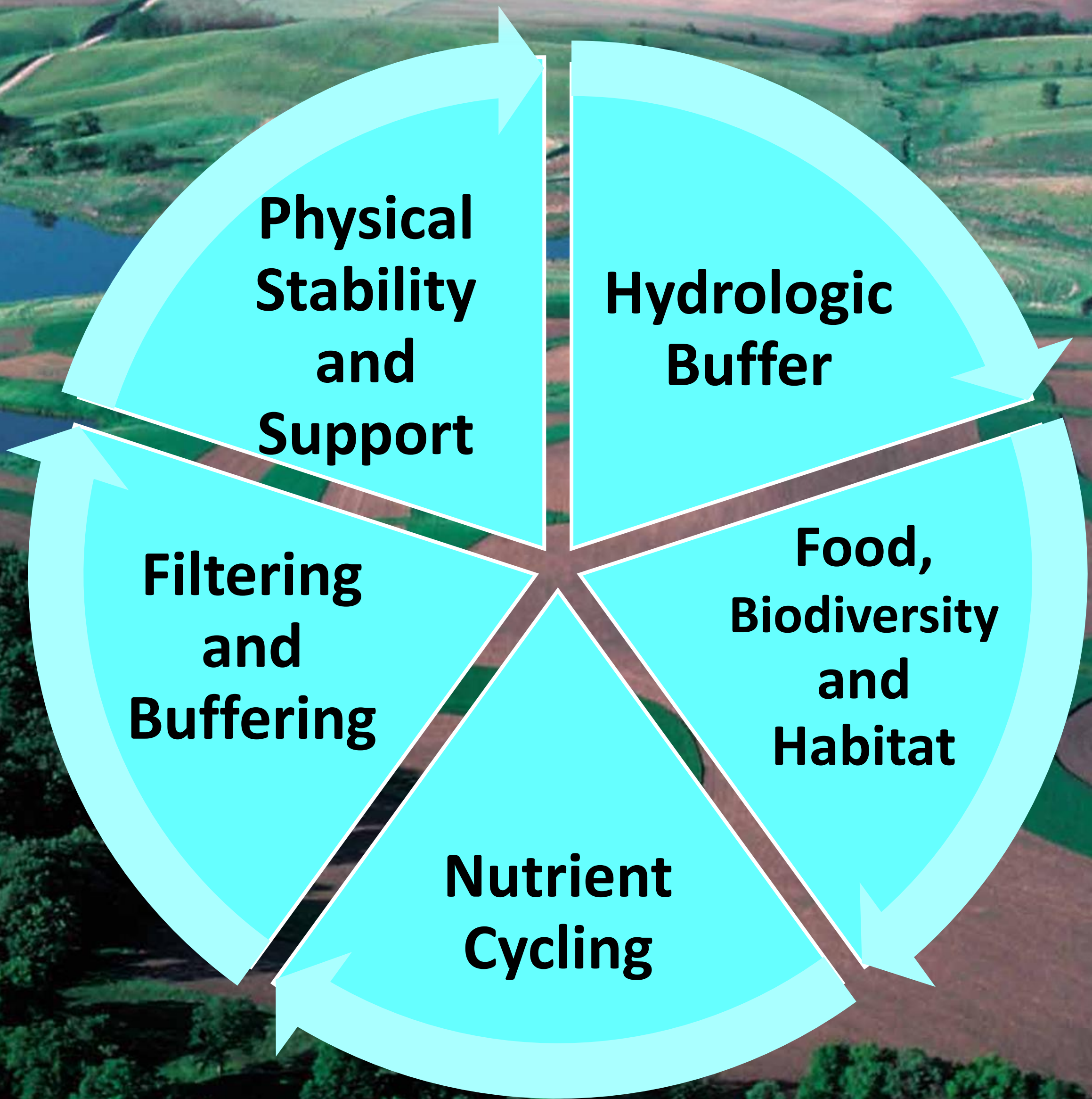
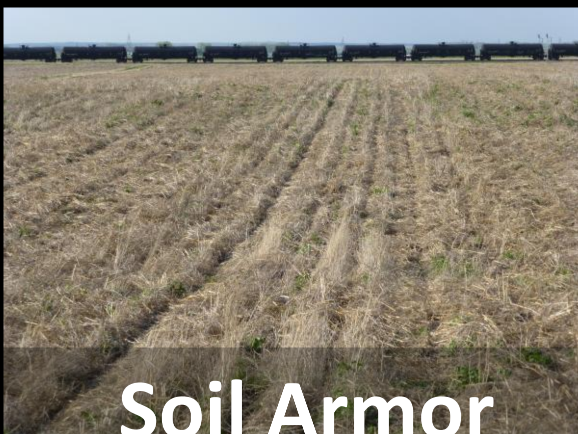
Soil Functions



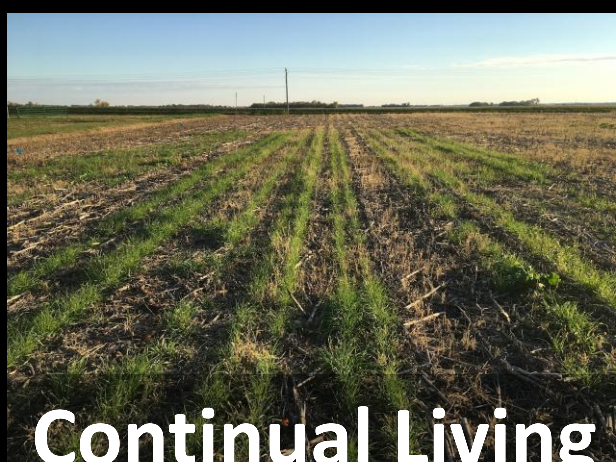
Soil health principles



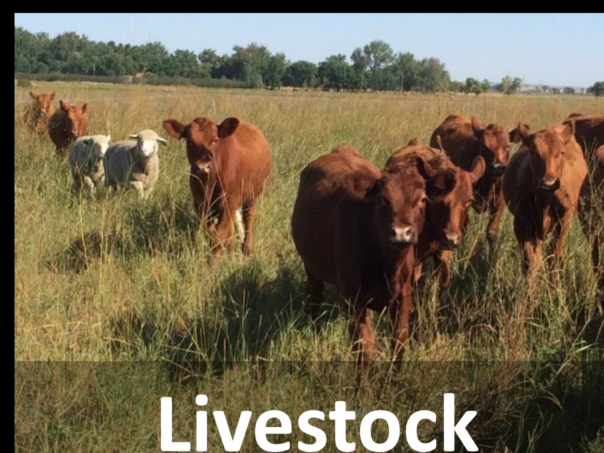
Soil Armor

Minimize Disturbance

Plant Diversity

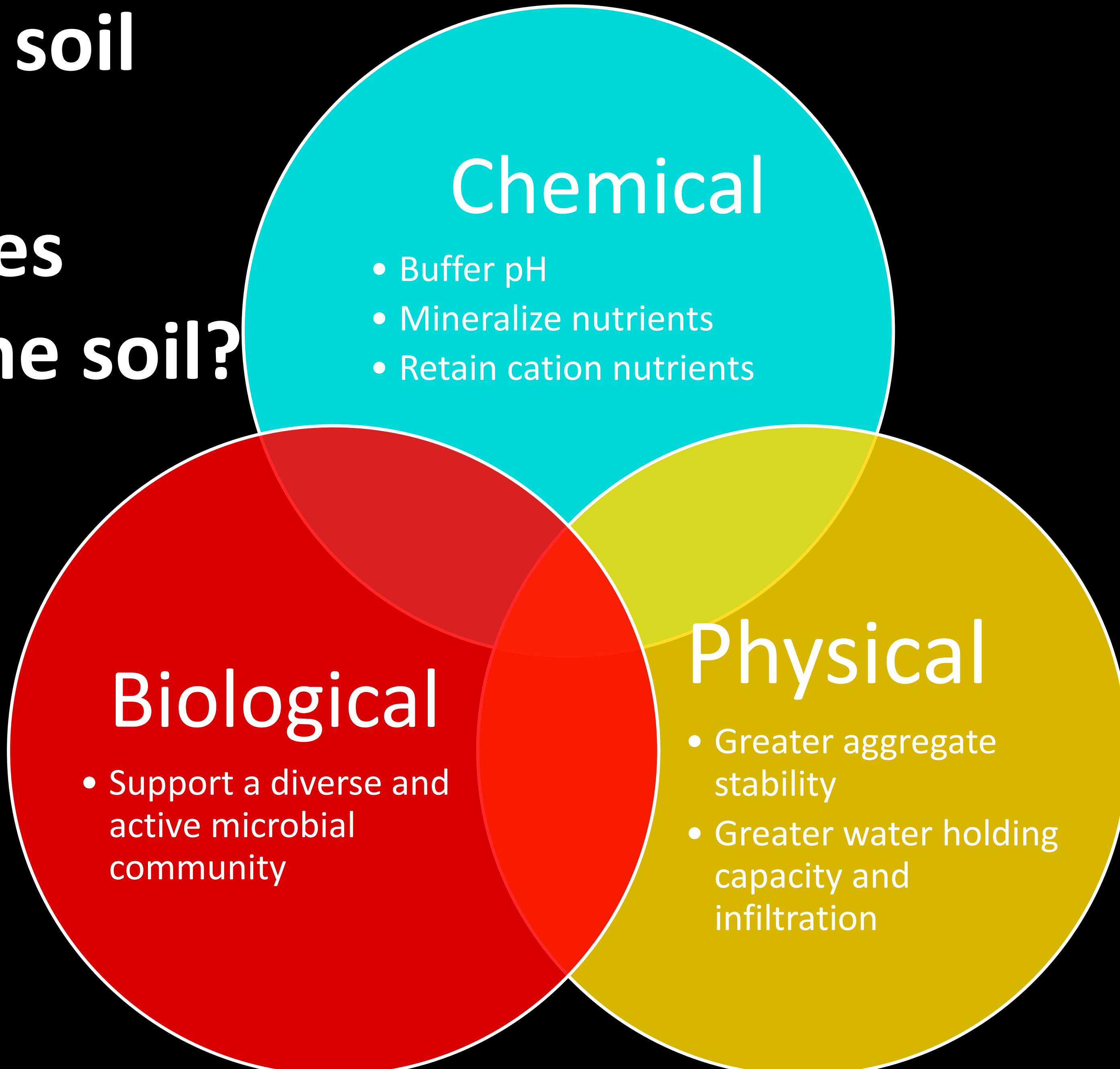


Continual Living Roots



Livestock Integration

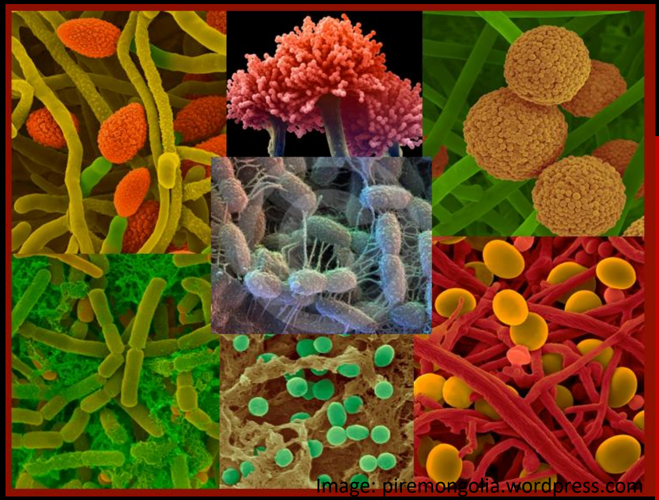
How do soil health principles affect the soil?



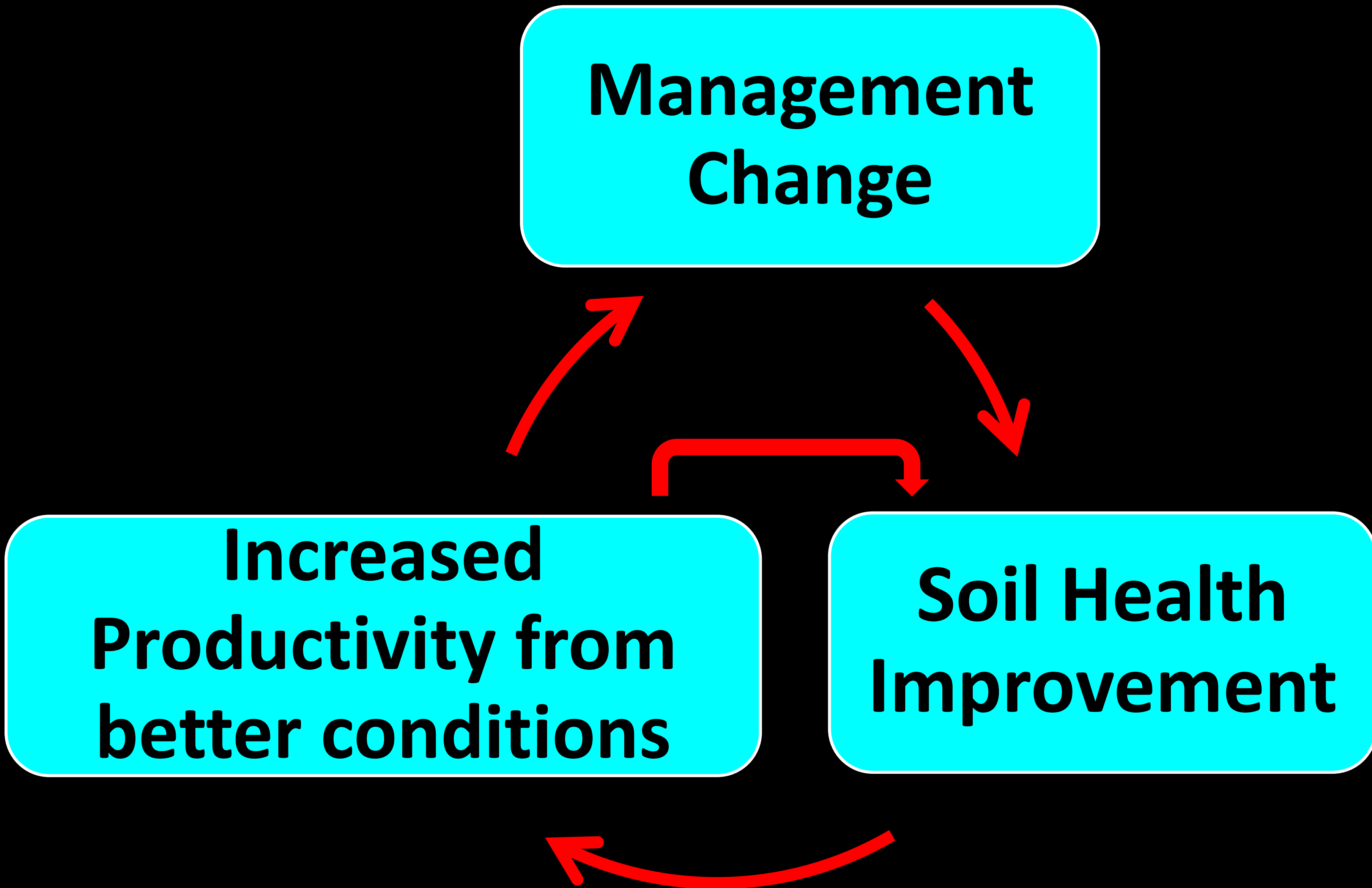
Source: Hanna Poffenbarger

"While the chemistry (and physics) of the soil system provides the context. . . it is the ***soil biota*** which is ***adaptive*** to changes in environmental circumstances"

-Kibblewhite et al. 2008



So… What is the relationship between management, soil health, and crop growth?



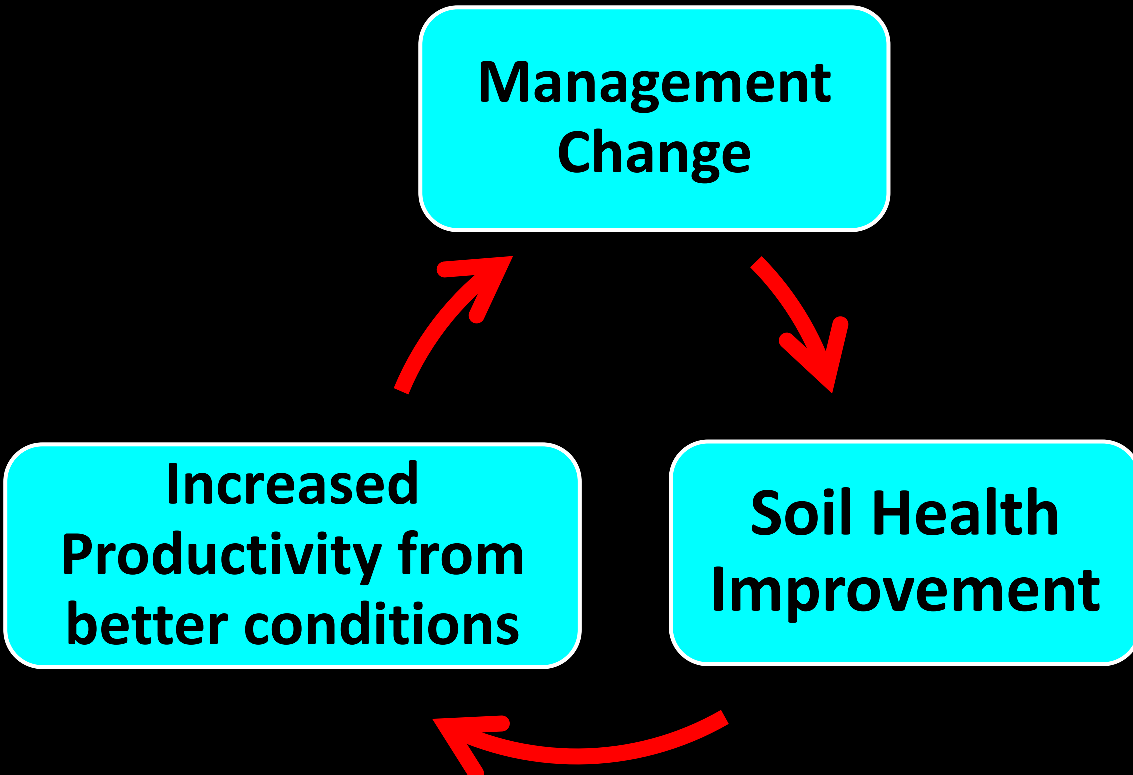
What management changes are we talking about?

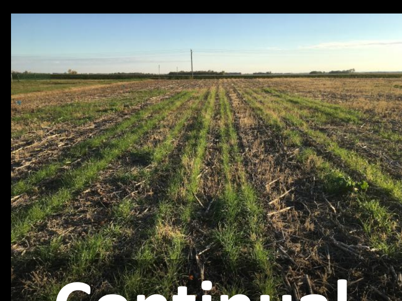
Management Change

Increased Productivity from better conditions

Soil Health Improvement

Soil health principles





How do we know our management change is making a difference?

We need to be able to measure the various changes in soil properties:

- Chemical
- Physical
- Biological

Soil Quality/ Soil Health

Soil Management Assessment Framework (SMAF)

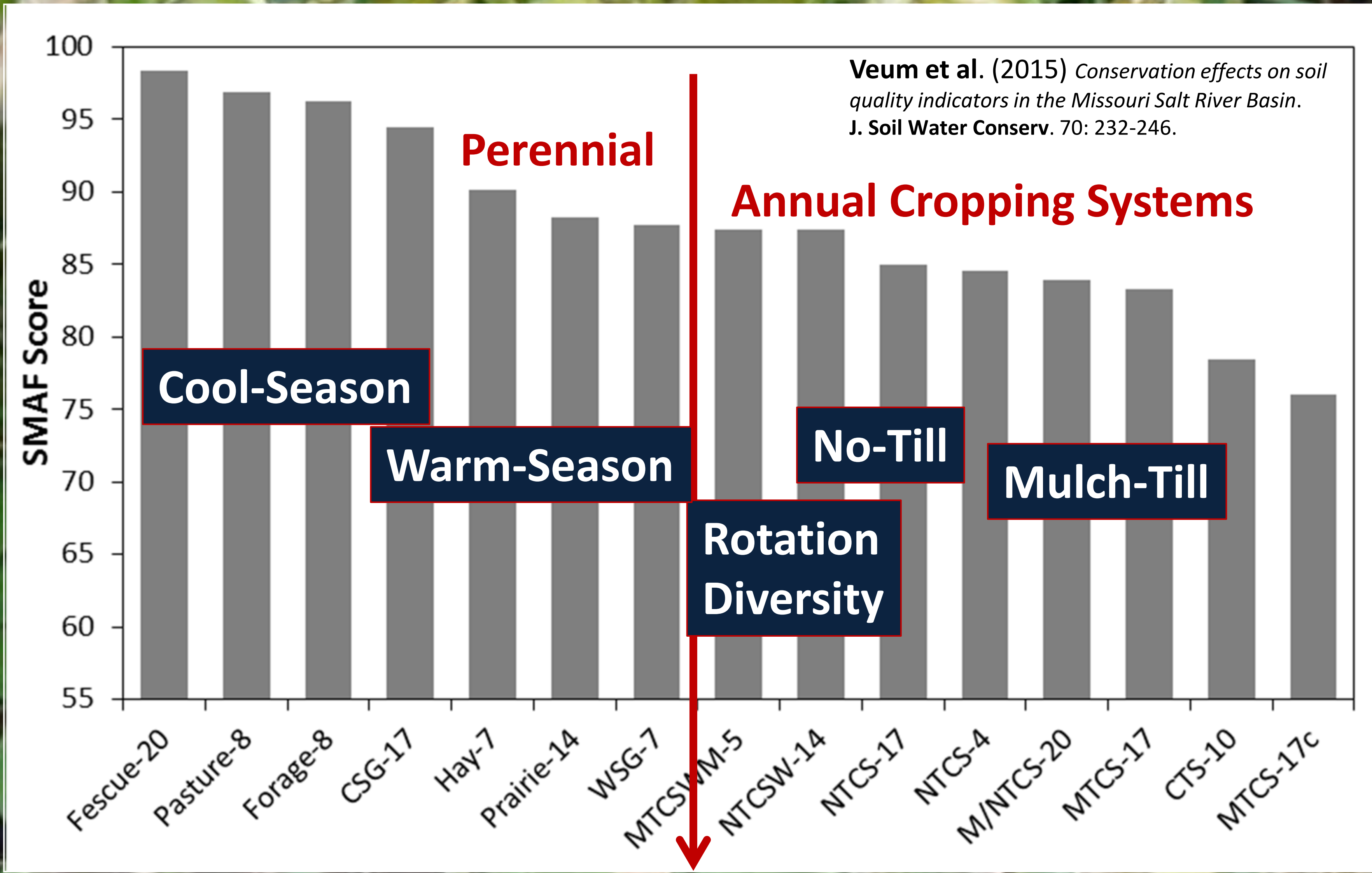
Physical Score
- bulk density
- water-filled pore space
- water-stable aggregates

Biological Score
- organic C
- B-glucosidase
- microbial C
- mineralizable N

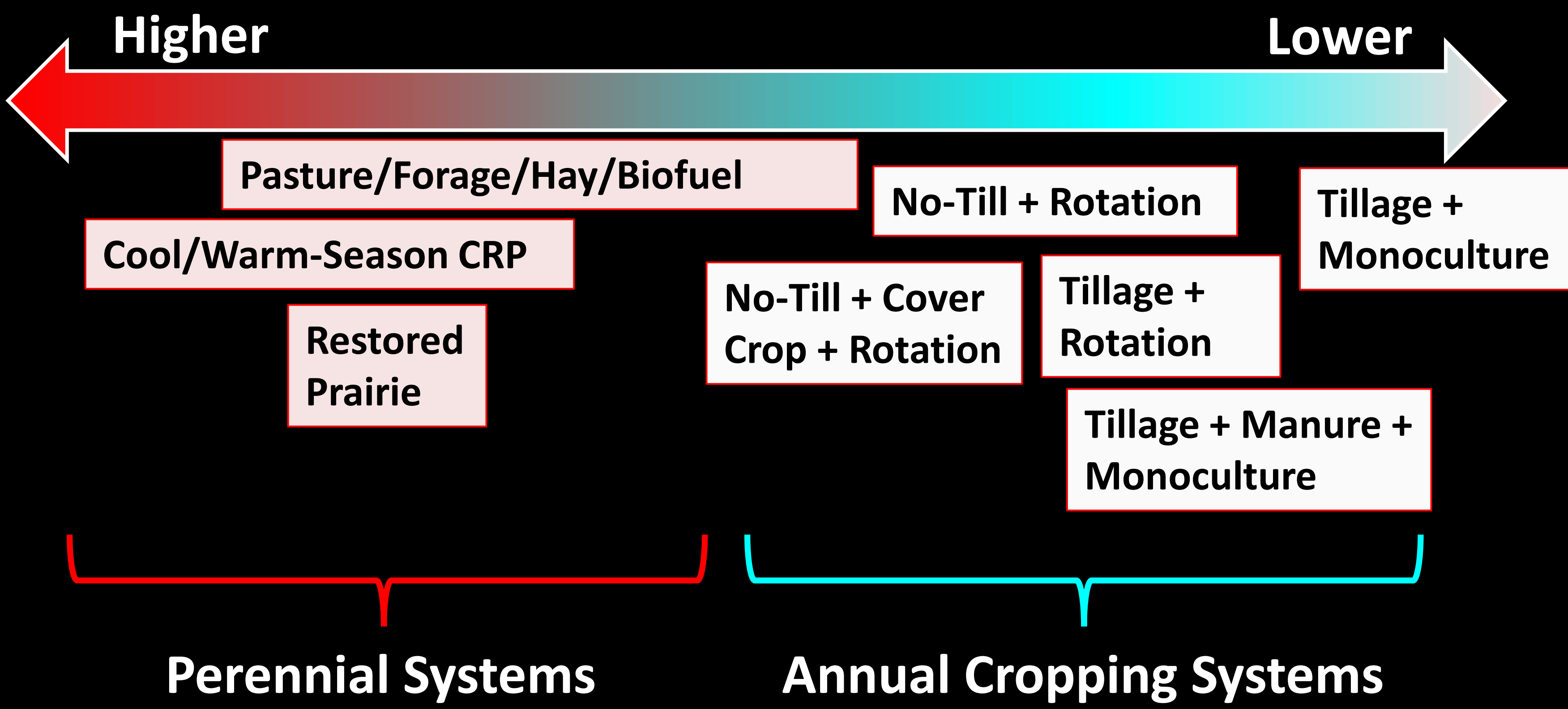
Chemical Score
- pH
- electrical conductivity

