Modernizing Fertilizer Recommendations: The Fertilizer Recommendation Support Tool (FRST)

ALTA Winter Meeting – March 1, 2023

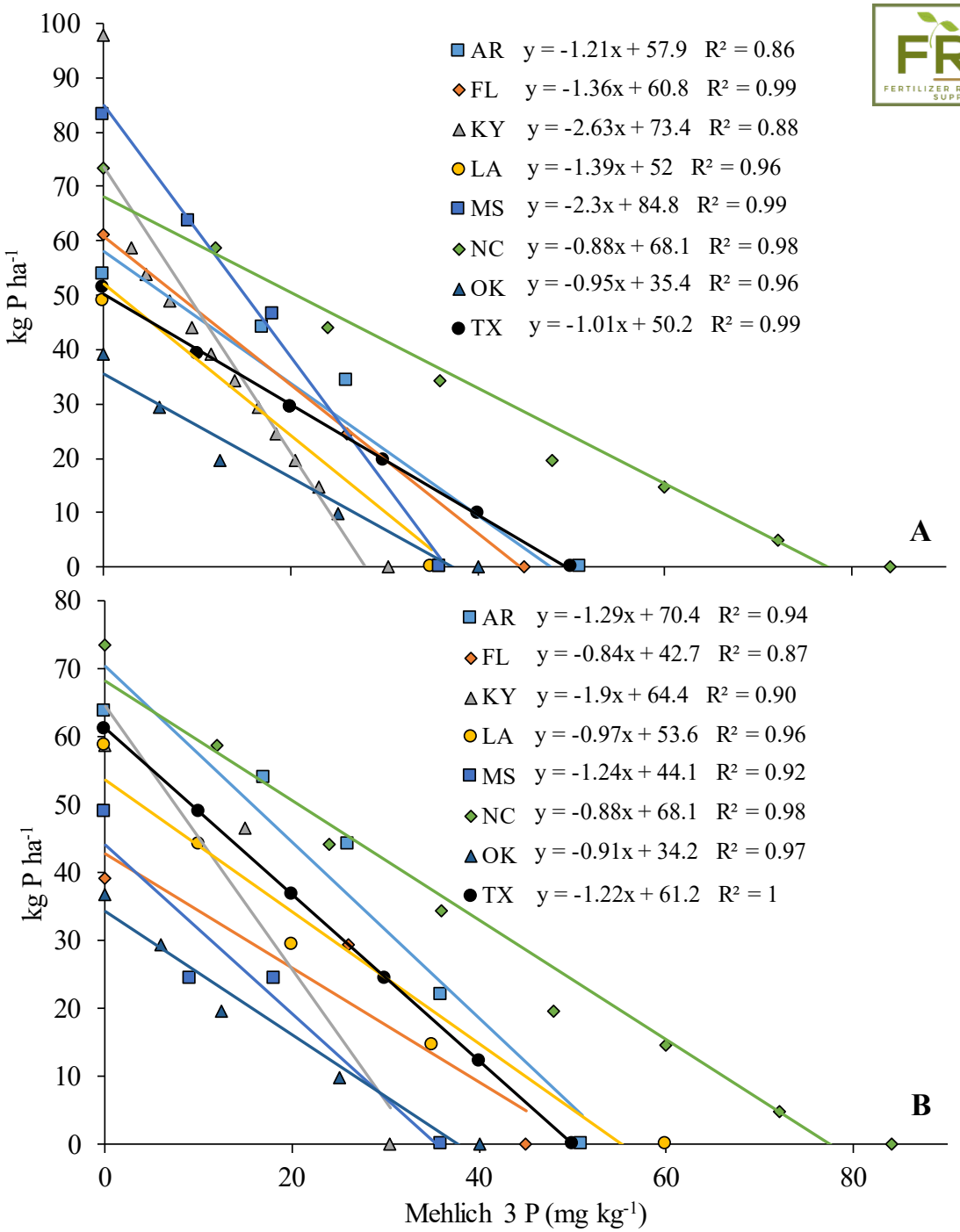
Dr. Sarah E. Lyons

Deanna Osmond, Nathan Slaton, John Spargo, Pete Kleinman,

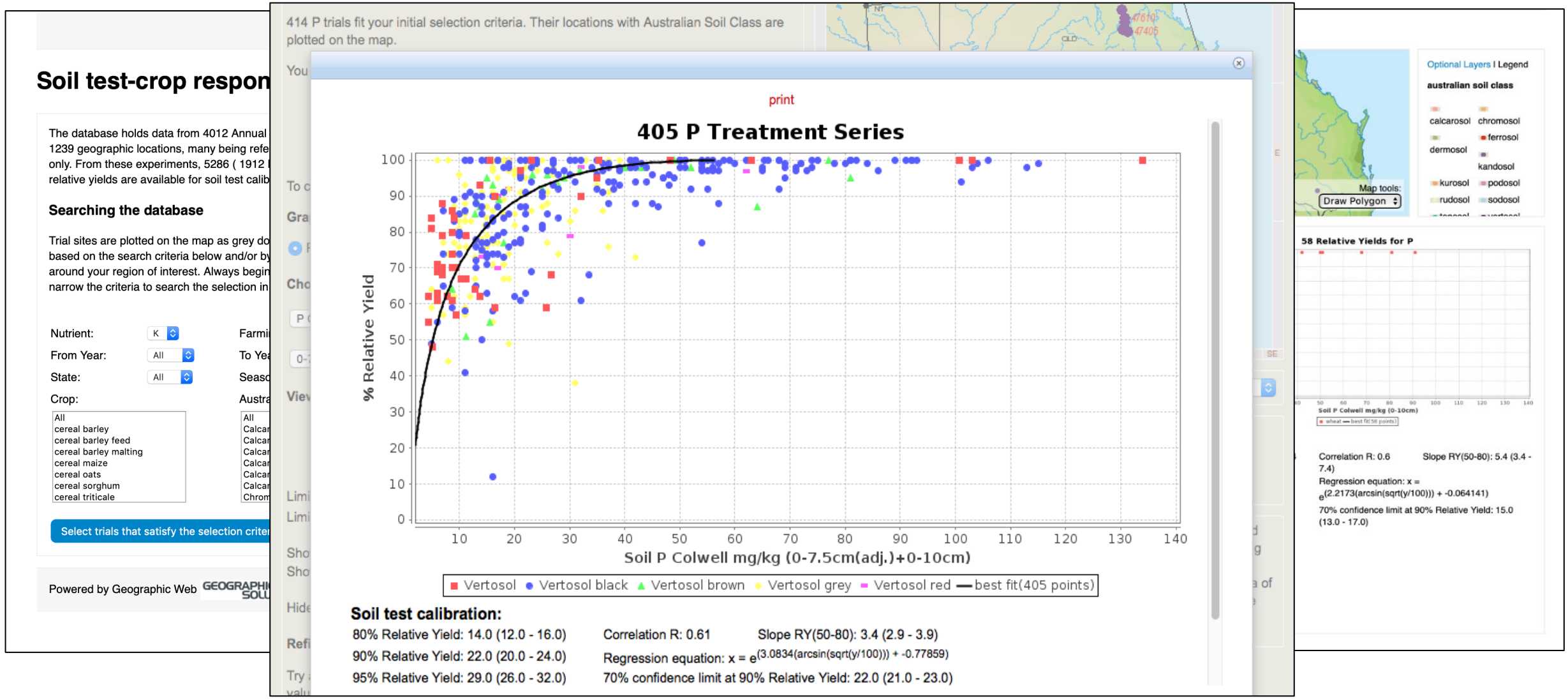
Daniel Kaiser, Matt Yost, & Greg Buol

The Need for FRST

- FRST Began with Southern Soil Fertility Working Group (June 2018)
- Realized large differences in P recommendations across states
- Zhang, H., J. Antonangelo, J.H. Grove, D.L. Osmond, S. Alford, R.J. Florence, G. Huluka, D.H. Hardy, J.T. Lessl, R.O. Maguire, R.S. Mylavarapu, L. Oldham, E.M. Pena-Yewtukhiw, T.L. Provin, N.A. Slaton, L.S. Sonon, D. Sotomayor, and J.J. Wang. 2020. Soil Test Based P and K Rate Recommendations across the Southeast: Similarities and Differences; Opportunities and Challenges. Soil Sci. Soc. Am. J. DOI: 10.1002/saj2.20280



Working together on a larger scale: Big Data



Fertilizer Recommendations Support Tool (FRST)

A Foundation for Modernizing Fertilizer Recommendations

Goal of FRST

To advance the accuracy of soil-test-based fertilizer recommendations by developing a database and decision tool from which recommendations can be scientifically developed and defended as best management practices.

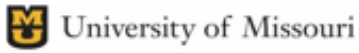
Objectives of FRST

1. Develop a community of practice to galvanize interest and participation around soil fertility.
2. Develop a searchable tool that provides soil test correlation and calibration graphs with statistical confidence intervals for the area of interest (general users)
3. Provide data for nutrient management scientists and modelers to for in-depth analysis of soil test calibration and correlation data (researchers)

FRST Team + Collaborators

Nutifafa Adotey	University of Tennessee
Shannon Alford	Clemson University
Brian Arnall	Oklahoma State University
Dana Ashford	USDA-NRCS
Doug Beegle*	Penn State
Carl Bolster	USDA-ARS
Sylvie Brouder	Purdue University
Tom Bruulsema	IPNI-Canada
Michael Buser	USDA-ARS
Miguel Cabrera	University of Georgia
Ignacio Ciampitti	Kansas State University
Jason Clark	South Dakota State Univ.
Adrian Correndo	Kansas State University
Steve Culman	Washington State Univ.
Leo Deiss	Ohio State University
Jagman Dhillon	Mississippi State Univ.
Gerson Drescher	University of Arkansas
Bhupinder Farmaha	Clemson University
Joshua Faulkner	University of Vermont
Bronc Finch	University of Arkansas
Robert Florence	University of Tennessee
Robert Flynn	New Mexico State Univ.
Luke Gatiboni	North Carolina State Univ.
Daniel Geisseler	Univ. of California - Davis
John Grove	University of Kentucky
David Hardy	NCDA&CS
Daren Harmel	USDA-ARS
Joseph Heckman	Rutgers University
John Hoban	East Carolina University
Bryan Hopkins	Brigham Young University
Gobena Huluka	Auburn University
Javed Iqbal	University of Nebraska
Jim Ippolito	Colorado State University
Sindhu Jagadamma	University of Tennessee
John Jones	University of Wisconsin
Daniel Kaiser	University of Minnesota
Gurpreet Kaur	University of Missouri
Quirine Ketterings	Cornell University
Gene Kim	USDA-NRCS
Pete Kleinman	USDA-ARS
Greg LaBarge	Ohio State University
Gabe LaHue	Washington State Univ.
Jay Lessl	University of Georgia
Sarah Lyons	North Carolina State Univ.
Rory Maguire	Virginia Tech University
Antonio Mallarino	Iowa State University
Andrew Margenot	University of Illinois
Emma Matcham	University of Florida
Marshall McDaniel	Iowa State University
Fernando Miguez	Iowa State University
Robert Miller	Formerly Colorado State
Amber Moore	Oregon State University
Tom Morris*	University of Connecticut
Jake Mowrer	Texas A&M University
Stephanie Murphy	Rutgers University
Rao Mylavarapu	University of Florida
Kelly Nelson	University of Missouri
Nathan Nelson	Kansas State University
Leanna Nigon	The Fertilizer Institute
Deanna Osmond	North Carolina State Univ.
Rasel Parvej	Louisiana State University
Austin Pearce	North Carolina State Univ.
Eugenia Pena-Yewtukhiw	Univ. of West Virginia
Tim Pilkowski	USDA-NRCS
Rishi Prasad	Auburn University
Tony Provin	Texas A&M University
Vaughn Reed	Mississippi State Univ.
Mark Reiter	Virginia Tech University
Edwin Ritchey	University of Kentucky
Matthew Ruark	University of Wisconsin
Dorivar Ruiz Diaz	Kansas State University
Amir Sadeghpour	Southern Illinois University
Hubert Savoy*	University of Tennessee
Charles Shapiro*	University of Nebraska
Lakesh Sharma	University of Florida
Andrew Sharpley *	University of Arkansas
Amy Shober	University of Delaware
Frank Sikora	University of Kentucky
Gurbir Singh	University of Missouri
Jasdeep Singgh	University of Missouri
Sintem	University of Georgia
Nathan Slaton	University of Arkansas
Jared Spackman	University of Idaho
Carissa Spencer	USDA-FSA
David Sotomayor	University of Puerto Rico
John Spargo	Penn State
Kurt Steinke	Michigan State University
Haiying Tao	University of Connecticut
David Tarkalson	USDA-ARS
Gurpal Toor	University of Maryland
Teferi Tsegaye	USDA-ARS
Pete Vadas	USDA-ARS
Jeff Volenec	Purdue University
Jordon Wade	University of Missouri
Forbes Walker	University of Tennessee
Jim Wang	Louisiana State University
Charles White	Penn State
Stephen Wood	The Nature Conservancy
Matt Yost	Utah State University
Frank Yin	University of Tennessee
Hailin Zhang	Oklahoma State University

*Retired



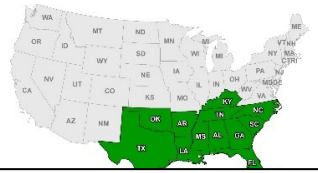
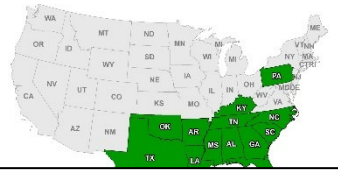
Visit **soiltestfrst.org**

Thanks to our sponsors:

