Soil Test Correlation Modeling Decisions for the FRST Decision Aid

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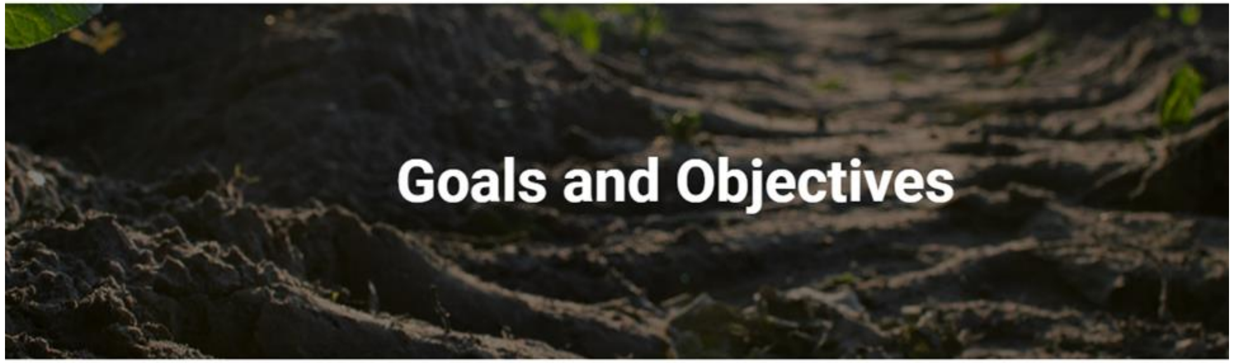
19-20 August 2024 ALTA Summer Meeting

FRST
FERTILIZER RECOMMENDATION SUPPORT TOOL

Why FRST is Important

FRST
FERTILIZER RECOMMENDATION SUPPORT TOOL

GOALS AND OBJECTIVES | TOOL | FUNDING | PROJECT TEAM AND COLLABORATORS | PRESENTATIONS | RESOURCES



Goals

The **primary goal** of FRST is to increase soil testing transparency by promoting clear and consistent interpretations of fertilizer recommendations by removing political and institutional (public and private) bias from soil test interpretation and providing the best possible science in order to enhance end-user adoption of nutrient management recommendations. A **secondary goal** is to provide a catalyst for innovation in soil fertility – useful to those making recommendations as well as those evaluating those recommendations.

Provide information that can be used to augment (not replace) existing state recommendation systems.

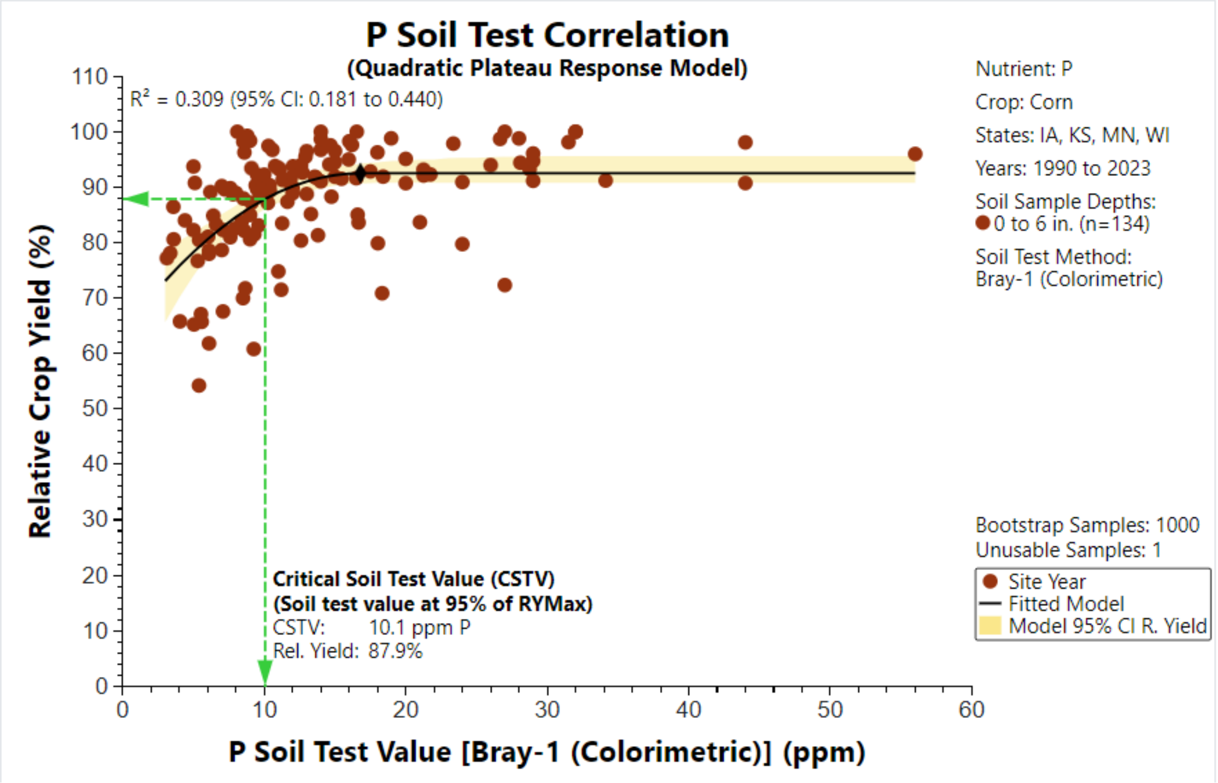
Fertility Costs Are In Focus As Farmers Consider Cutting Back

spreading fertilizer in field
(Darrell Smith, Farm Journal)

By AGDAY TV August 14, 2024

Soil Test Correlation

- **First Step of Soil Testing** - *Process of determining the relationship between a soil test nutrient concentration and crop response to fertilization*
- Answers the question *"Can a soil test distinguish between <u>nutrient deficient</u> and <u>nutrient sufficient soils</u>?"*
  - *Provides no information about how much fertilizer is needed*
- *Affected by data quality, data management, and modeling decisions (Figure →)*



Source: Rutgers, FS719, Heckman

Modeling Decisions to Determine the Critical Soil Test Value

- CSTV is key component to soil test correlation and fertilizer recommendations
  - Black Box knowledge
- Influential Factors
  - Data quality
  - Relative yield calculation
  - Model choice
  - Model interpretation (Sufficiency)
  - Confidence limits of predictions