Nutrient Score
- extractable P
- extractable K

Centralia 2008 SMAF Scores



Agricultural Continuum of Soil Health

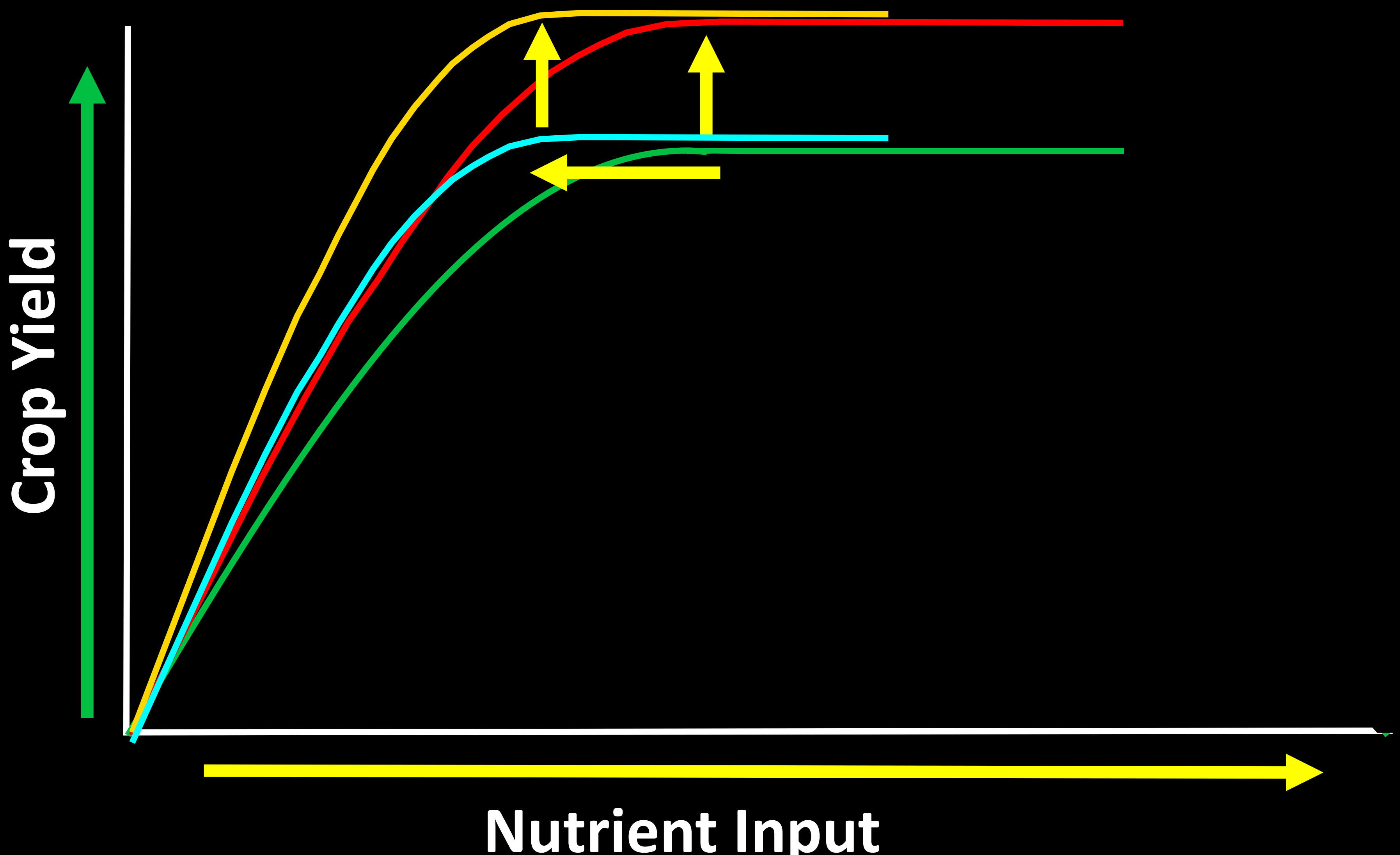


Veum KS, Goyne KW, Kremer RJ, Miles RJ, Sudduth KA (2014) Biological indicators of soil quality and soil organic matter characteristics in an agricultural management continuum. **Biogeochemistry**

Veum KS, Kremer RJ, Sudduth KA, Kitchen NR, Lerch RN, Baffaut C, Stott DE, Karlen DL, Sadler EJ (2015) Conservation effects on soil quality indicators in the Missouri Salt River Basin. **J. Soil Water Conserv.**

What about nutrient management?

Improved management practices can help with crop yield and fertilizer inputs

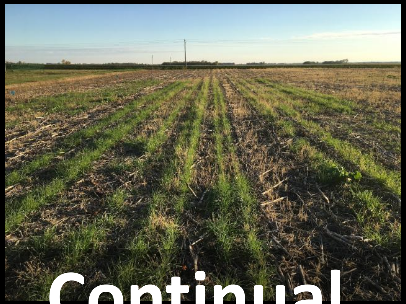


How do these changes affect fertilizer management

Management Change

Soil Health Improvement

Increased Productivity from better conditions

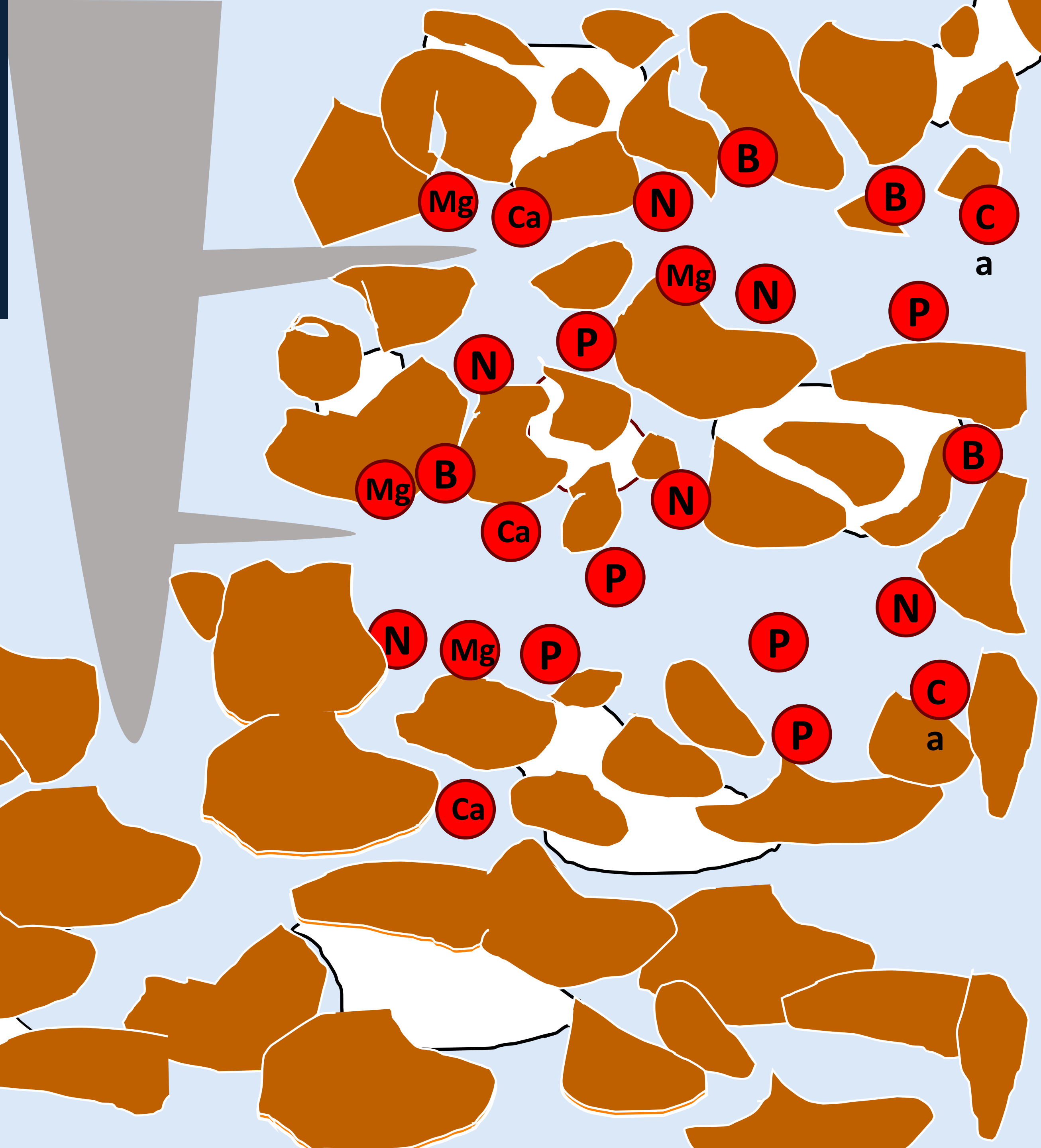


Nutrient uptake

- It’s important to note how P is taken up to see how management can affect it

Nutrient Uptake

- Mass Flow
- Diffusion
- Root Interception



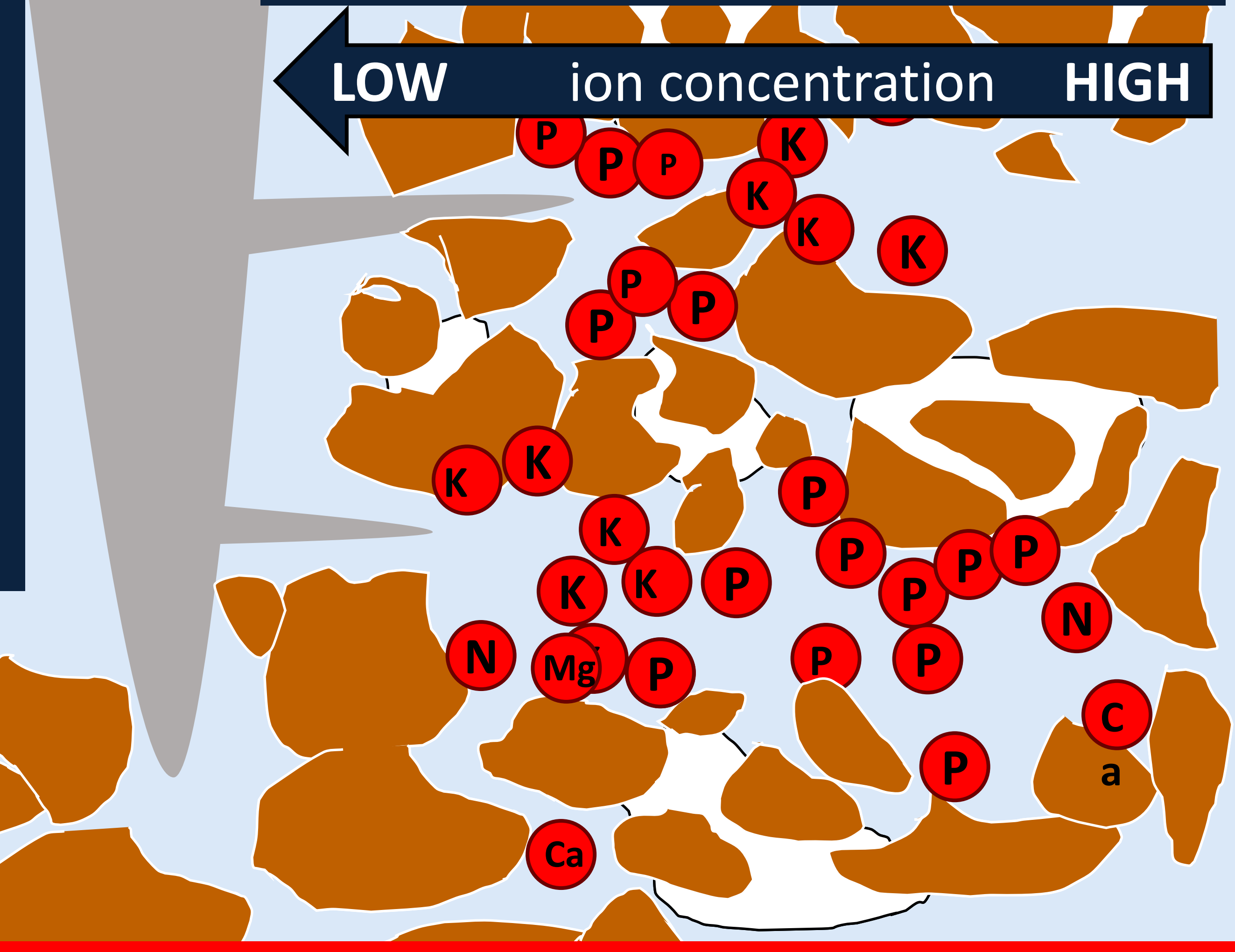
Diffusion

- Phosphorus
- Potassium

<u>Can supply</u>

- Iron
- Sulfur
- Zinc

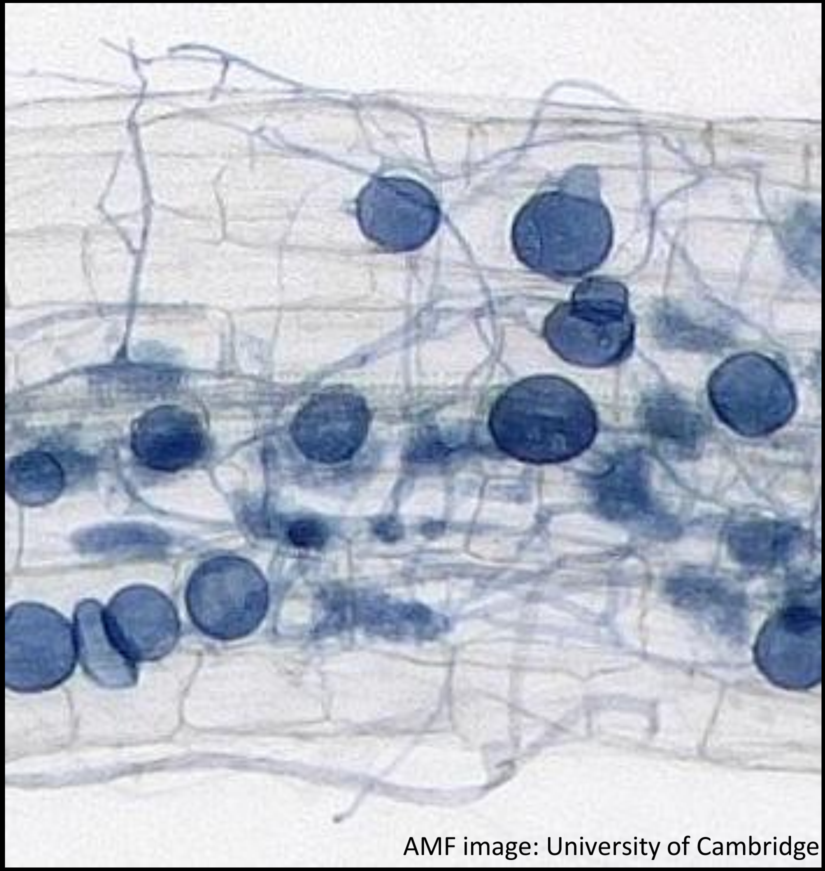
Follows an ion concentration gradient



Is there a way to increase P uptake?

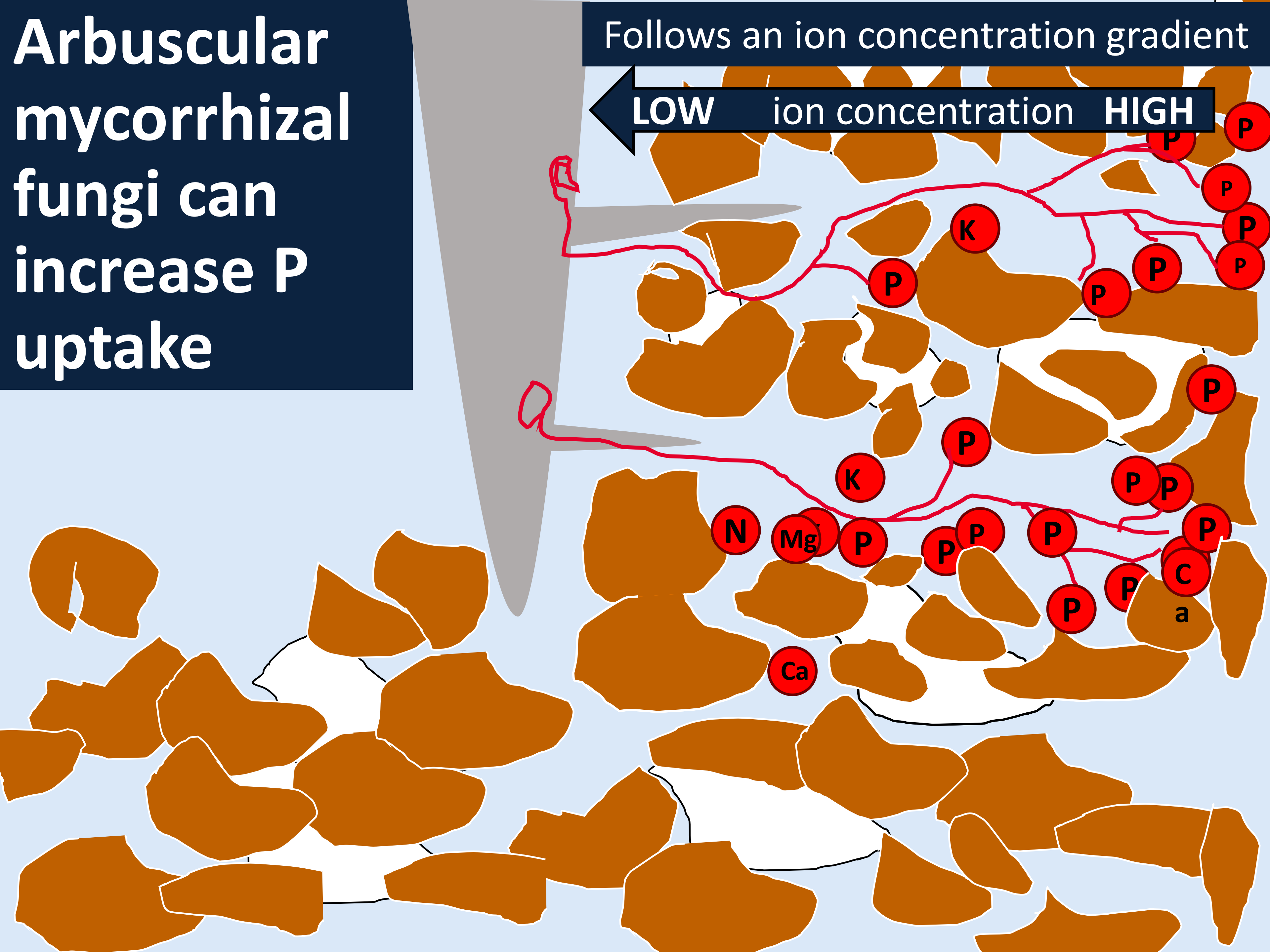
Arbuscular mycorrhizal fungi (AMF) help with P uptake

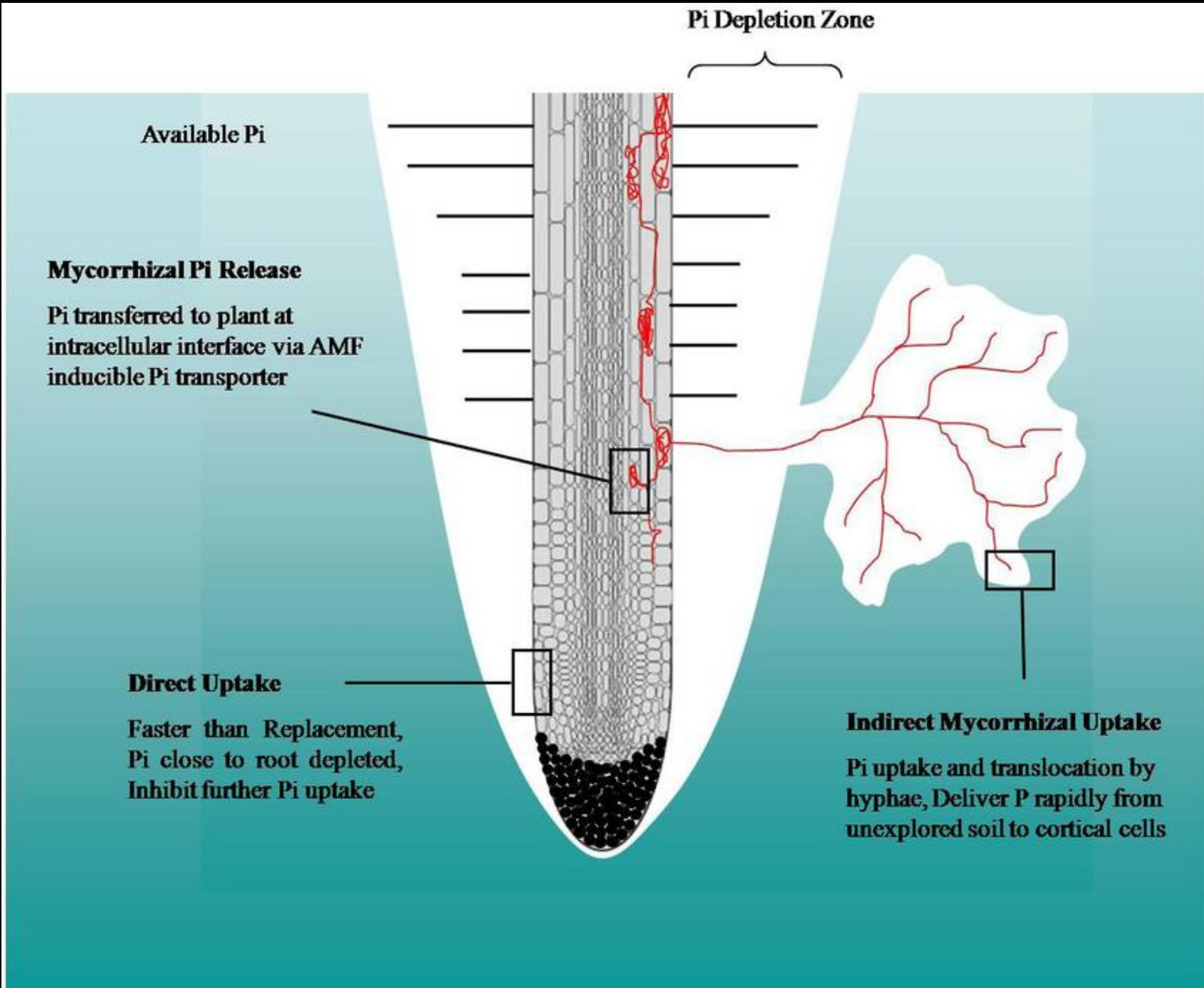
- Dissolves P
- Drought resistance
- Aggregate stability
- AMF populations increase in no-till systems



AMF image: University of Cambridge

Arbuscular mycorrhizal fungi can increase P uptake

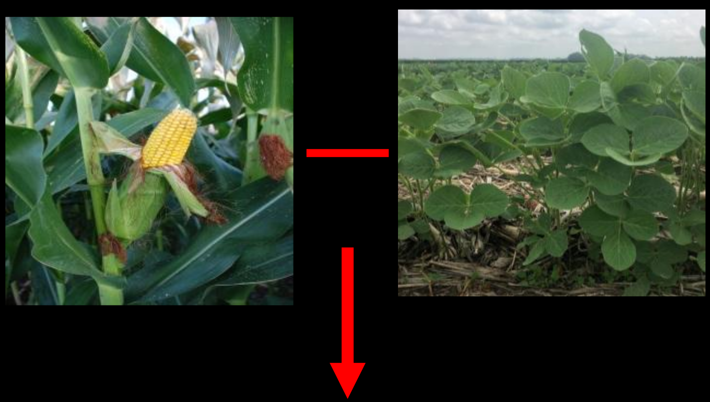



Pi Depletion Zone
Available Pi
Mycorrhizal Pi Release
Pi transferred to plant at intracellular interface via AMF inducible Pi transporter
Direct Uptake
Faster than Replacement, Pi close to root depleted, Inhibit further Pi uptake
Indirect Mycorrhizal Uptake
Pi uptake and translocation by hyphae, Deliver P rapidly from unexplored soil to cortical cells