USDA-NRCS
69-3A75-17-45
NR203A7500010C00C

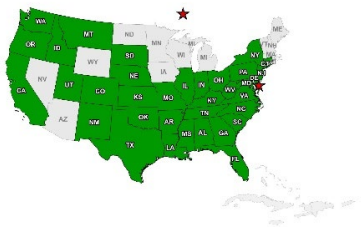
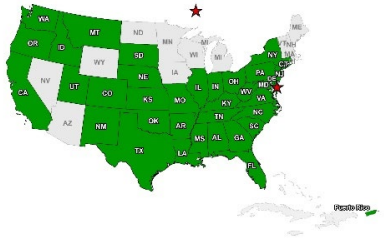
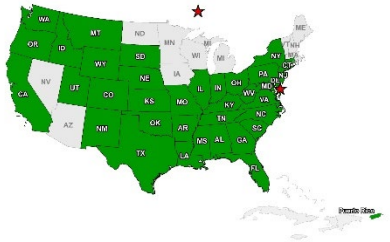
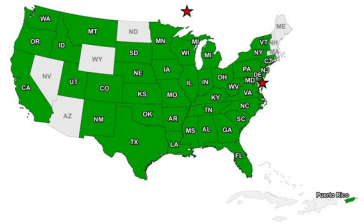
USDA-ARS
58-8070-8-016

FRST Project Collaboration: 2018-2022

Buy-in from the community

- In-person meetings 2019, 2020
- Monthly conference calls
- Volunteers for specific activities

FRST Project: Step-wise activities

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2. Define a minimum dataset for soil test correlation and calibration trials (Slaton)
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6. Sampling depth study (Culman and Spargo)
7. Modeling soil test correlation data (Pearce, Gatiboni, and Slaton)
8. WERA-103 comparison of P and K recommendations (Yost)
9. Develop a user-friendly, searchable interface (decision tool) and internal structure that allows for input, output, and geospatial context (Buol and Osmond)
10. FRST-associated project: lime equations (Miller)

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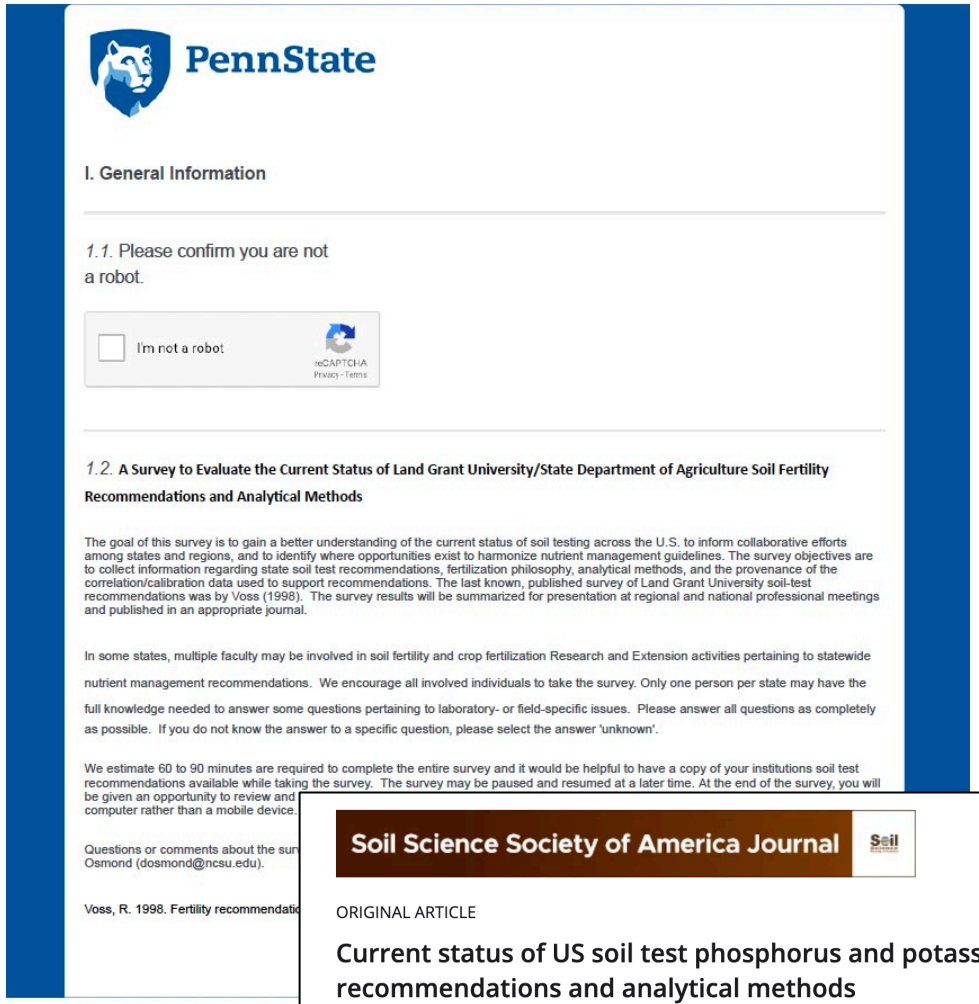
National Land Grant University Soil Fertility Survey

- Goals are to gain a better understanding of the current status of soil testing across the U.S. to direct collaborative efforts among states and regions, and to identify where opportunities exist to harmonize recommendation guidelines.
- Collected Information About:
  - Analytical methods
  - Fertilizer recommendations and philosophy used
  - Status of correlation/calibration data
    - Correlation: Relationship between crop yield and a soil test nutrient
    - Calibration: Crop response to fertilization at specific nutrient concentrations

National Land Grant University Soil Fertility Survey

- 48 states and Puerto Rico
- 100 questions in 9 different categories, including laboratory and research funding, soil test recommendations, soil analysis methods, soil sampling, and soil health
- Survey and data published in Ag Data Commons (Spargo et al., 2022, doi:10.15482/USDA.ADC/1526506)
- SSSAJ article: doi.org/10.1002/saj2.20536



PennState

I. General Information

1.1. Please confirm you are not a robot.

I'm not a robot

1.2. A Survey to Evaluate the Current Status of Land Grant University/State Department of Agriculture Soil Fertility Recommendations and Analytical Methods

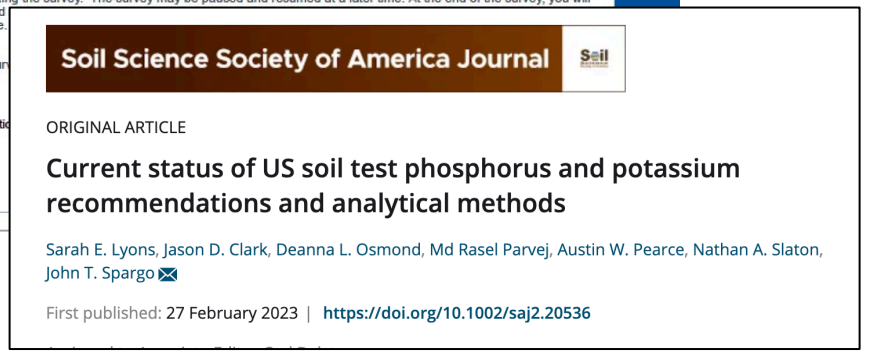
The goal of this survey is to gain a better understanding of the current status of soil testing across the U.S. to inform collaborative efforts among states and regions, and to identify where opportunities exist to harmonize nutrient management guidelines. The survey objectives are to collect information regarding state soil test recommendations, fertilization philosophy, analytical methods, and the provenance of the correlation/calibration data used to support recommendations. The last known, published survey of Land Grant University soil-test recommendations was by Voss (1998). The survey results will be summarized for presentation at regional and national professional meetings and published in an appropriate journal.

In some states, multiple faculty may be involved in soil fertility and crop fertilization Research and Extension activities pertaining to statewide nutrient management recommendations. We encourage all involved individuals to take the survey. Only one person per state may have the full knowledge needed to answer some questions pertaining to laboratory- or field-specific issues. Please answer all questions as completely as possible. If you do not know the answer to a specific question, please select the answer 'unknown'.

We estimate 60 to 90 minutes are required to complete the entire survey and it would be helpful to have a copy of your institutions soil test recommendations available while taking the survey. The survey may be paused and resumed at a later time. At the end of the survey, you will be given an opportunity to review and computer rather than a mobile device.

Questions or comments about the sur Osmond (dosmond@ncsu.edu).

Voss, R. 1998. Fertility recommendatio



Soil Science Society of America Journal

ORIGINAL ARTICLE

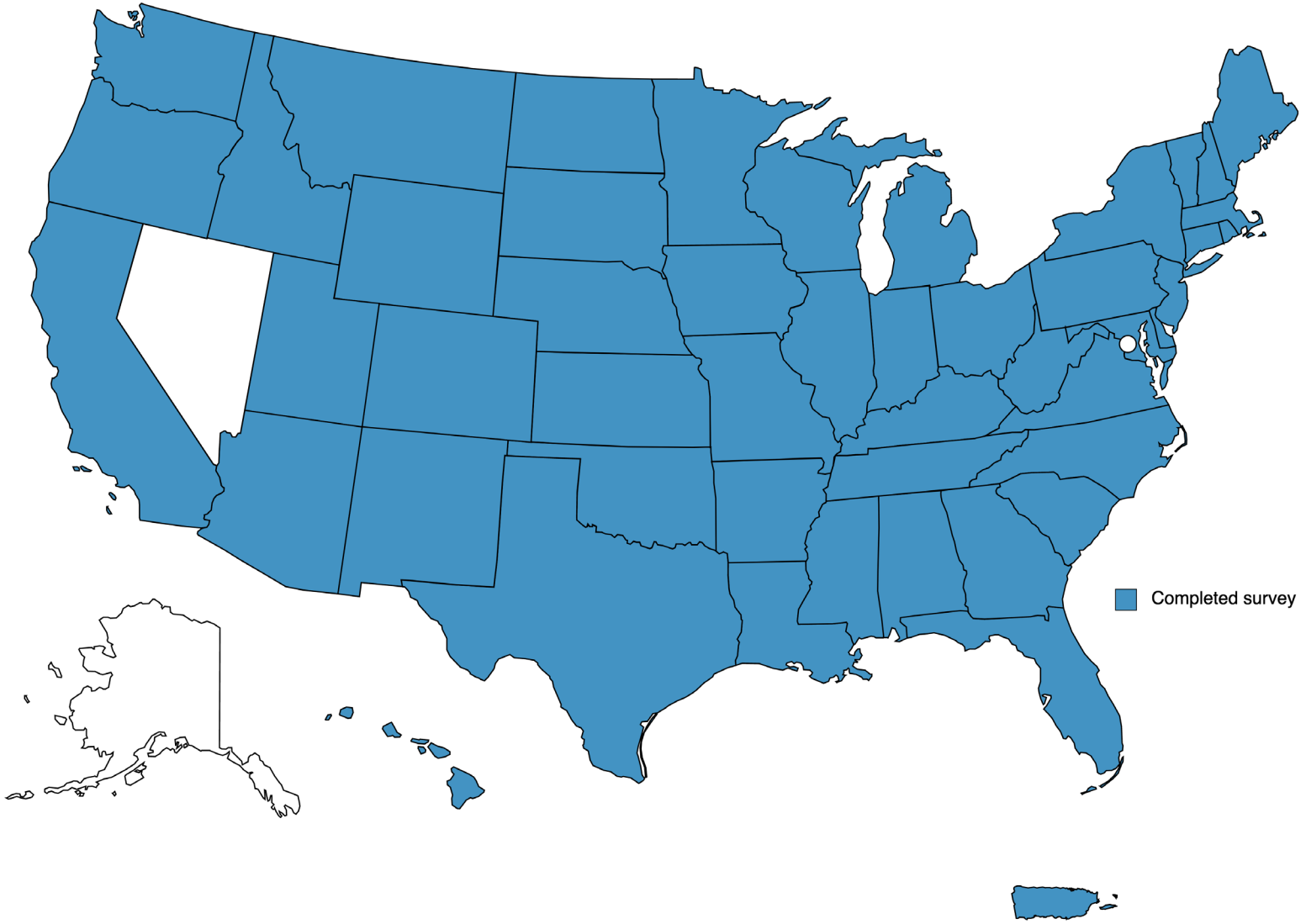
Current status of US soil test phosphorus and potassium recommendations and analytical methods

Sarah E. Lyons, Jason D. Clark, Deanna L. Osmond, Md Rasel Parvej, Austin W. Pearce, Nathan A. Slaton, John T. Spargo

