Nov 3 2022

Assessing Relationships between Precision Irrigation Sensing Technologies and Phosphorous Transport in Southeast Florida Soils

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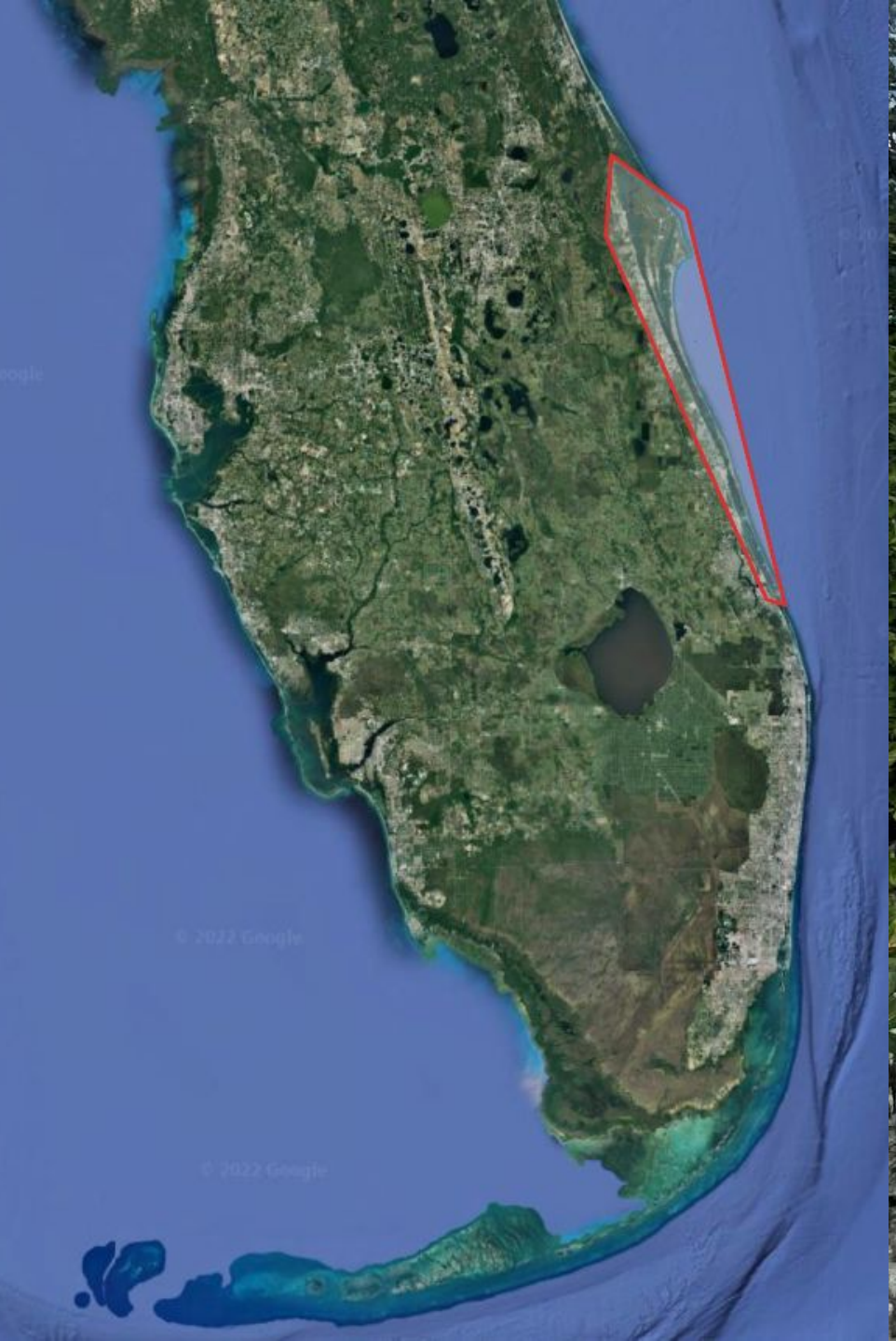
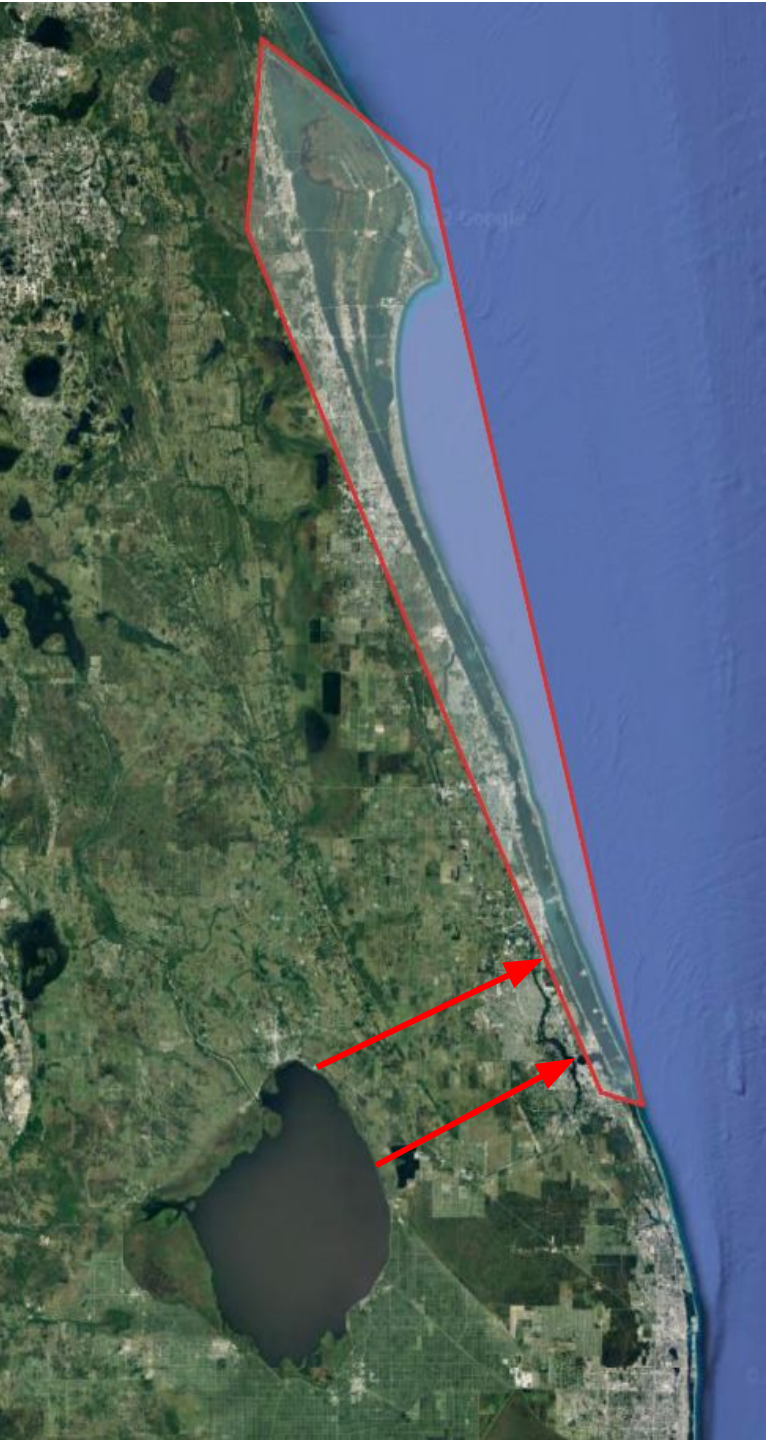
Agricultural and Biological Engineering Indian River Research and Education Center (IRREC) University of Florida



Indian River Lagoon

Black and Red Mangroves-*Hannah Atsm*



Roseate Spoonbill – *FWC*

Bull Sharks – *FWC*

Indian River Lagoon home to over 2,098 plant species and 2,117 animal species

Blue Land Crab – *Florida State Parks*

Bottlenose Dolphins – *Save the Seagrass*

Red Mangroves – *Hannah Atsma*

The Phosphate Problem

Phosphorus is Poisoning Lake Okeechobee and the Everglades

July 3, 2020

By Matisse Emanuele, Staff Writer & Researcher for Save The Water™ | July 3, 2020

PHOSPHORUS POLLUTION IN FLORIDA'S WATERS

The Need for Aggressive Action to Protect Florida's Rivers and Streams from Nutrient Runoff

Decades of Nutrient Pollution in the Indian River Lagoon and Possible Solutions

Josh Bailey July 20, 2020

South Florida Waterways

Crisis in the Indian River Lagoon: Solutions for an Imperiled Ecosystem

There is an ecological crisis in Indian River Lagoon.

South Florida blue-green algae health alerts

Share

25 WPBF NEWS

Updated: 2:34 PM EDT Apr 8, 2022

As New Algae Bloom Spreads Across Lake Okeechobee, Florida Urged to Set Standards Critical to Protecting People, Wildlife From Harmful Toxins

NEWS

Florida's East Coast Manatee Population Died At A Record Rate This Winter

By Jan Wesner Childs · August 05, 2021

A manatee swims near a dock over the barren bottom of the Indian River Lagoon in Brevard County, Florida, in March 2021. A mass die-off of manatees this year is being blamed on starvation due to lack of seagrass in the lagoon.