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ORIGINAL ARTICLE

Agricultural Soil and Food Systems

Models and sufficiency interpretation for estimating critical soil test values for the Fertilizer Recommendation Support Tool

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NUTRIENT MANAGEMENT & SOIL & PLANT ANALYSIS

Defining relative yield for soil test correlation and calibration trials in the fertilizer recommendation support tool

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Methods

- 3 datasets selected for CSTV evaluation
- Use relative yield calculation from Pearce et al. (2022)
- 5 modeling approaches
    - Arcsine Log Calibration Curve (ALCC) @ 95% of maximum
    - Exponential @ 95% maximum (95M)
    - Linear Plateau @ join point (JP)
    - Quadratic Plateau
        - Join Point
        - 95% of maximum
- 2 other modeling approaches considered
    - Cate-Nelson
    - Model Averaging

Dataset	Nutrient of Interest	Total site-years (responsive‡)	Soil Test Range	RY Range†
		#	ppm	%
Mehlich-1	K	41 (14)	16 – 196	21-100
Mehlich-3	K	55 (26)	46 – 353	59-100
Olsen	P	87 (28)	3 – 67	73-100

† Relative yield of the control (received no nutrient-of-interest)

‡ Responsive defined as site-year with ANOVA p-value ≤0.05 (Olsen data) or 0.10 (Mehlich-1 and Mehlich-3 data)

The **modeling approach** includes model and sufficiency level selection

Dataset Properties - Model goodness of fit

Model	Sufficiency Level	Dataset		
		Mehlich-1	Mehlich-3	Olsen P
		R^2		
Arcsine Log	95% Maximum	0.83	0.52	0.09
Exponential	95% Maximum	0.87	0.54	0.14
Linear Plateau	Join Point	0.87	0.51	0.12
Quadratic Plateau	Join Point	0.88	0.53	0.13
Quadratic Plateau	95% Maximum	0.88	0.53	0.13

R^2 is measure of goodness of fit with a range of 0.0 to 1.0 where
0 means there is no relationship and 1 means the relationship is perfect.

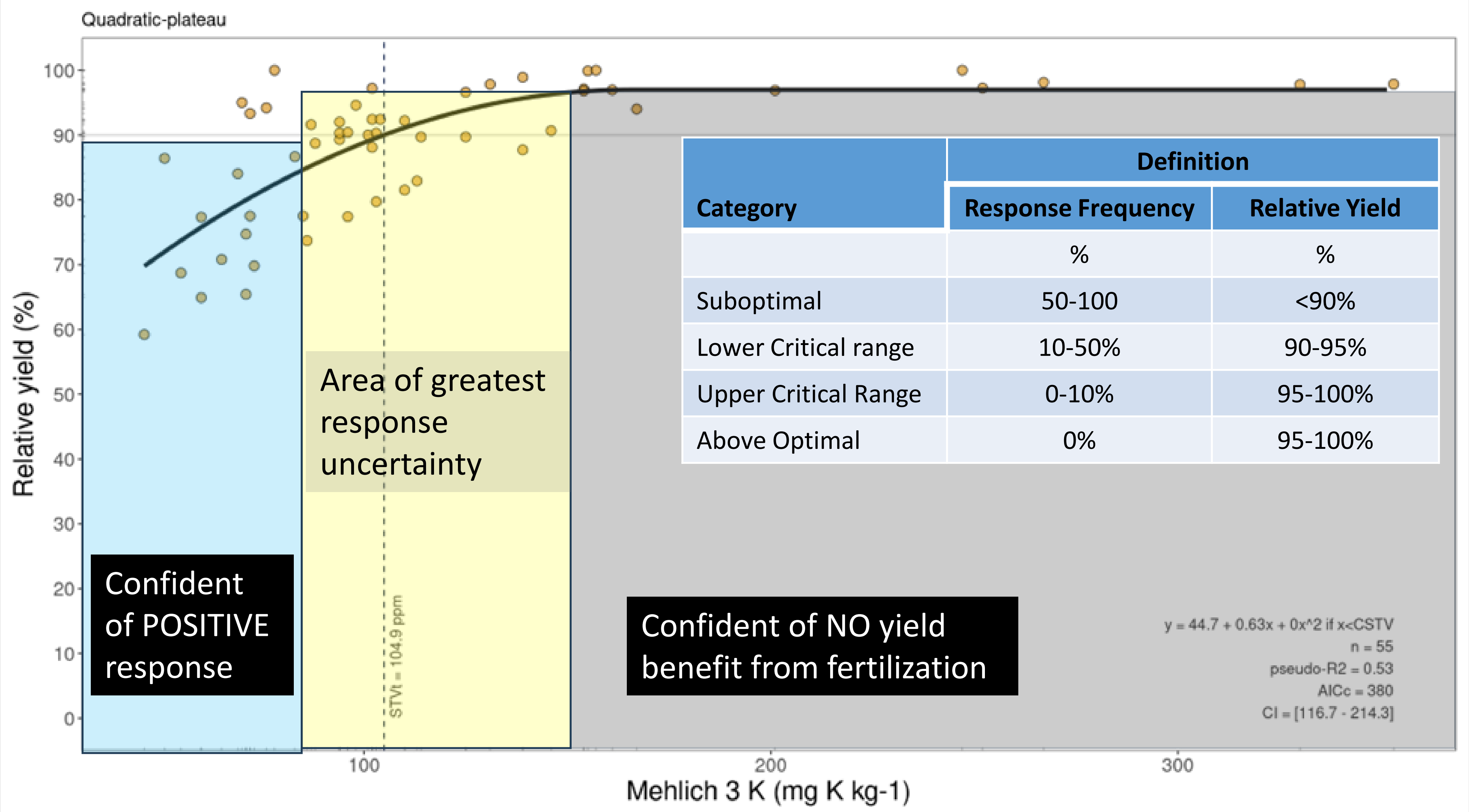
Dataset and Result Properties

Dataset	Observations (site-years)		Mean CSTV range	CSTV 95% CI width
	total	response	mg kg^{-1}	mg kg^{-1}
Mehlich-1 K	41	14	46-68	13-26
Mehlich-3 K	55	28	116-168	30-129
Olsen P	87	26	9-25	3-58
Response, mean site-years with a significant yield increase from fertilization				