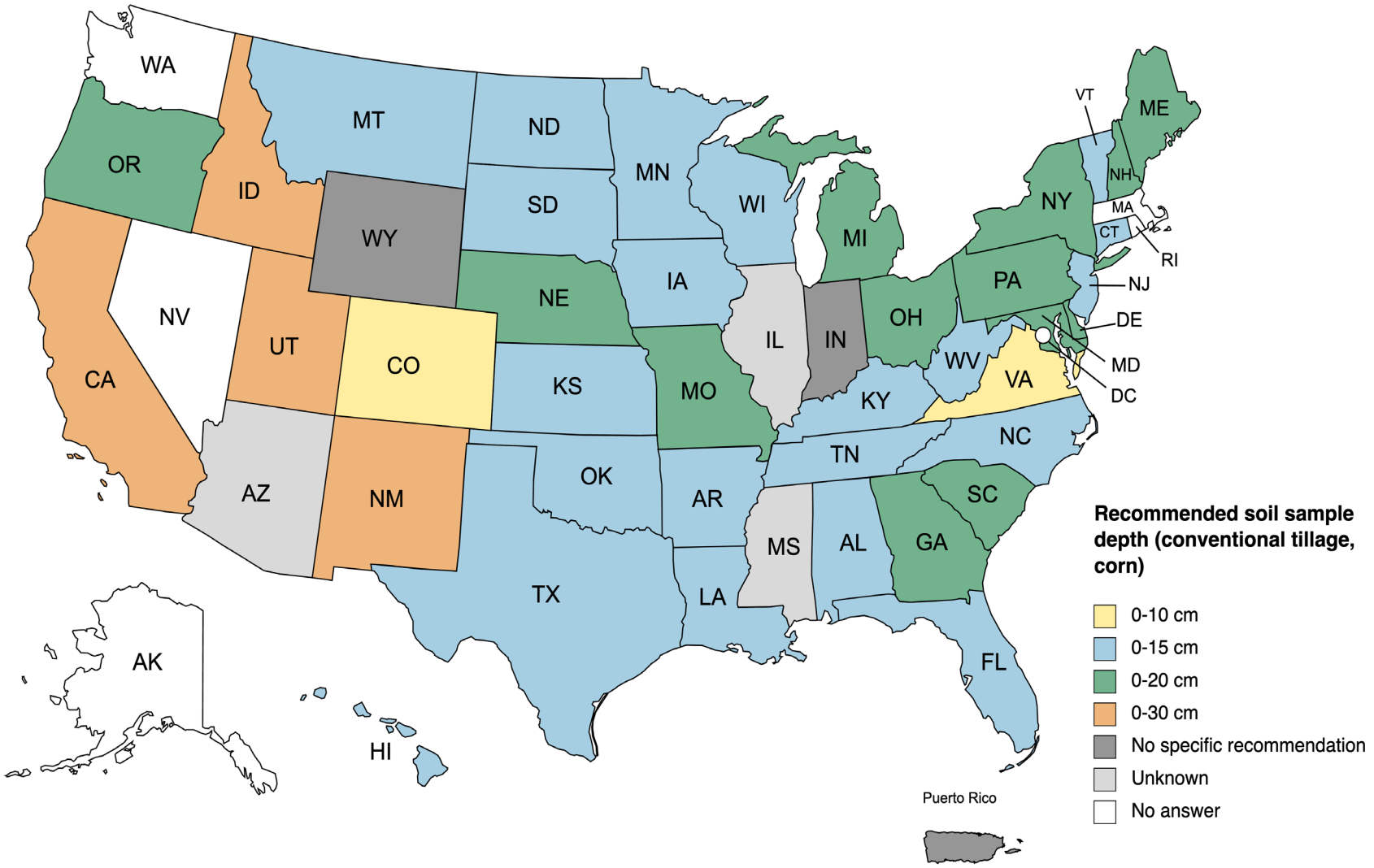
First published: 27 February 2023 | https://doi.org/10.1002/saj2.20536

National Soil Fertility Survey: Participation

- By June 2nd, 2020, 60 responses representing 48 states and Puerto Rico were received.



National Soil Fertility Survey: Results



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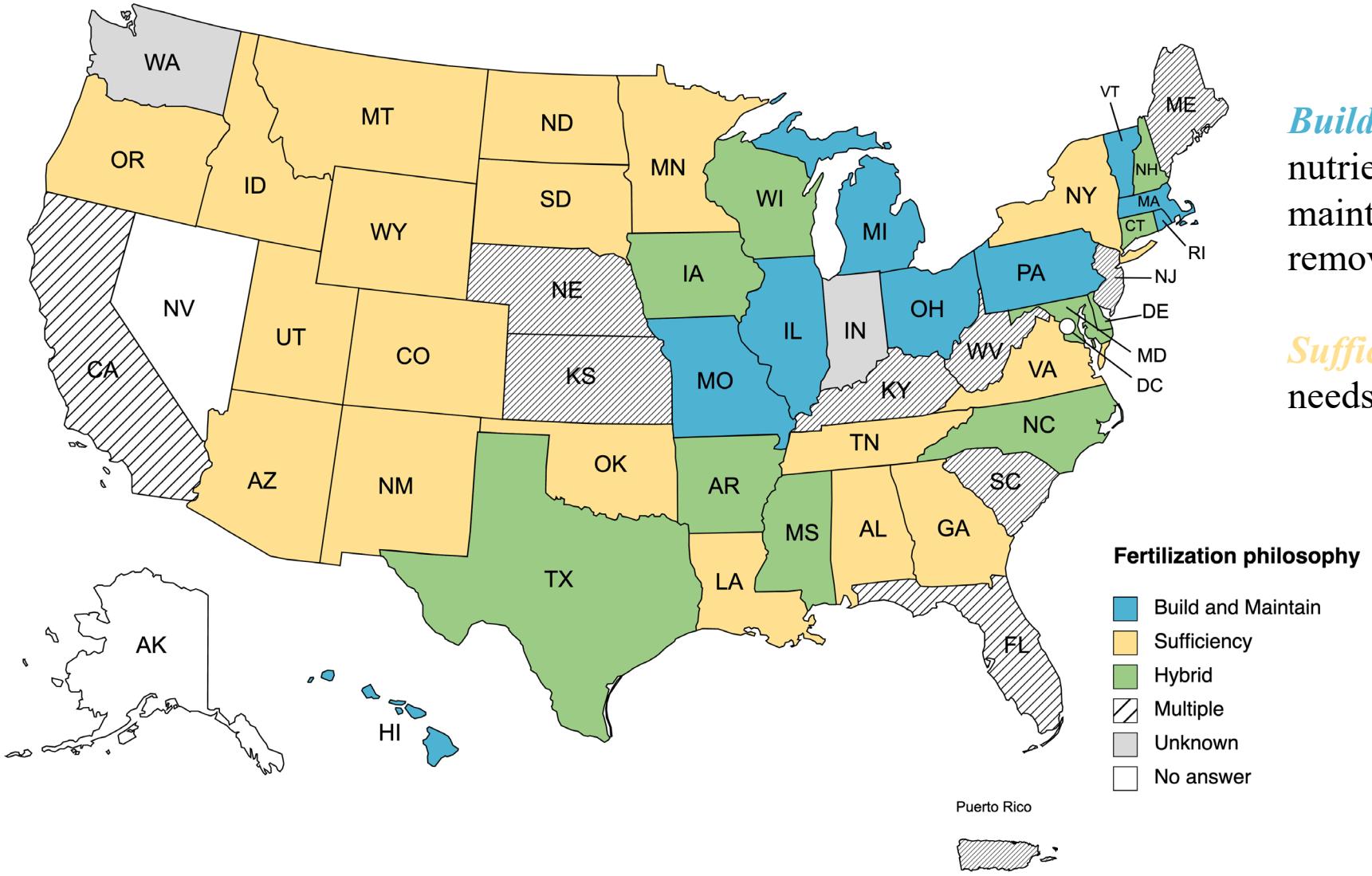
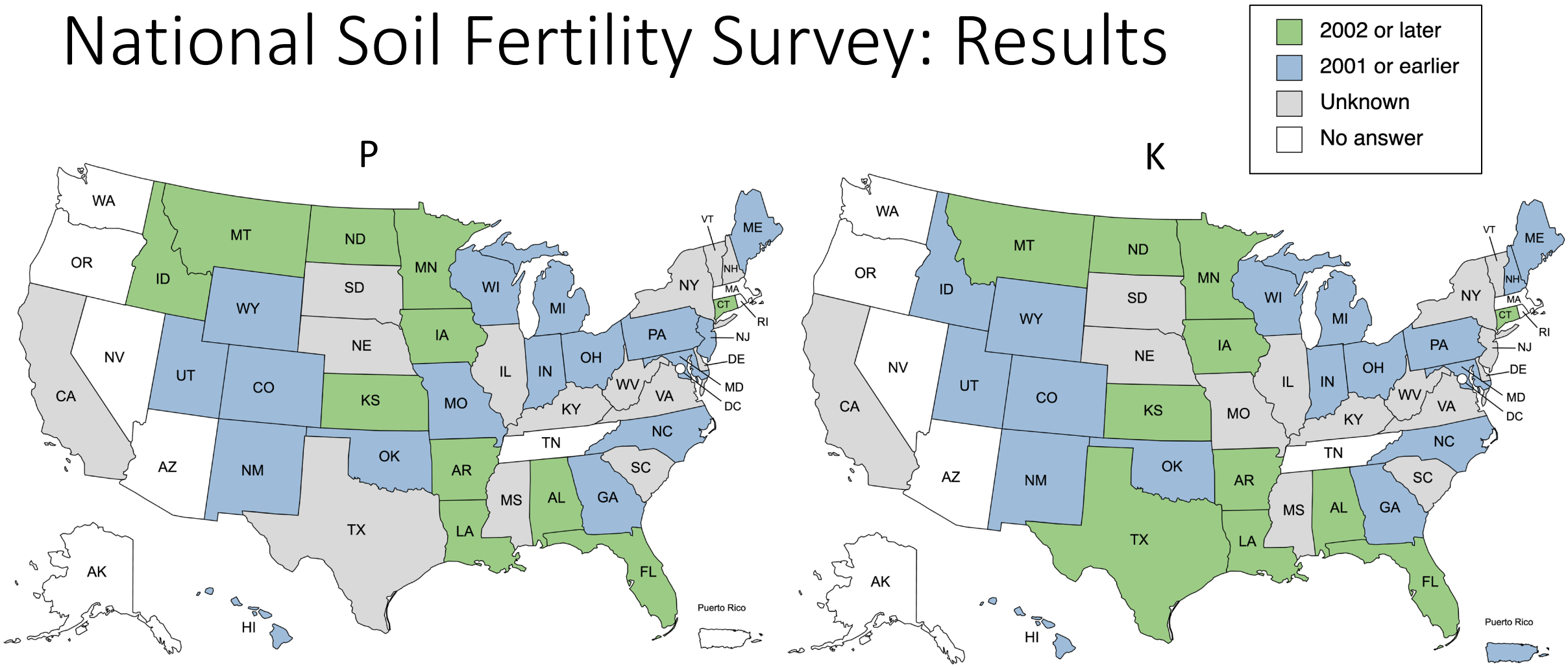


Build and Maintain: Build soil nutrients to optimum range, then maintain by applying at crop removal

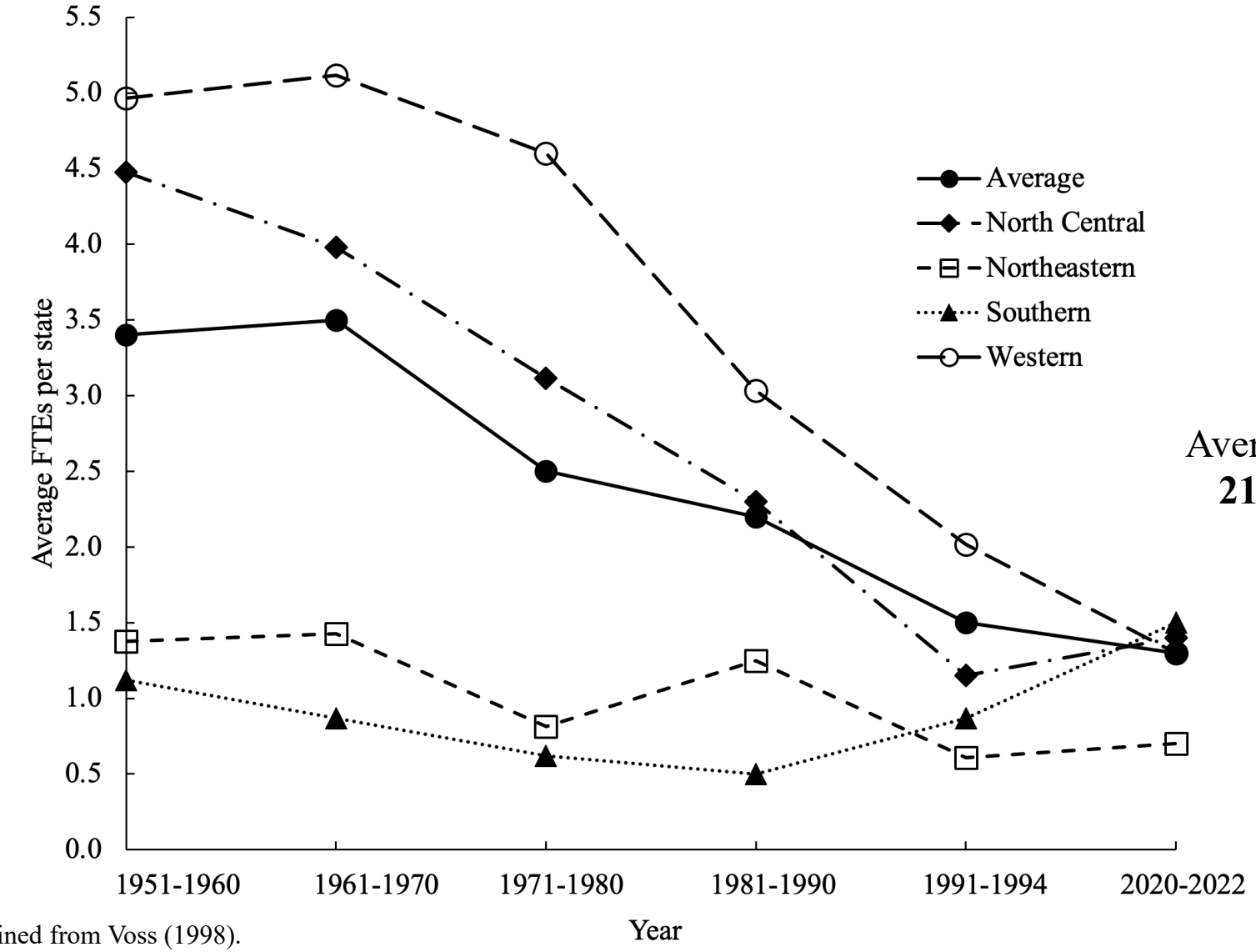
Sufficiency: Apply to meet crop needs, not build soil fertility

National Soil Fertility Survey: Results



Year current soil test field correlation was last established or validated for corn

National Soil Fertility Survey: Results



Average decrease in FTEs:
21.5% every ten years

Data for years 1951-1994 obtained from Voss (1998).