- **Manatee Deaths 2021: 1,101**
- **5-year Average: 625**
- **Solutions?**

BMP Cost Share Programs:

1. Maximize water use for crop production
2. Minimize environmental impacts

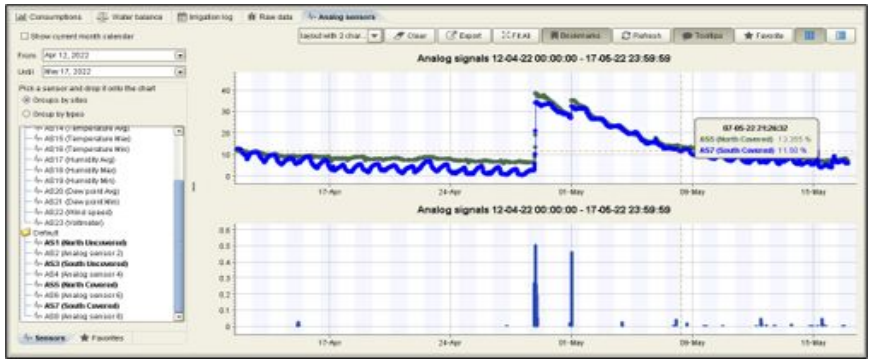
FDACS

FDEP

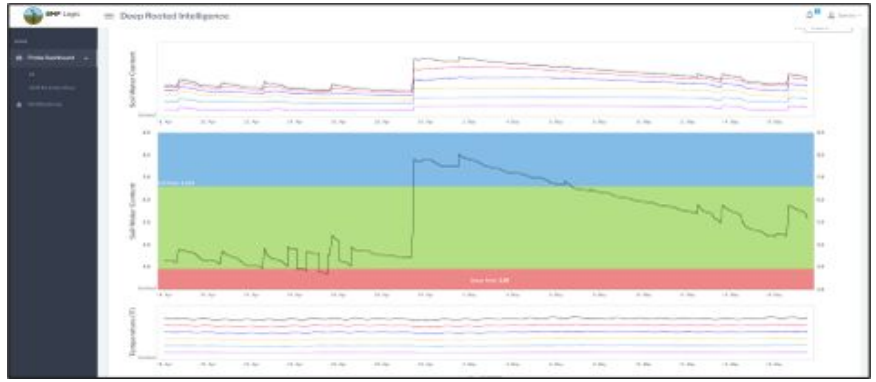
USDA-Natural Resources Conservation Services

State agencies subsidize precision irrigation technologies for farmers, including soil moisture sensors (SMS)

Soil moisture sensor installation in Southeast Florida

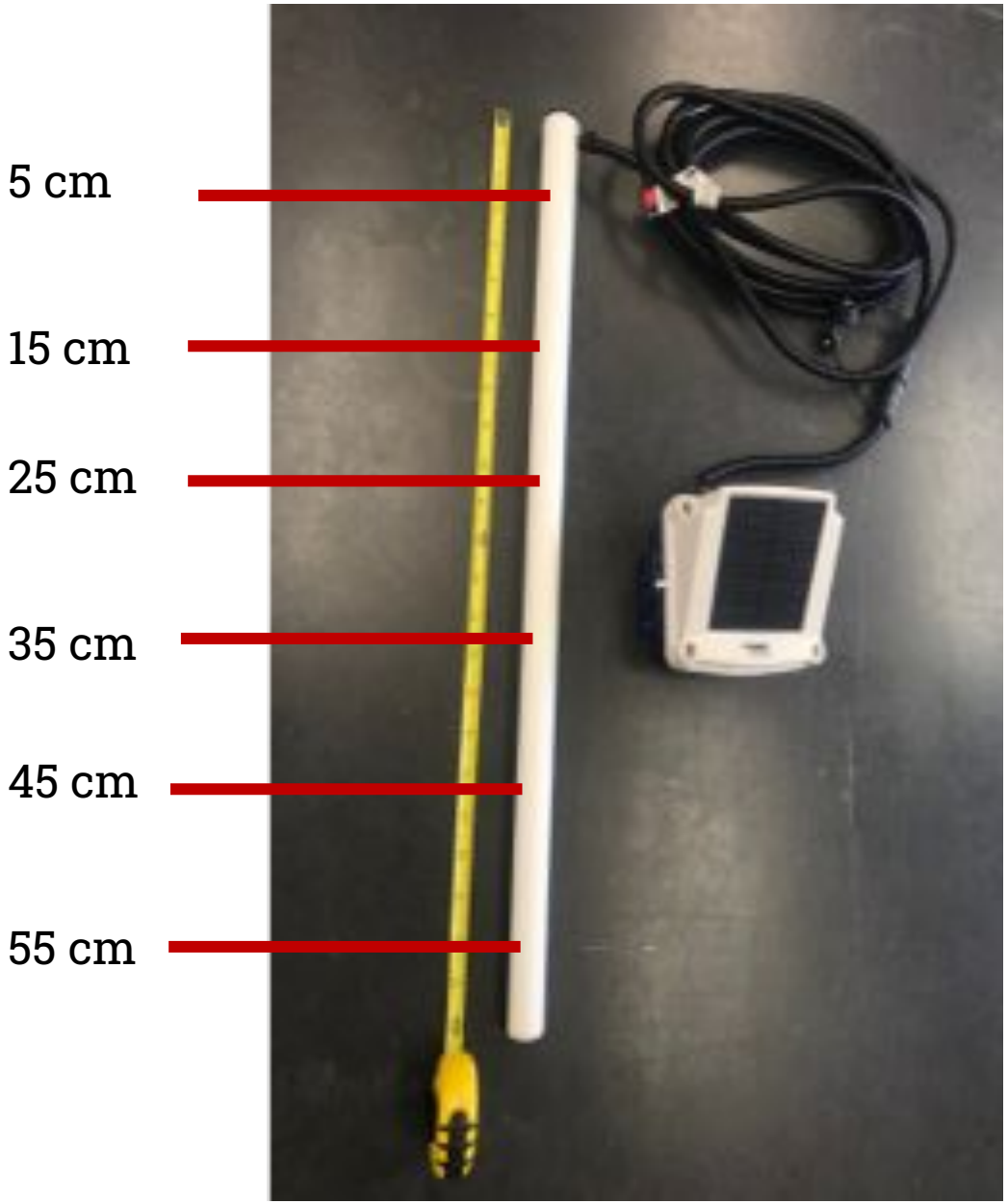


Growers taking advantage of these programs are **required** to report water quality and water quantity data



Irrigation management decision support systems used by farmers

Soil moisture probe (collection of sensors) installation in Southeast Florida



One of these technologies already in use is the **Sentek Drill-and-Drop Soil Moisture Probe**

6 sensors at depths 5, 15, 25, 35, 45, and 55 cm

Sentek Drill-and-Drop Probe

SM

VIC

Temperature

Sentek Drill-and-Drop Probe

SM – Currently being used to manage irrigation

VIC

Temperature

Sentek Drill-and-Drop Probe

SM – Currently being used to manage irrigation

VIC – What we hypothesize we could use to manage fertigation

Temperature

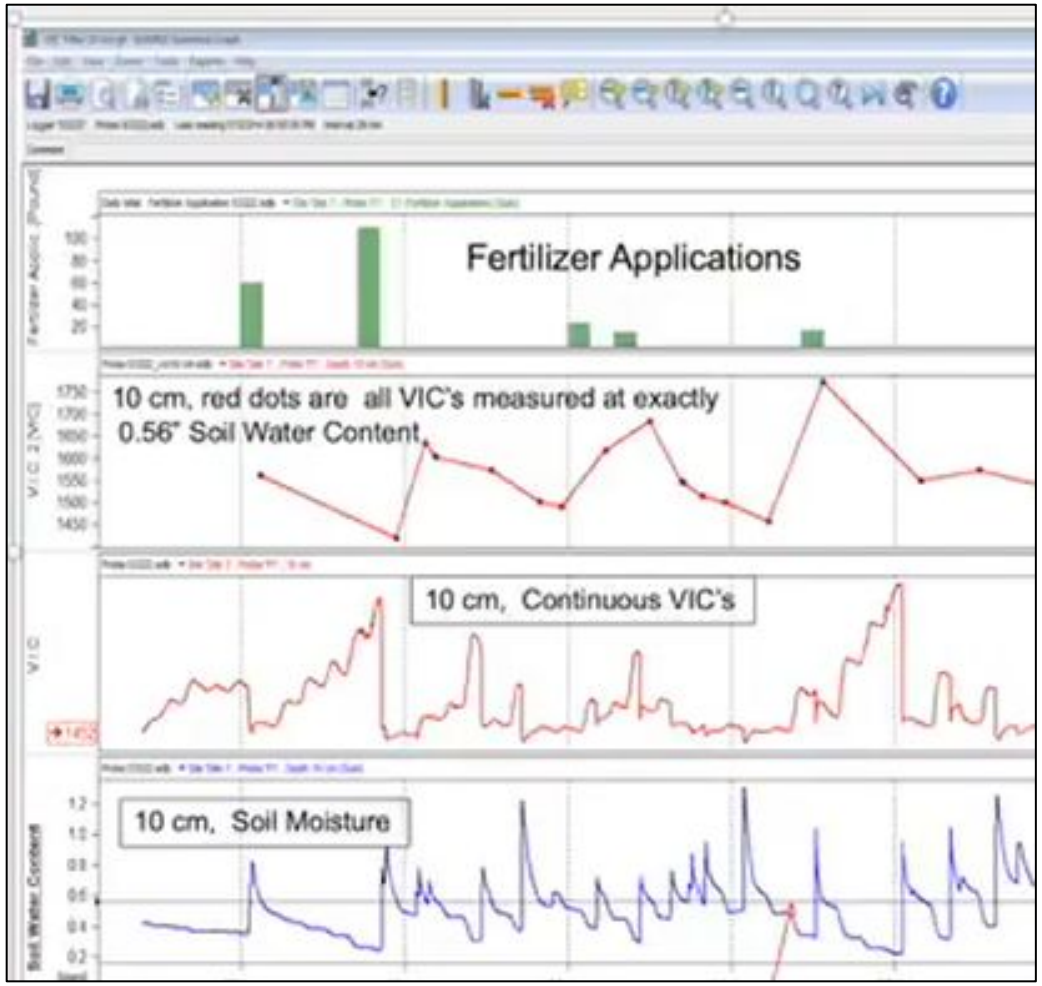
Why this Company?