Soil Health and P Project

SOIL HEALTH PRACTICES

Developed study to see how no-till and plant diversity influence P needs



Transitioned from typical corn-soybean rotation to Soybean-wheat/cover crop-soybean-corn-corn

Location: Dakota Lakes Research Farm

No-till

Since 1990

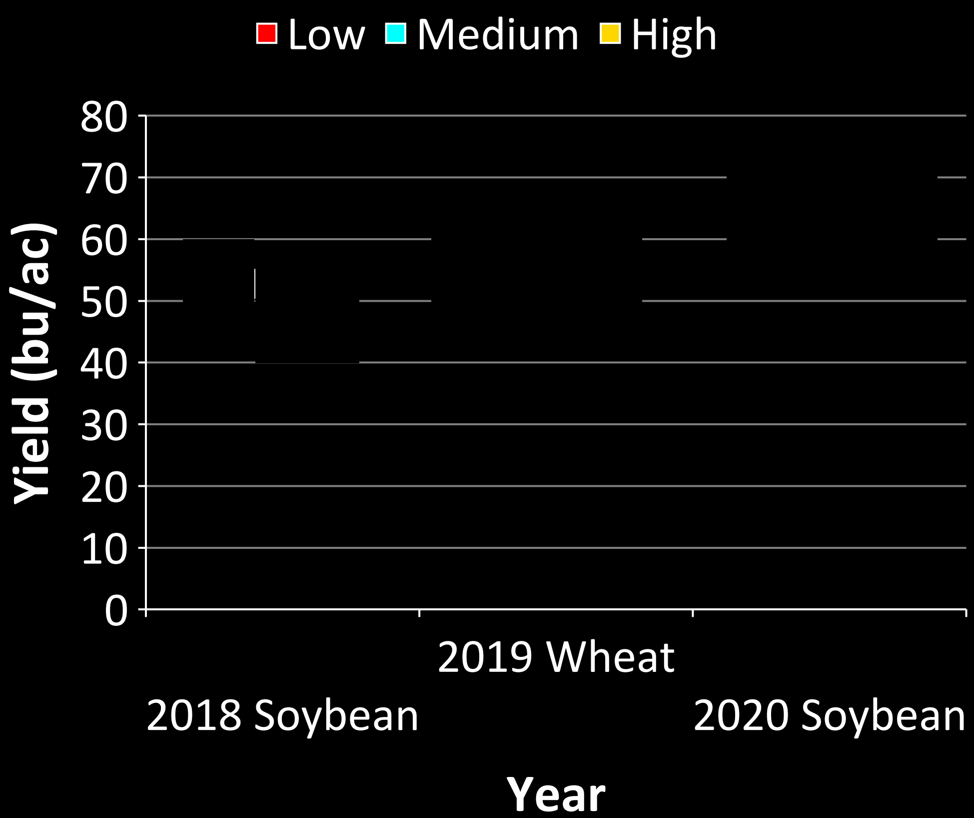
5-year diverse crop rotation

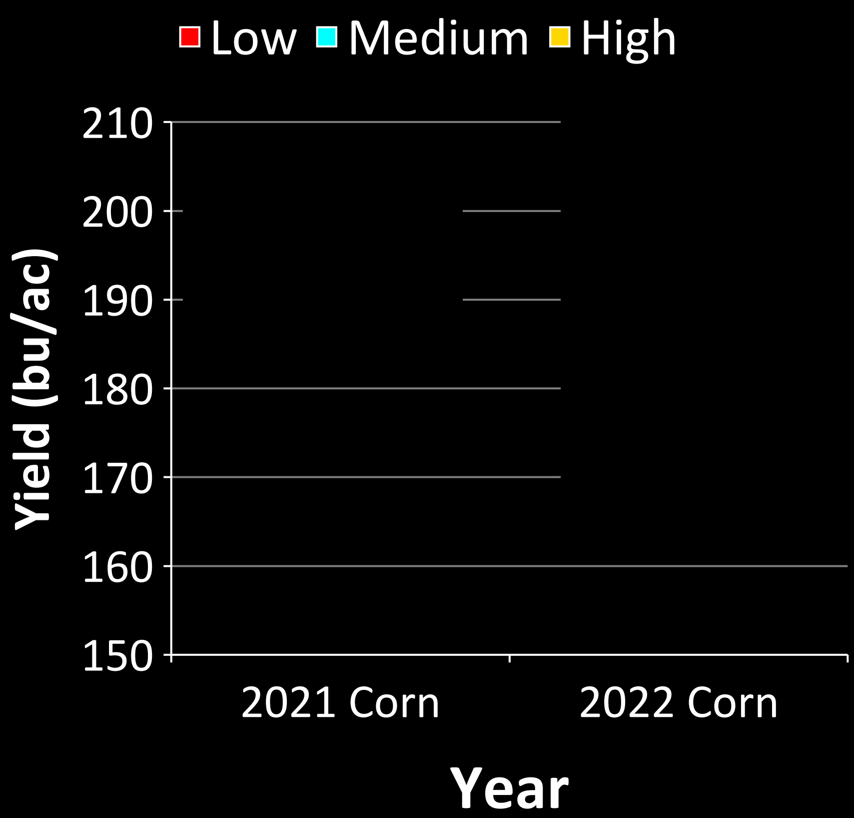
Soybean-wheat/cover crop-soybean-corn-corn

Establish and Maintained 3 soil test P levels:

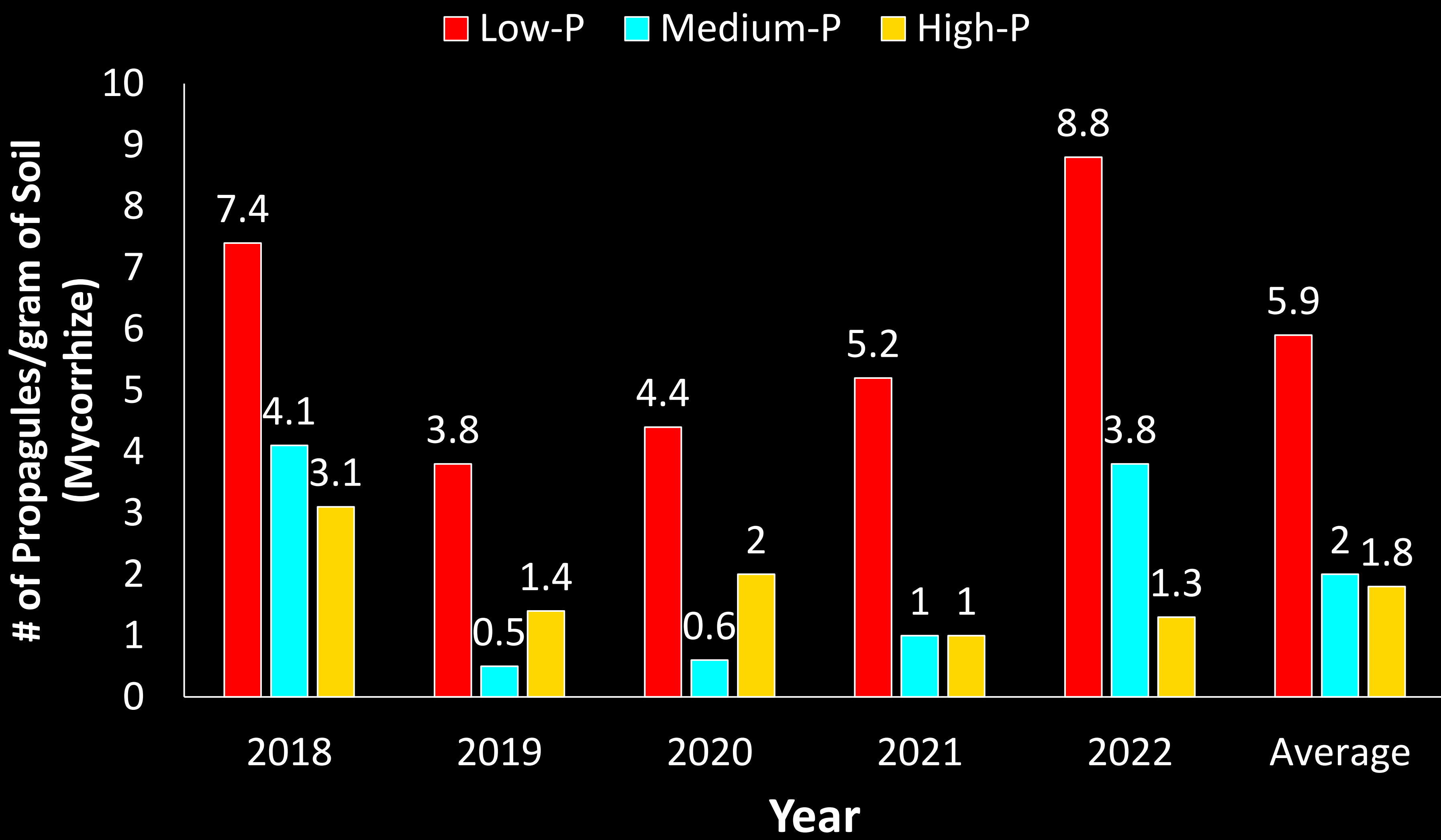
- Low
    - 70% chance of response to P
    - Fertilizer recommended
- Medium
    - 50% chance of response to P
    - Fertilizer recommended
- Very high
    - <20% chance of response to P
    - No fertilizer recommended

Minimal yield response in different P levels





Mycorrhizae may be reason for no difference in P response



P Conclusions

- Long-term no-till with diverse rotation have potential to:
    - Increase AMF fungi
    - Reduce soil test P levels without yield reduction
    - Increase economics due to lower P fertilizers needed

P recommendations across South Dakota

Use soil test data to estimate fertilizer rate

20000

SOIL TEST REPORT

Soil Testing Laboratory - Box 2207A - South Dakota State University - Brookings, SD 57007-1096 - ph. 605/688-4766 - fax 605/688-4667

Submitted by: Ima Gardener
12345 200th St
Anywhere SD 57000

Date Sampled: 7/27/2005
Date Received: 7/29/2005
Date Reported: 8/2/2005

INTERPRETATION OF SOIL TEST LEVELS

Alkaline		Satis-factory	SS				K	HIGH
			SS				K	
			SS				K	
			SS			P	K	
Satis-factory		Possible Problem	SS			P	K	MEDIUM
			SS			P	K	
			SS	OM		P	K	
	pH		SS	OM	NO3	P	K	
Acid	pH	Poor	SS	OM	NO3	P	K	LOW
	pH		SS	OM	NO3	P	K	
	pH		SS	OM	NO3	P	K	
	pH		SS	OM	NO3	P	K	

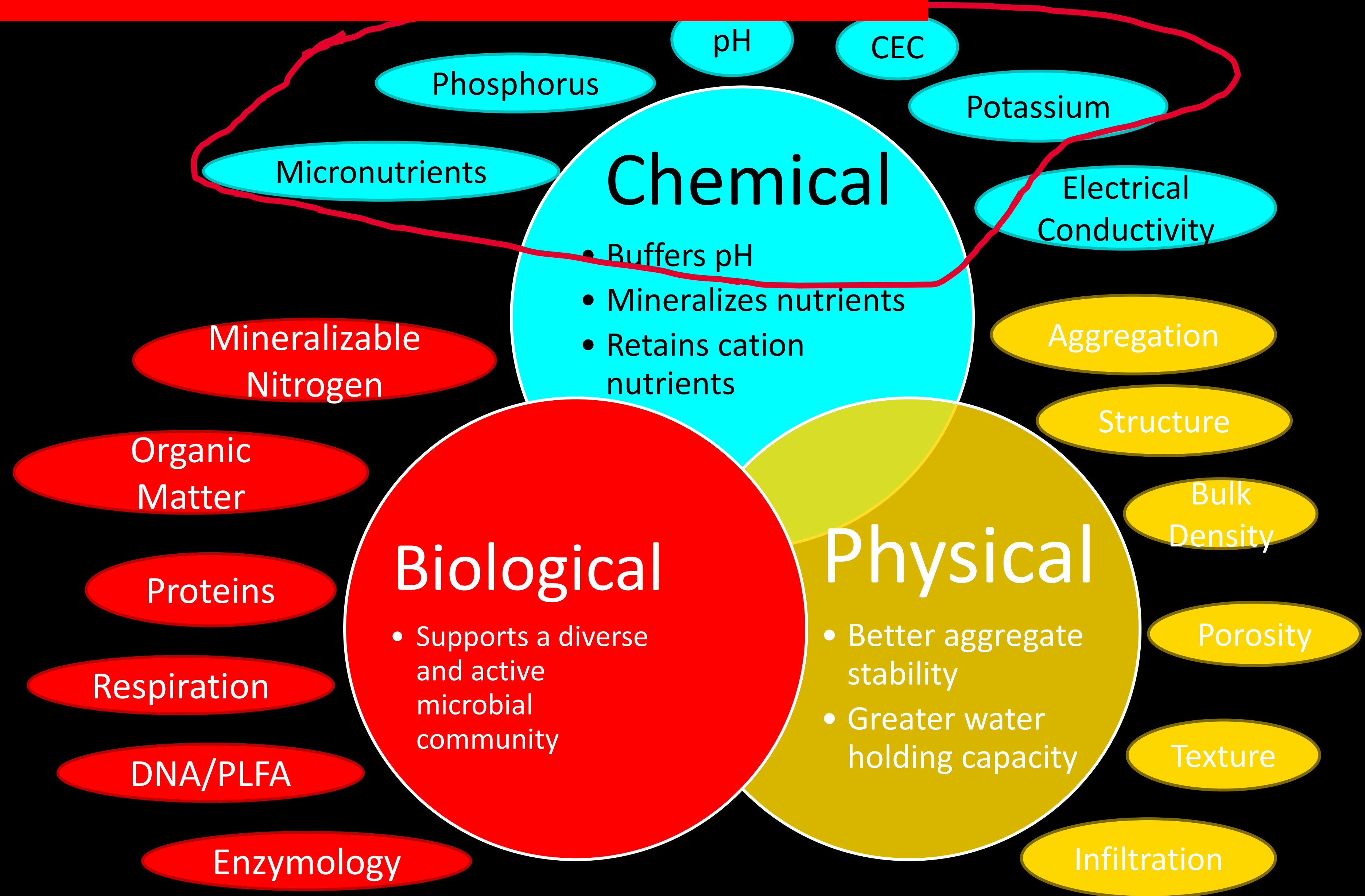
SOIL TEST RESULTS

Sample or Field ID	Texture Class	pH	Buffer pH	Soluble Salts mmho /cm	Sod-ium me/l	O.M. %	Nitrogen NO3-N lbs/A	P Olsen ppm	P Bray ppm	K ppm	Sulfur SO4-S lbs/A	Zn ppm	Fe ppm	Mn ppm	Cu ppm	Ca ppm	Mg ppm	Chlo-ride lbs/A	B pp
Garden	**Medium**	**6.5**		**0.5**		**3.2**	**60**	**12**		**250**									
Depth 1: 0" - 6"							**60**												

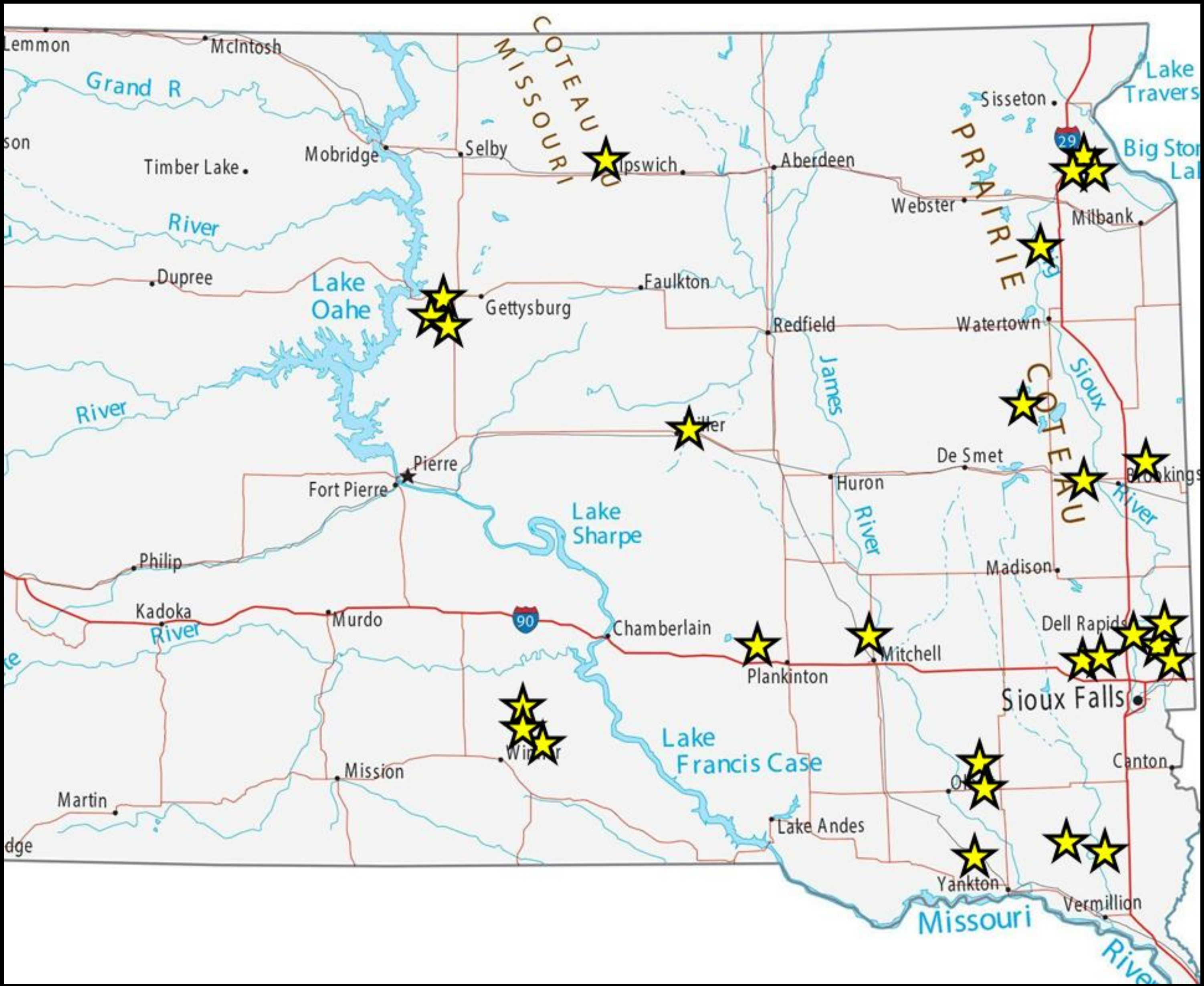
RECOMMENDATIONS (lbs/1000 sq. ft)

		N	P2O5	K2O	S	Zn	Fe	Mn	Cu	Ca	Mg	Cl	B
1st choice	**Garden**	**1.7**	**0.8**	**0**									
2nd choice													

What additional tests can improve our fertilizer use decisions?

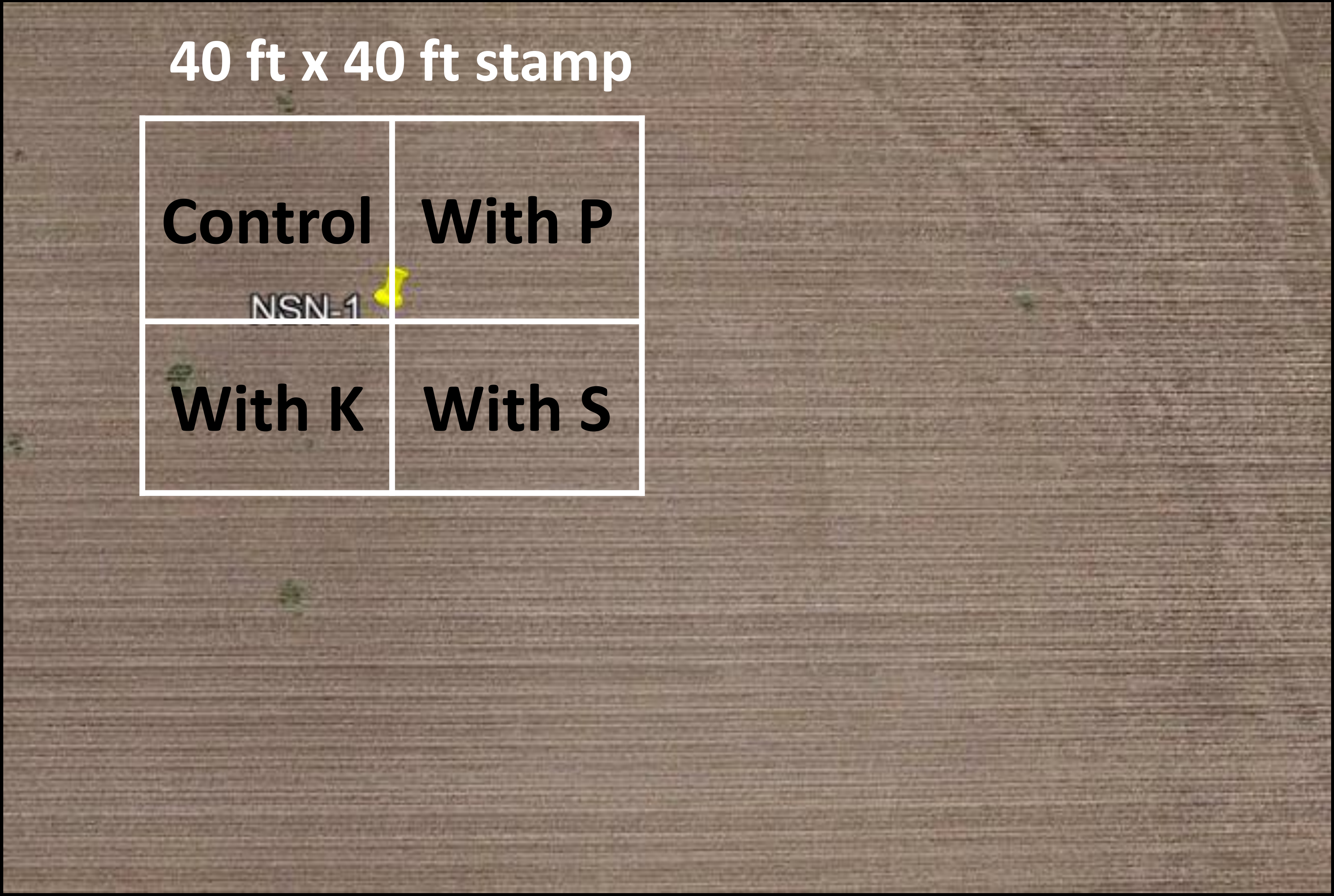


28 locations across 3 growing seasons



3-5 “stamps” within a field

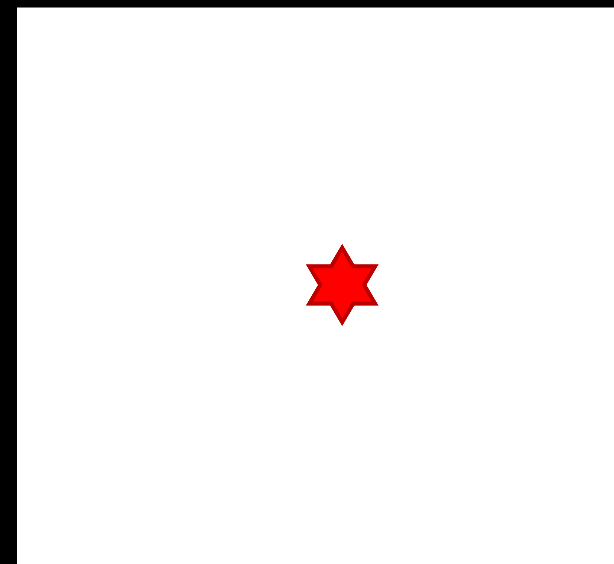
P, K, and S treatments within a stamp



Comprehensive Sampling/Measurement Monitoring Sites

- Soil Profile (4 ft):
  - Texture
  - Organic matter/SOC
  - Subsoil P and K
  - Bulk Density

40 ft x 40 ft stamp

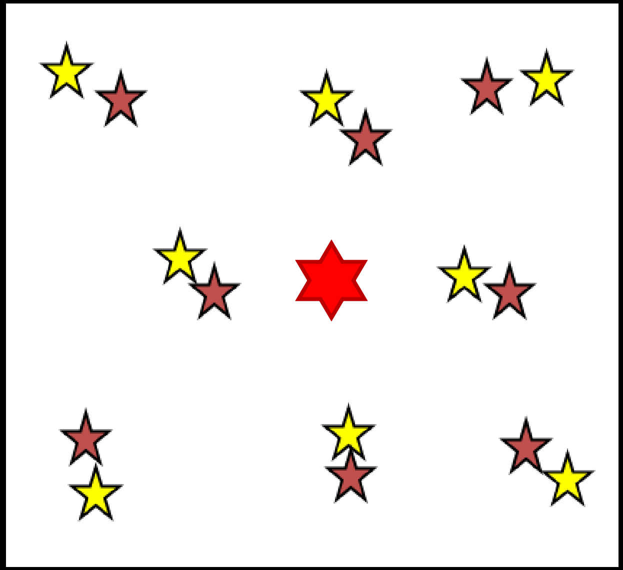


Soil profile cores

Comprehensive Sampling/Measurement Monitoring Sites

- Soil Fertility:
  - extractable P
  - extractable K
  - pH
  - CEC
  - paste EC
- Soil Health:
  - β-glucosidase activity
  - soil respiration
  - total protein
  - active C
  - PLFA