Model & Sufficiency Value Approaches

Dataset	Model	SI-RY	Mean CSTV	95% Confidence Interval	
				Lower	Upper
Mehlich-3 K Soybean			- - - - - - - - - mg kg^{-1}- - - - - - - -		
	Arcsine Log @ 95% Maximum	95.0	**128**	112	142
	Exponential at 95% Maximum	93.3	**130**	93	181
	Linear Plateau @ Join Point	96.7	**129**	92	163
	Quad Plateau @ 95% Maximum	92.1	**116**	82	143
	Quad Plateau @ Join Point	97.0	**168**	102	231

Concept of Responsiveness to Fertilization



Category	Definition	
	Response Frequency	Relative Yield
	%	%
Suboptimal	50-100	<90%
Lower Critical range	10-50%	90-95%
Upper Critical Range	0-10%	95-100%
Above Optimal	0%	95-100%

Categorical Response Frequency by Model Mehlich-3 Dataset

		Category											
		Suboptimal			Lower critical range			Upper critical range			Above Optimal		
Dataset	**Model**	**Total**	**RS**	**MRY**	**Total**	**RS**	**MRY**	**Total**	**RS**	**MRY**	**Total**	**RS**	**MRY**
		#	%	%	#	%	%	#	%	%	#	%	%
Mehlich-3 K soybean	ALCC	35	71	84	4	50	90	3	0	95	13	8	97
	EXP-95M	20	80	80	19	58	89	10	10	96	6	0	98
	LP-JP	20	80	80	19	58	89	9	11	96	7	0	97
	QP-95M	**15**	**80**	**79**	**22**	**64**	**88**	**5**	**20**	**94**	**13**	**8**	**97**
	QP-JP	30	76	83	19	32	92	1	0	97	5	0	98

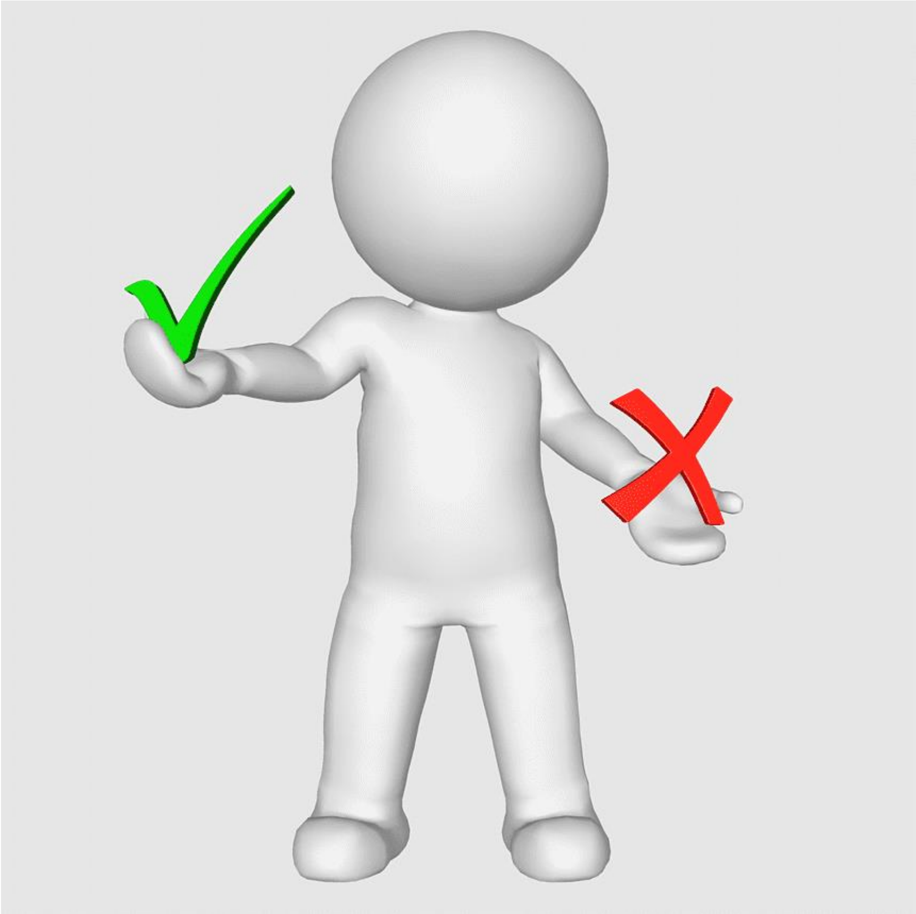
Legend
Total, number of site-years in each category
RS, Response Frequency or % site-years with significant yield increase
MRY, mean relative yield of site-years in category

Relative-Accuracy Assessment Based on Response Frequency, Quadratic Plateau @ 95% of Maximum

Dataset	Responsive Area Prediction			Unresponsive Area Prediction			Overall Prediction		
	LCL	$\bar{x}$ CSTV	UCL	LCL	$\bar{x}$ CSTV	UCL	LCL	$\bar{x}$ CSTV	UCL
	%	%	%	%	%	%	%	%	%
Mehlich-1 K	100	92	67	87	93	91	90	93	80
Mehlich-3 K	**80**	**70**	**64**	**60**	**89**	**92**	**66**	**76**	**71**
Olsen P	100	43	31	71	89	100	71	62	33
Mehlich-1 K	*40 ppm*	*46 ppm*	*53 ppm*						
Mehlich-3 K	*82 ppm*	*116 ppm*	*143 ppm*	<------------Values that correspond to LCL, Mean CSTV, & UCL					
Olsen P	*4 ppm*	*11 ppm*	*32 ppm*	*LCL, lower confidence limit, $\bar{x}$ CSTV, mean CSTV; & UCL, Upper Confidence limit*					
	Difference from 100 represents the **% false positive errors**			Difference from 100 represents the **% false negative errors**			Difference from 100 represents the **% of combined errors**		