Already used by growers

A large barrier with new technologies is adoption. If Sentek SM Probes can track phosphorus, years could be saved by skipping the barriers of implementation

Why this Company?

It's already being claimed capable of tracking nutrients through the soil profile.



Company Website: "[SM Probe] uses two frequencies.
One frequency measures soil moisture, and one frequency measures all ion activity. A model separates moisture from all ion activity to give VIC. **This allows it to be a great tool for tracking fertilizer** to see **its passage through the profile** and concentration of fertigation **whether it's leaching through the profile.**"

Evaluation of Phosphate Movement from Fertigation

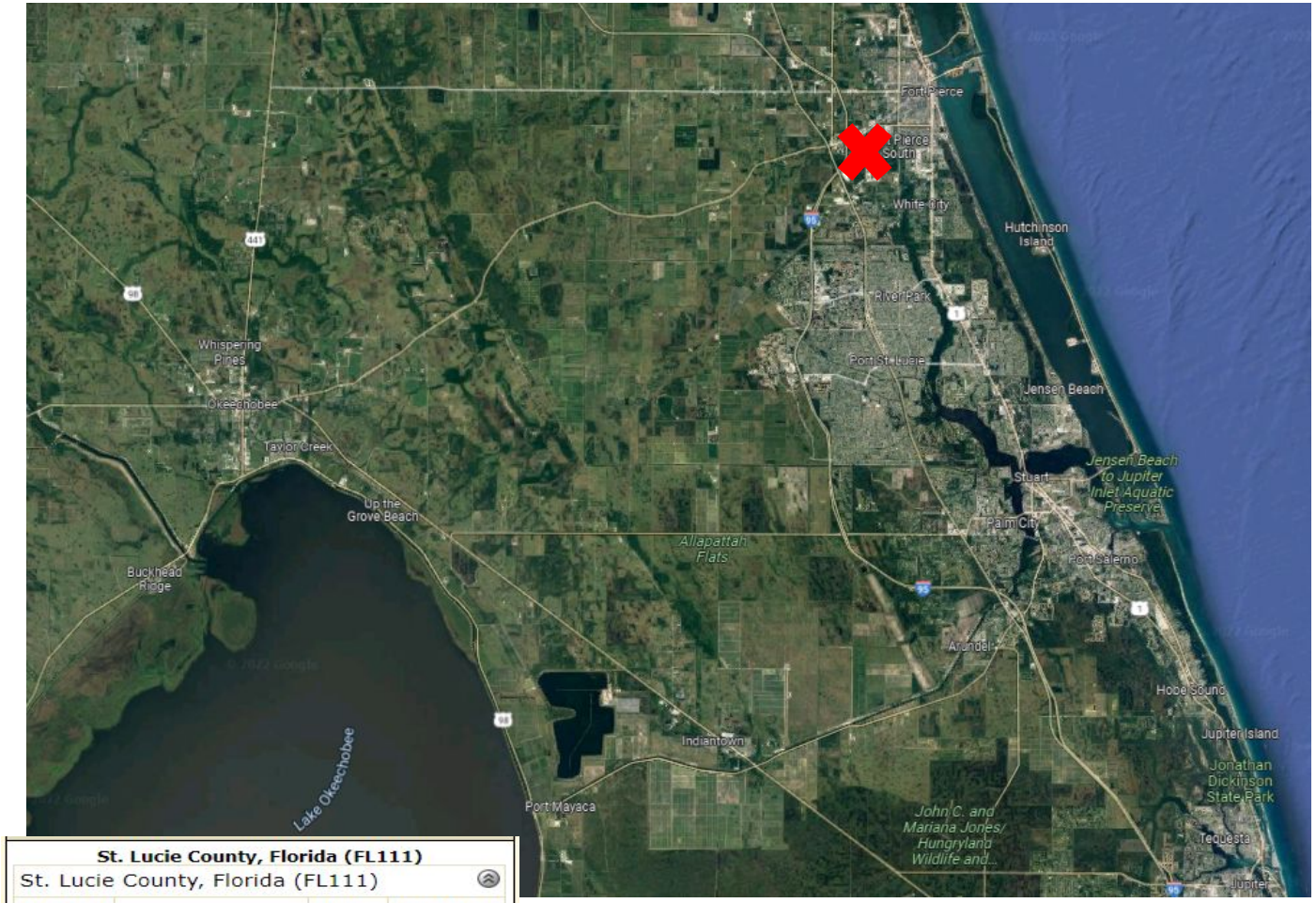
Methods

STEPS
Science and Technologies for Phosphorus Sustainability

UF IFAS
UNIVERSITY of FLORIDA
INDIAN RIVER
Research and
Education Center

Location

- Southeast Florida, Fort Pierce
- Indian River Research and Education Center, UF IFAS
- Soil Type 1: Pure Sand - **Control**
- Soil Type 2: ”Salt block”-land previously irrigated by high salinity waters (ocean water)
- Wabasso Sand



St. Lucie County, Florida (FL111)

St. Lucie County, Florida (FL111)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
2	Ankona and Farmton sands	7.4	54.7%
26	Oldsmar sand, depressional	1.6	12.0%
48	Wabasso sand, 0 to 2 percent slopes	4.5	33.4%
Totals for Area of Interest		**13.6**	**100.0%**

UF | IFAS
UNIVERSITY of FLORIDA

Field Assembly

- Soil compaction at each sensor depth was determined

Sensor Depth (cm)	Soil Mass (g)
5	1475.9
15	2436.6
25	2746.1
35	2733.4
45	2769.1
55	2693.8

- Soil cores were rebuilt in the field using the previously determined soil compaction rates

Data Collection

PO4 Solutions

- 0 ppm (control)
- 10 ppm
- 100 ppm

Each sensor within the probe measures every 30 minutes

Total trial time = 24 hours

Data Collection

5 cm

15 cm

25 cm

35 cm

45 cm

55 cm

Evaluation of Phosphate Movement from Fertigation

Results

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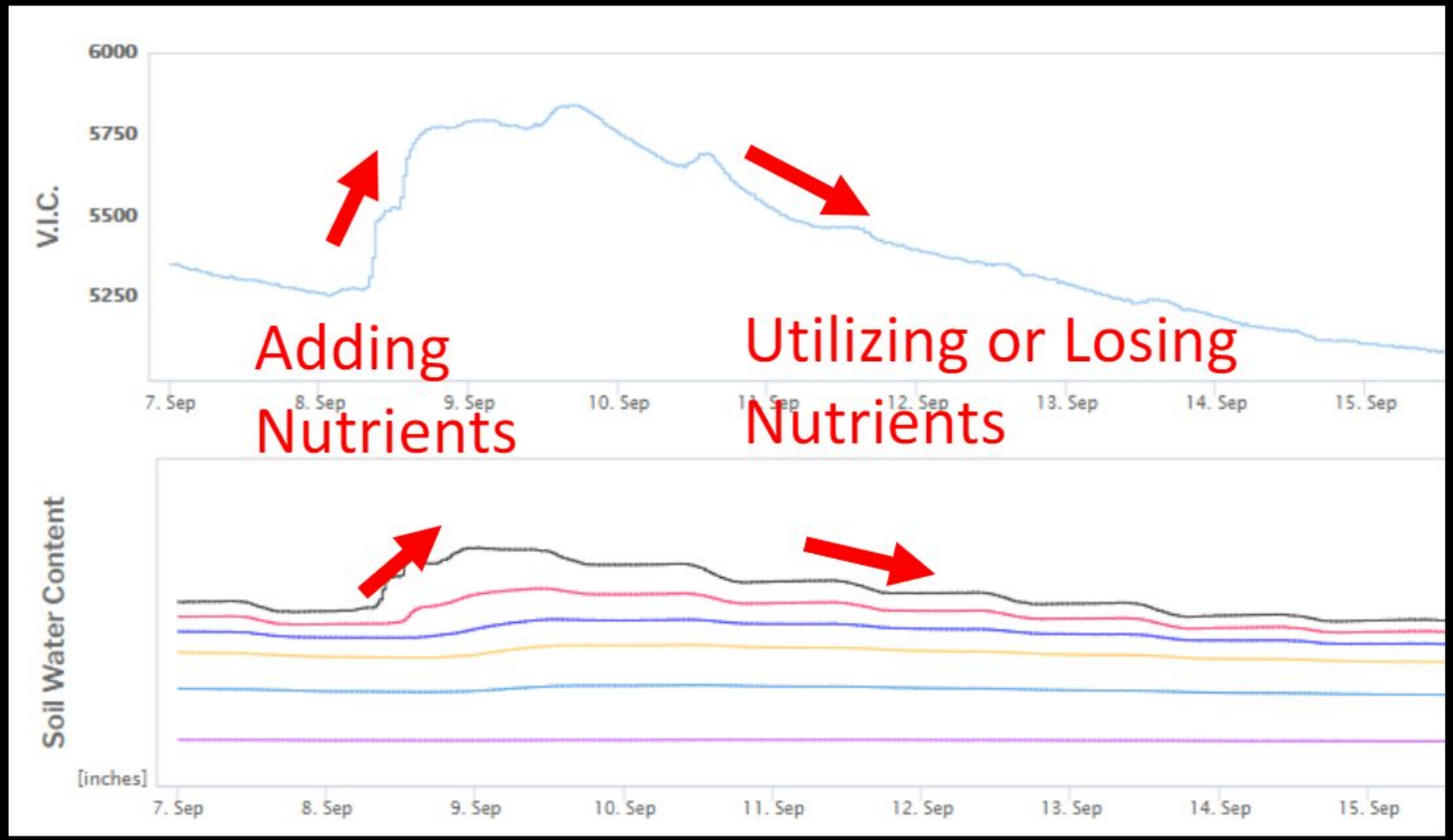
Research and
Education Center