40 ft x 40 ft stamp



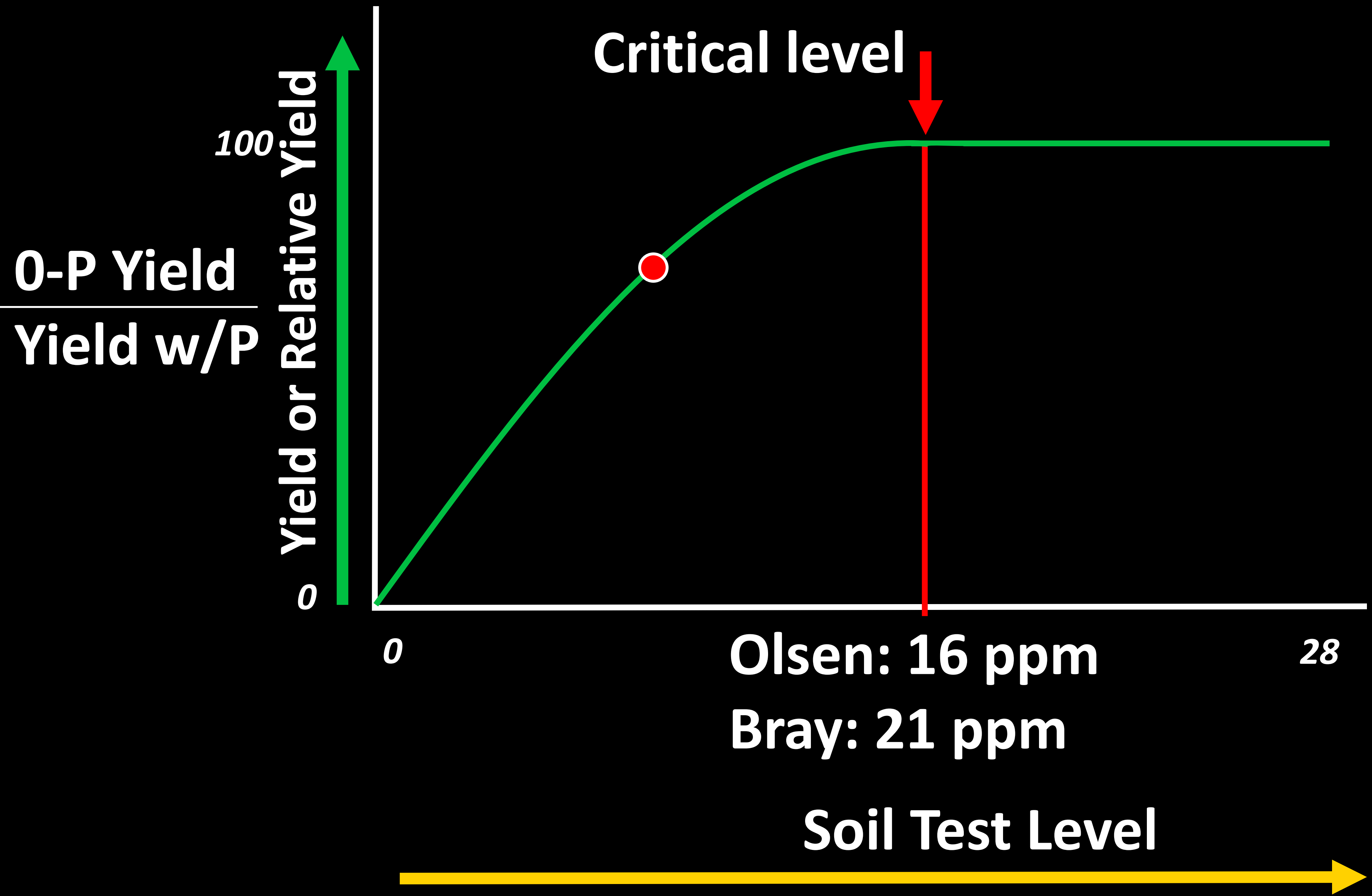
Collect 8 cores (each split into 0-2 and 2-6 inch sections) for the soil health sample.

Collect 8 cores (0-6") for the soil fertility sample.

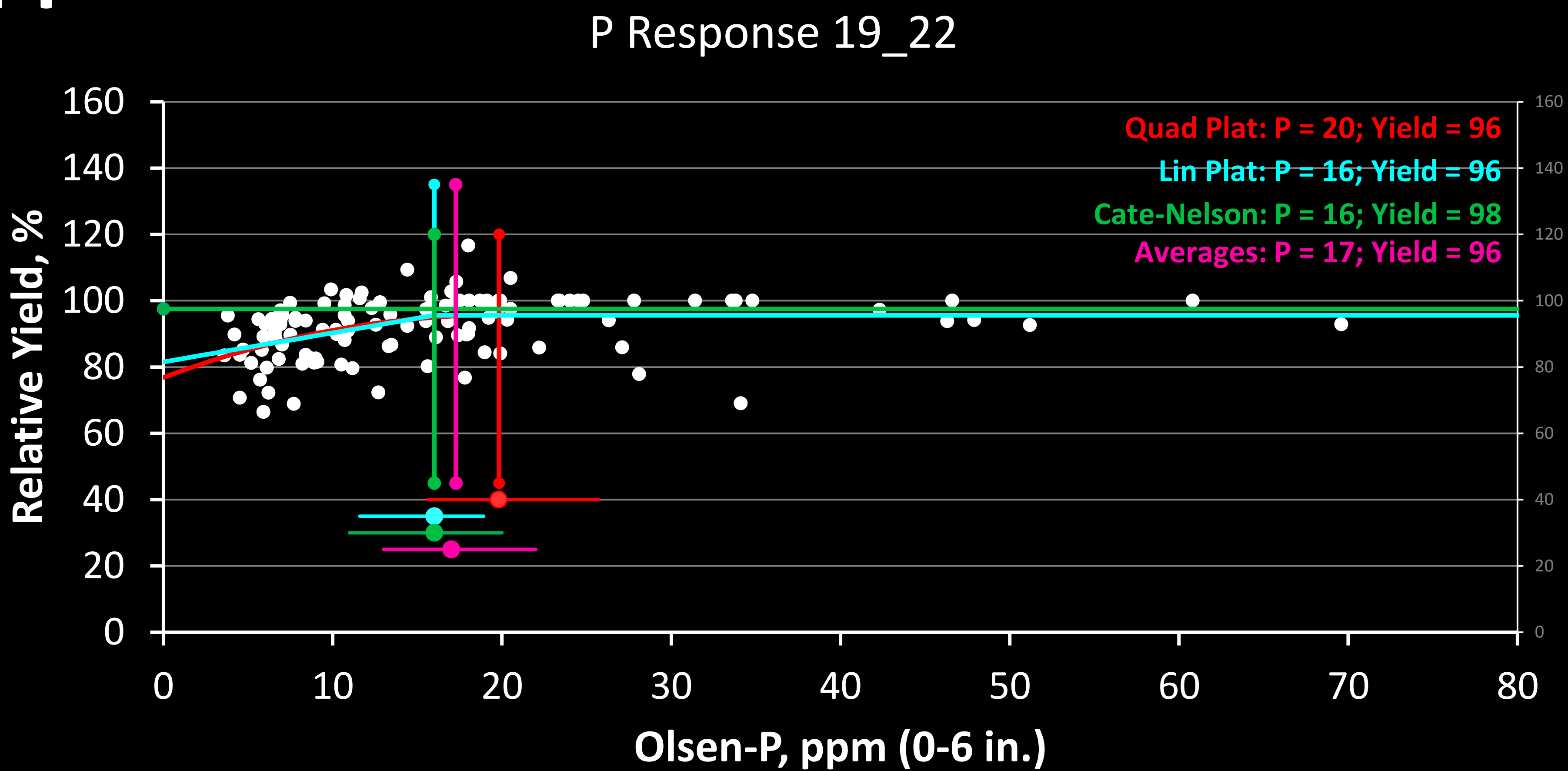
Soil profile cores

Evaluating critical soil test P alone

Phosphorus critical value:



Current P critical value is accurate: 16 ppm

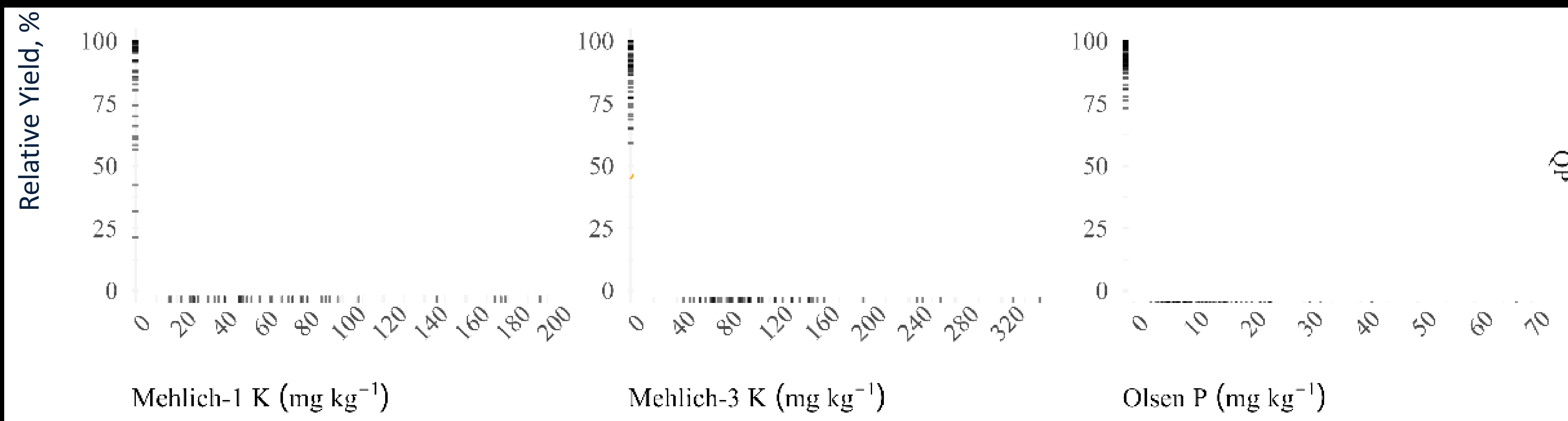


Data is different based on crop and area

K Soybean:
Virginia, Maryland, North Carolina

K Soybean:
Arkansas

P Corn:
Iowa, Minnesota, South Dakota



Critical Value: 57 ppm

Critical Value: 168 ppm

Critical Value: 16 ppm

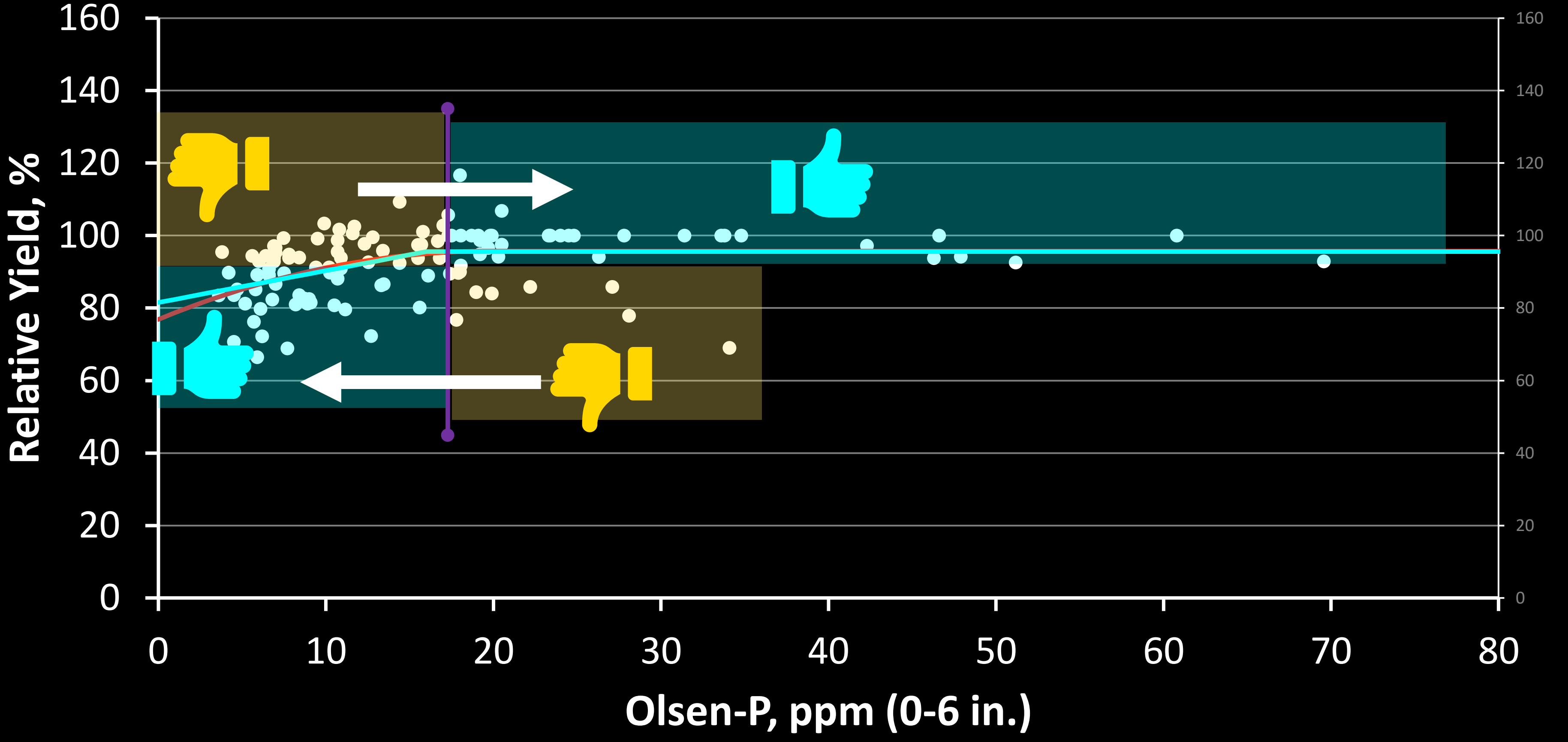
P Critical Value Summary

- Critical Value: **16-20 ppm**
- Confidence Range: **13-22 ppm**
- 5% or 5 bu/ac response: **16 ppm**

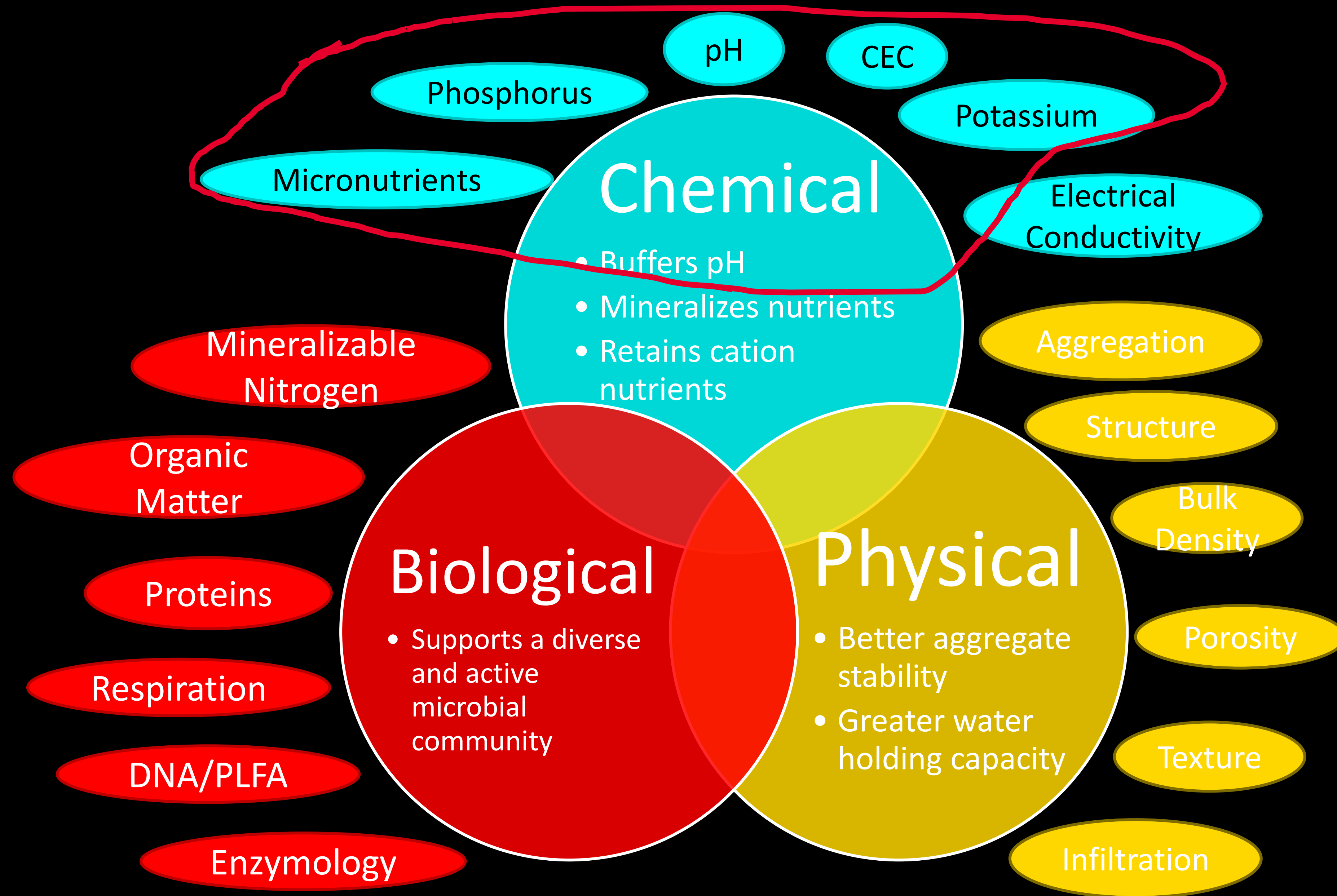
Can soil health measurement help improve accuracy?

Correctly predicted <u>68%</u> as responsive or non-responsive

Where is the error and how can we improve?

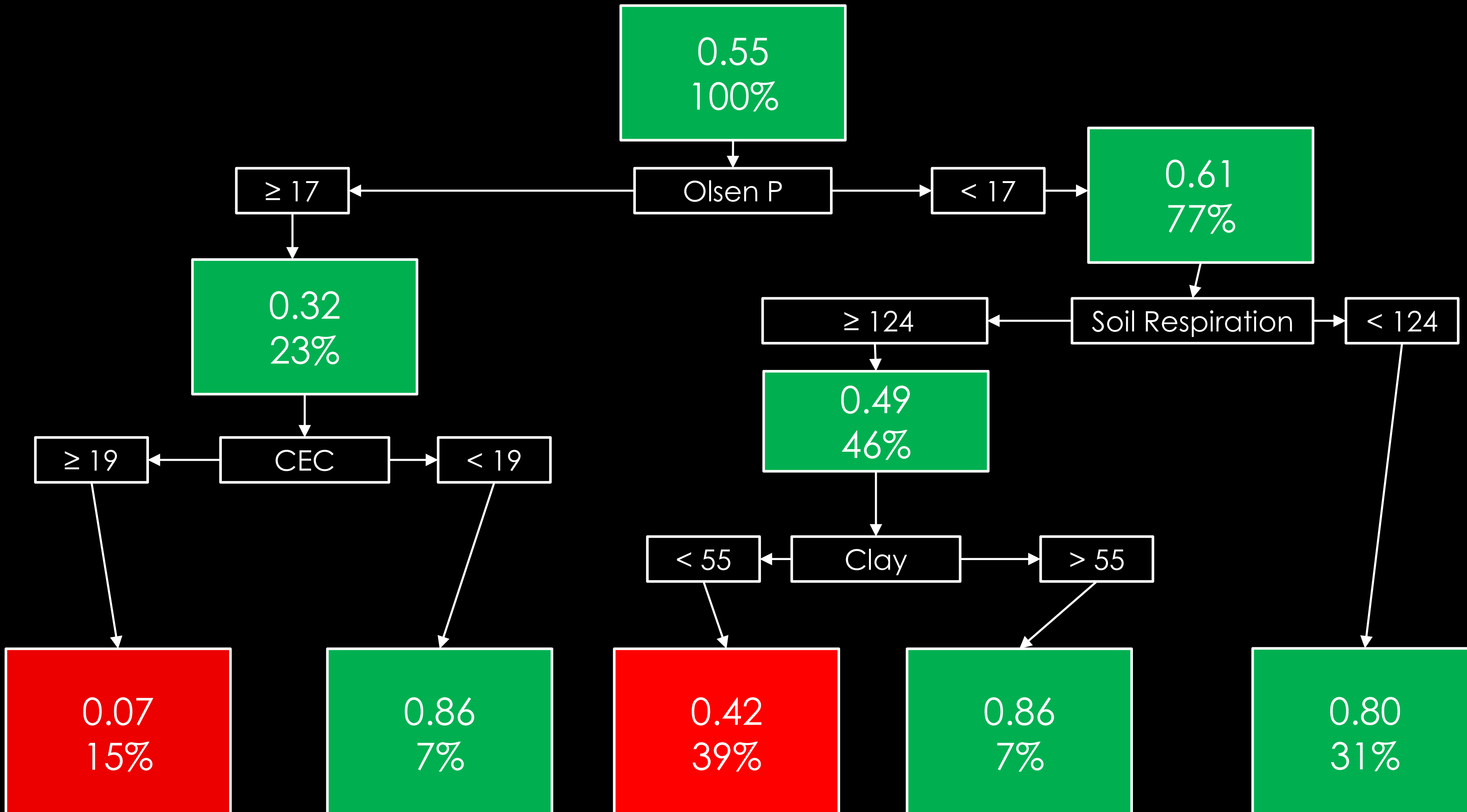


Phosphorus & Potassium



What variables improved P recommendations?

- Olsen P
- Soil respiration
- CEC
- Clay


0.55
100%
Olsen P
≥ 17
< 17
0.32
23%
0.61
77%
CEC
≥ 19
< 19
Soil Respiration
≥ 124
< 124
0.49
46%
Clay
< 55
> 55
0.07
15%
0.86
7%
0.42
39%
0.86
7%
0.80
31%

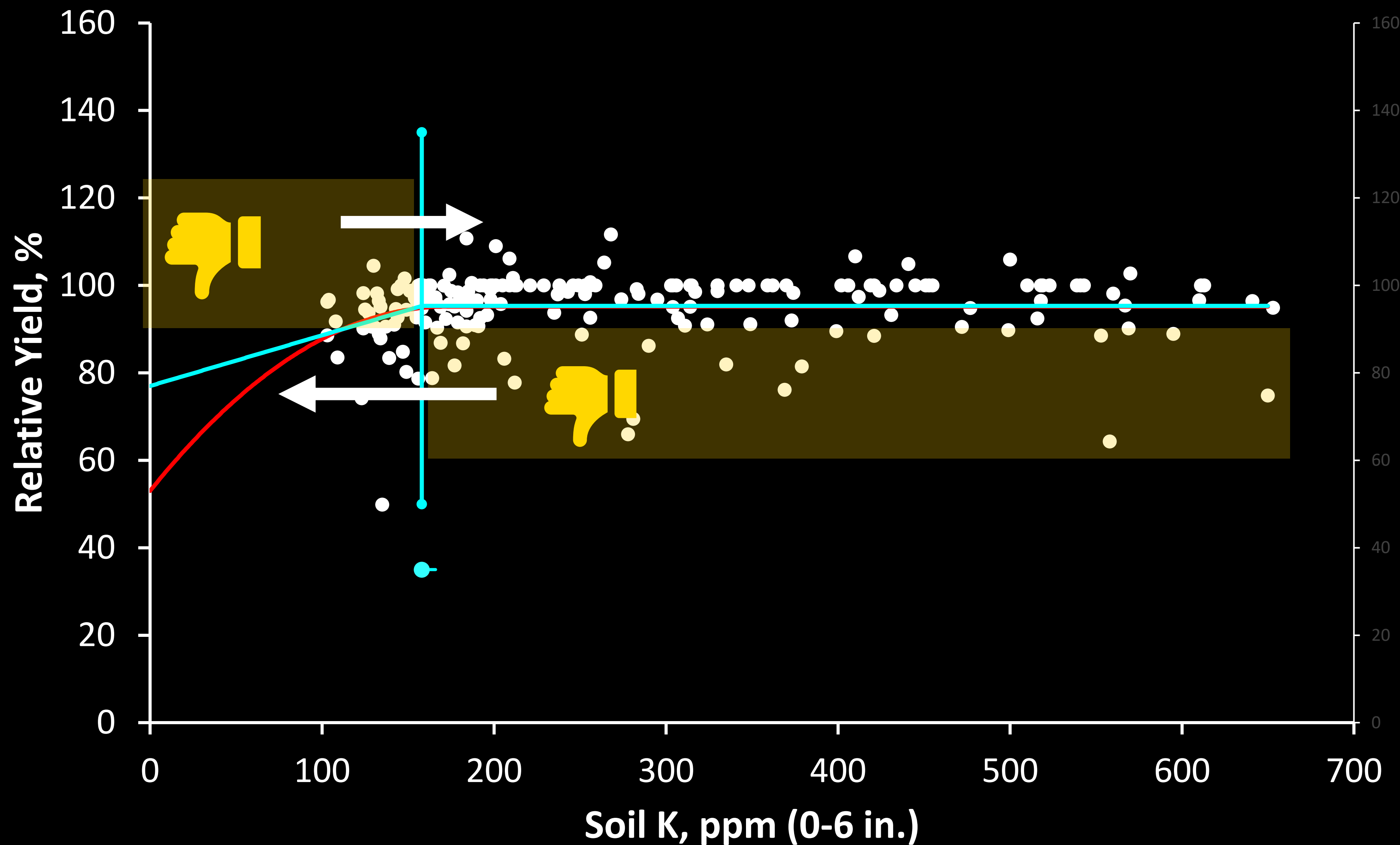
Answer:
What about adding soil health to the equation?