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Development of a Minimum Dataset Protocol for Soil Test Correlation and Calibration Trials

- Standardize information/data that should be collected to guide soil-test correlation and calibration research
  - Consensus among scientists
  - Guide research protocols and publication of research results
  - Qualify data for inclusion in meta-analyses
  - Promote good science but not be overly restrictive
    - Required vs recommended data
- Facilitate data sharing

Minimum Dataset Organization

- Data origin and ownership
- Soil sample collection and processing details
- Soil analysis and properties
- Metadata
  - Trial & treatment description
  - Cropping system metadata
  - Field management
  - Location & weather
  - Harvest details
  - Experiment design, structure and analysis
- Data
  - Means vs plot-level data

Received: 23 May 2021 | Accepted: 14 September 2021
DOI: 10.1002/saj2.20338
Soil Science Society of America Journal
REVIEW & ANALYSIS

Minimum dataset and metadata guidelines for soil-test correlation and calibration research

Nathan A. Slaton[1] | Sarah E. Lyons[2] | Deanna L. Osmond[2] | Sylvie M. Brouder[3] | Steve W. Culman[4] | Gerson Drescher[1] | Luciano C. Gatiboni[2] | John Hoben[5] | Peter J. A. Kleinman[6] | Joshua M. McGrath[7] | Robert O. Miller[8] | Austin Pearce[2] | Amy L. Shober[9] | John T. Spargo[10] | Jeff J. Volenec[3]

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[10] Agricultural Analytical Services Lab., PA State Univ., University Park, PA 16802, USA

Correspondence
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Email: nslaton@uark.edu

Assigned to Associate Editor David Hardy.

Funding information
Agricultural Research Service, Grant/Award Number: 58-8070-8-016; Natural Resources Conservation Service, Grant/Award Numbers: 69-3A75-17-45, NR203A7500010C00C

Abstract
Soil-test correlation and calibration data are essential to modern agriculture, and their continued relevance is underscored by the expansion of precision farming and the persistence of sustainable soil management priorities. In support of transparent, science-based fertilizer recommendations, we seek to establish a core set of required and recommended information for soil-test P and K correlation and calibration studies, a minimum dataset, building on previous research. The Fertilizer Recommendation Support Tool (FRST) project team and collaborators are developing a national database that will support a soil-test-based nutrient management decision aid tool. The FRST team includes over 80 scientists from 37 land-grant universities, two state universities, one private university, three federal agencies, two private not-for-profit organizations, and one state department of agriculture. The minimum dataset committee developed and vetted a robust set of factors fo minimum dataset consideration that includes information on soil sample collection and processing, soil chemical and physical properties, experimental design and statistical analyses, and metadata

Abbreviations: 4RNS, 4R Nutrient Stewardship; BFDC, Better Fertilizer Decisions for Cropping Systems; FRST, Fertilizer Recommendation Support Tool.

Soil Sci. Soc. America J. (2022) 86:19-33
DOI: 10.1002/saj2.20338

Minimum Dataset for Correlation and Calibration Trials

Category	Required data	Recommended data
Soil sample collection and processing metadata	9	5
Soil chemical and physical properties	6	19
Crop, soil, and nutrient management metadata	26	17
Experimental design and statistical analysis	8	9

Soil Sci. Soc. America J. (2022) 86:19-33
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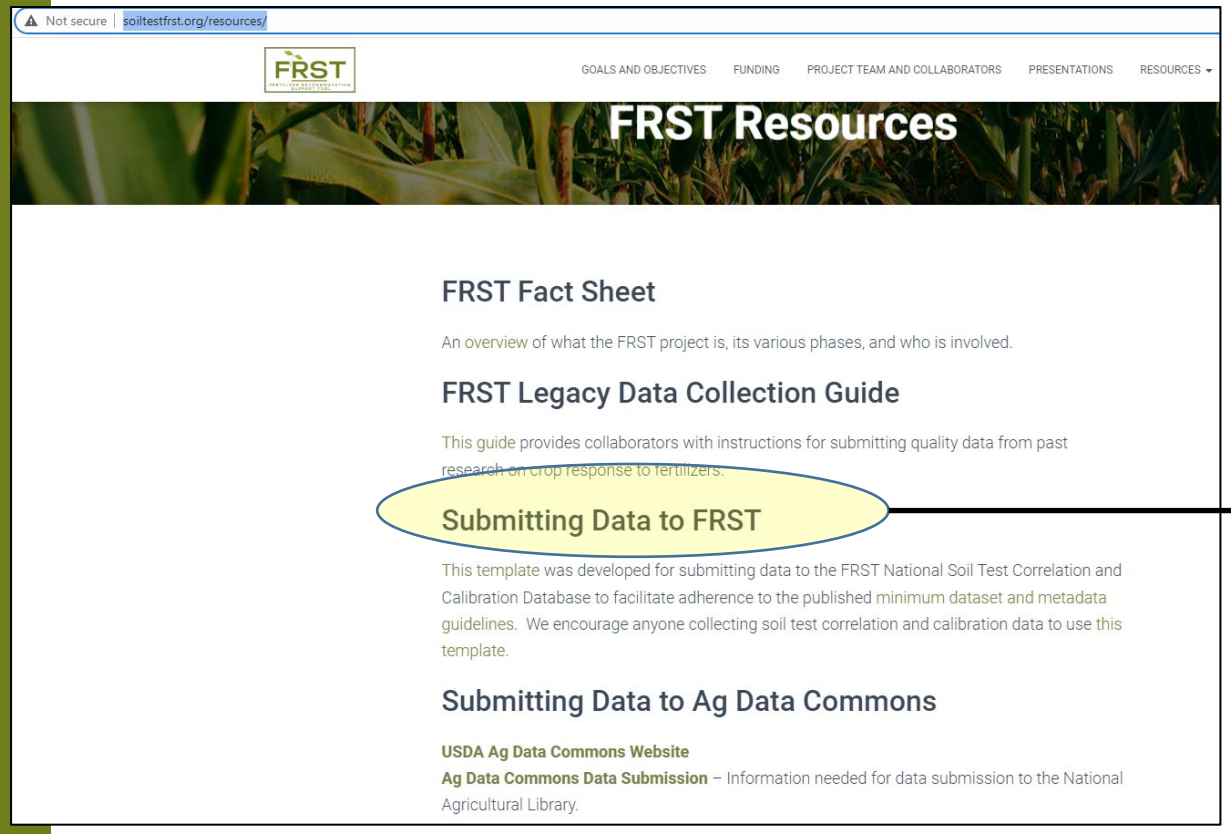
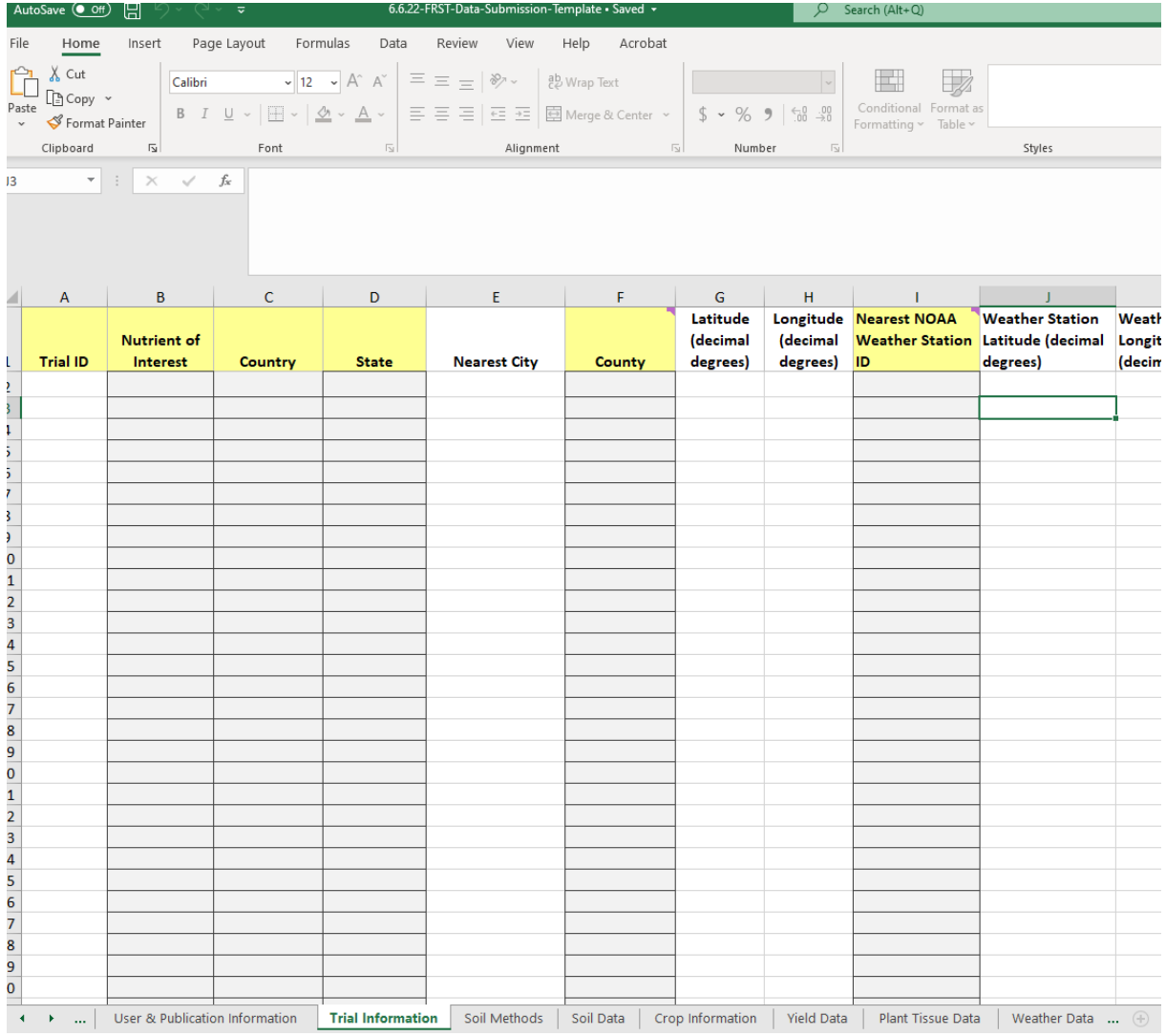
Soil-test property or information[a]	Minimum dataset category[b]	Level of measurement[c]		Data[d]
		SYT	MYT	
pH	Required	Block	Treatment	n, $\bar{x}$, variance
SOM	Required	Block	Treatment	n, $\bar{x}$, variance
P	Required	Block	Treatment	n, $\bar{x}$, variance
K	Required	Block	Treatment	n, $\bar{x}$, variance
Ca	Required	Block	Treatment	n, $\bar{x}$, variance
Mg	Required	Block	Treatment	n, $\bar{x}$, variance
Na	Recommended	Site	Site	$\bar{x}$
PSD	Recommended	Site	Site	$\bar{x}$
Ex. acidity	Recommended	Site	Site	$\bar{x}$
Buffer pH	Recommended	Site	Site	$\bar{x}$
CEC	Recommended	Site	Site	$\bar{x}$
Total P	Recommended	Site	Site	$\bar{x}$
Al	Recommended	Site	Site	$\bar{x}$
S	Recommended	Site	Site	$\bar{x}$
Fe	Recommended	Site	Site	$\bar{x}$
Mn	Recommended	Site	Site	$\bar{x}$
Zn	Recommended	Site	Site	$\bar{x}$
Cu	Recommended	Site	Site	$\bar{x}$
B	Recommended	Site	Site	$\bar{x}$
EC	Recommended	Site	Site	$\bar{x}$
$CaCO_3$ content	Recommended	Site	Site	$\bar{x}$