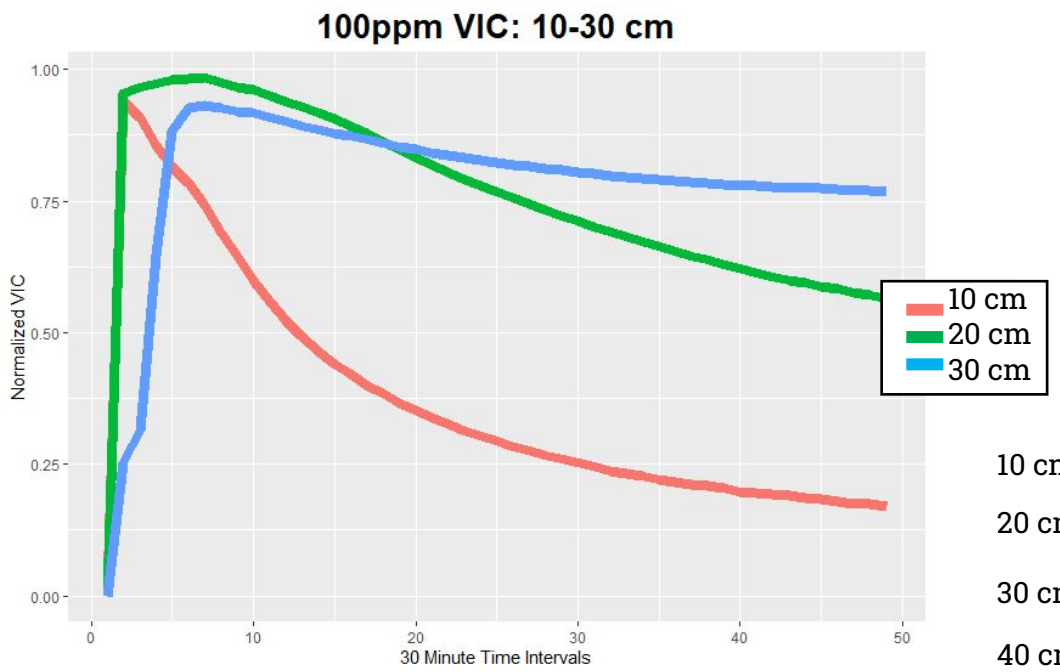
To evaluate the movement of fertilizers in the soil, the company recommended monitoring the probes' VIC trends over time.

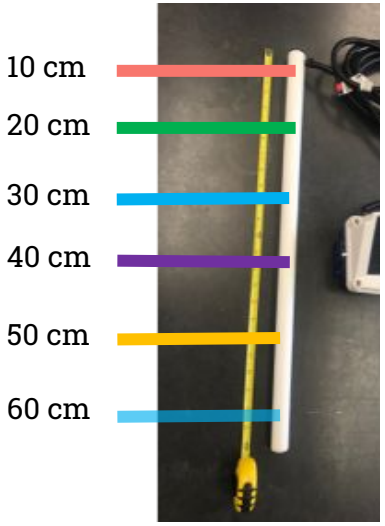
A guide from a 3rd party company utilizing Sentek's VIC capabilities