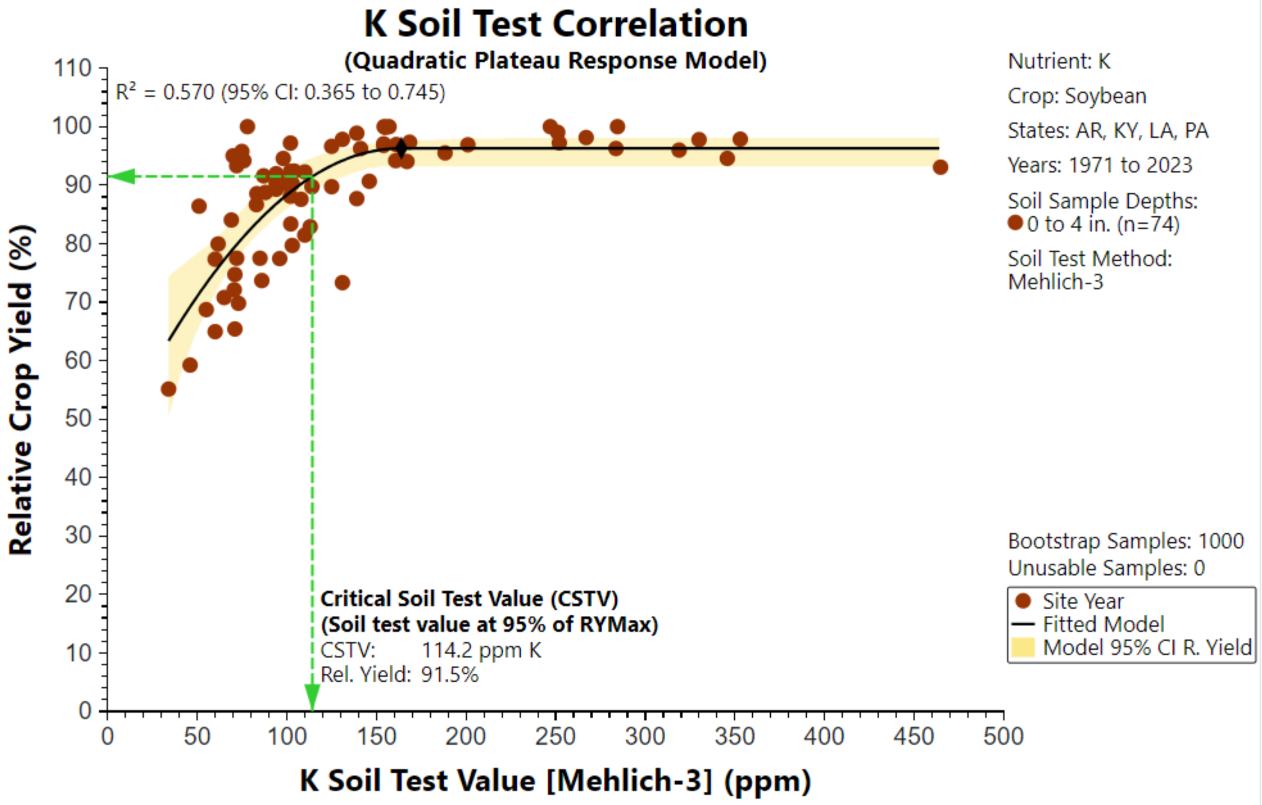
Conclusions/Summary Points

- ***Model and sufficiency level selection influences CSTV***
- CSTV error range is broad for most soil test datasets
- Use of $\bar{x}$ CSTV to define responsiveness to fertilization minimizes the number of false negative and false positive errors (compared to lower & upper critical limits)



CSTV Process - Critical Points

- Quadratic Plateau Model with a CSTV @ 95% of the plateau relative yield selected as modeling approach for FRST
  - No single modeling approach will be the best model for all datasets
- FRST **relative yield calculation** and **modeling approach** suggested as benchmark processes to reduce the influence of these components on CSTV predictions
  - Not intended to be an exclusive process for soil test correlation
  - Examination of other modeling approaches is encouraged
  - Evaluate other important correlation metrics and metadata (e.g., response frequency)



Estimated Model Parameters Using Bootstrapping

Parameter	Value	Description
STVJP(♦)	163.9	Nutrient soil test value (ppm) where relative crop yield is constant. (Join Point)
RYMax(♦)	96.3	Relative crop yield (%) maximum value. (Plateau relative crop yield)
Int	43.9	Relative crop yield (%) at nutrient soil test value of 0