Accuracy of yield response prediction:

- Olsen P: **68%**
- Olsen P + soil respiration + CEC + Clay: **74%**

Potassium

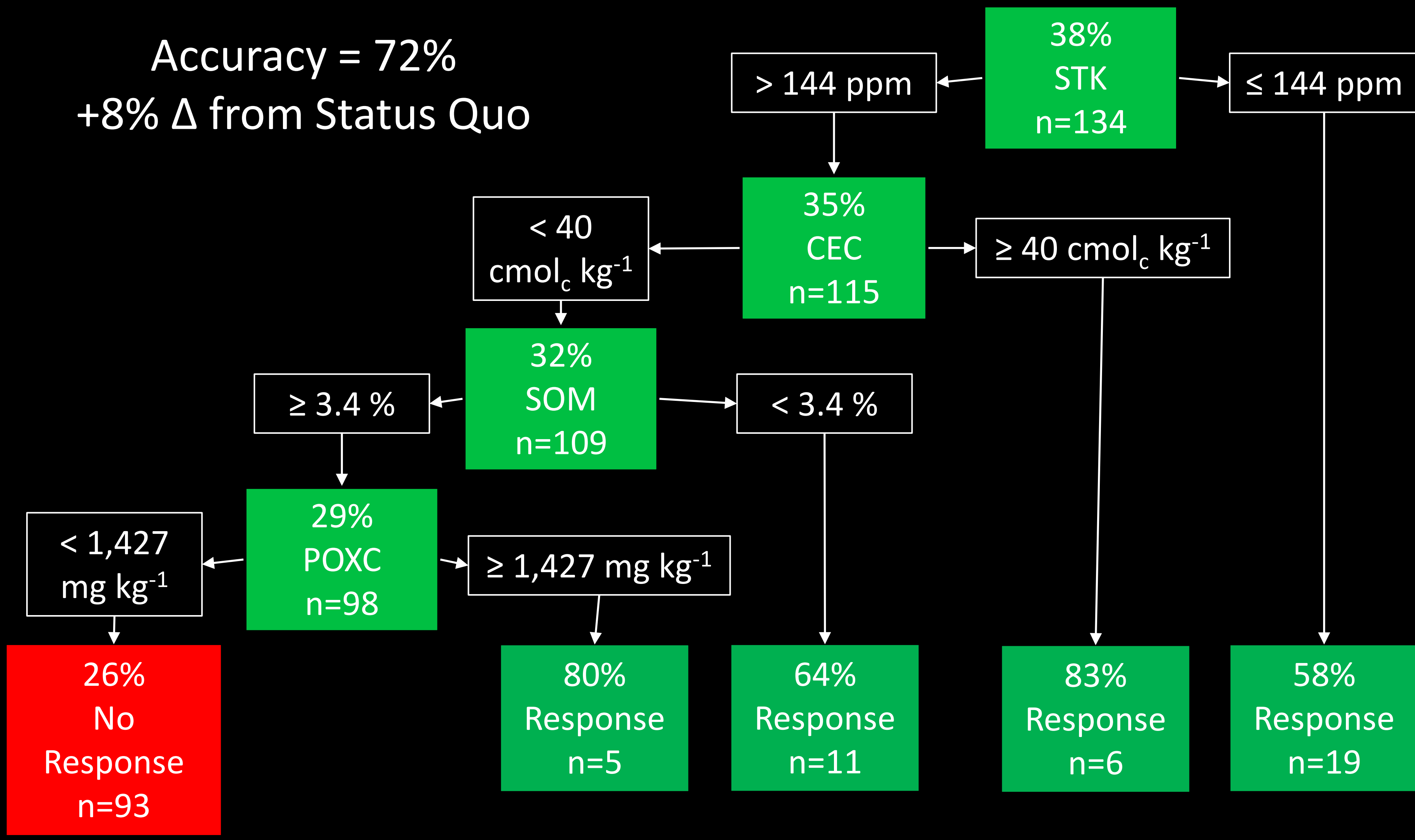
Critical K value: 144 ppm



What variables improved K recommendations?

- Ammonium acetate K
- CEC
- Soil organic matter (SOM
- Permanganate oxidizable C (POX-C)

Accuracy = 72%
+8% Δ from Status Quo



What about adding soil health to the equation?

Accuracy of yield response prediction:

- Soil test K: **64%**
- Soil test K + CEC + organic matter + POX-C: **72%**

Take Homes

<u>Diverse crop rotations and no-till</u>

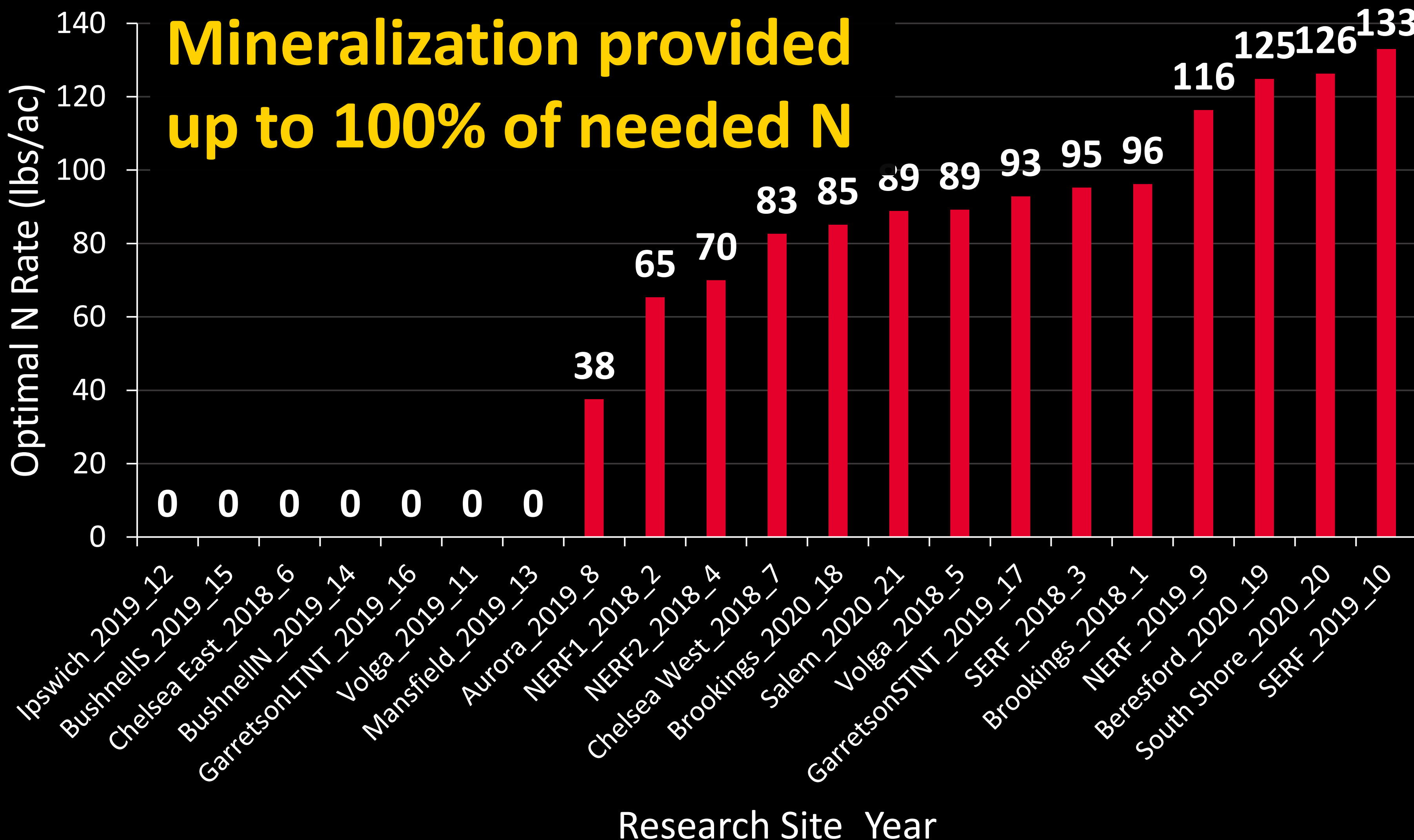
- Lower soil test P needs

<u>Phosphorus and Potassium Recommendations</u>

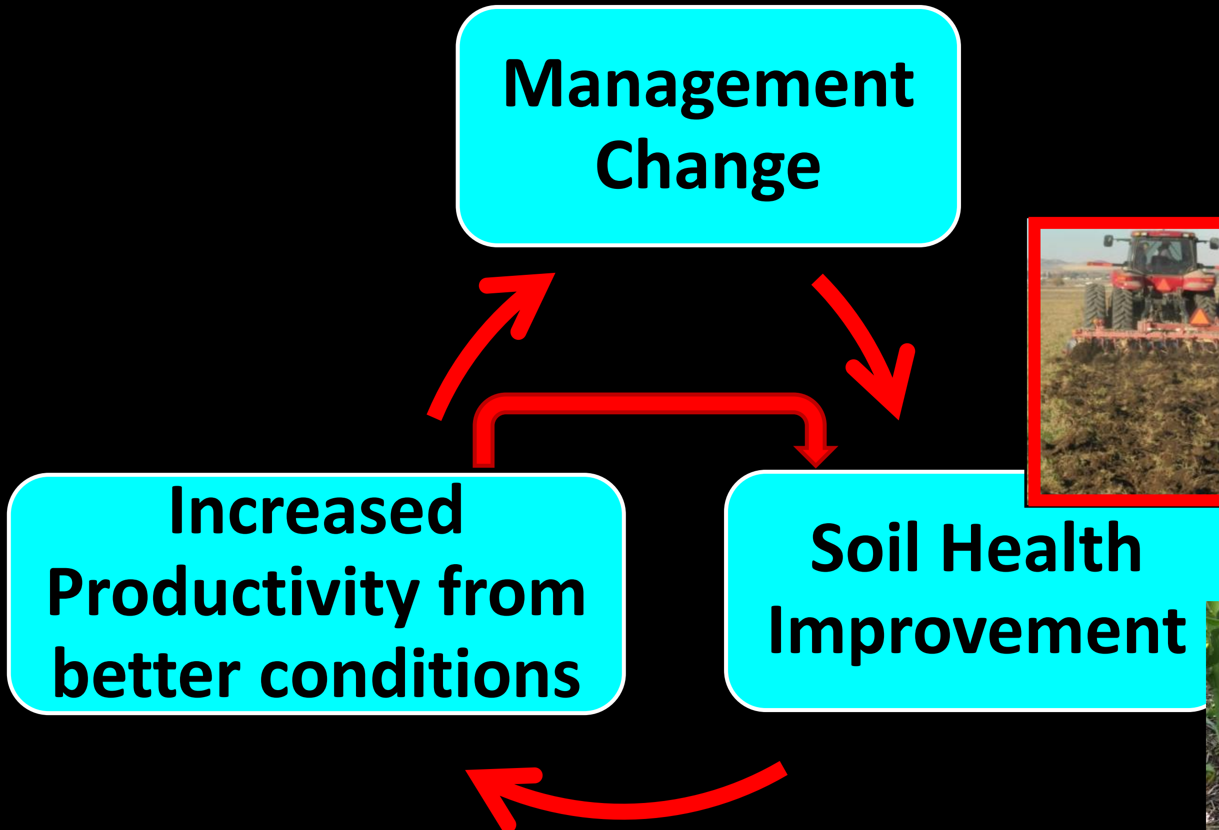
- Additional soil biological and physical measurements can help

Nitrogen

SD Optimal N fertilizer rate: 0 to 133 lbs/ac



Management change: Cover crops



Cover Crop Benefits

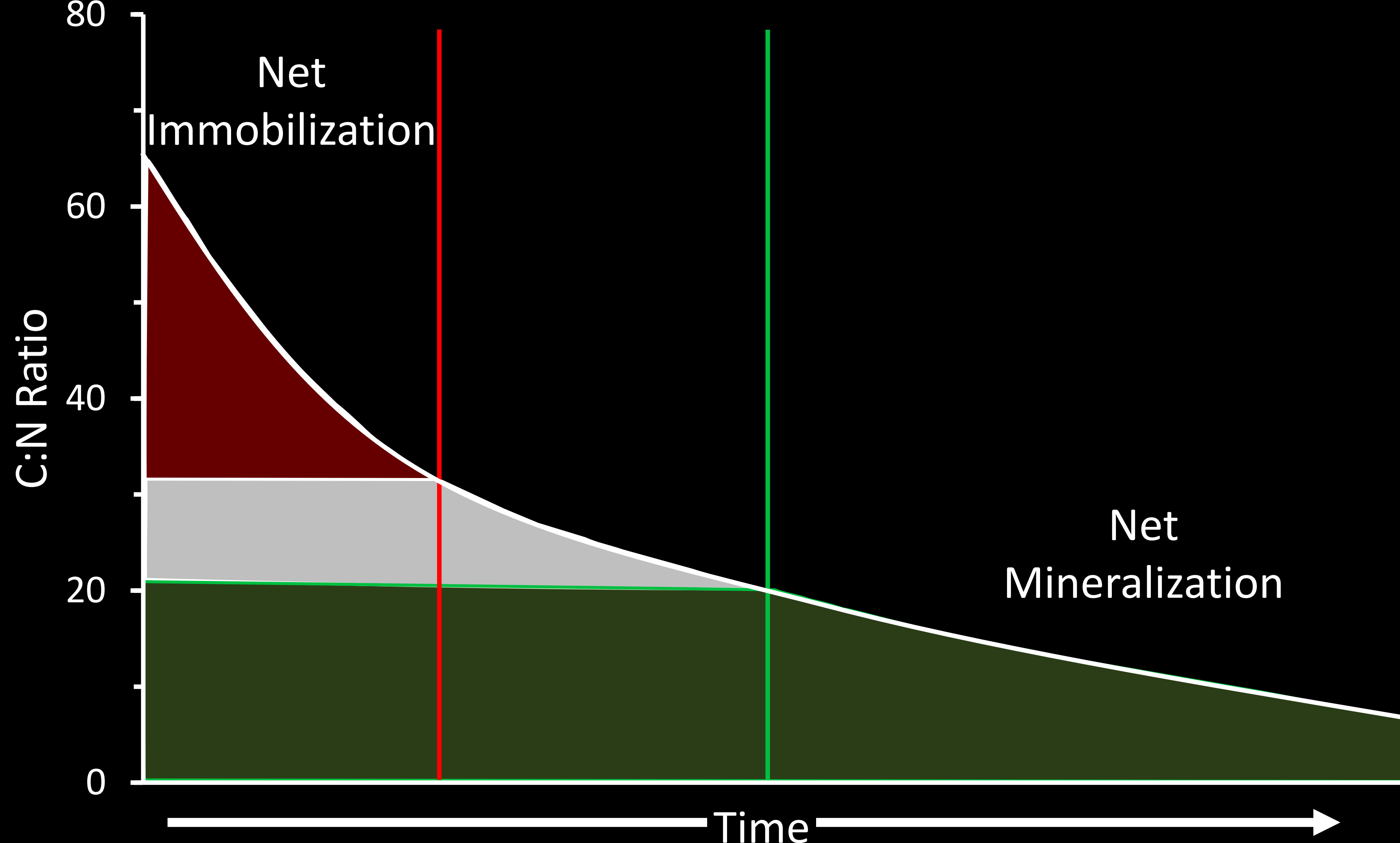
Benefits

- Increase Organic Matter
- Increase Water infiltration
- Reduce erosion

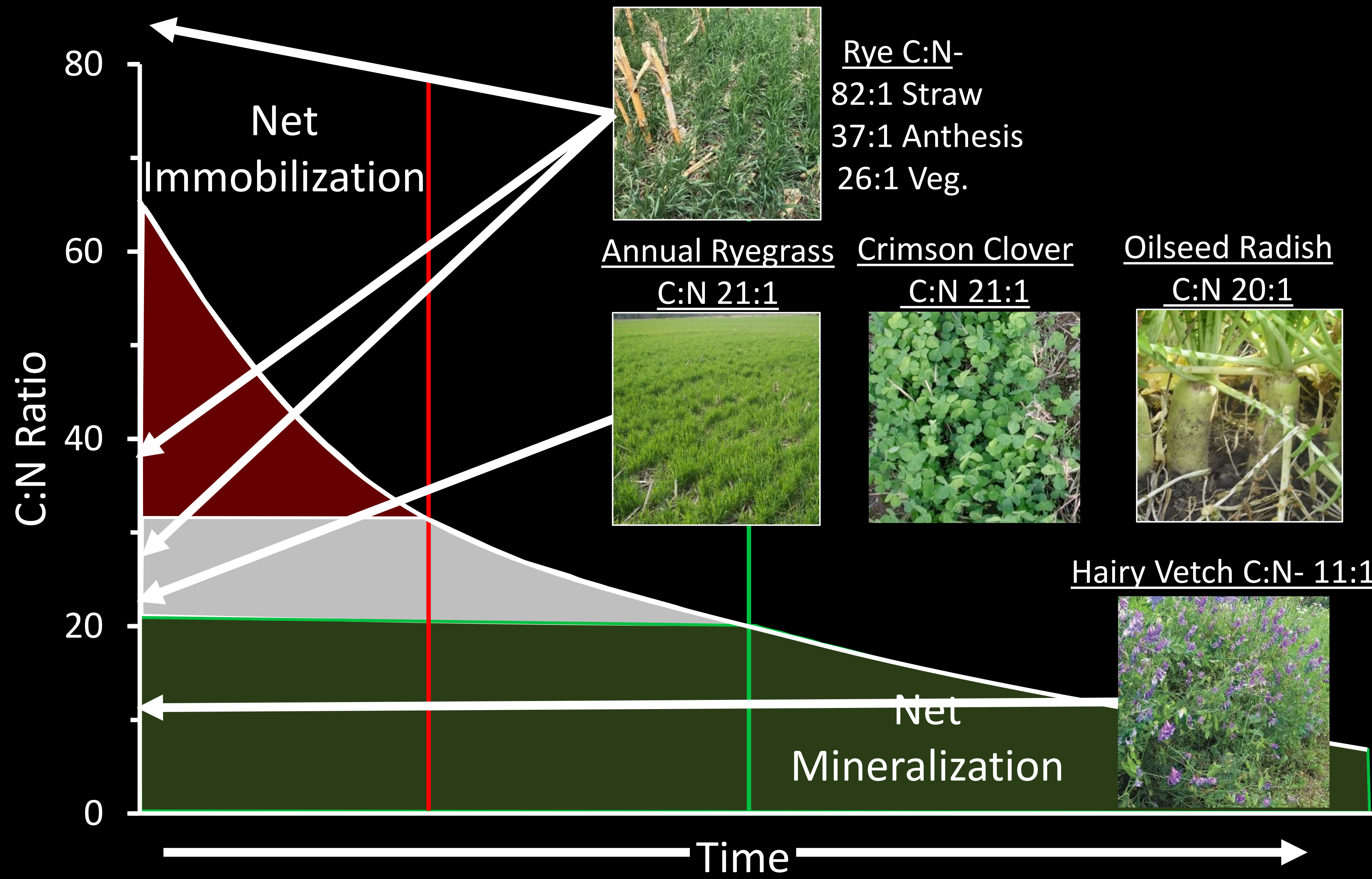
Questions

- How do cover crops influence:
  - N fertilizer requirement

Speed of decomposition depends on C:N ratio

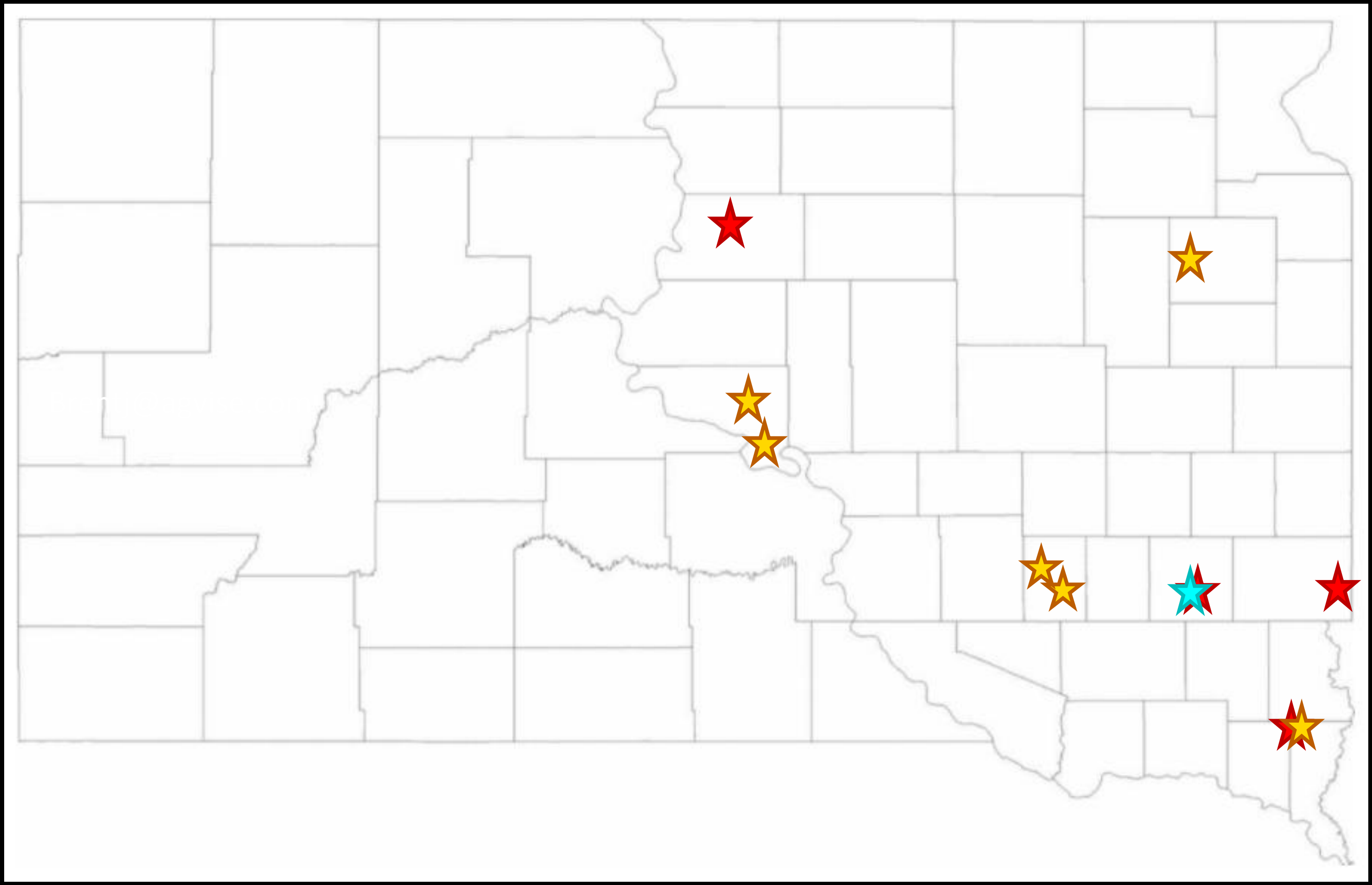


How do cover crops influence mineralization?