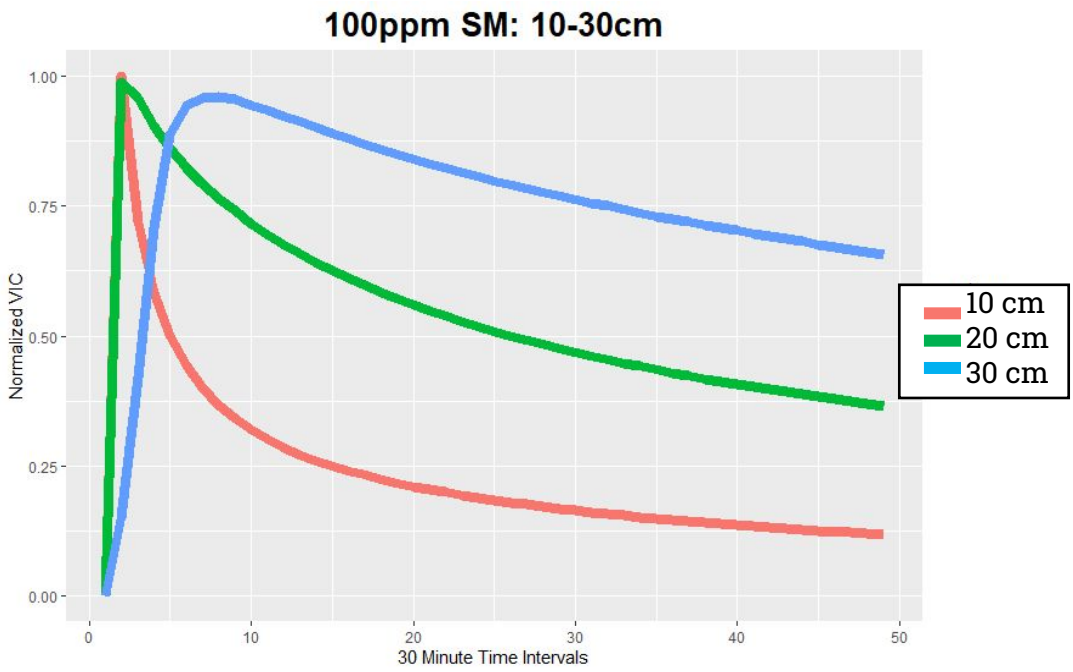
Transformation Stage 2

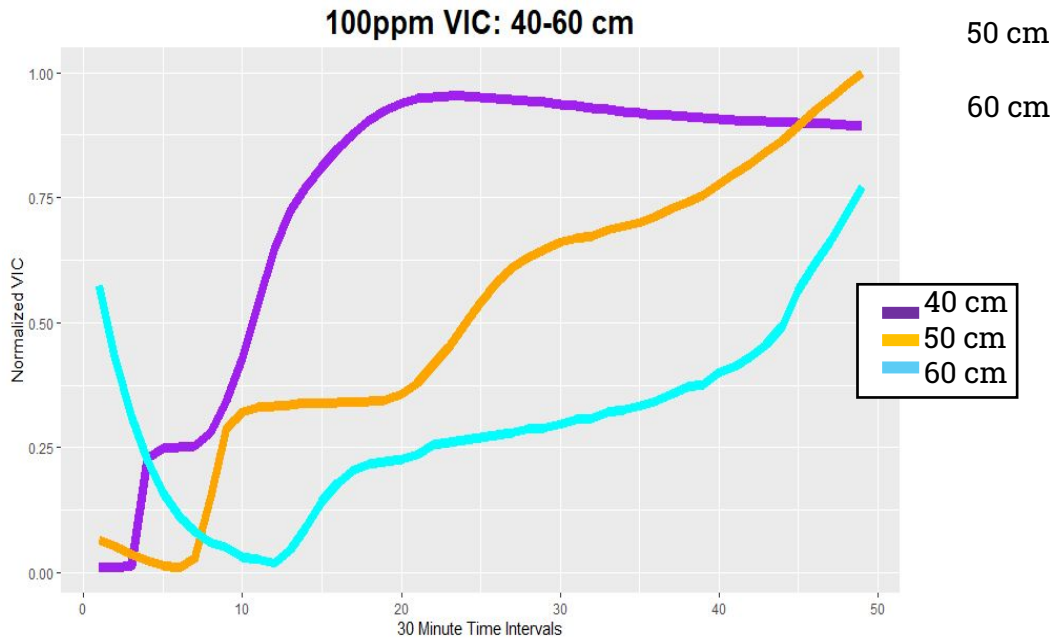
Trends in Fertilizer

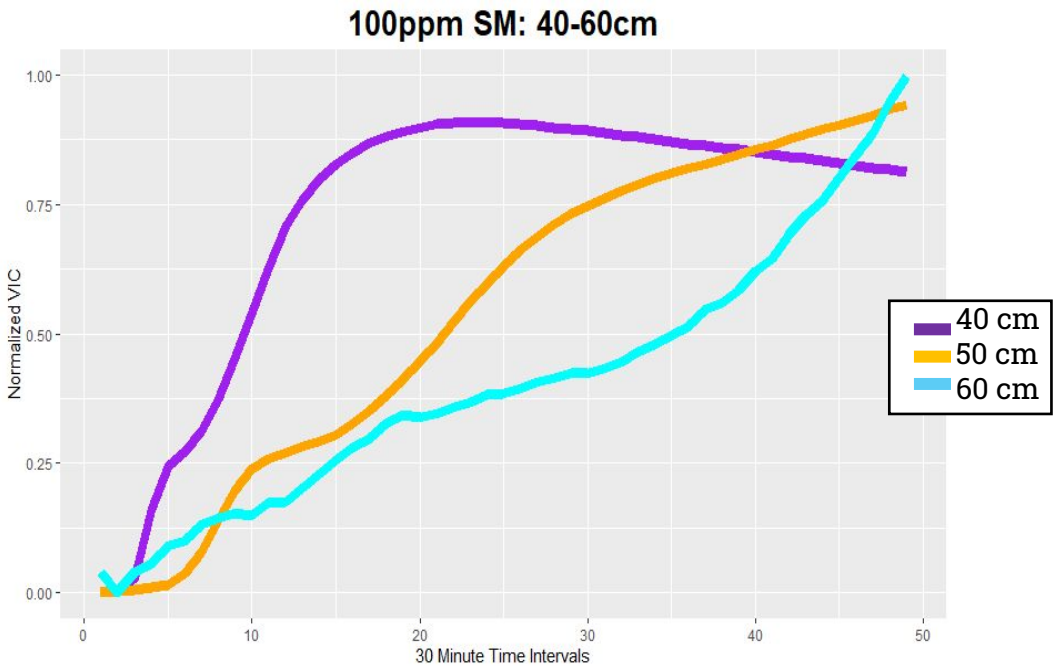


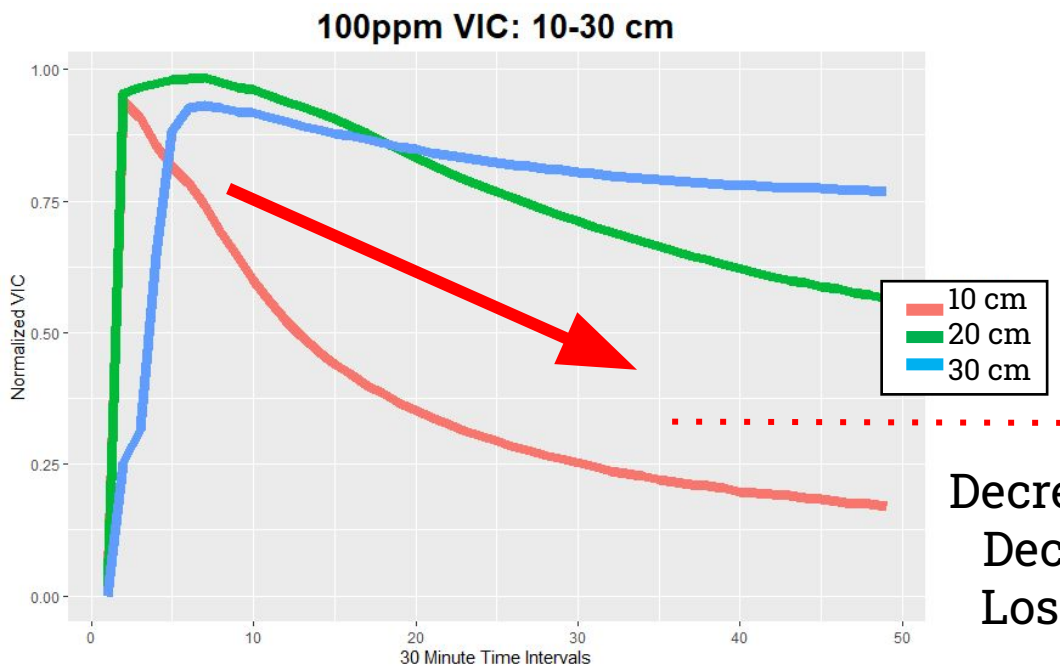

100ppm VIC: 10-30 cm
Normalized VIC
30 Minute Time Intervals
10 cm
20 cm
30 cm

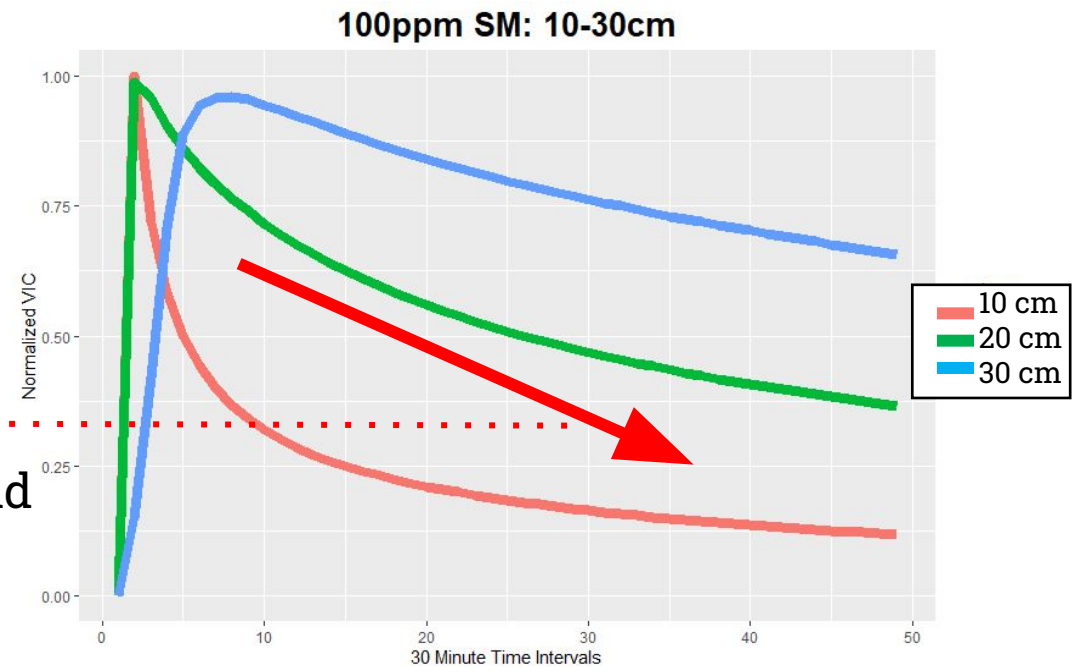

10 cm
20 cm
30 cm
40 cm
50 cm
60 cm


100ppm SM: 10-30cm
Normalized VIC
30 Minute Time Intervals
10 cm
20 cm
30 cm

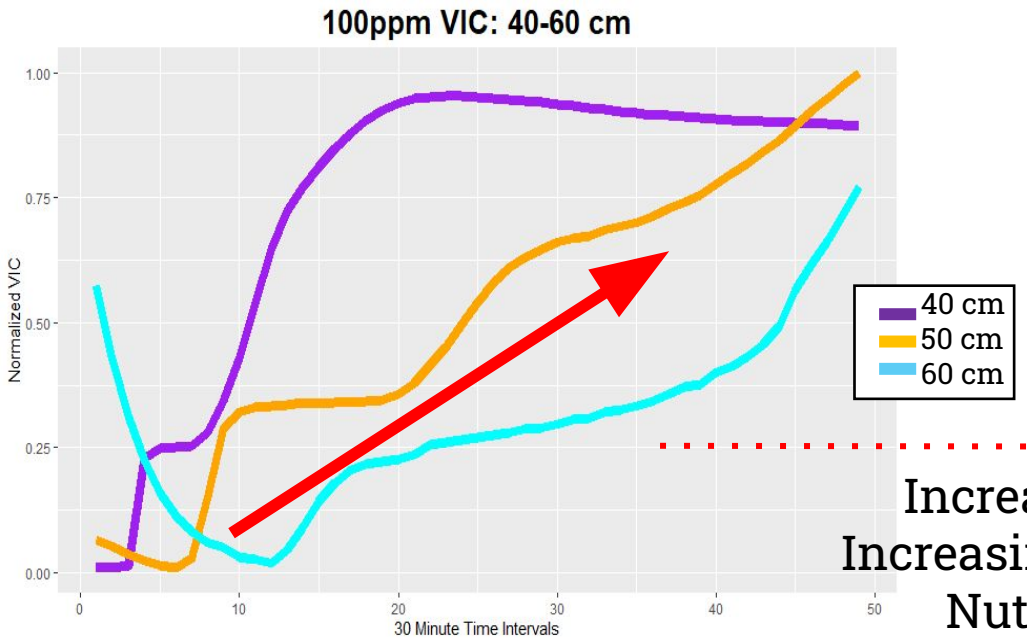