Template for Data Submission

- www.soiltestfrst.org/resources





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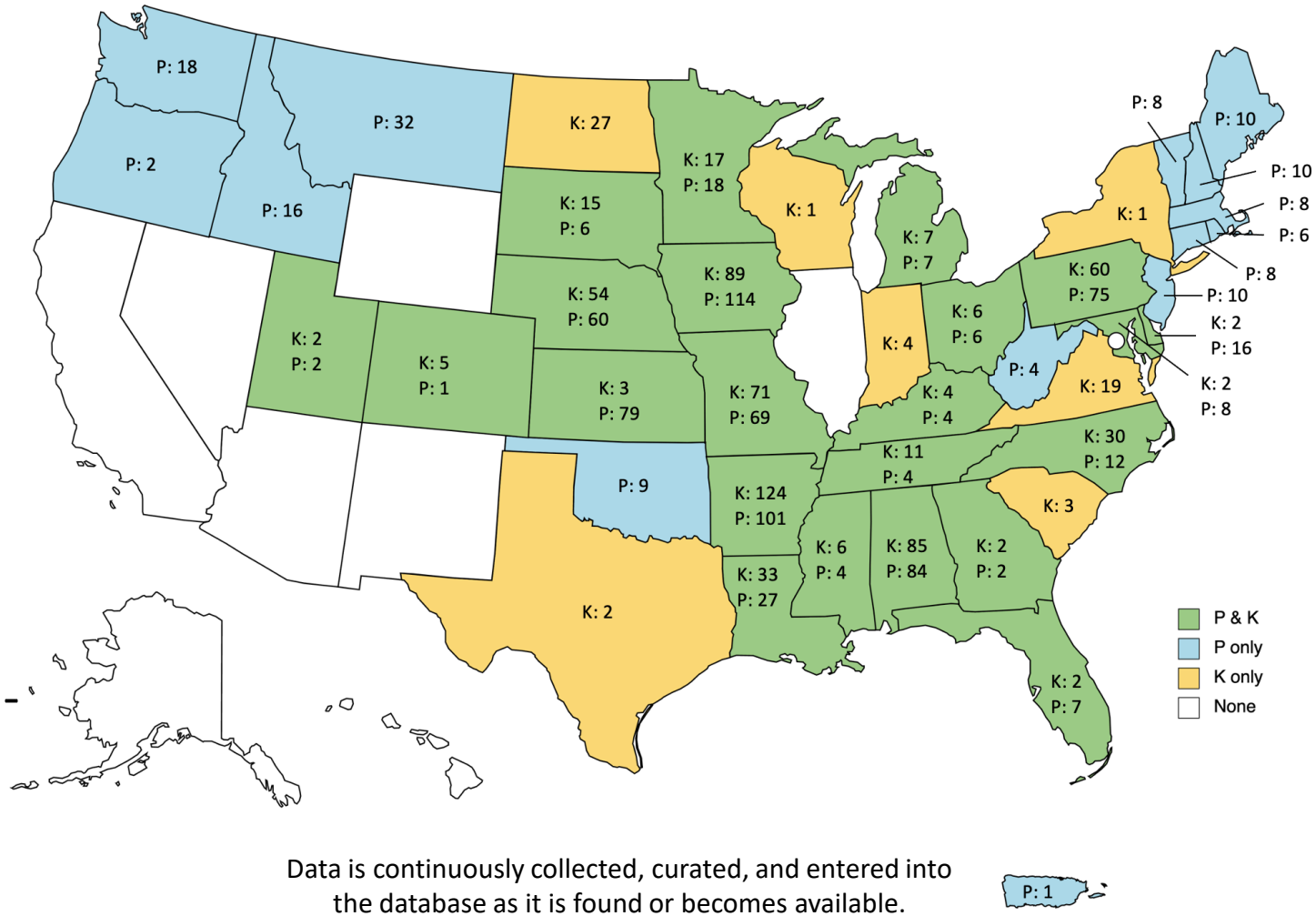
FRST Legacy Database

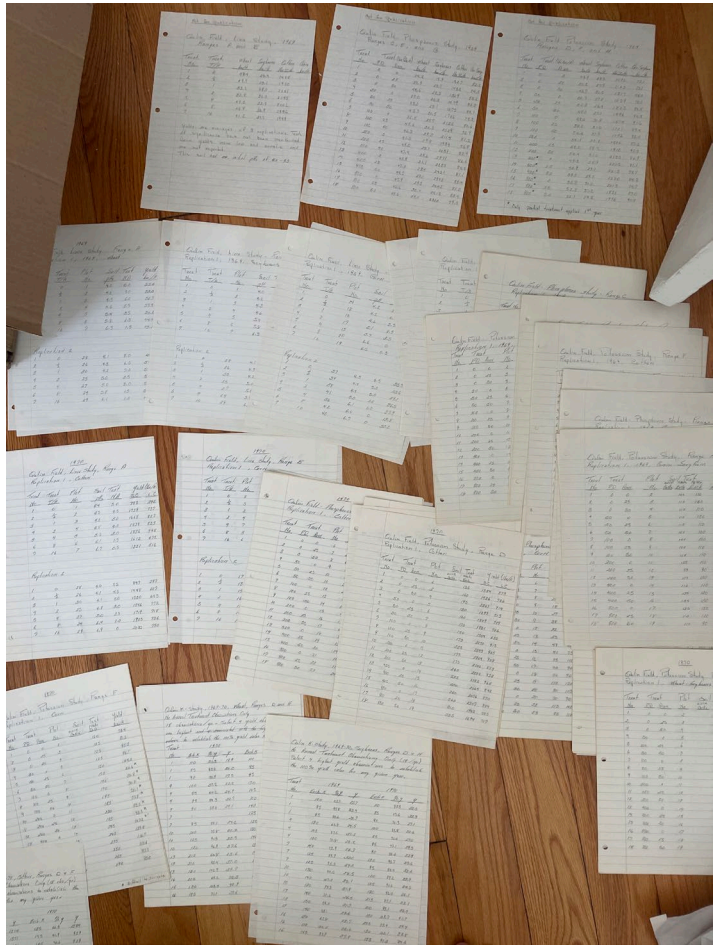
- Database accessed by the Fertilizer Recommendation Support Tool (FRST)
- Contains USA soil-test P and K correlation and calibration trial data
- Data collected from many sources
  - Journal articles, extension and research bulletins, conference proceedings, dissertations and theses, spreadsheets, and word-processing documents
  - Raw and summarized

P and K Trials in the FRST Database



Data is continuously collected, curated, and entered into the database as it is found or becomes available.

Collecting Legacy Data

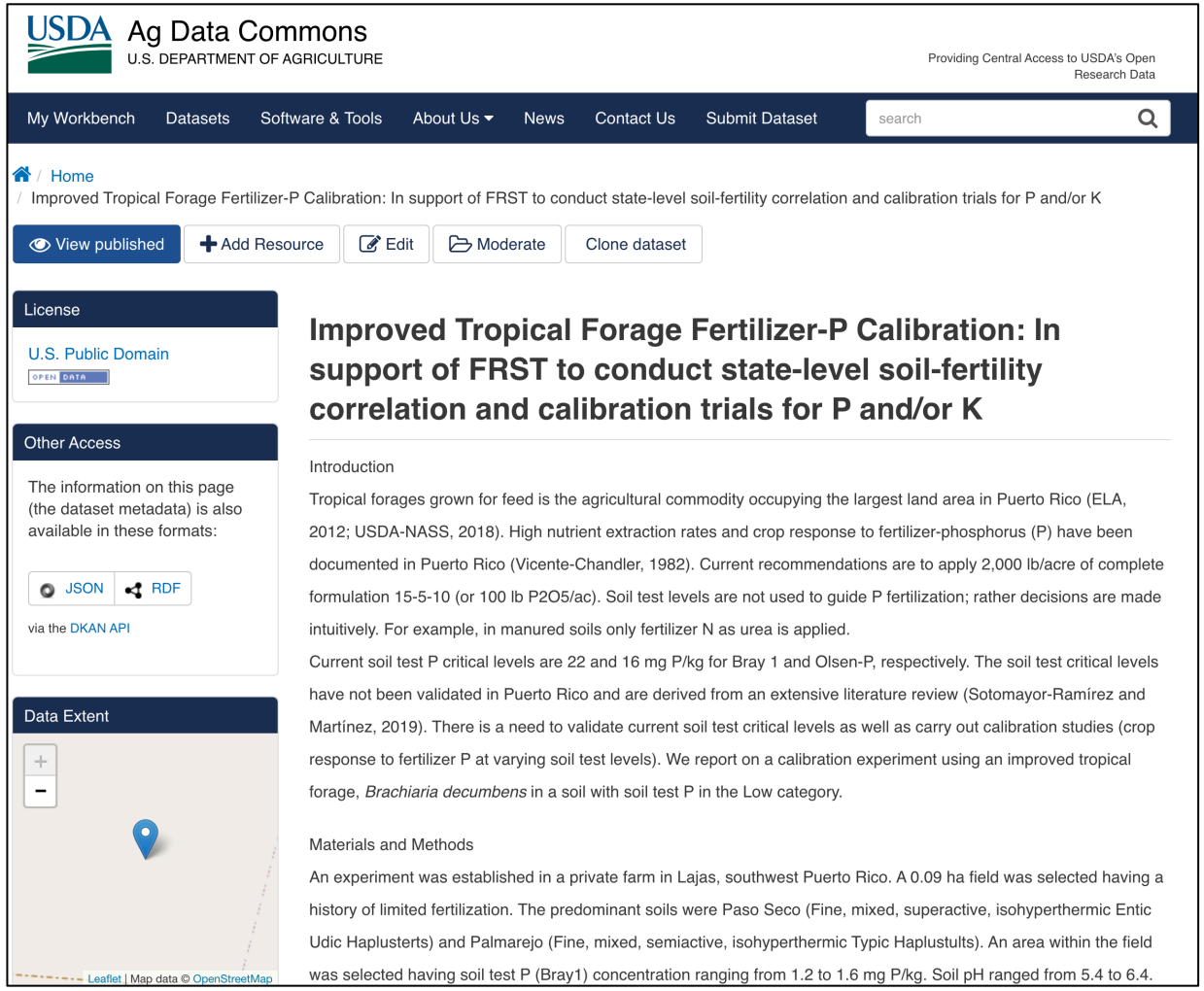


FRST Legacy Database Summary

Trials	1,566	Years	1949 - 2022
Crops	Alfalfa, bahiagrass, barley, bermudagrass, brachiariagrass, camelina, corn (grain and silage), chickpea, clover/grass mix, cotton, flax, lentil, oat, pea, peanut, potato, rice, sorghum, sorghum x sudangrass, soybean, sugarcane, sweet potato, wheat	P methods	Mehlich-1 & -3, Bray-1 & -2, Olsen, Morgan, Modified Morgan, MS Soil Test (Lancaster), acetic acid, resin, Pi, water, double acid, total P, Oxalate, ammonium acetate, Haney, Truog, sodium acetate, oxalate, AB-DTPA
States	AL, AR, CO, CT, DE, FL, GA, IA, ID, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NY, OH, OK, OR, PA, PR, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV	K methods	Mehlich-1 & -3, ammonium acetate, nitric acid, saturation, rate of release, MS Soil Test (Lancaster), Olsen, Morgan, Modified Morgan, resin, tetraphenylboron, calcium chloride

Data is continuously collected, curated, and entered into the database as it is found or becomes available.

FRST Legacy Database: Data Publications



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Home / Improved Tropical Forage Fertilizer-P Calibration: In support of FRST to conduct state-level soil-fertility correlation and calibration trials for P and/or K

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The information on this page (the dataset metadata) is also available in these formats:

JSON | RDF

via the DKAN API

Data Extent

Leaflet | Map data © OpenStreetMap

Improved Tropical Forage Fertilizer-P Calibration: In support of FRST to conduct state-level soil-fertility correlation and calibration trials for P and/or K

Introduction

Tropical forages grown for feed is the agricultural commodity occupying the largest land area in Puerto Rico (ELA, 2012; USDA-NASS, 2018). High nutrient extraction rates and crop response to fertilizer-phosphorus (P) have been documented in Puerto Rico (Vicente-Chandler, 1982). Current recommendations are to apply 2,000 lb/acre of complete formulation 15-5-10 (or 100 lb P_2O_5/ac). Soil test levels are not used to guide P fertilization; rather decisions are made intuitively. For example, in manured soils only fertilizer N as urea is applied.

Current soil test P critical levels are 22 and 16 mg P/kg for Bray 1 and Olsen-P, respectively. The soil test critical levels have not been validated in Puerto Rico and are derived from an extensive literature review (Sotomayor-Ramírez and Martínez, 2019). There is a need to validate current soil test critical levels as well as carry out calibration studies (crop response to fertilizer P at varying soil test levels). We report on a calibration experiment using an improved tropical forage, *Brachiaria decumbens* in a soil with soil test P in the Low category.

Materials and Methods

An experiment was established in a private farm in Lajas, southwest Puerto Rico. A 0.09 ha field was selected having a history of limited fertilization. The predominant soils were Paso Seco (Fine, mixed, superactive, isohyperthermic Entic Udic Haplusterts) and Palmarejo (Fine, mixed, semiactive, isohyperthermic Typic Haplustults). An area within the field was selected having soil test P (Bray1) concentration ranging from 1.2 to 1.6 mg P/kg. Soil pH ranged from 5.4 to 6.4.