FRST
08-19-2024

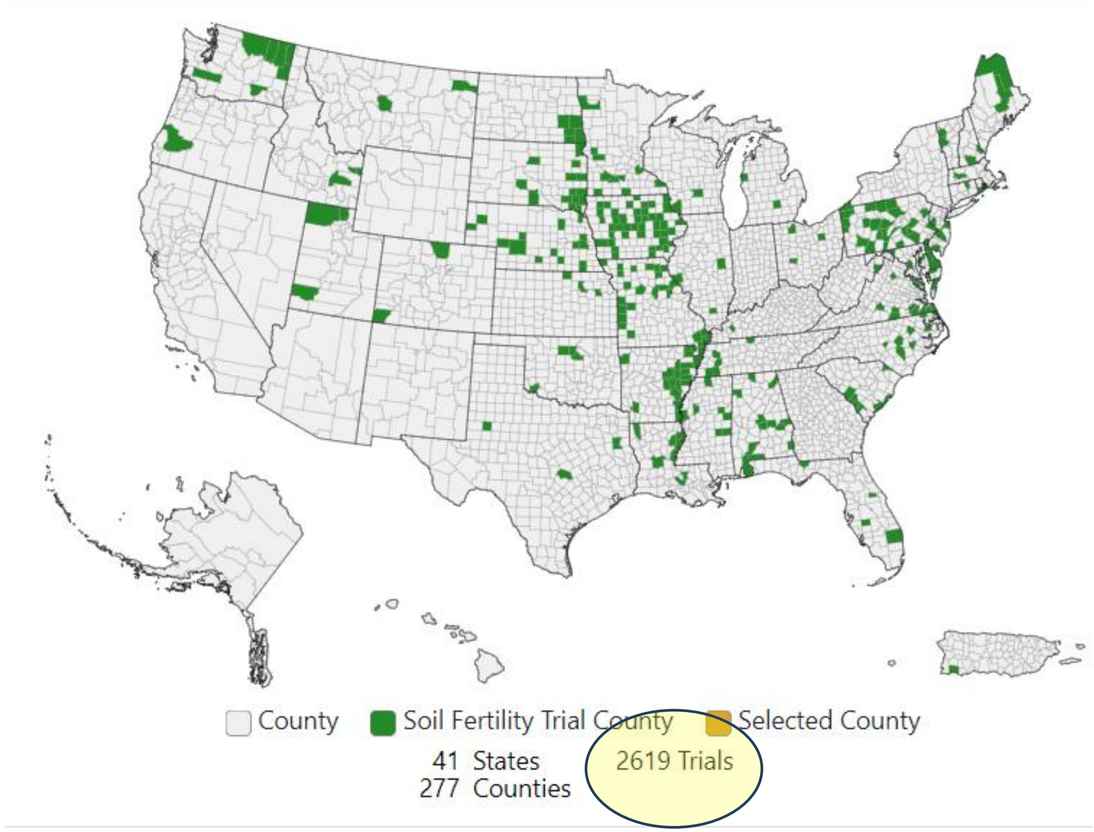
Update on FRST Activities

New Activities

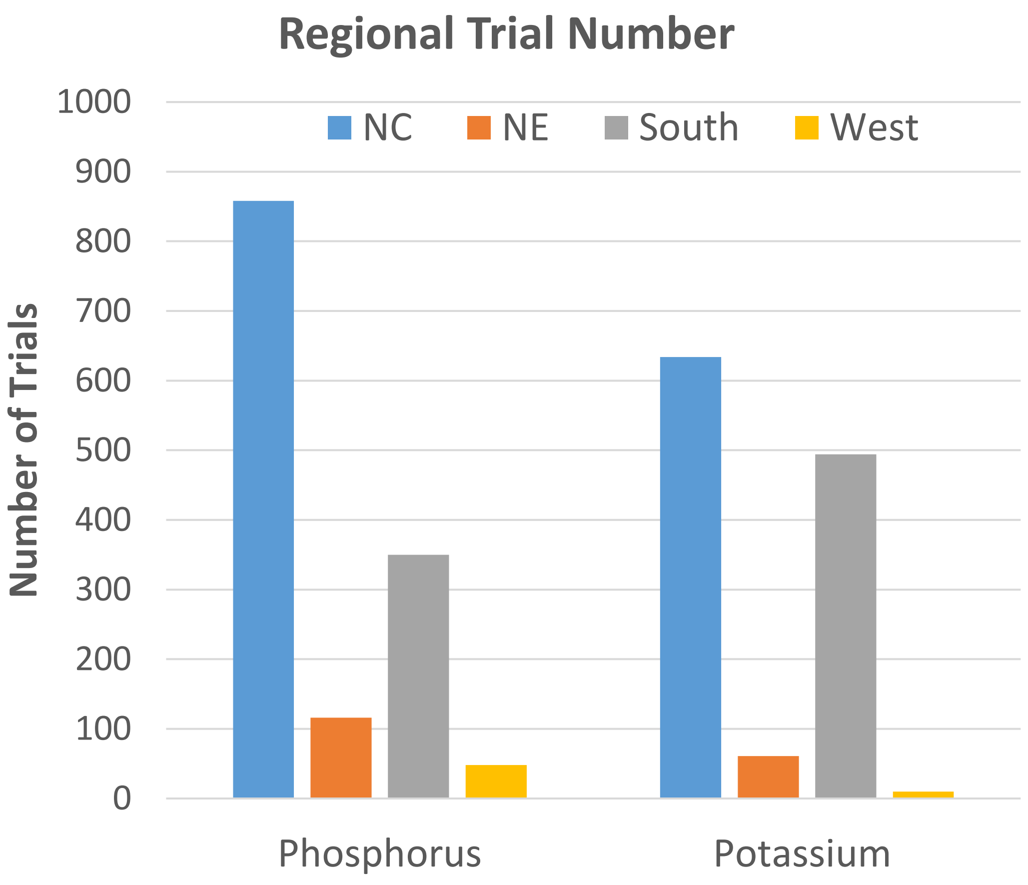
- Soil Sample Depth Project (Culman)
- Develop a minimum dataset for sulfur and add crop response to S trials to the database (Yost)
- Calibration Modeling (Gatiboni)
- Lime Rate Comparison (Jones & Miller)
- Lime Rate Calibration Committee (Shober & Miller)
- ALTA and FRST Survey (Slaton, Sawyer, Lacey, Spargo, etc)
- Evaluate LGU Fertilizer Recommendation Strategies (Slaton & Postdocs)
- Modeling frequency of response (Buol)
- Grow database (Everyone)

Database Inventory – 08.15.2024

- **P database, 1374 observations**
  - 38 states represented
  - Corn data, 25 states
  - Soybean data, 15 states
  - 85% of data from corn & soybean
- **K database, 1245 observations**
  - 28 states represented
  - Corn data, 22 states
  - Soybean data, 17 states
  - 79% of data from corn & soybean



Geography of Soil-Test Correlation Database

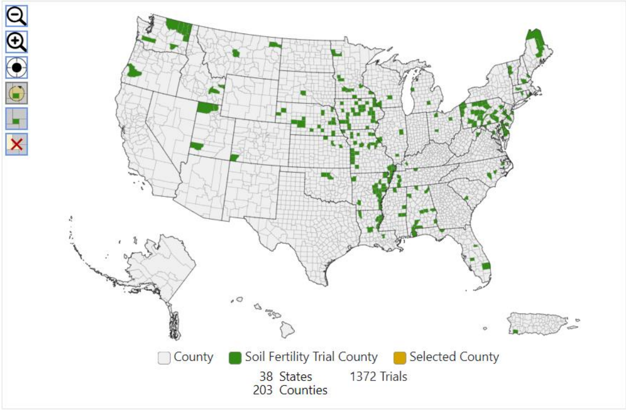


- **Does the database population reflect regional nutrient issue priorities?**
  - NC Region has more P data than K data
  - South has more K data than P data

Region	Phosphorus		Potassium	
	trials	%	trials	%
NC	858	63	634	53
NE	116	9	61	5
South	350	26	494	41
West	48	<4	10	<1
Total	1372	--	1199	--