100ppm VIC: 40-60 cm
Normalized VIC
30 Minute Time Intervals
40 cm
50 cm
60 cm

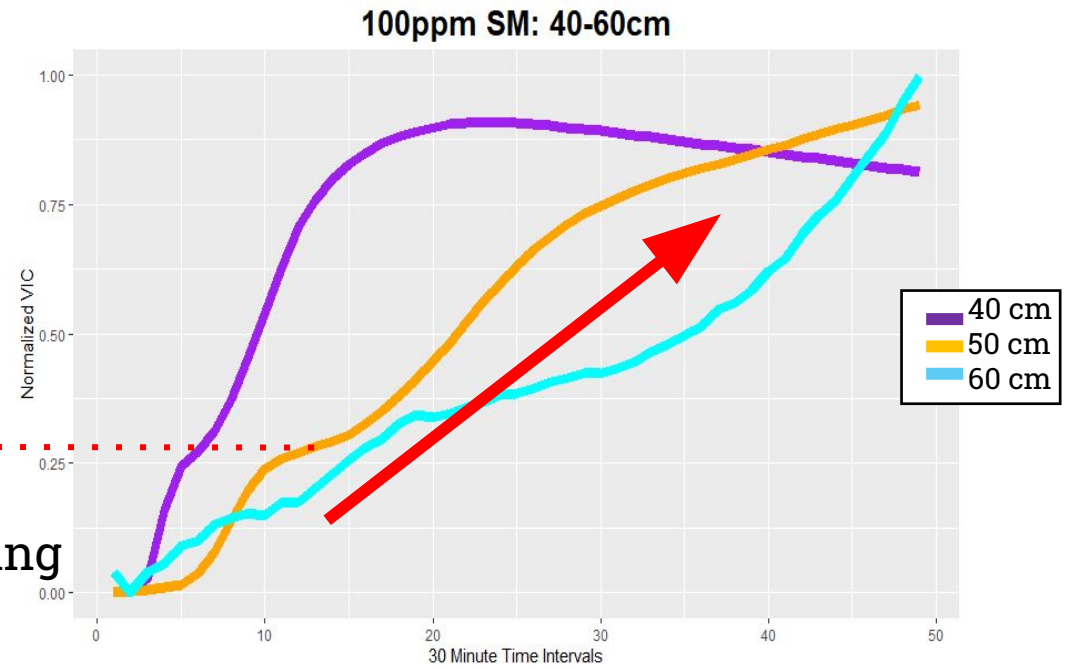

100ppm SM: 40-60cm
Normalized VIC
30 Minute Time Intervals
40 cm
50 cm
60 cm



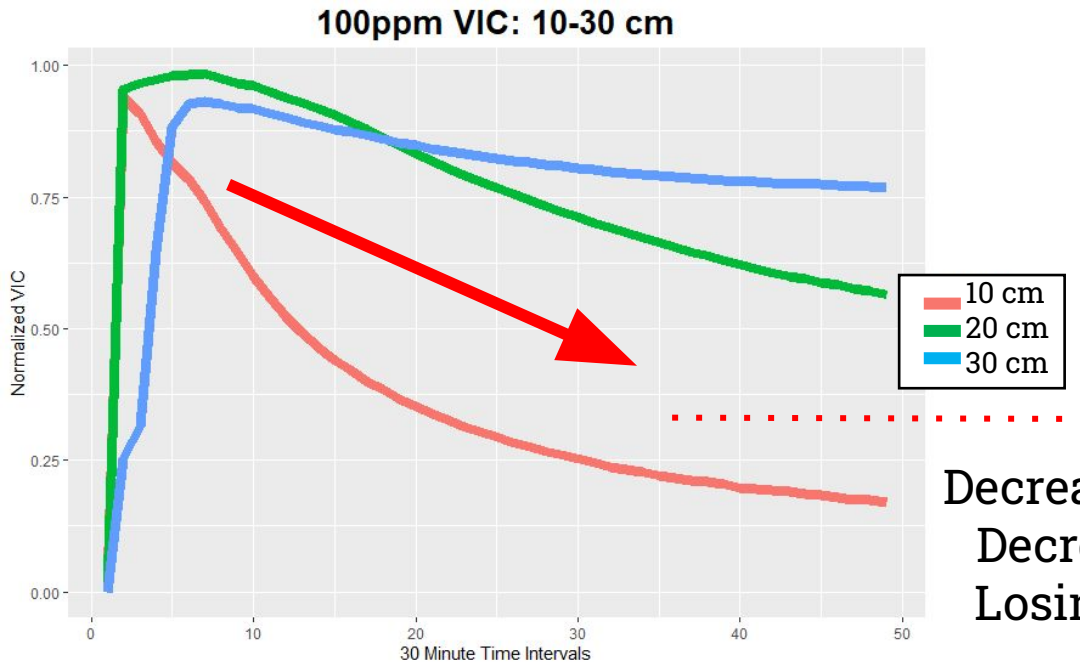


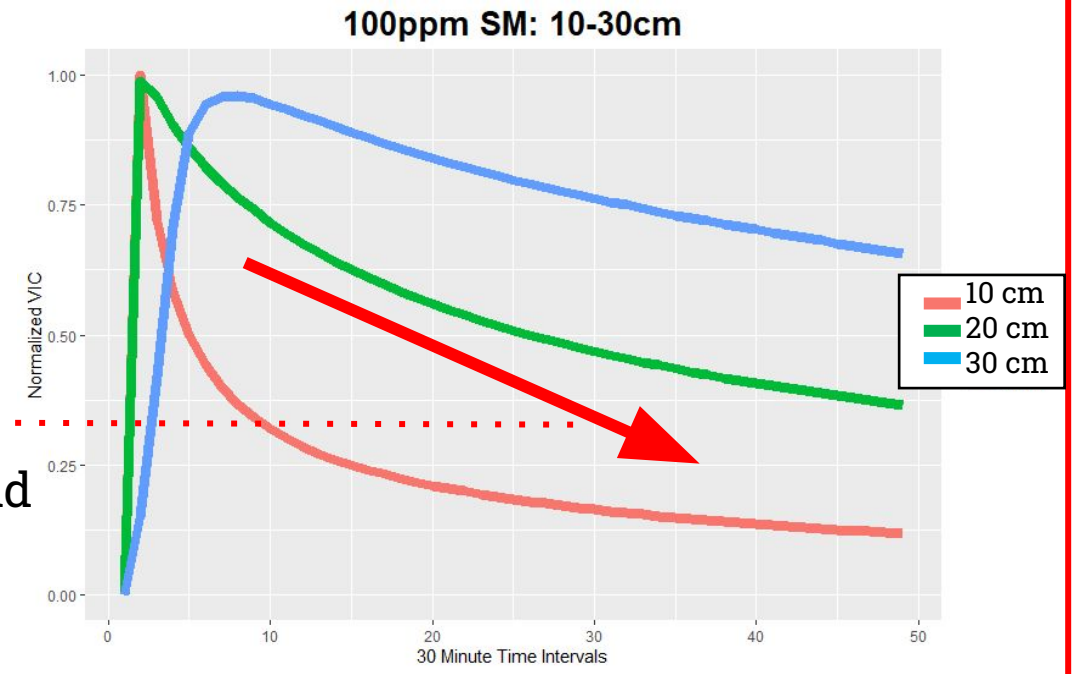
Decreasing VIC and Decreasing SM = Losing Nutrients (PO4)



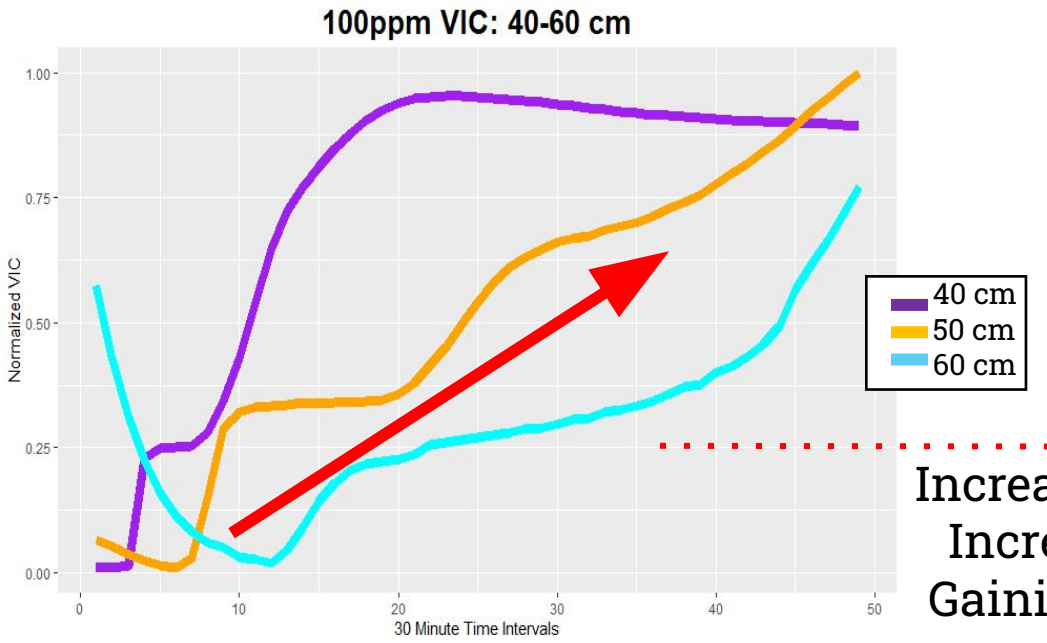


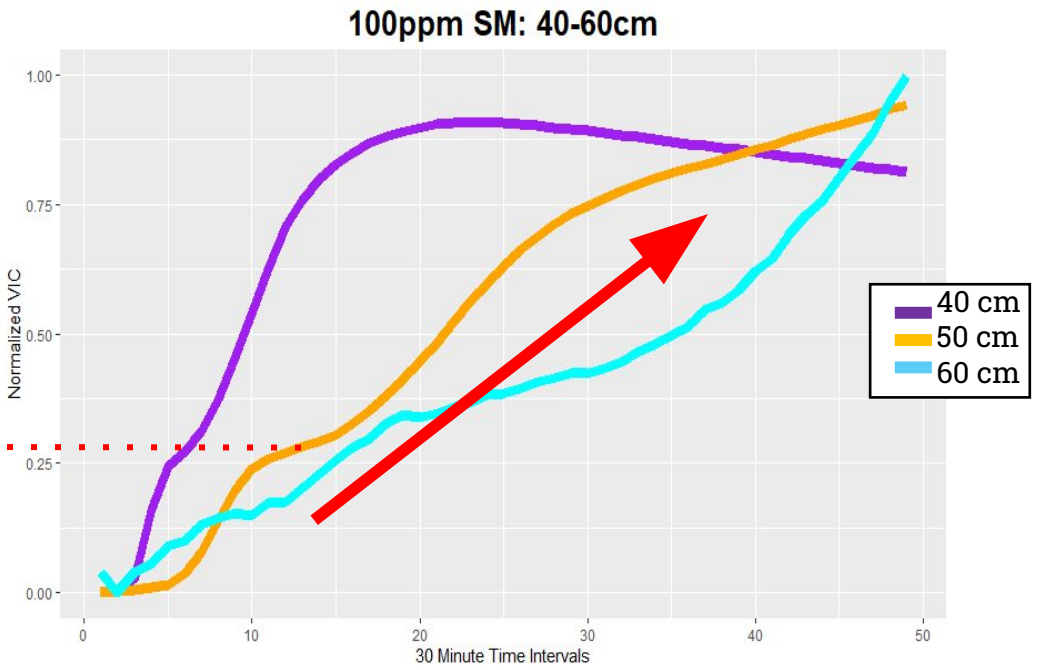
Increasing VIC and Increasing SM = Gaining Nutrients (PO4)