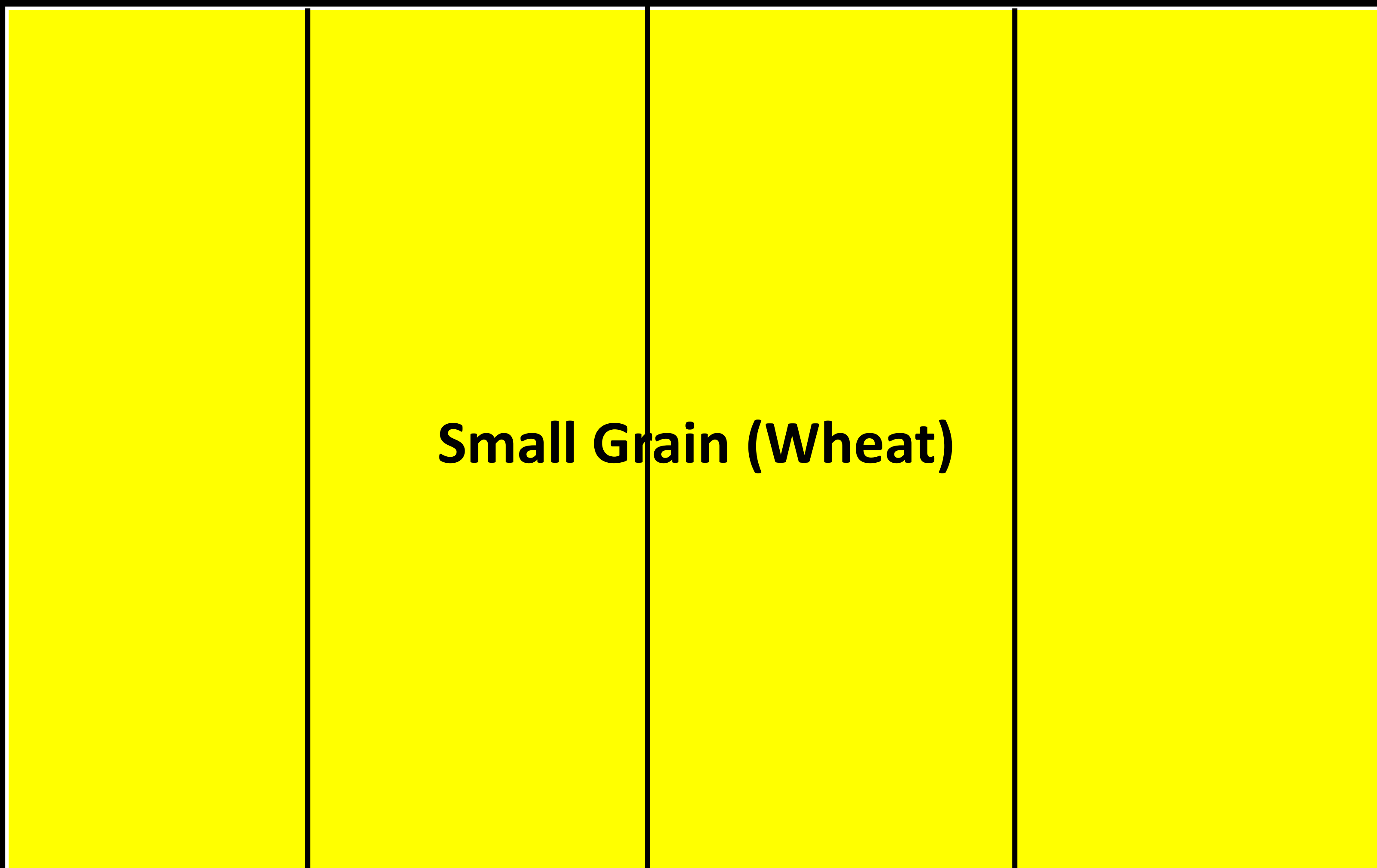
11 Site-Years

- 2018
  - Beresford
  - Salem
  - Garretson
  - Gettysburg
- 2019
  - Salem
- 2020
  - Pierre
  - Blunt
  - Beresford
  - Mitchell
  - Plankinton
  - Henry



Study Setup

Previous crop: Small grain



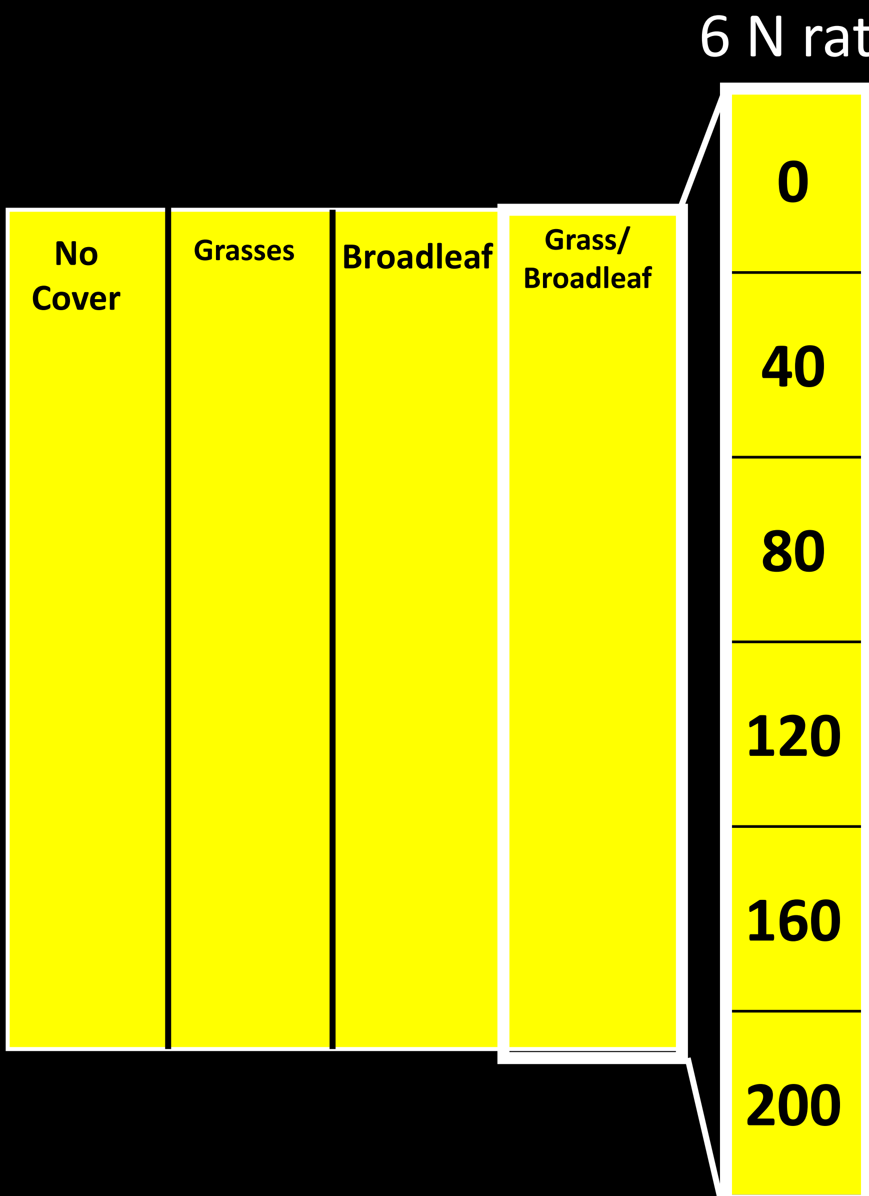
Study Setup

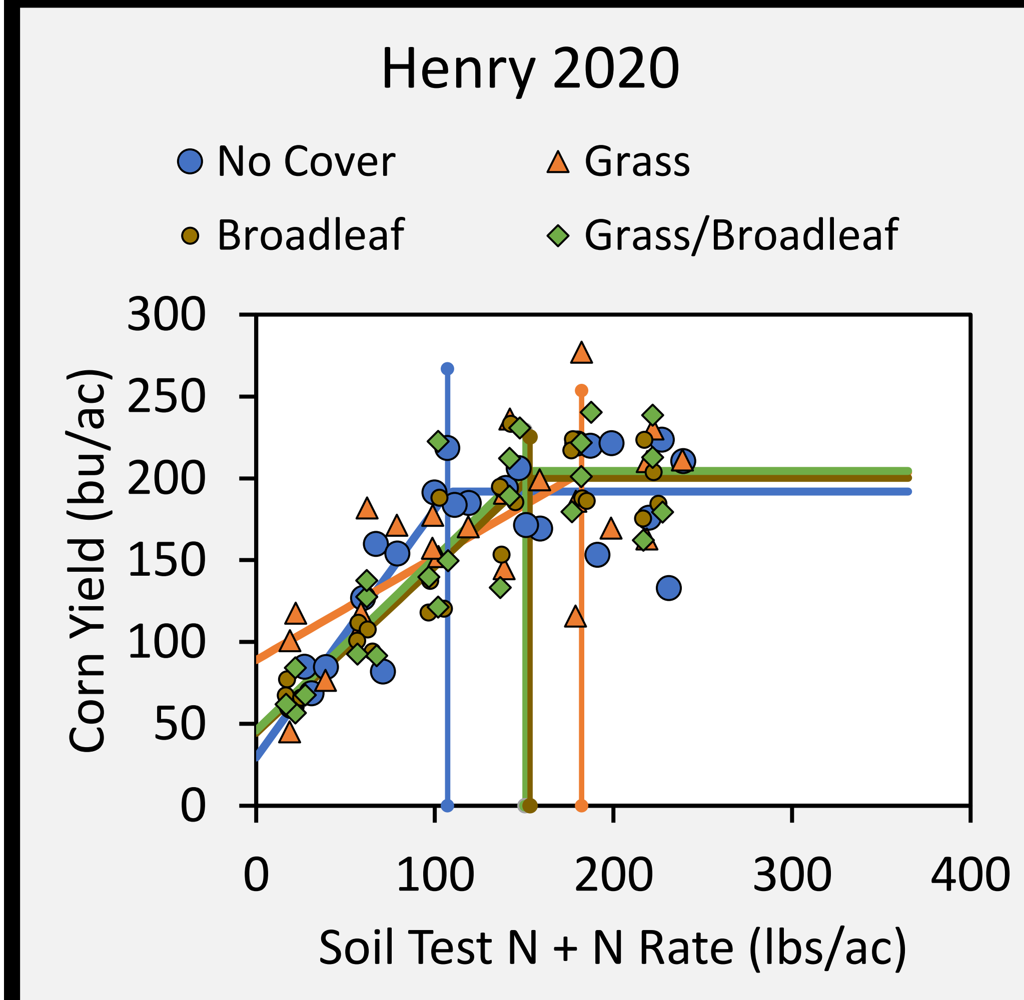
No cover crop + 3 Cover crops fall planted

No Cover	**Grasses**	**Broadleaf**	**Grass/ Broadleaf**
	• Barley • Foxtail millet • Sorghum sudan • oats	• Turnip • pea • lentil	• 50/50 mix

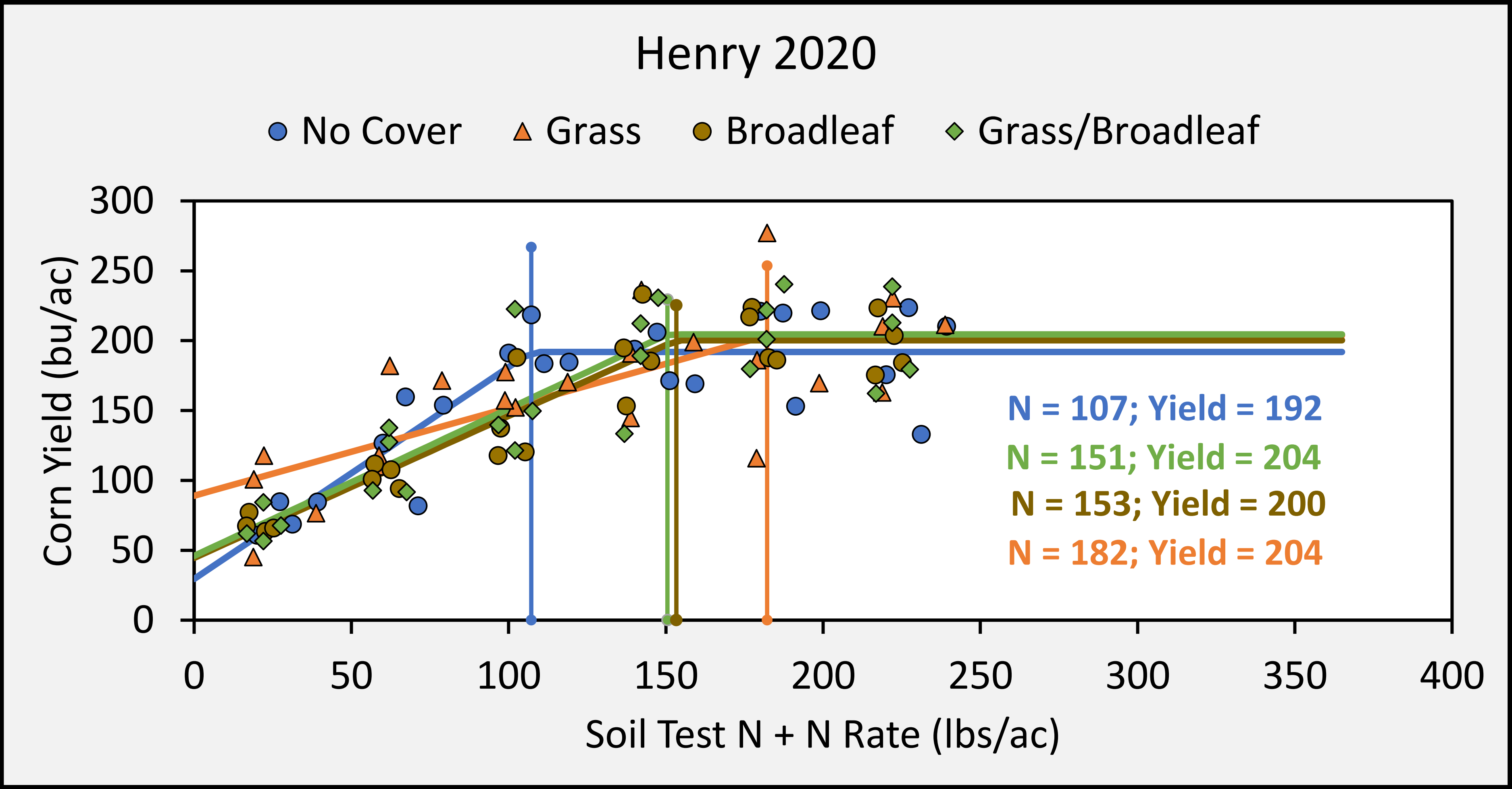
Small Grain (Wheat)

Study Setup

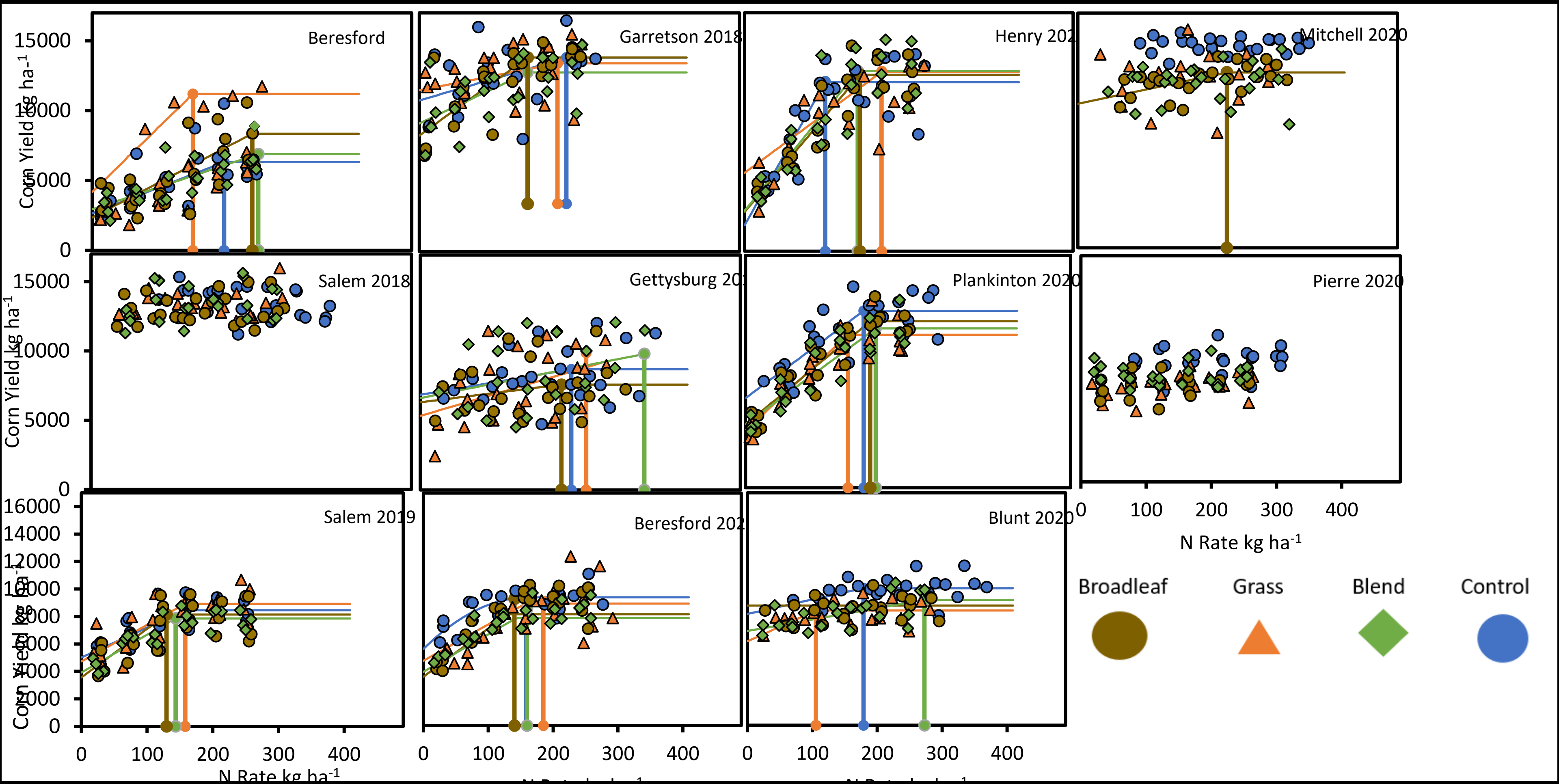

6 N rates
No Cover
Grasses
Broadleaf
Grass/ Broadleaf
0
40
80
120
160
200


Henry 2020
No Cover
Grass
Broadleaf
Grass/Broadleaf
Corn Yield (bu/ac)
300
250
200
150
100
50
0
0
100
200
300
400
Soil Test N + N Rate (lbs/ac)

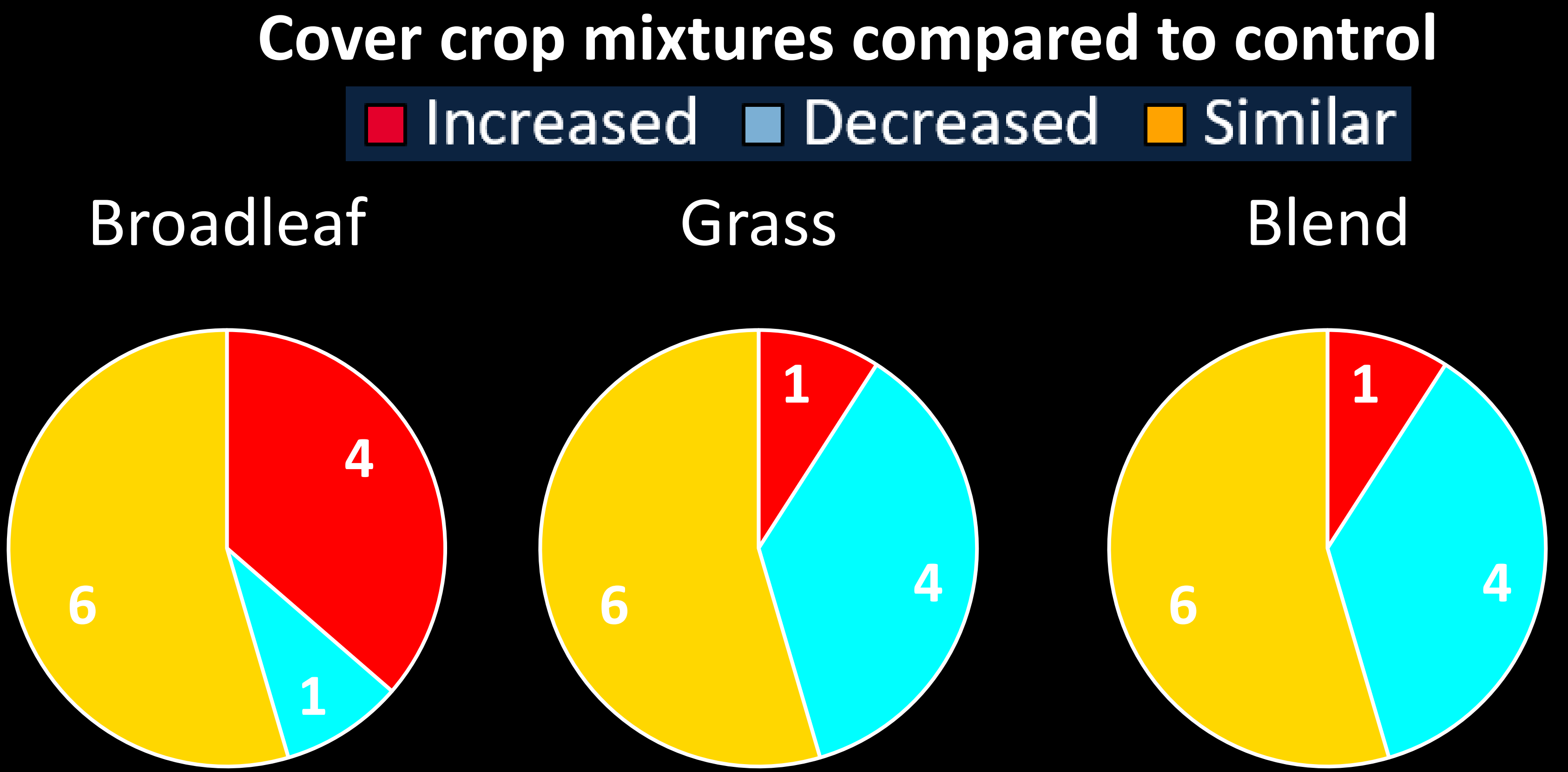
Cover crops: Yield and corn N requirement



Cover crop influence on N needs was variable…



Yield at EONR: Generally similar (within 16 bu/ac)

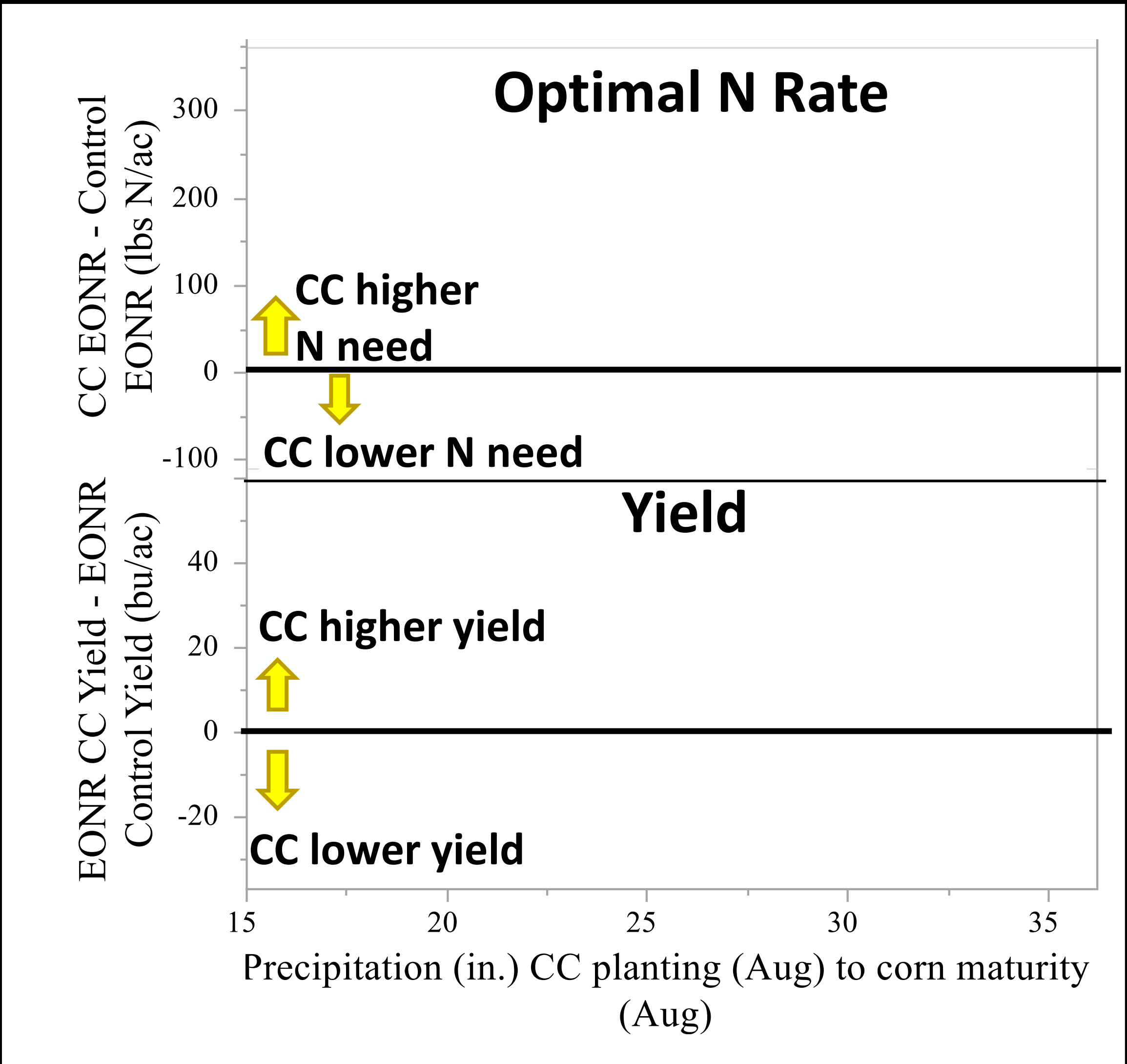


Trend	Mean Yield, bu/ac
Increased	+ 42
Decreased	- 44
Similar	± 8

Why the variability?