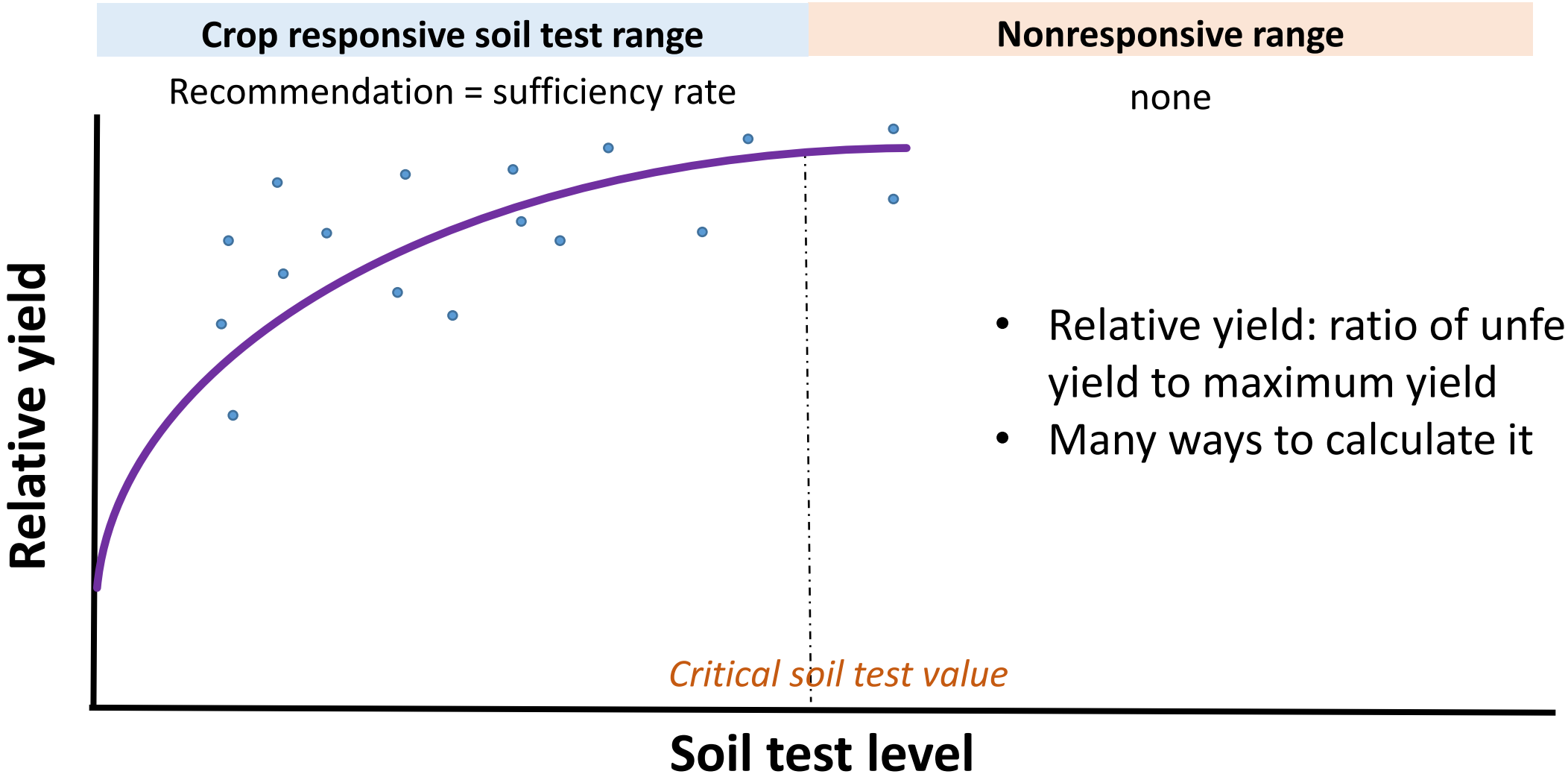
FRST Facilitated Submissions

- Fisher, T. R., Lyons, S. E., Roth, J. A., & Fisher, T. E. (2021). Legacy Phosphorus and Potassium Correlation Experiments: Qulin, Missouri. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1524293**
- Jagadamma, S., & Savoy, H. J. (2020). Comparison of four extractants used in soil phosphorus and potassium testing for two soils in a corn-wheat-soybean rotation in Tennessee receiving various amounts of P and K fertilizer. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1519155**
- Rogers, C. W., Dari, B., & Liang, X. (2022). Plant, grain, and soil response of irrigated malt barley as affected by cultivar, phosphorus, and sulfur applications on an alkaline soil. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1526436**
- Savoy, H. J., Leib, B. G., & Grant. T. (2021). Alfalfa response to potassium rate and timing of application. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1520724**
- Slaton, N. A., Pearce, A. W., Lyons, S. E., Drescher, G. L., & Smartt, A. D. (2022). Soybean Yield Response to Fertilizer-Phosphorus Rate on Soils having different Mehlich-3 Phosphorus Values in Arkansas. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1524648**
- Sotomayor, D. R., & Araya, K. (2021). Improved Tropical Forage Fertilizer-P Calibration: In support of FRST to conduct state-level soil-fertility correlation and calibration trials for P and/or K. *Ag Data Commons*. **https://doi.org/10.15482/USDA.ADC/1524294**

FRST Project: Step-wise activities

1. Survey of land grant faculty on current soil test practices and recommendations (Spargo)
2. Define a minimum dataset for soil test correlation and calibration trials (Slaton)
3. Collect legacy soil test correlation and calibration data and develop an accompanying relational database (Lyons and Buol)
4. **Determine the most appropriate relative yield definition for FRST (Pearce, Lyons and Slaton)**
5. Collaborator soil test fertility trials (Osmond and Lyons)
6. Sampling depth study (Culman and Spargo)
7. Modeling soil test correlation data (Pearce, Gatiboni, and Slaton)
8. WERA-103 comparison of P and K recommendations (Yost)
9. Develop a user-friendly, searchable interface (decision tool) and internal structure that allows for input, output, and geospatial context (Buol and Osmond)
10. FRST-associated project: lime equations (Miller)

Importance of Relative Yield

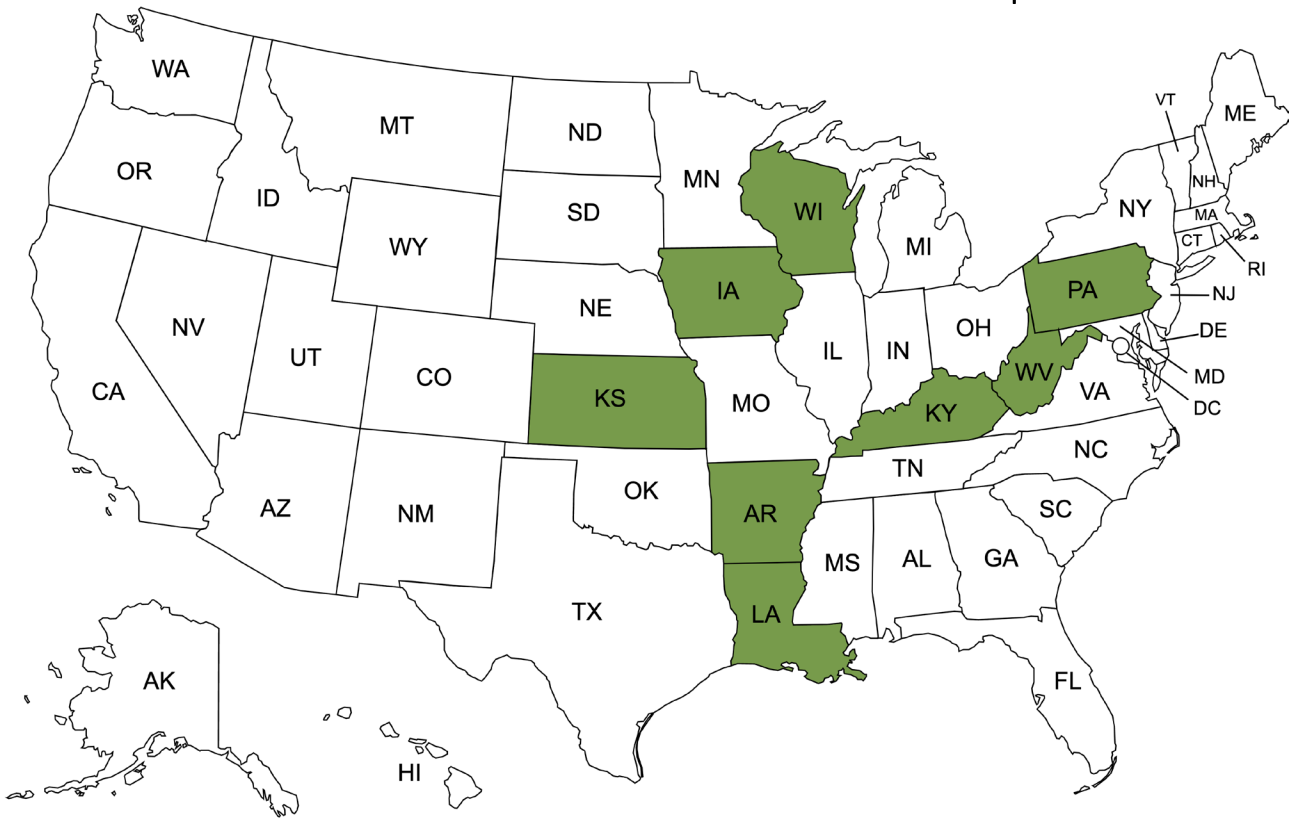


- Relative yield: ratio of unfertilized yield to maximum yield
- Many ways to calculate it

Relative Yield Study

- Goal: Determine which definition(s) will be used in the Fertilizer Recommendation Support Tool (FRST).
- Consensus: Control yield/ Numerical maximum among all treatments (including control)
- SSSAJ doi:10.1002/saj2.20450

FRST Relative Yield Definition: Participation



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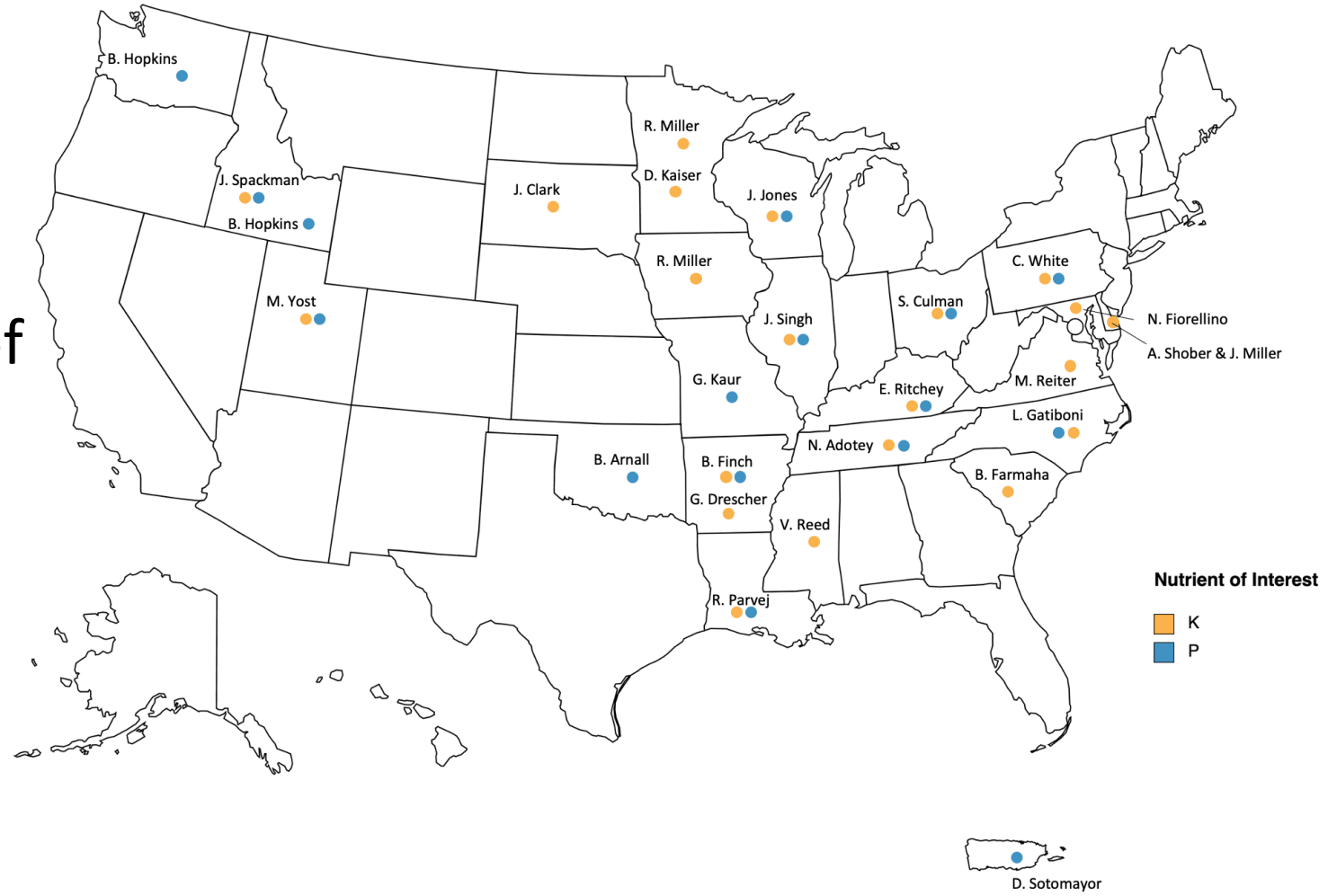
Collaborator (State-level) Soil Test Correlation and Calibration Trials (2021-2023)