Decreasing VIC and Decreasing SM = Losing Nutrients (PO4)





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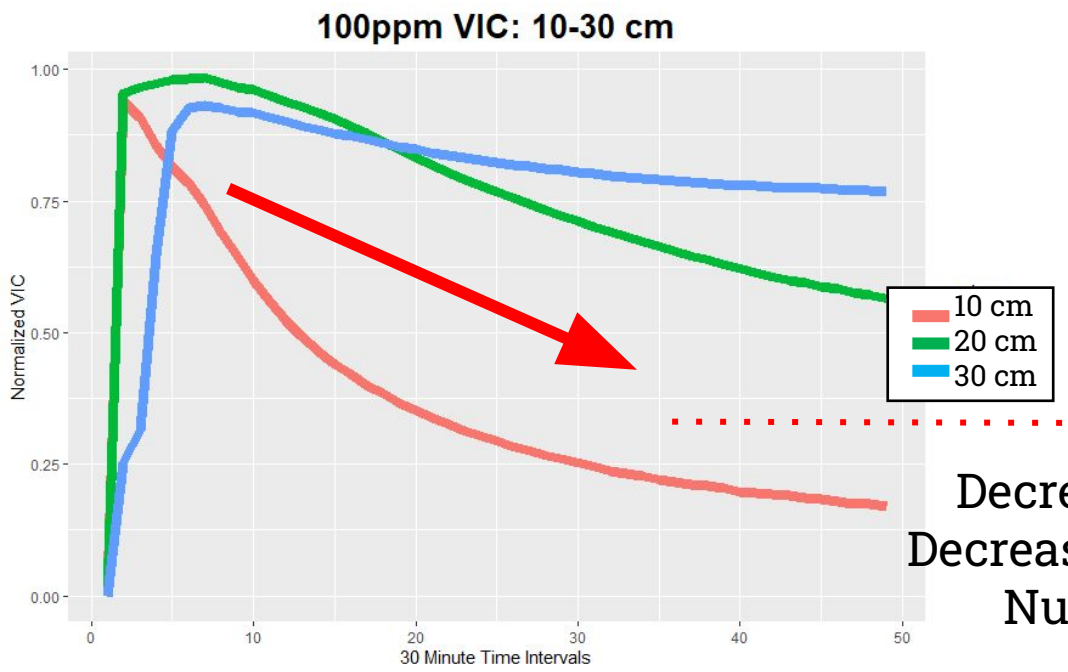
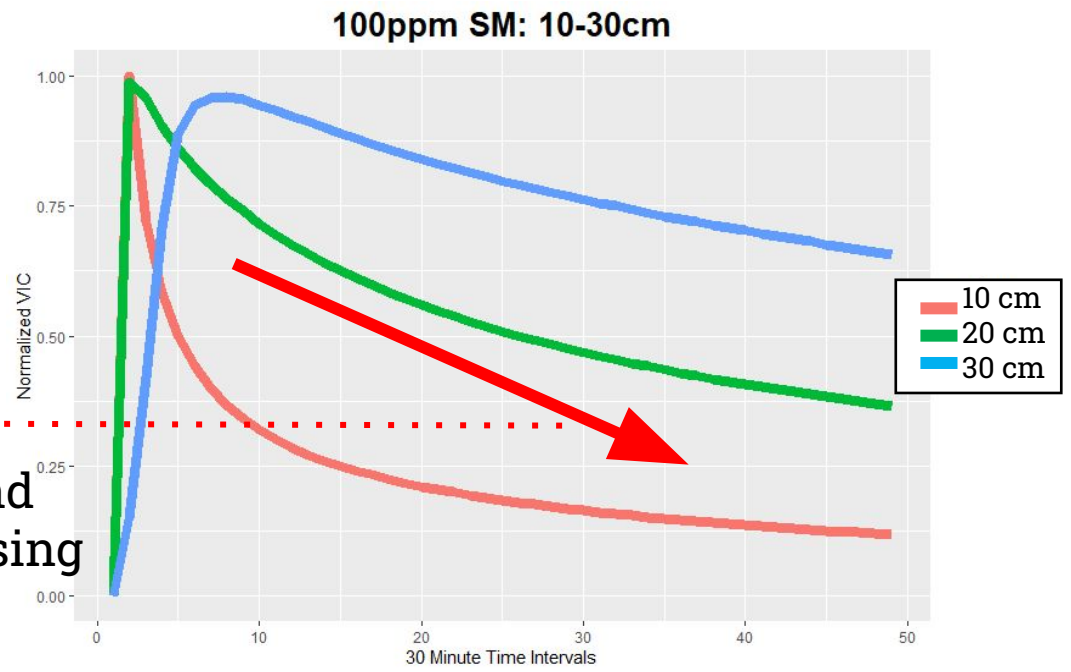
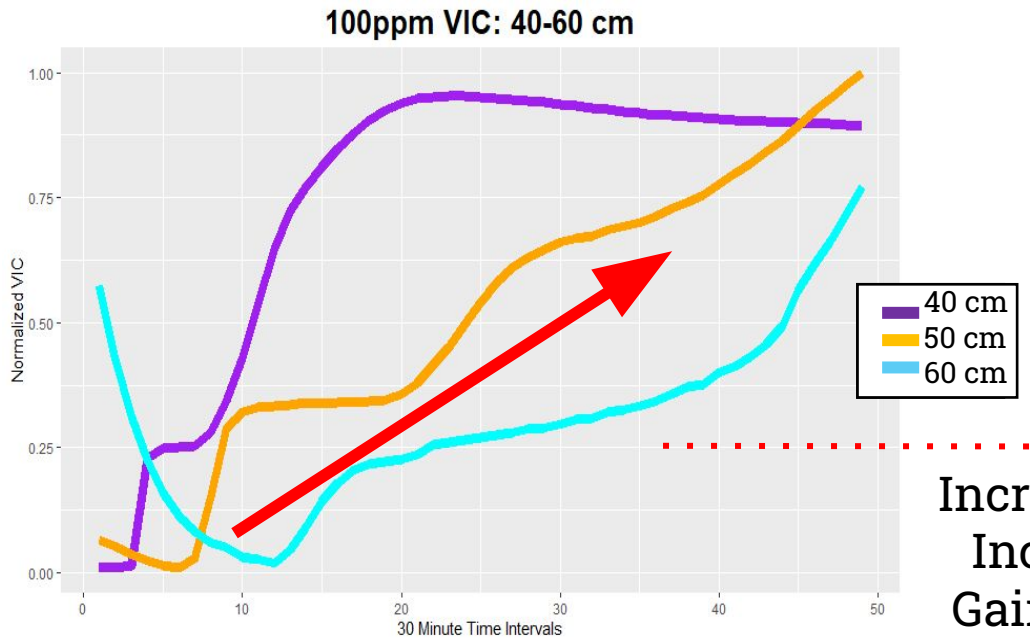
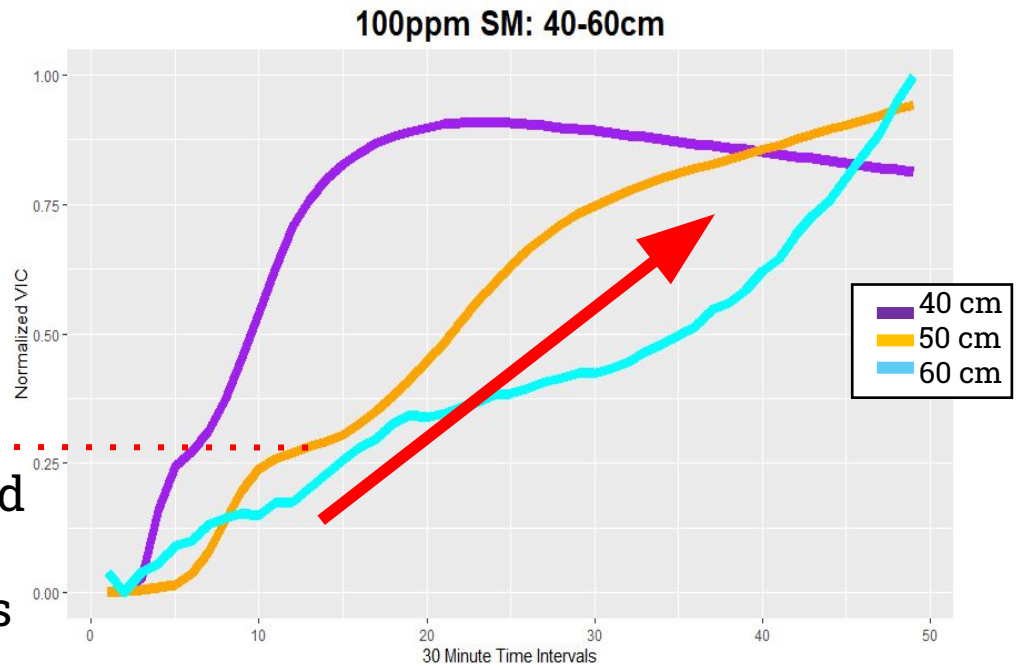




Decreasing VIC and Decreasing SM = Losing Nutrients (PO4)