Likely answer: Rain and cover crop biomass

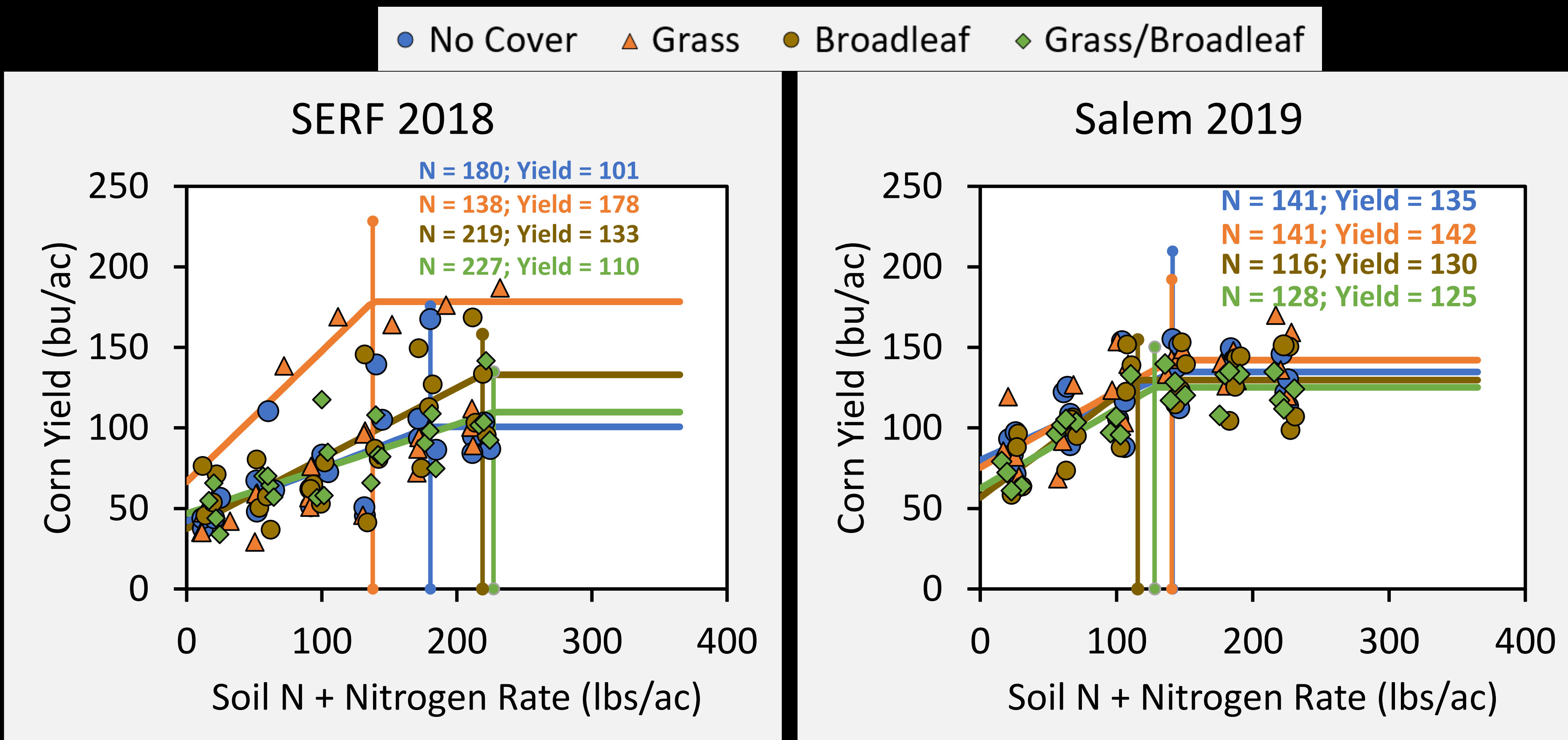
As precipitation increased, less differences in yield and needed nitrogen for corn growth occurred when cover crops planted



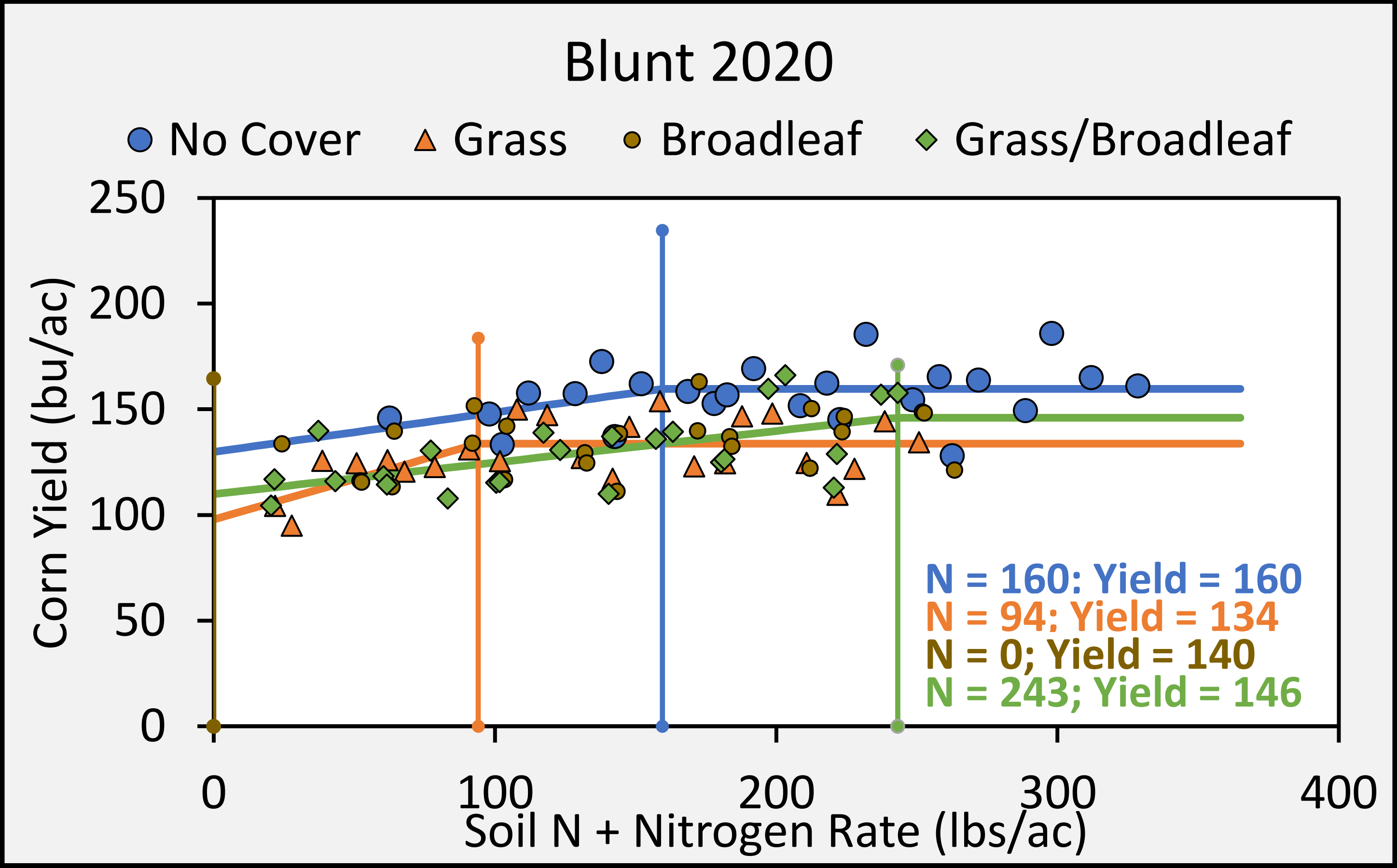
Notes:

0 means cover crop and no cover crop had same N need or yield

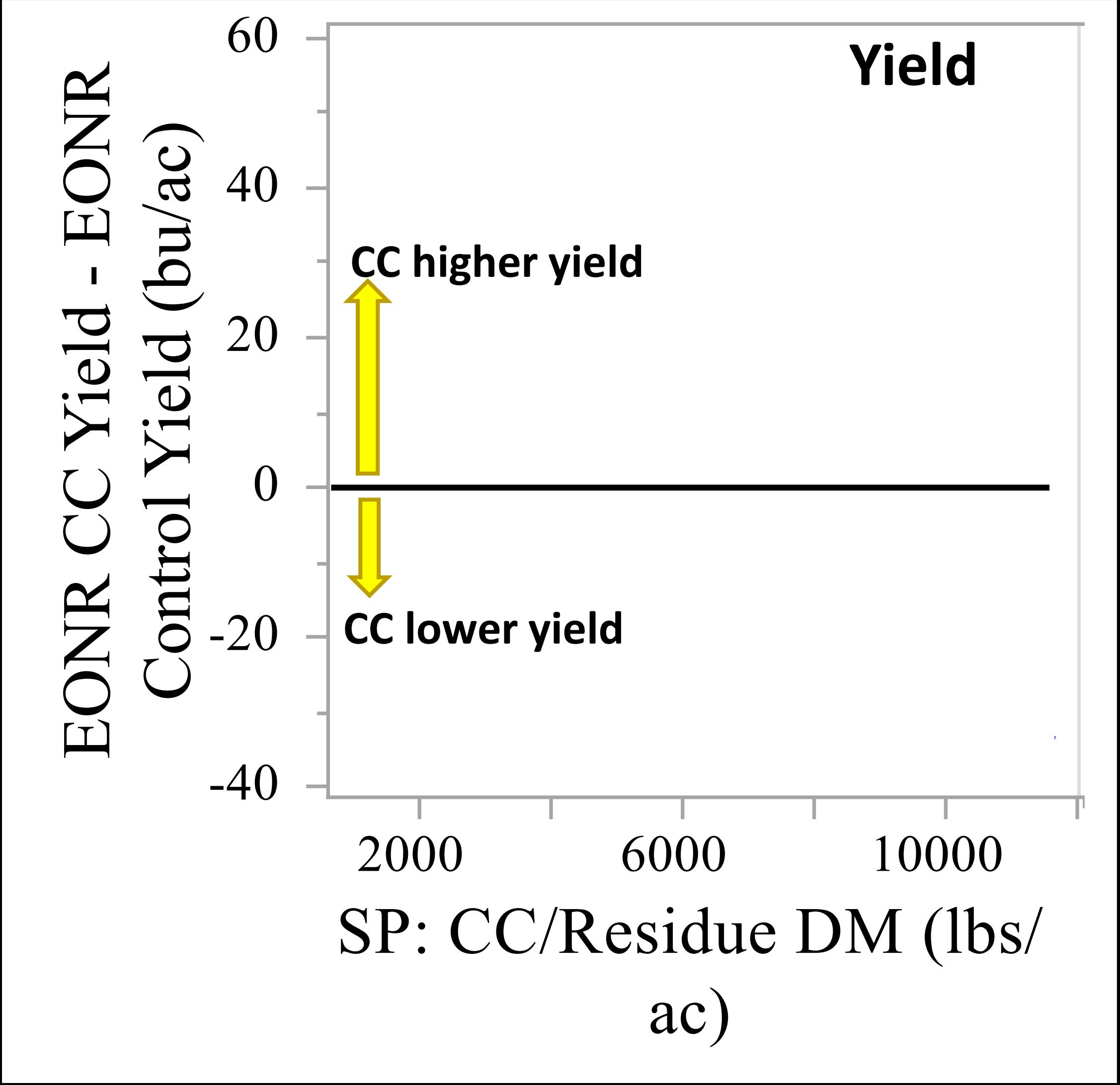
Wetter site-years



Dry site-year



As cover crop biomass increased, more differences in yield and needed nitrogen for corn growth occurred when cover crops planted



Notes:

0 means cover crop and no cover crop had same N need or yield

Another reason why cover crops were variable

Location: Kentucky

Cropping System: Continuous corn

Comparing:

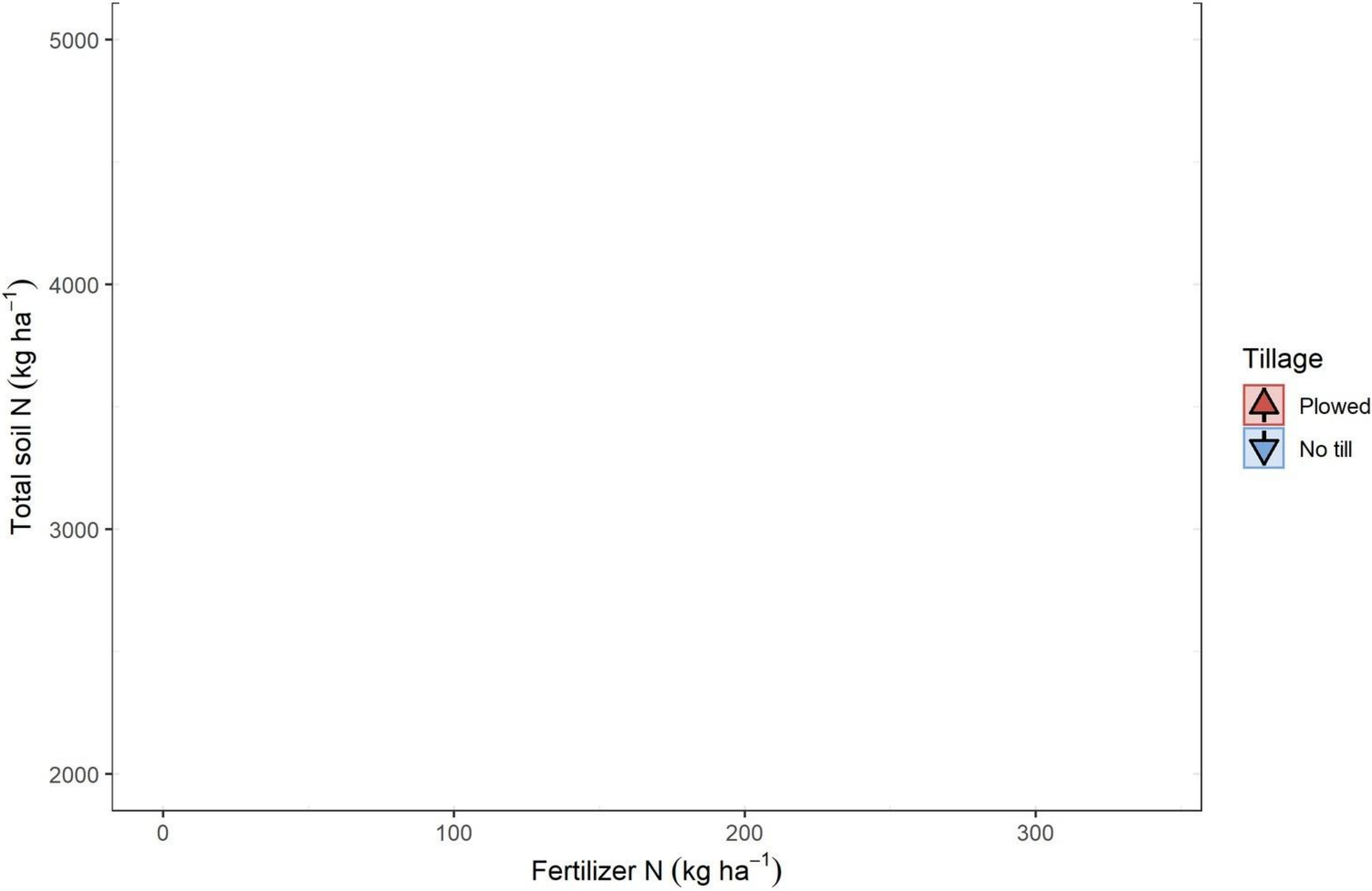
Till

No-till

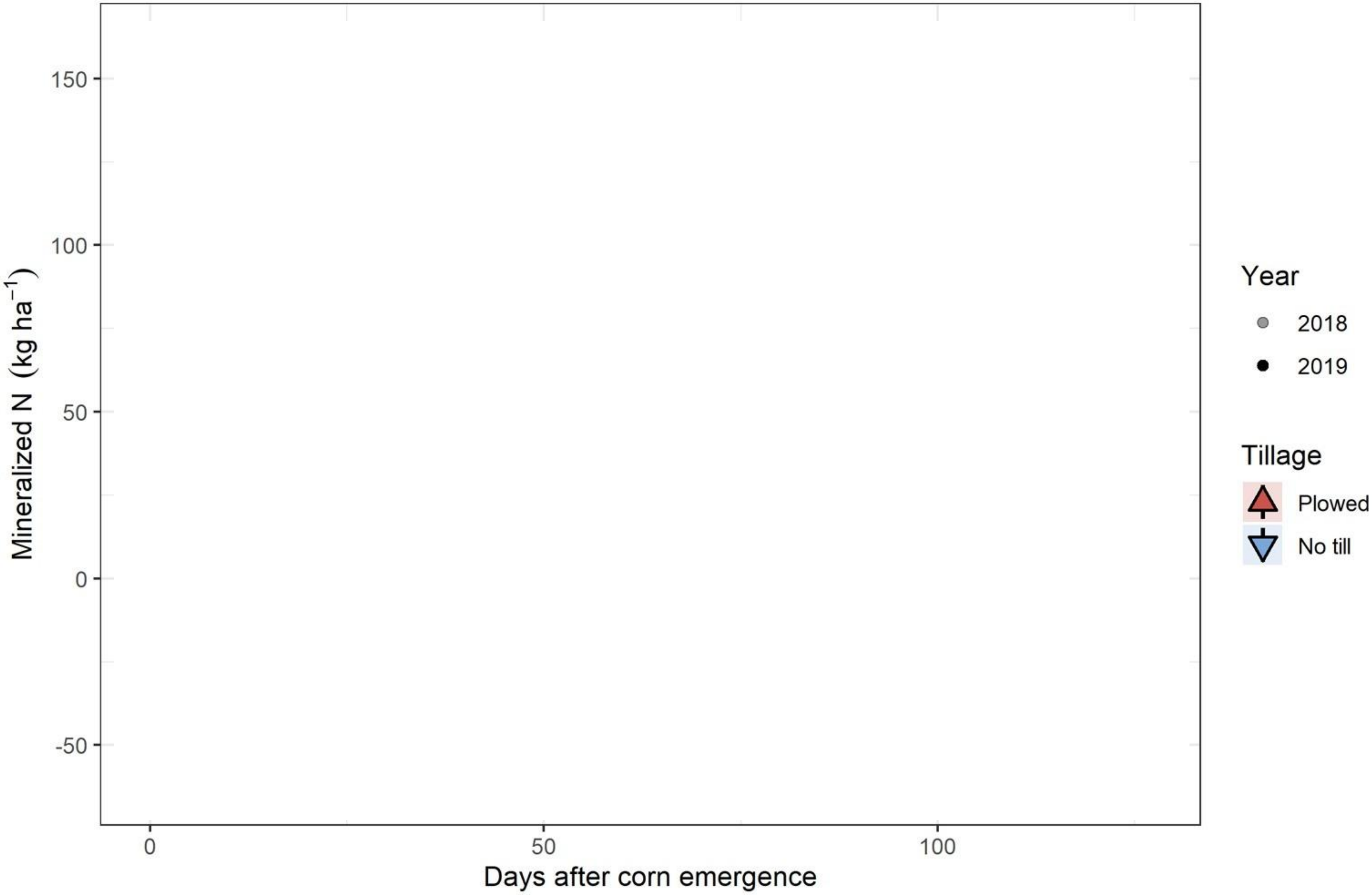
Measuring:

- Total N
- Mineralizable N (N coming from decomposition)
- N needed to optimize yield
- Yield

No-till increased total nitrogen in soil



No-till increased nitrogen released to soil from decomposition



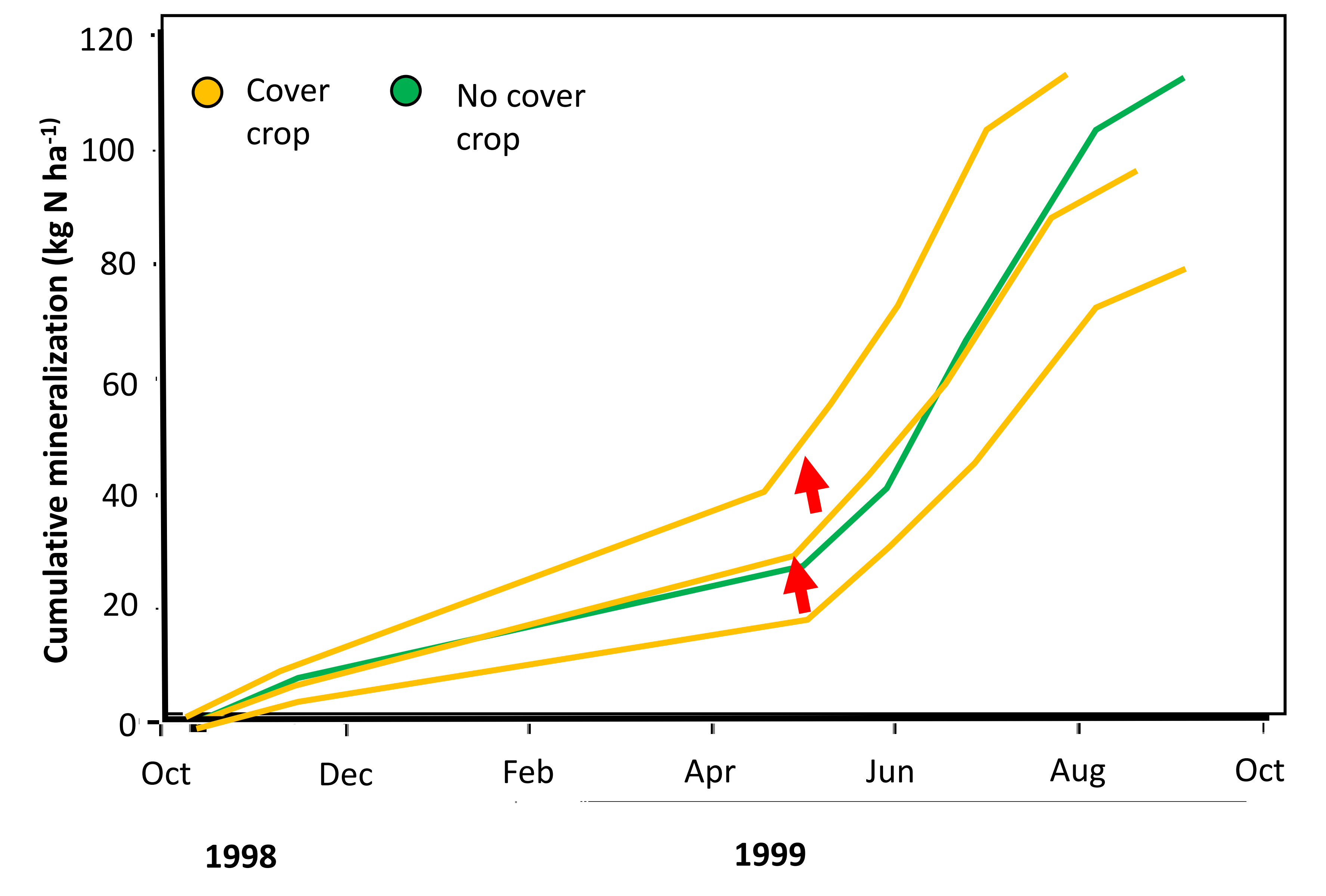
No-till increased yield, but required same nitrogen rate

It took 10 years to get to this point

First 10 years:

- Corn yielded greater in plowed system
- No-till increased organic matter by 30%

N mineralization needs to adapt to the addition of the cover crop



What about interseeding cover crops into corn and soybean?