Values from 05.31.2024

FRST Database Summary - Phosphorus

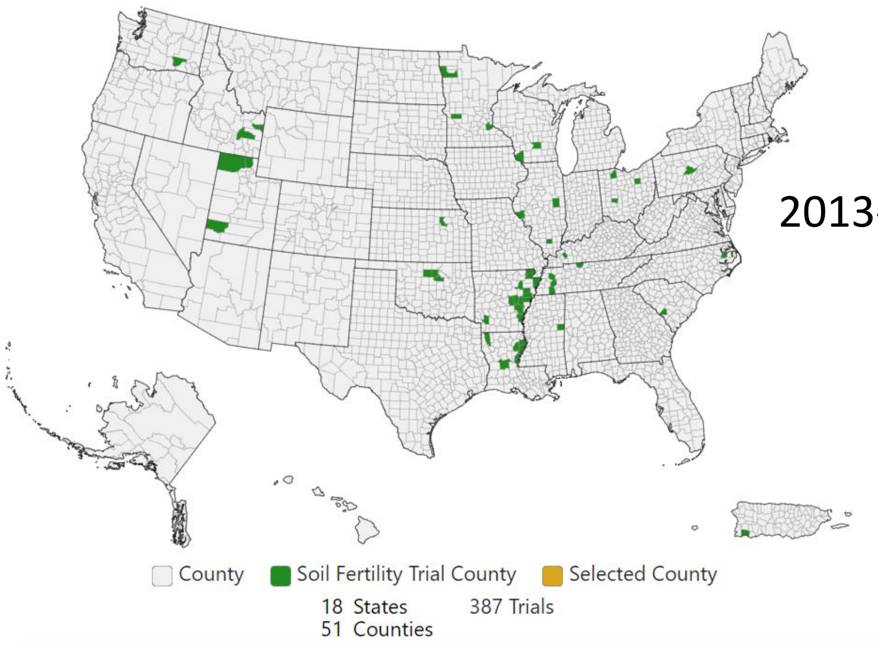


Phosphorus Crops	Trials	States	Counties	Years
Alfalfa	16	3	7	1967-2023
Bermudagrass	**41**	**2**	**3**	**1960-2012**
Corn	**702**	**25**	**145**	**1955-2023**
Corn Silage	26	7	12	1998-2023
Cotton	**25**	**2**	**9**	**1957-1994**
Rice	24	1	4	2013-2015
Soybean	**457**	**15**	**67**	**1975-2023**
Winter Wheat	**31**	**5**	**13**	**1990-2016**

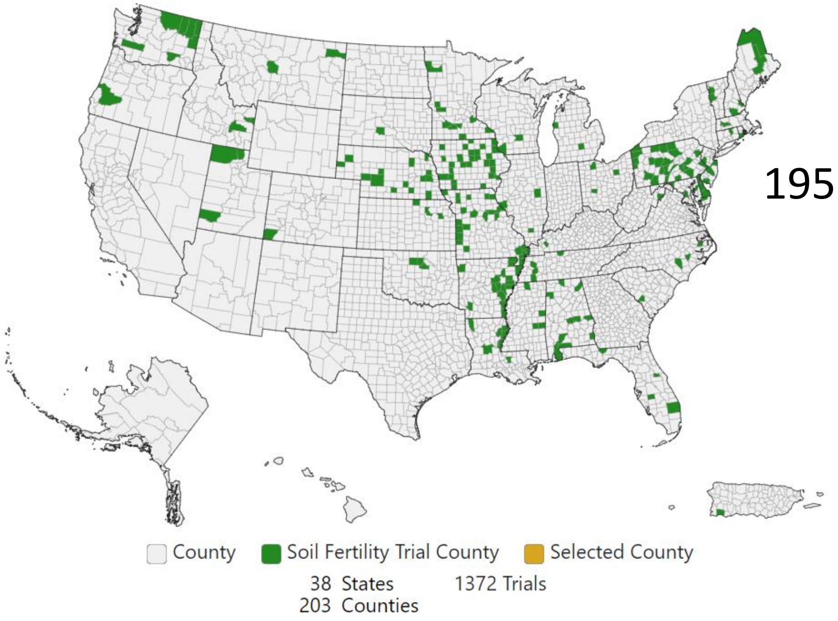
Phosphorus Crops	Trials	States	Counties	Years
Bahiagrass	2	2	2	1990-2023
Barley	2	1	2	2023
Brachiariagrass	1	1	1	2021
Clover–Grass	2	1	1	1976-1977
Lentil	4	1	1	2004-2005
Lentil Forage	2	1	1	2004
Pea	7	2	2	1962-2005
Pea Forage	4	1	1	2004-2005
Potato	3	2	3	2021
Sorghum	1	1	1	1993
Spring Wheat	6	2	3	1967-2023
Sweet Potato	3	1	1	1976-1978

Data Age – Phosphorus data since 2013

Phosphorus Crop	Trials	States	Counties	% of Total
Total	387	18	51	28%
Corn	187	11	31	27%
Soybean	149	9	24	33%
Winter Wheat	13	2	5	42%
Bermudagrass	0	--	--	0%
Corn Silage	4	1	3	15
Cotton	0	--	--	0%
Rice	24	1	4	100%
Alfalfa	1	1	1	6%