Objectives

- Involve more collaborators
- Collect additional data
- Test scripting and upload of minimum dataset from Excel into the relational database
- Determine ease of use of minimum dataset



soiltestfrst.org/presentations

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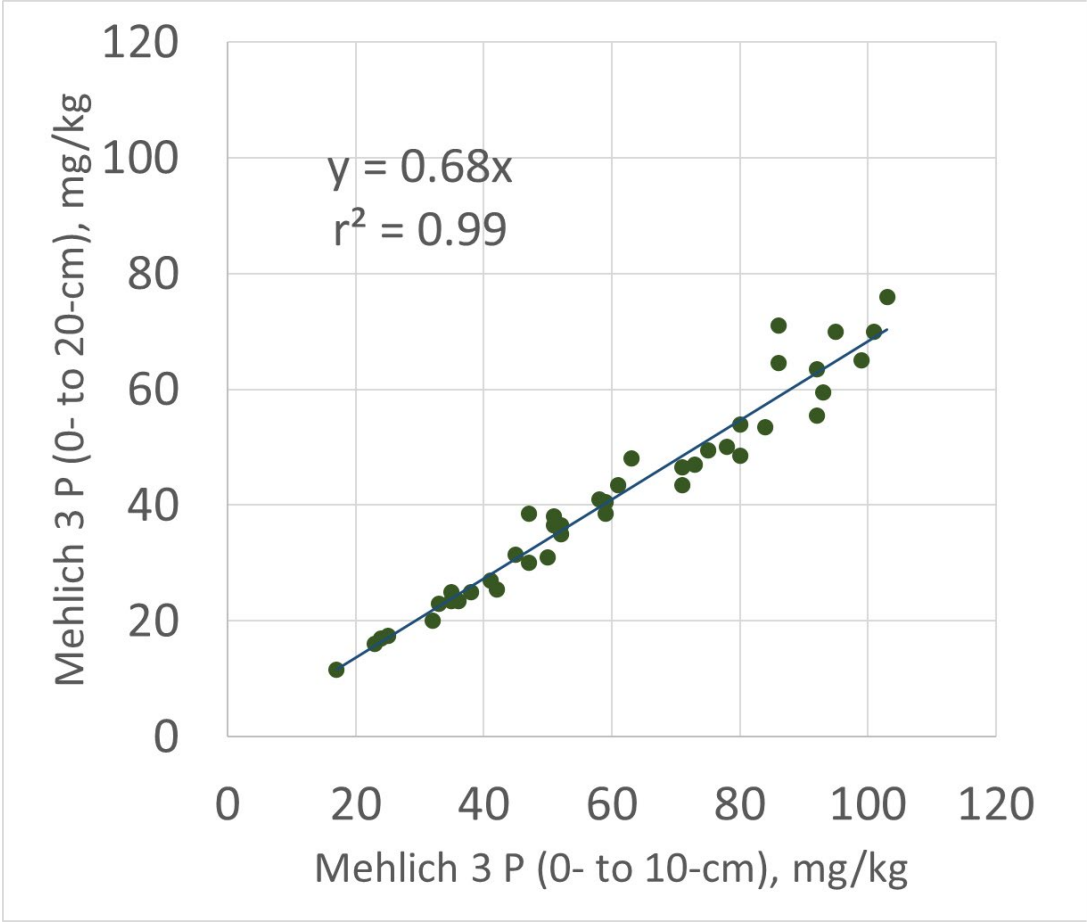
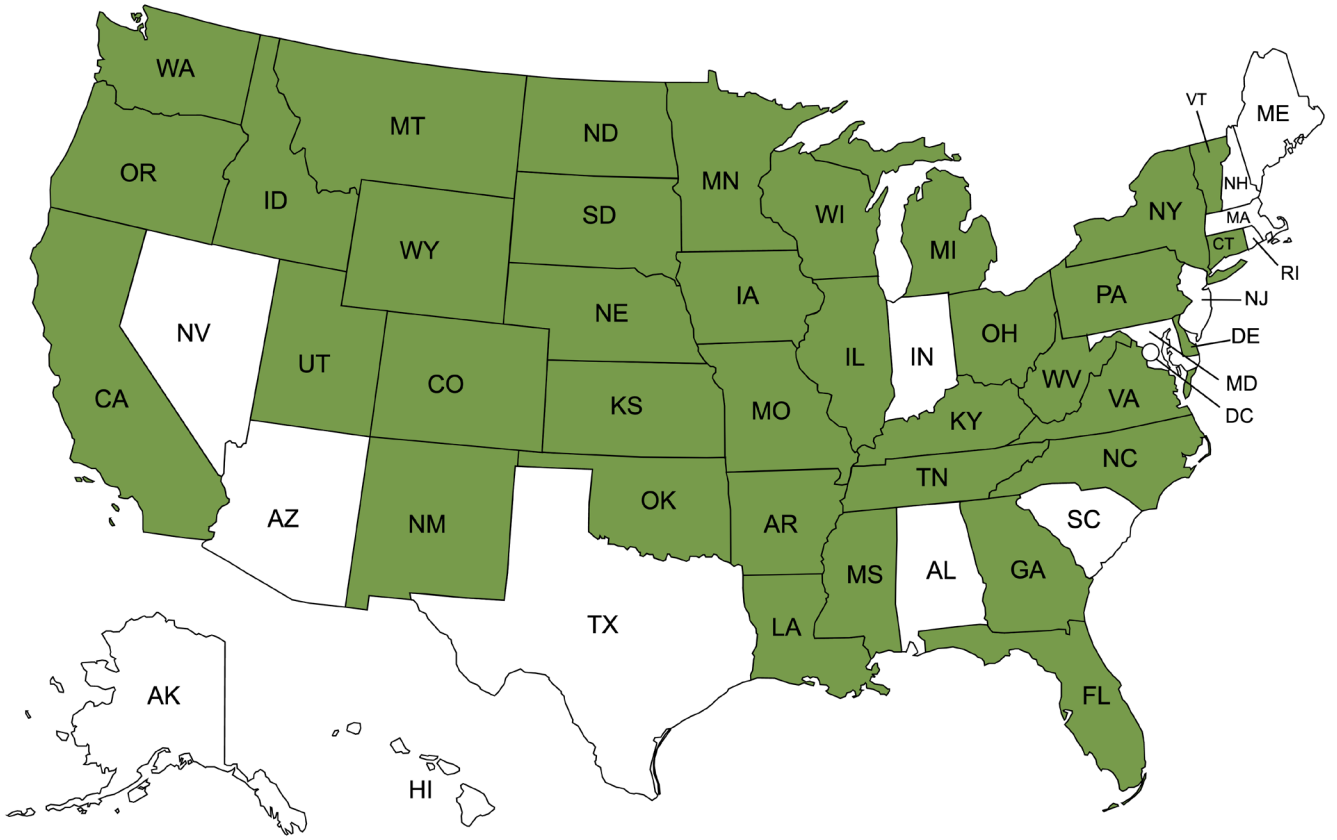
FRST Sampling Depth Study: Goals

- Define a correction factor that can used to estimate equivalent soil test levels (and critical ranges) for different depths based on different metadata:
  - Cropping system
  - Management
  - Region/soil type



FRST Sampling Depth Study: Participation & Methods

- 5-10 fields per state
- Samples to PSU for Mehlich 3, OM, pH; if northeastern state to Maine for Modified Morgan; if pH > 7.2 to KSU for Olsen
- Western states add a depth, 8-12”
- Metadata collected
- Results coming soon



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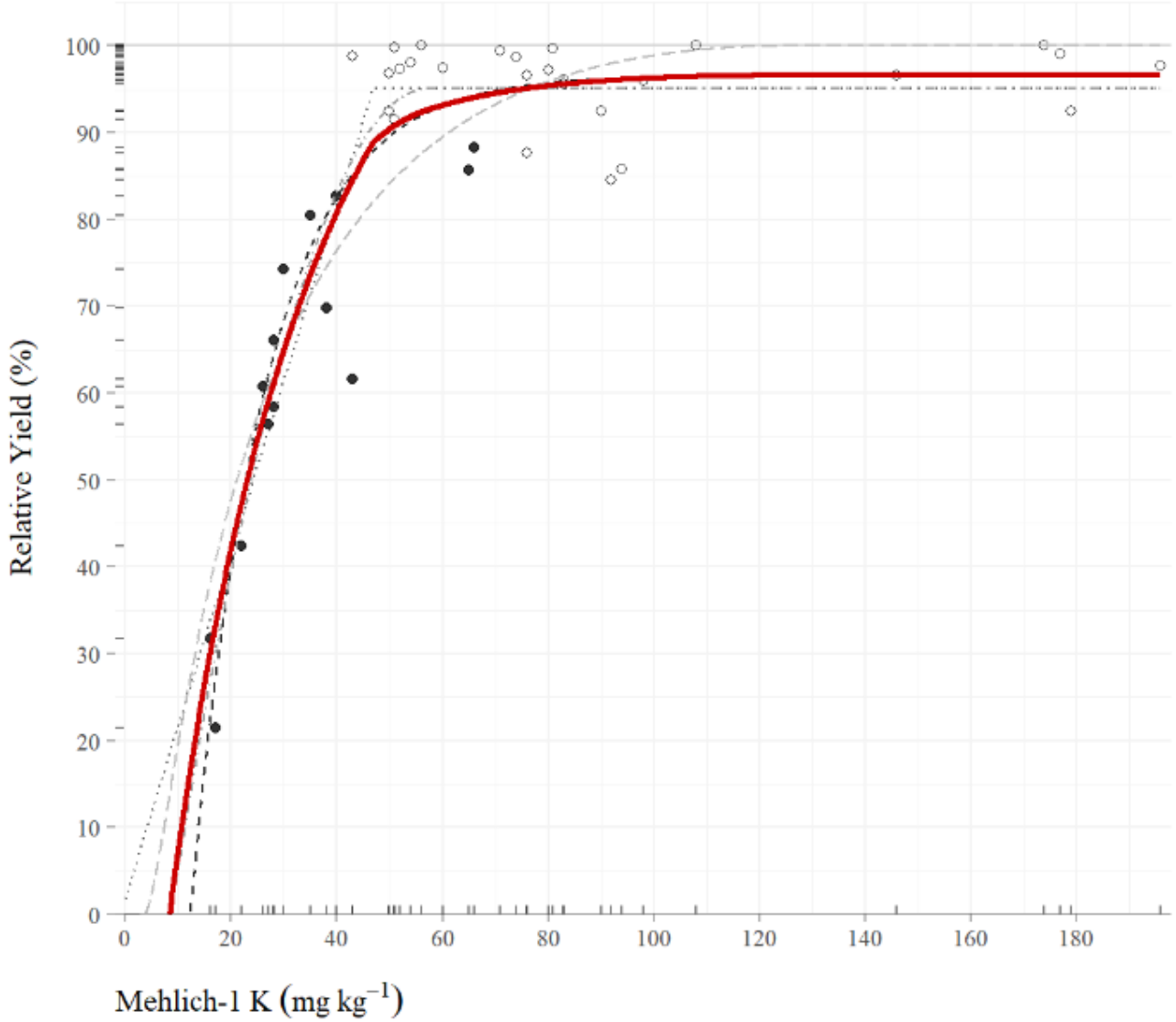
Model Selection for Critical Soil Test Value



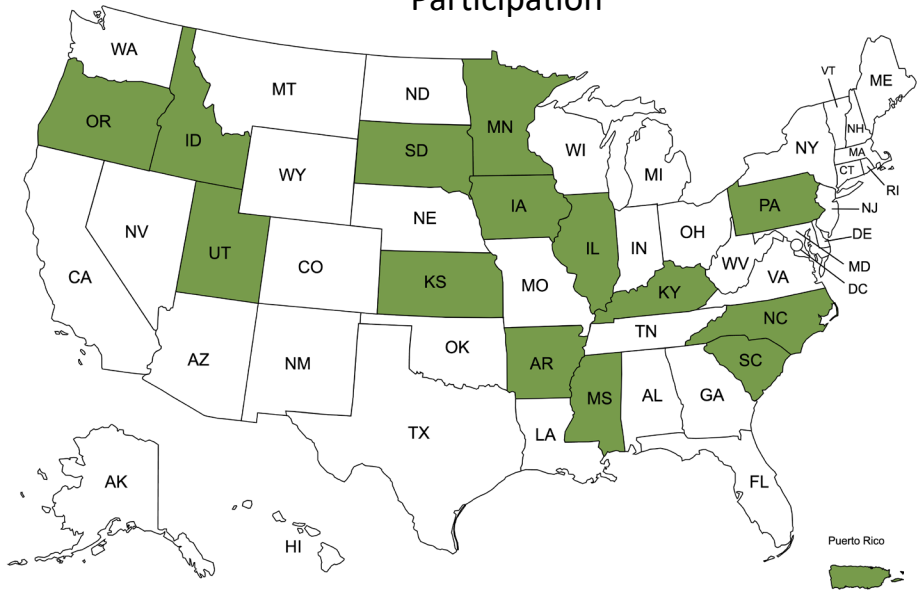
model

- Exponential
- Linear plateau
- Quadratic plateau
- ALCC
- Model average

Response to Fertilization

- Responsive
- Unresponsi

Participation



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10. FRST-associated project: lime equations (Miller)

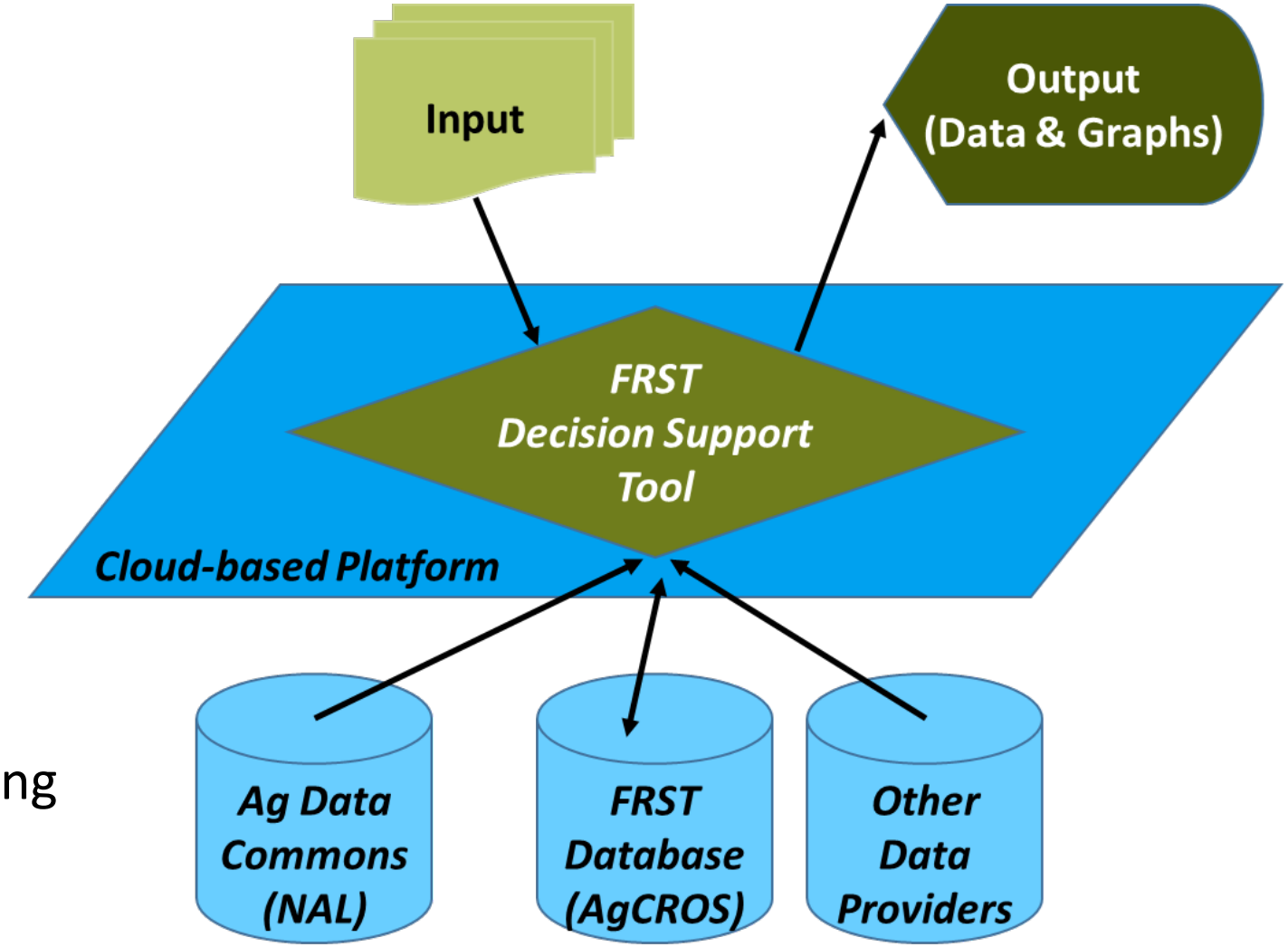
FRST Decision Support Tool

Principles of model development:

- Resides in neutral space
- Software “perpetuity”
- Credit for contribution

Status

- Data is imported
- Tool mechanisms + graphics being programmed
- Interface ready for beta testing this summer



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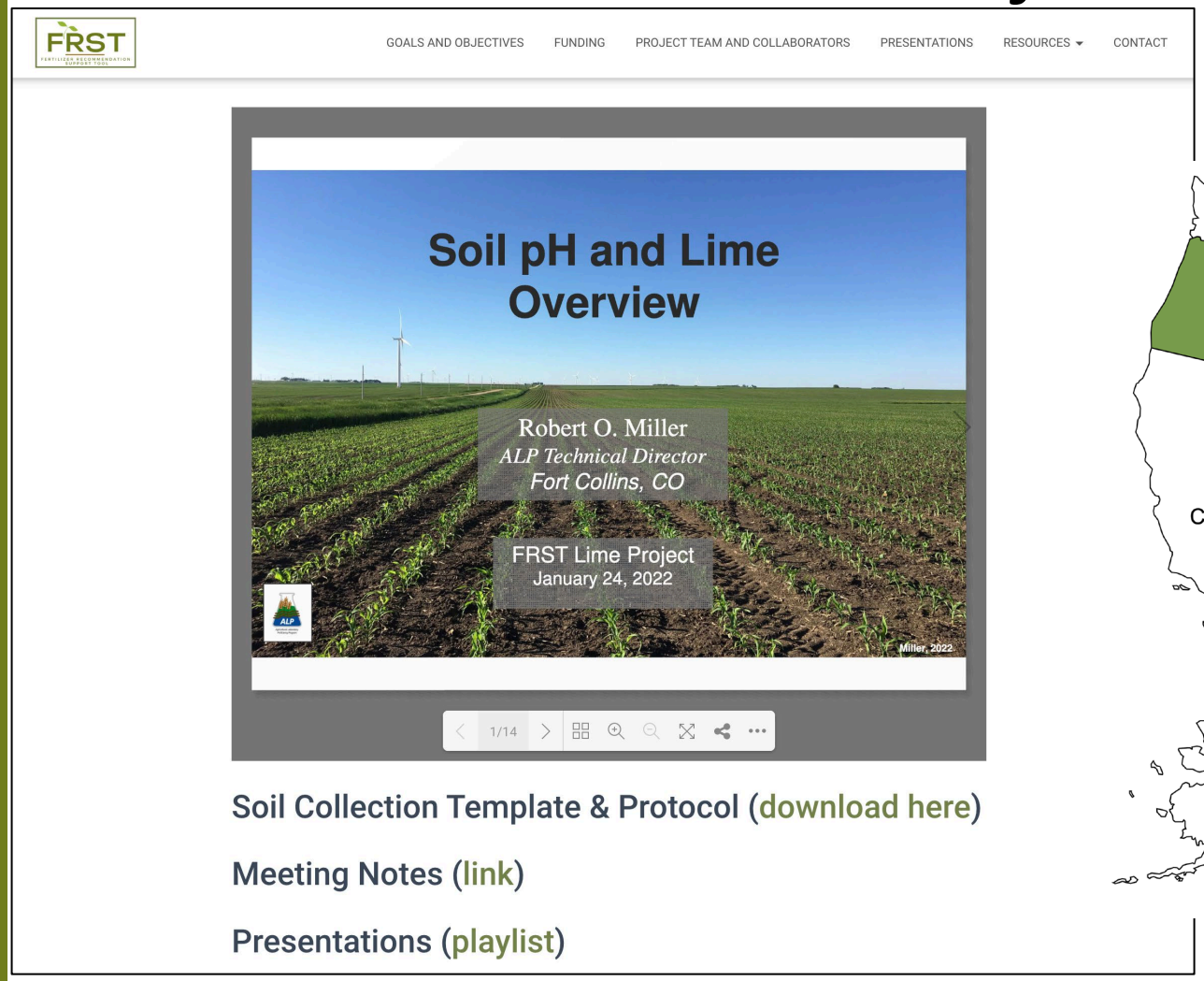
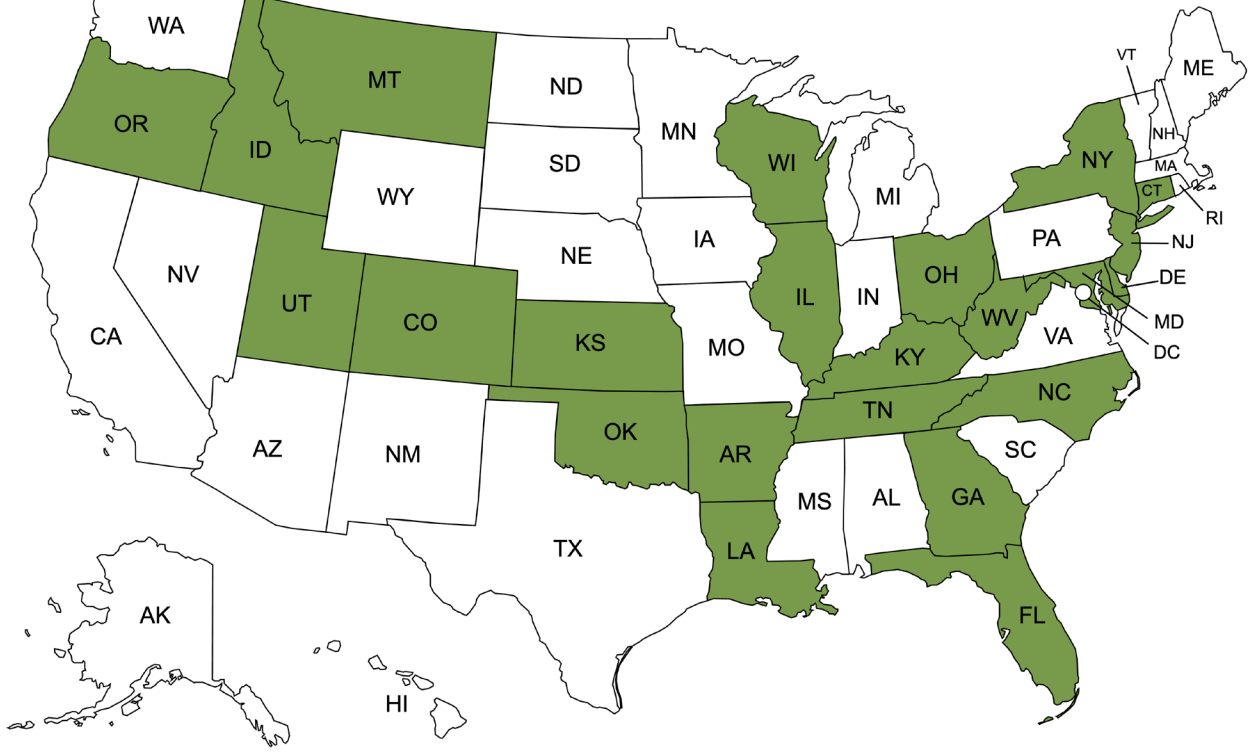
FRST-Associated Project: Lime

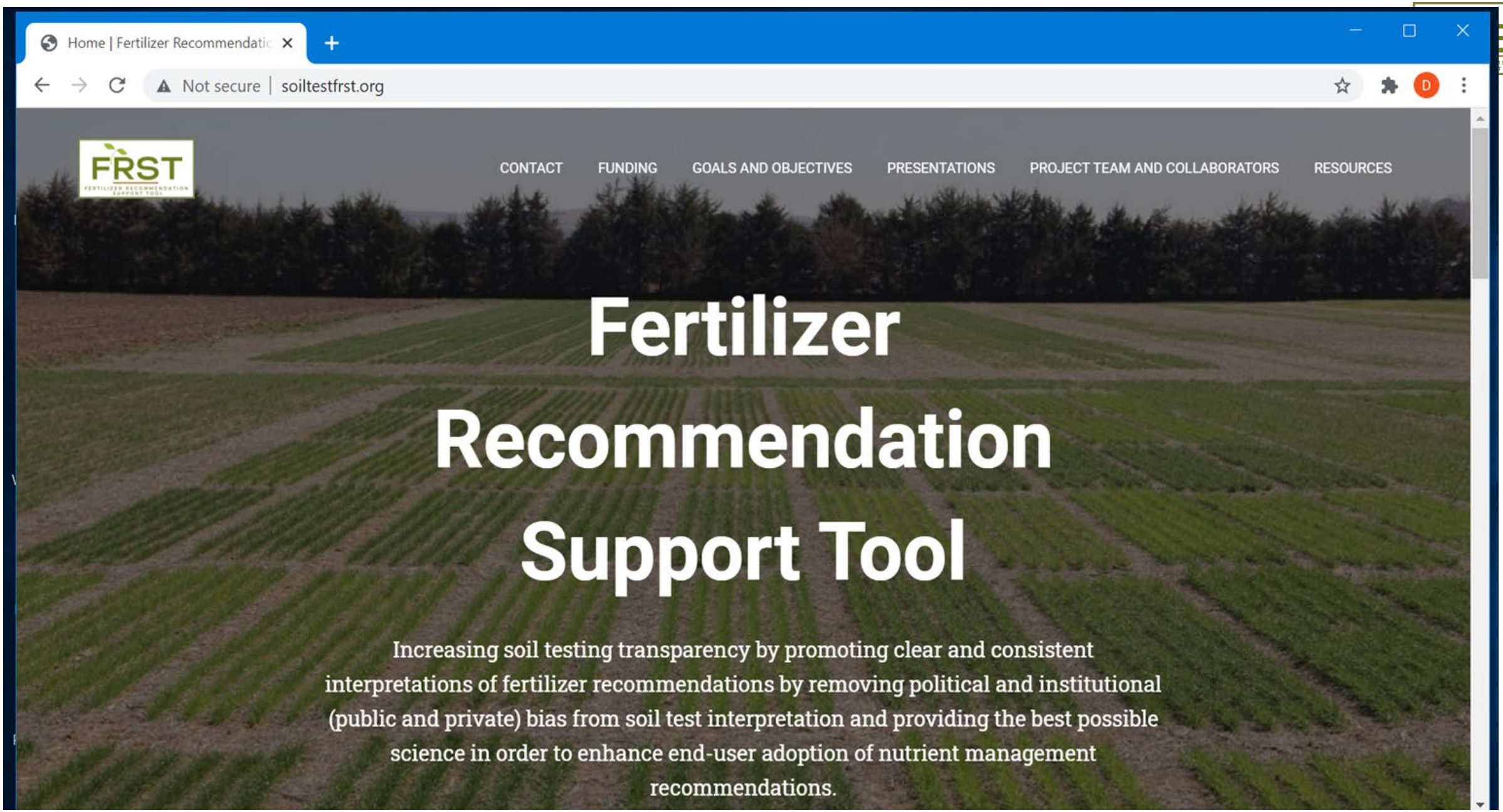




www.soiltestfrst.org/lime

How ALTA Can Help FRST and Vice-versa

- FRST & ALTA have begun discussions for working together
  - ALTA team consists of some of the ALTA leadership (Corey Lacey, Tim Smith, Dustin Sawyer, and Bob Miller)
  - FRST team consists of some executive members (Deanna Osmond, Nathan Slaton, John Spargo, Matthew Yost, Daniel Kaiser, and Sarah Lyons)
- Regular meetings to discuss the state of soil testing and the FRST project
  - ALTA interested in having FRST provide short presentations on their work to their membership
  - ALTA-FRST group is developing a survey on how fertilizer recommendations are developed. ALTA will lead the effort to interview about 10 individuals
- ALTA will help beta test the FRST decision tool
  - We are looking for similar input/cooperation from across the USA to ensure a range of differences in geography and soil testing are represented in the FRST decision tool



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Questions?

- Deanna Osmond, dosmond@ncsu.edu
- Sarah Lyons, selyons@ncsu.edu
- www.soiltestfrst.org
- Thank you to our sponsors, USDA-NRCS & USDA-ARS