Locations

Brookings

- Mean Precipitation: 24 in.
- Mean temperature: 43ºF
- Growing degree-days: 2390

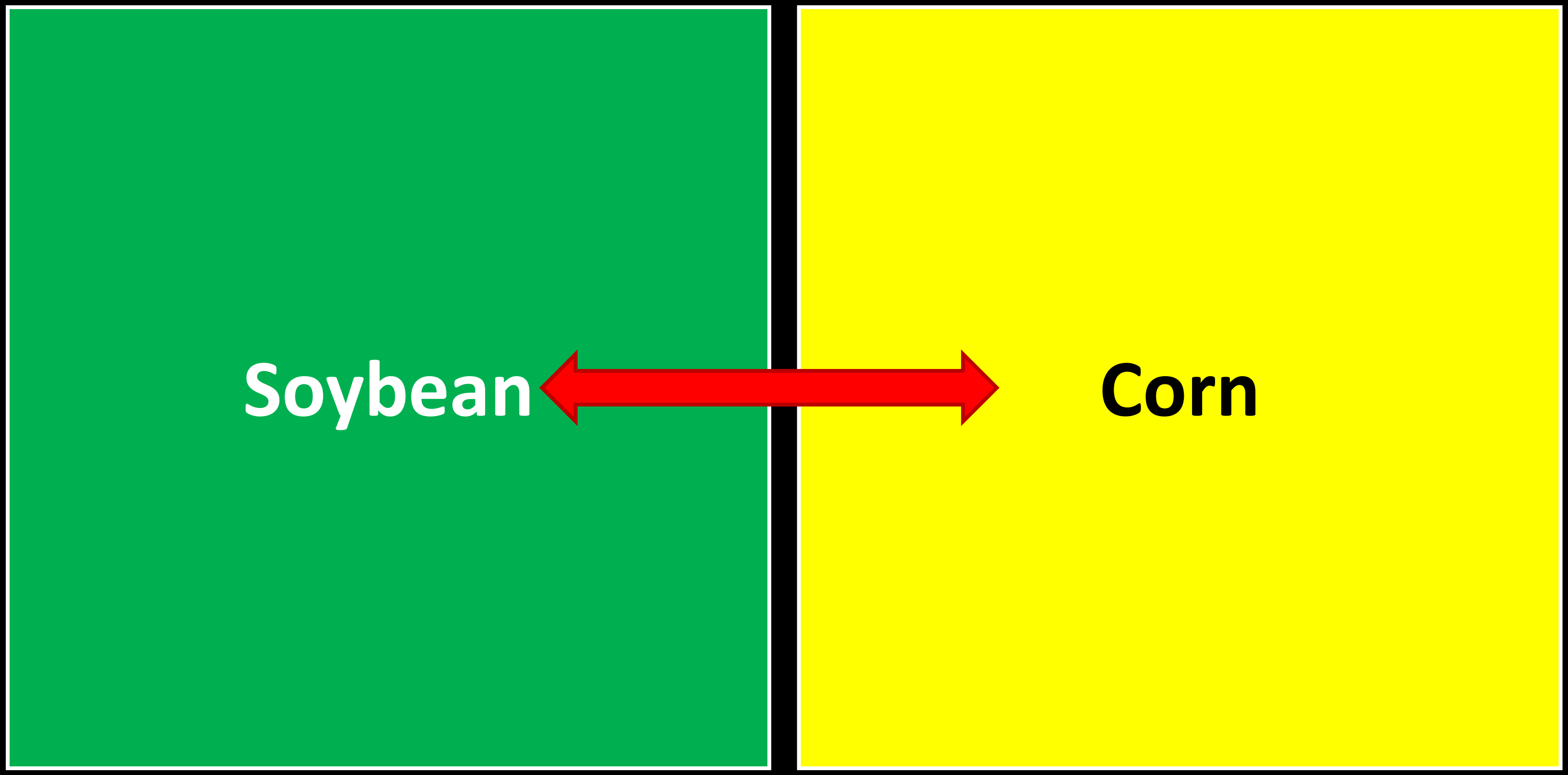
Beresford

- Mean Precipitation: 26 in.
- Mean temperature: 47ºF
- Growing degree-days: 2750

No-till > 5 years

Study Setup

Corn and soybean blocks rotate each year



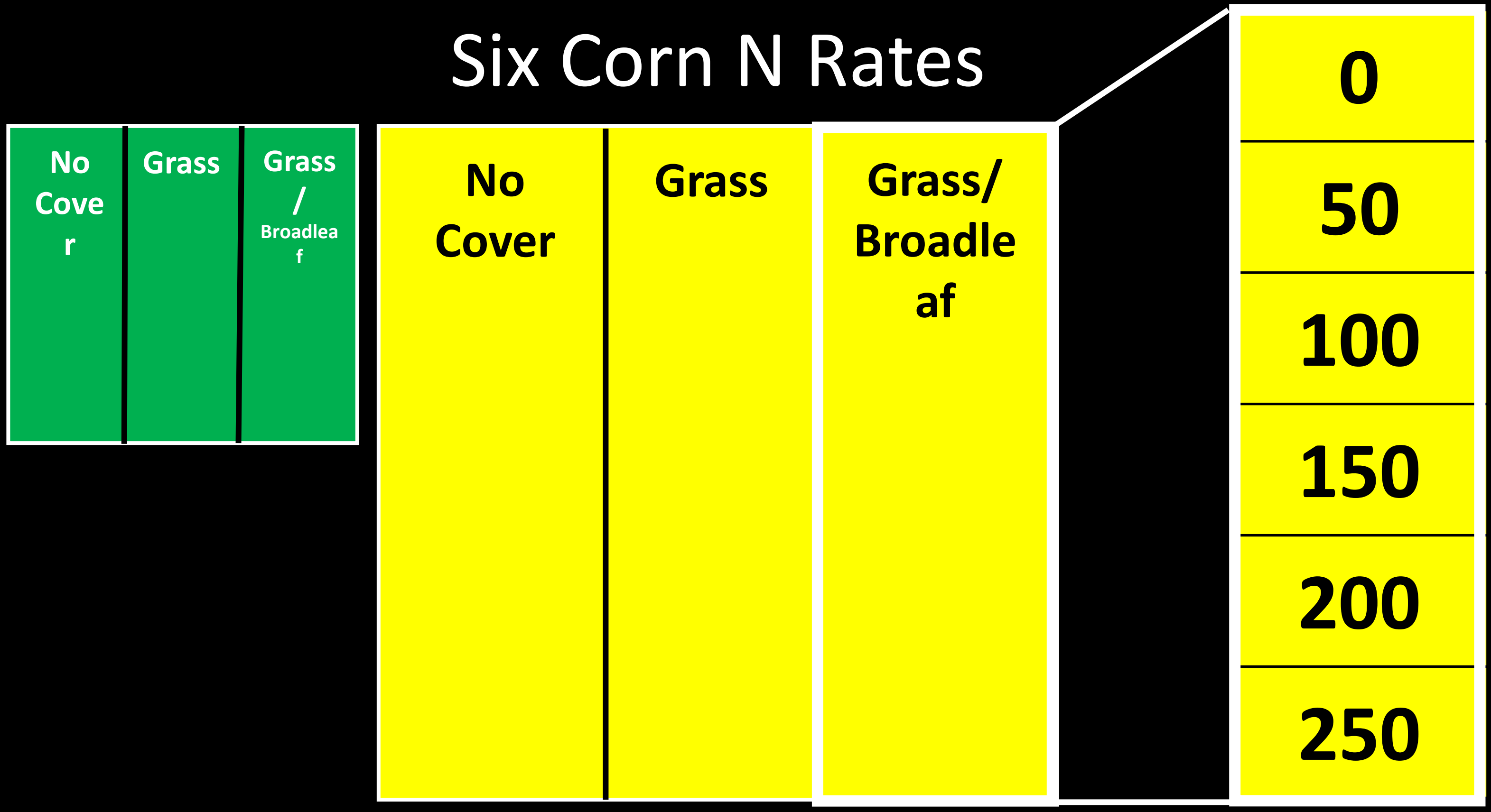
Study Setup

Three cover crop treatments

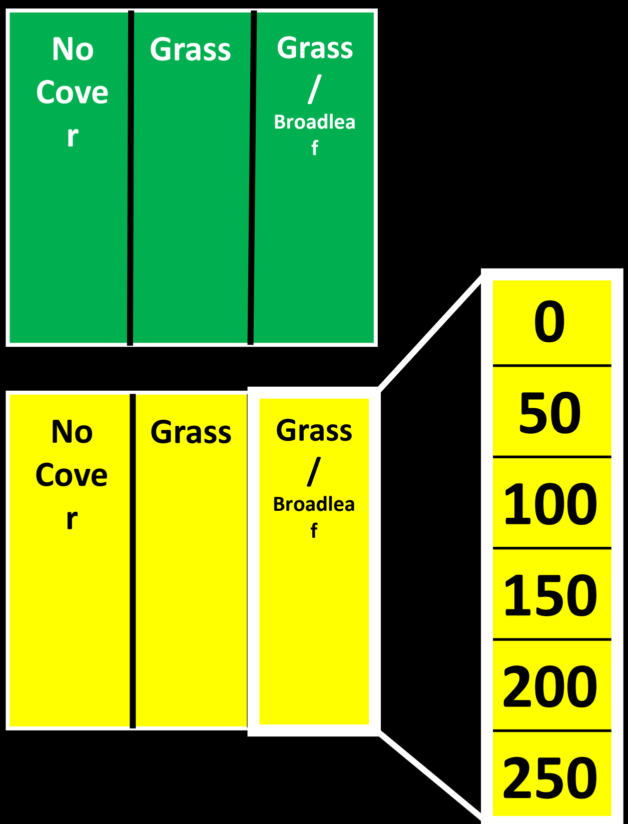
No Cover	Grass	Grass/ Broadleaf
	• Annual Rye Grass	• Annual Rye Grass • Crimson Clover • Turnip • Radish

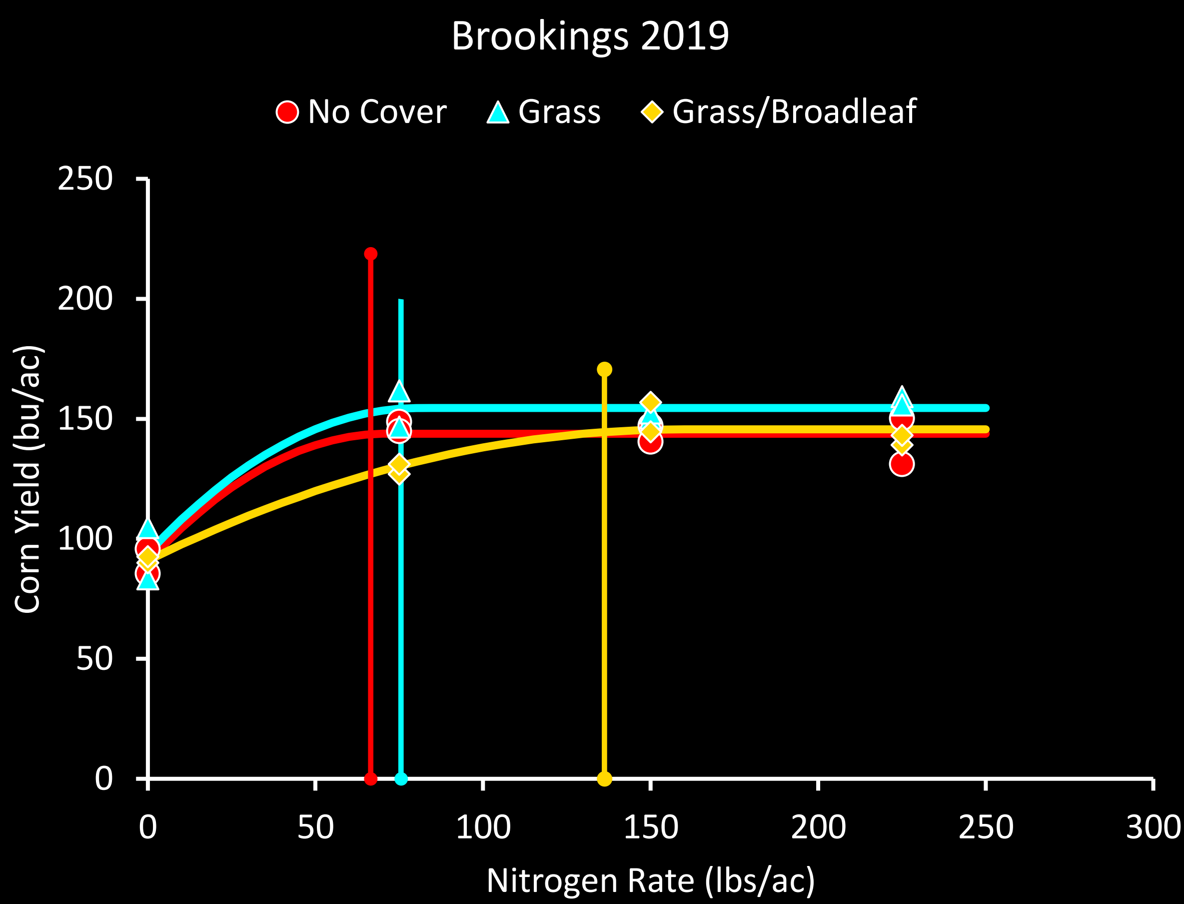
No Cover	Grass	Grass/ Broadleaf
	• Annual Rye Grass	• Annual Rye Grass • Crimson Clover • Turnip • Radish

Study Setup


No Cover
Grass
Grass/ Broadleaf
Six Corn N Rates
No Cover
Grass
Grass/ Broadleaf
0
50
100
150
200
250

Study Setup


No Cove r
Grass
Grass / Broadlea f
No Cove r
Grass
Grass / Broadlea f
0
50
100
150
200
250


Brookings 2019
No Cover
Grass
Grass/Broadleaf
Corn Yield (bu/ac)
0
50
100
150
200
250
Nitrogen Rate (lbs/ac)
0
50
100
150
200
250
300

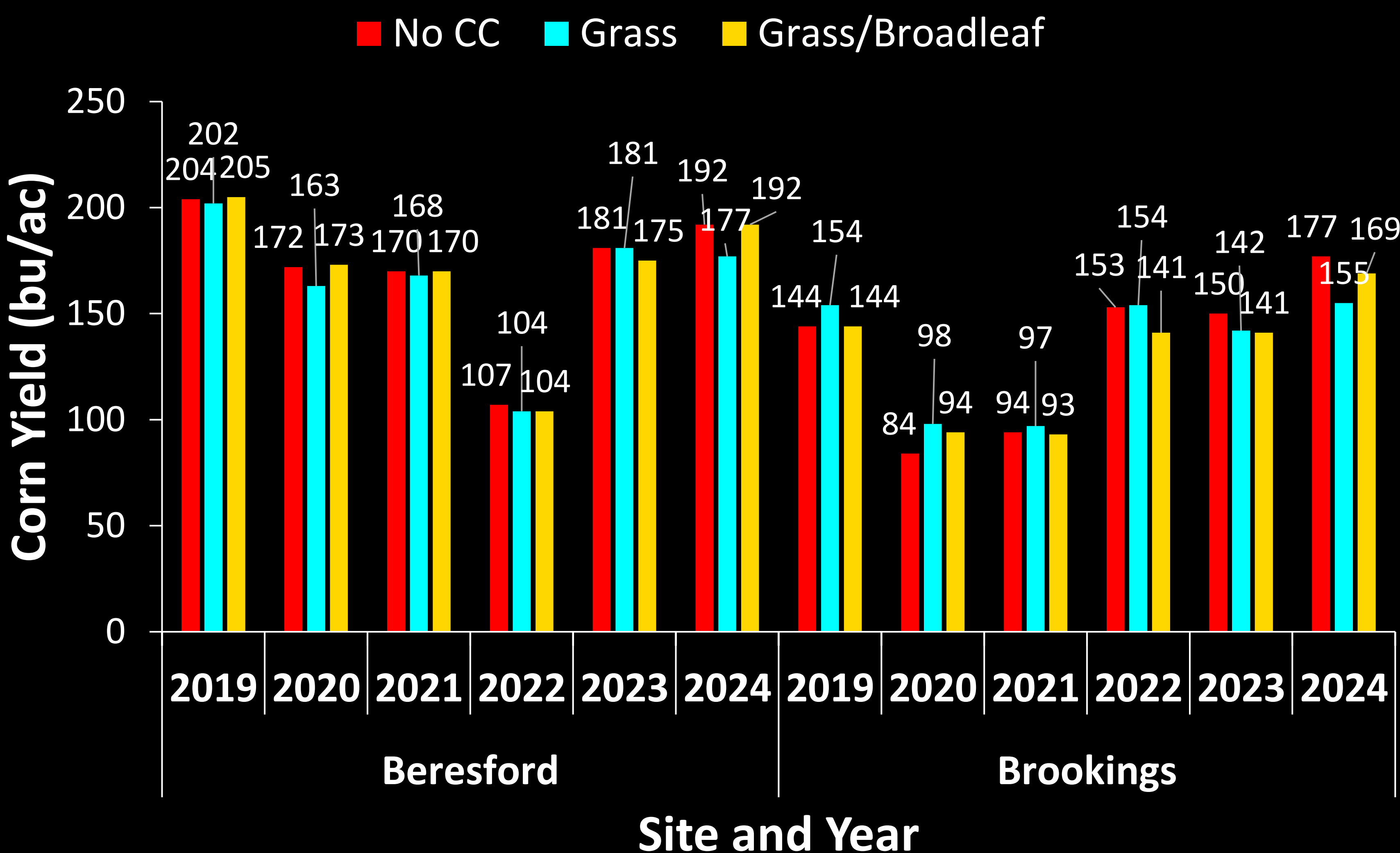
Results: Cover crop growth in corn


Corn

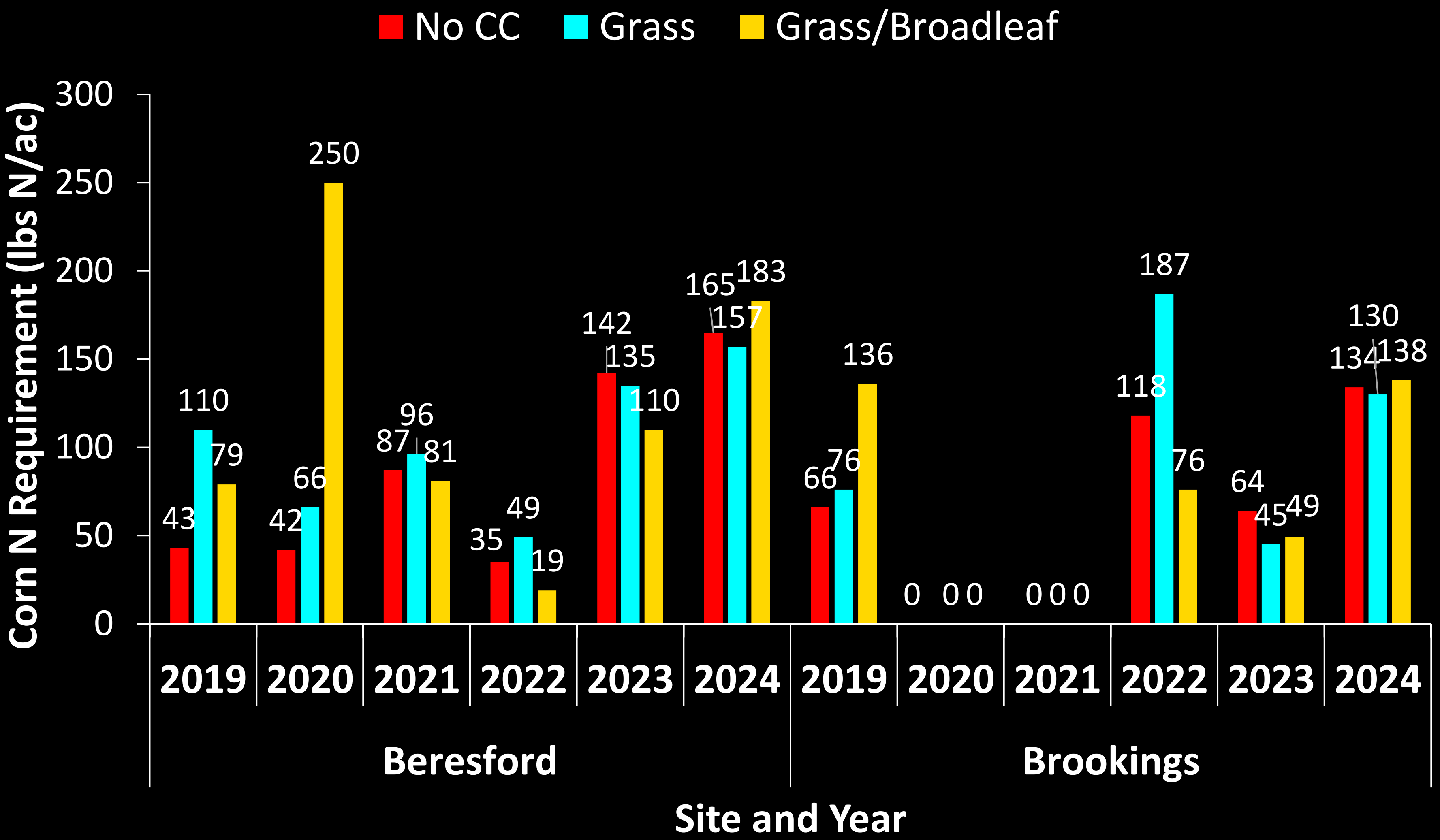


Results: Corn yield and N requirement (6 years)

Corn yield not affected by cover crop

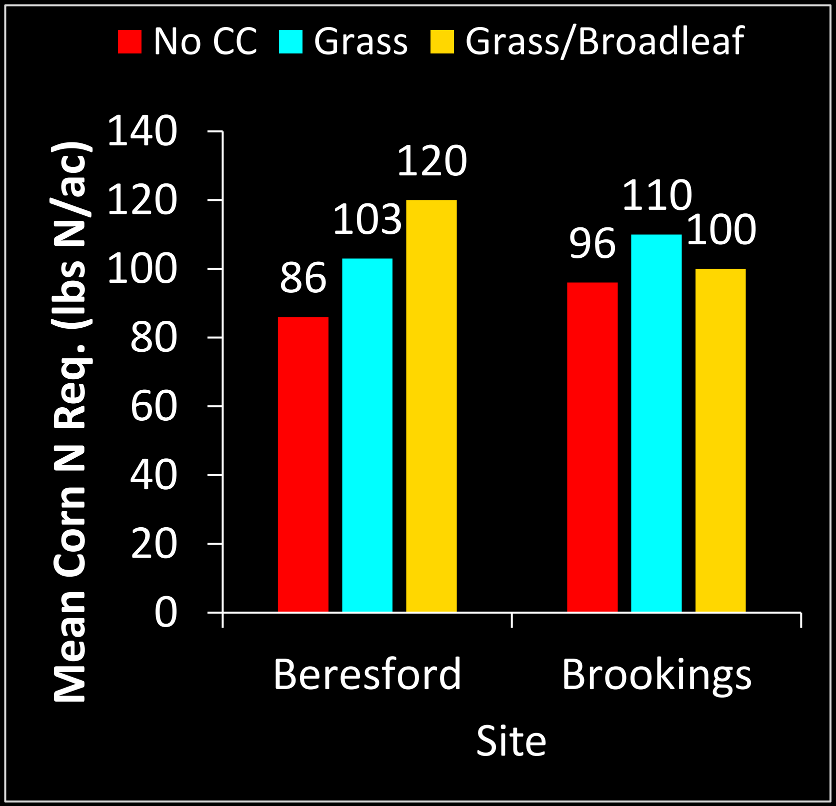


Variable N rate requirements through 6 years

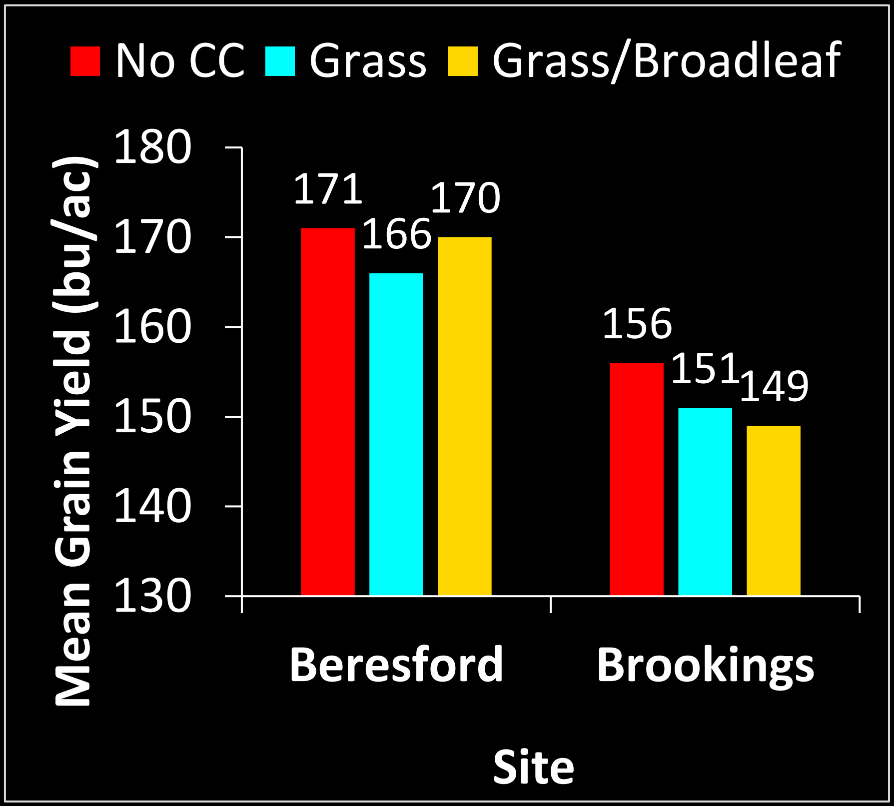


6 Year Average: No clear differences

Corn N Averages



Corn Yield Averages



Take Home

The effect of cover crops on corn is driven by

- Precipitation
- Cover crop biomass

Contact Information

Jason.D.Clark@sdstate.edu

2025 Corn Soil Fertility Trials

- N rate and Timing
- P and K rate and placement
  - K<120 ppm
  - P
    - <12 ppm Olsen P
    - <15 ppm Bray P-1
    - <17 ppm Mehlich 3 Color
    - <27 ppm Mehlich 3 ICP

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SDState Soil Fertility

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U.S. Department of Agriculture
Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, D.C. 20250-9410; or

fax:
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