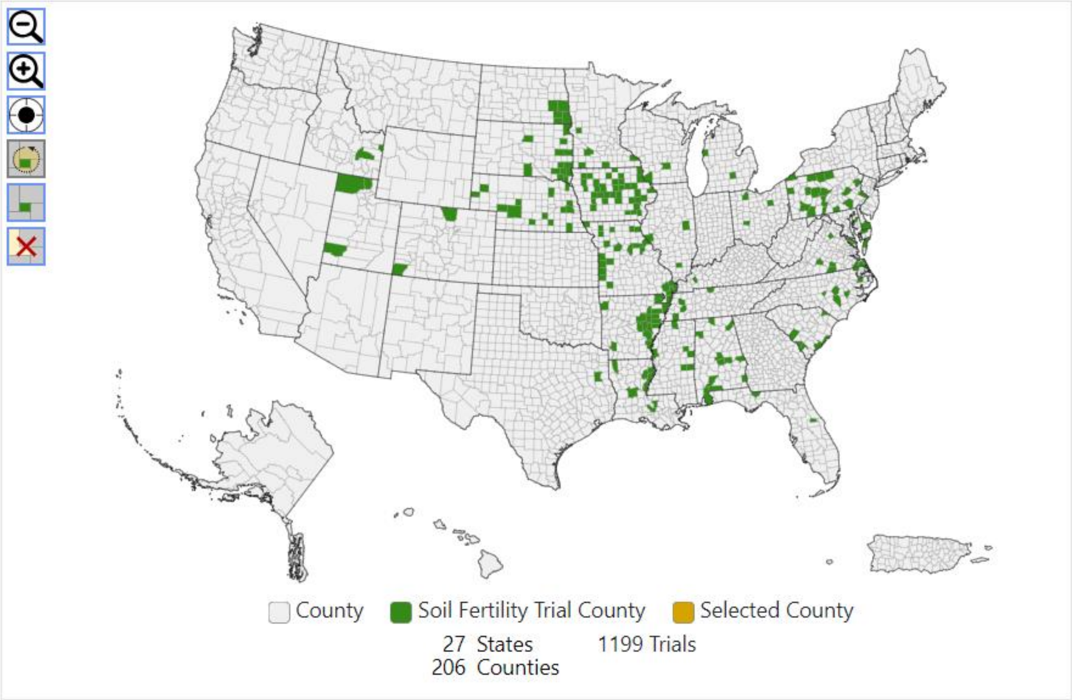
2013-2023



1955-2023

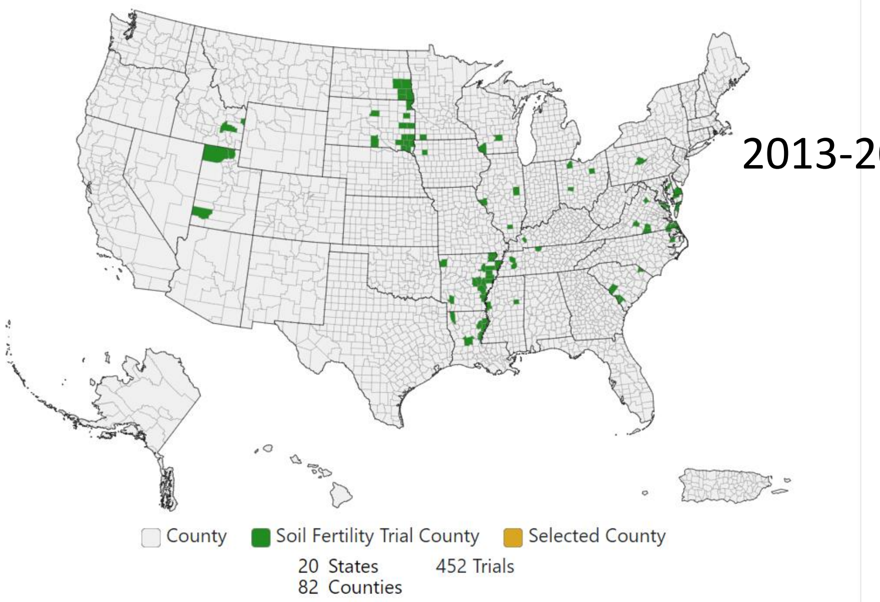
FRST Database Summary Potassium

Potassium Crops	Trials	States	Counties	Years
Alfalfa	12	3	4	1980-2023
Bahiagrass	1	1	1	2023
Barley	2	1	2	2023
Bermudagrass	**54**	**4**	**5**	**1955-2012**
Corn	**612**	**22**	**150**	**1955-2023**
Corn Silage	2	1	2	2021
Cotton	**65**	**5**	**22**	**1949-2023**
Rice	**55**	**1**	**7**	**2004-2015**
Soybean	**373**	**17**	**92**	**1971-2023**
Sugarcane	6	1	1	2007-2008
Sweet Potato	5	1	2	1976-1978
Winter Wheat	12	2	7	2001-2015

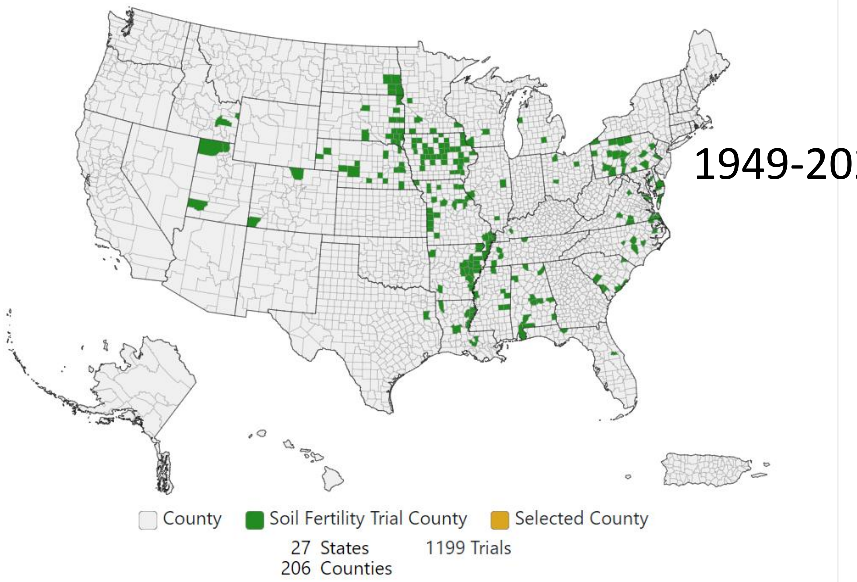


Data Age – Potassium data since 2013

Potassium Crop	Trials	States	Counties	% of Total
Total	452	20	82	37%
Corn	240	14	52	39%
Soybean	165	10	36	44%
Cotton	9	3	9	14%
Bermudagrass	0	0	0	0%
Rice	24	1	4	44%
Alfalfa	5	2	2	42%
Winter wheat	4	1	2	33%



2013-2023



1949-2023

FRST Objectives

1. Identify the factors that inhibit end-user adoption of soil-test services for nutrient management.
    - Survey land-grant institution soil-test-based recommendations to understand the complexity and variation of existing recommendations and provide a synthesis of results.
    - **Develop standardized terminology for use in soil-test-based nutrient management recommendations that enhance end-user understanding and adoption of soil testing.**
2. Establish minimum data requirements for legacy dataset inclusion and future correlation-calibration studies to standardize best practices.
3. Develop a database that archives soil fertility data and is populated with legacy and current data for soil-test correlation and calibration studies for major field crops grown in North America. The database should be:
    - Accessible and searchable through the decision-support tool.
    - Easy to use so that new data can be readily uploaded. The data should meet the minimum data requirements based on the protocol developed in objective 2.
4. Develop a searchable, decision support tool that:
    - Provides soil test correlation and calibration analysis output based on filter terms such as crop, soil-test method, soil sample depth, soil series, etc.
    - Provide soil test correlation and calibration data for nutrient management researchers and modelers for in-depth analysis.

Soil Test Levels (by State LGU)

- Soil test level has no official definition by the *Soil Science Society of America*
- Proposed FRST activity
  - Review soil test levels and the associated recommendations to develop and propose a structure with definitions for soil test levels

Soil Test Level Number	**Number of States**
None (no documentation)	6
3	12
4	10
5	20
6	3
As determined using literature from each land grant university.	

Soil Test Level Terms (Phosphorus)

Term	States with Level	Fertilizer Recommended	
		Yes	No
Very Low	19	x	
Low	31	x	
Deficient	3	x	
Below optimum	3	x	
Medium	27	x	
Marginal	1	x	
Adequate	1		x

Term	States with Level	Fertilizer Recommended	
		Yes	No
Sufficient	5	x (1)	x (4)
Optimum	18	x	
Above optimum	7		x
High	24	x (9)	x (16)
Very high	16	x (1)	x (15)
Excessive	7		x
Excessively high	1		x

Washington State University

Montana State University

University of Wyoming

University of Minnesota

Michigan State University

PennState

Virginia Tech

Oregon State University

South Dakota State University

Wisconsin University of Wisconsin-Madison

Purdue University

Cornell University

University of Kentucky

University of Illinois Urbana-Champaign

The Ohio State University

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UCONN University of Connecticut

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ALP

Plant Nutrition Canada

University of Guelph

UPR Recinto Universitario de Mayagüez

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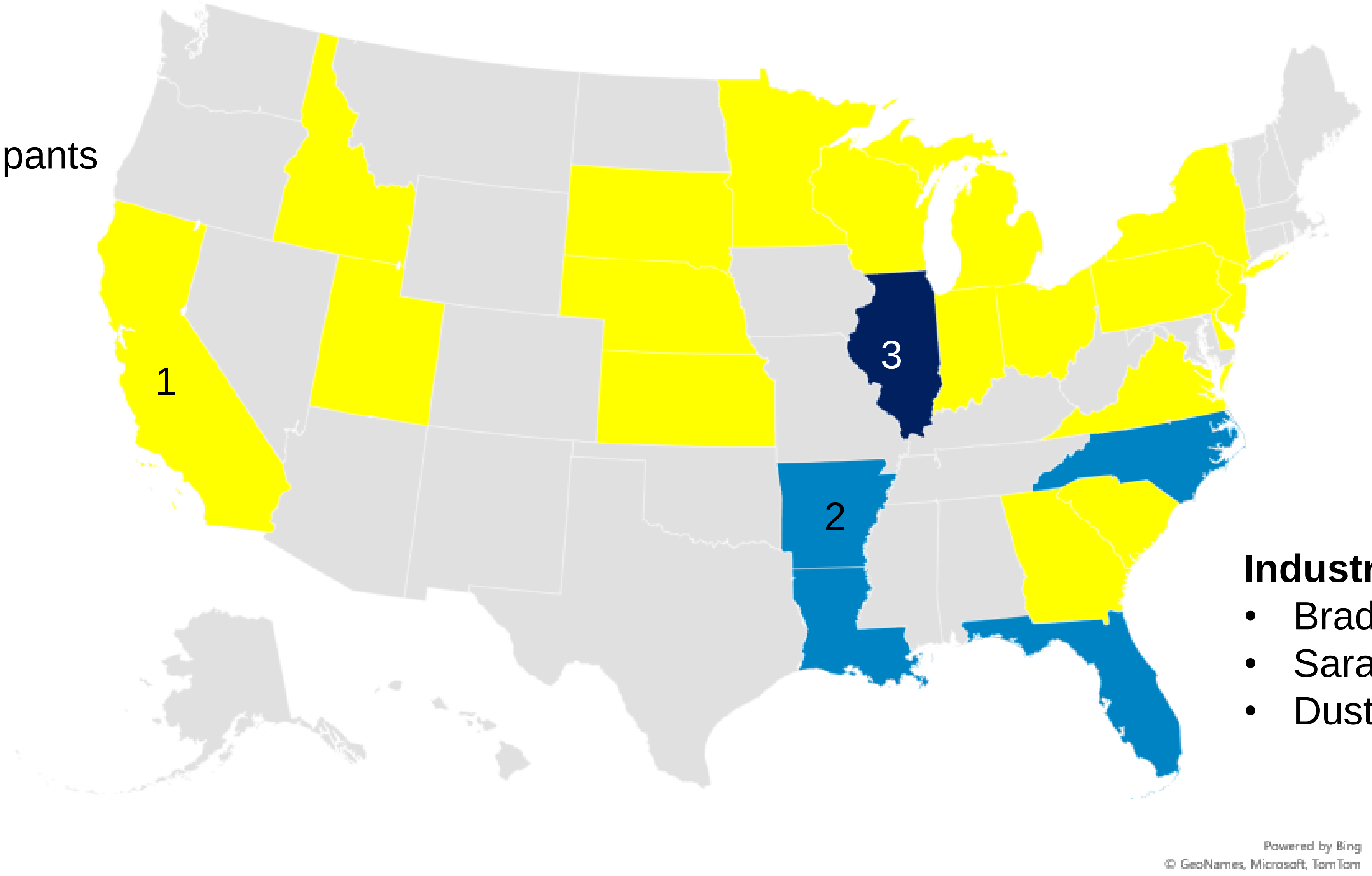
NRSP11 Participants August 2024

Legend (# participants

1

2

3



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