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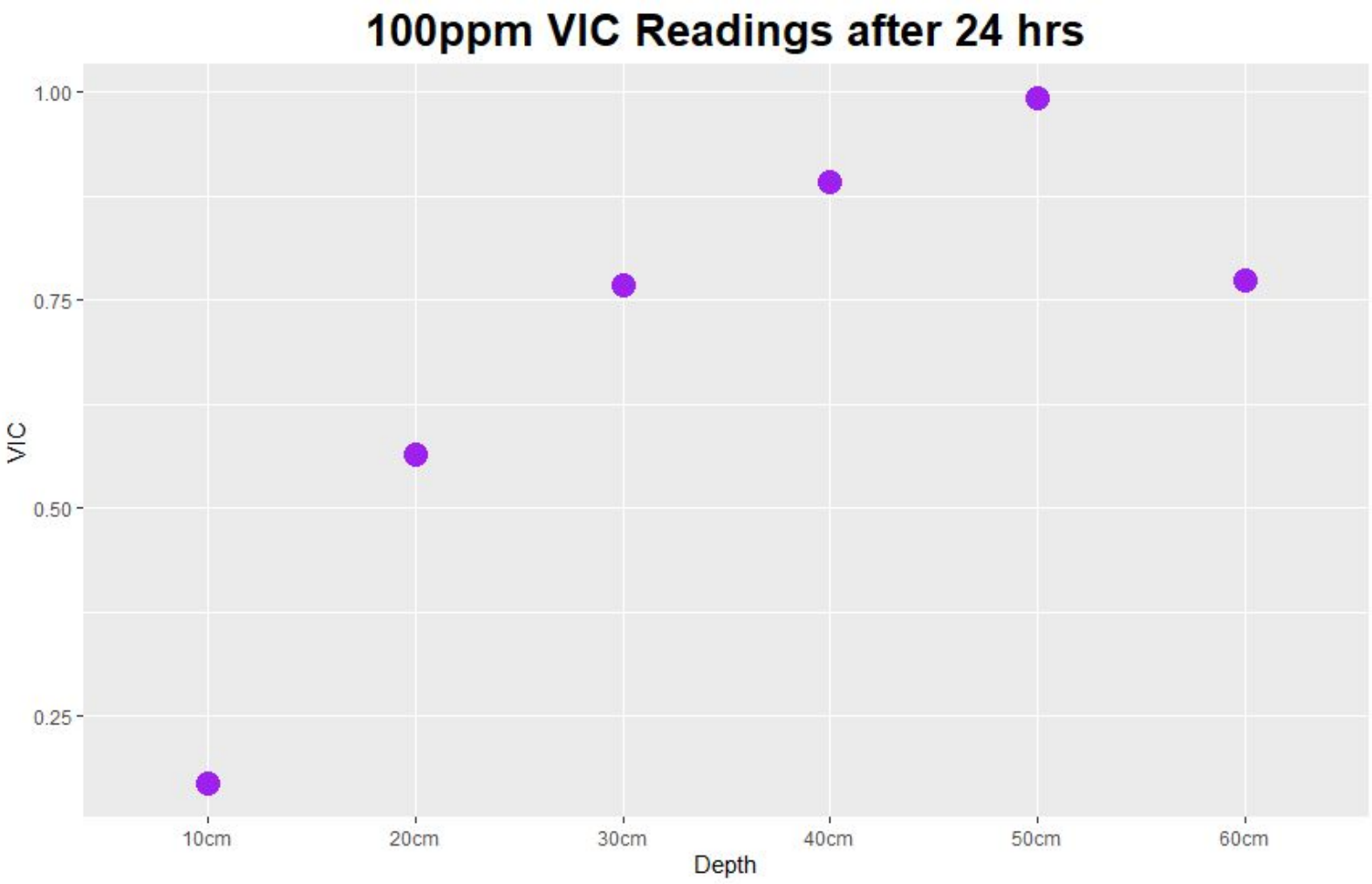
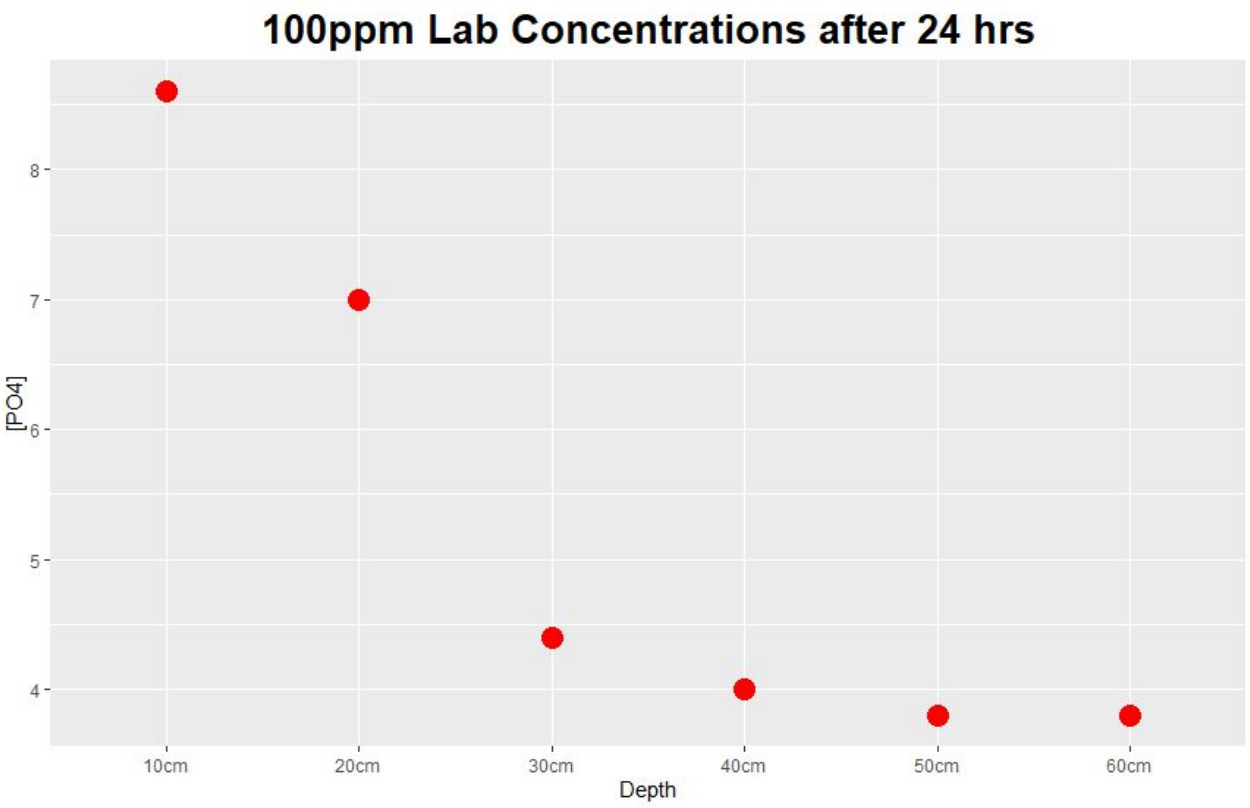
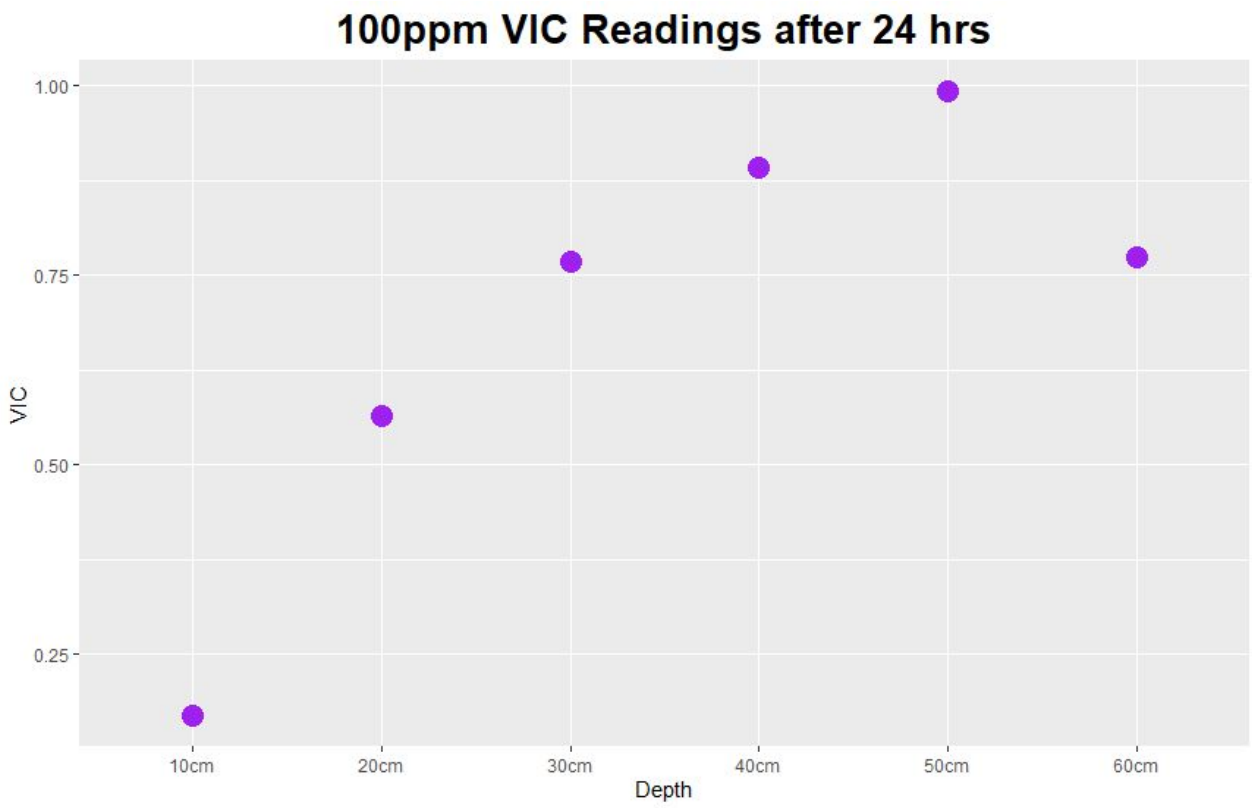
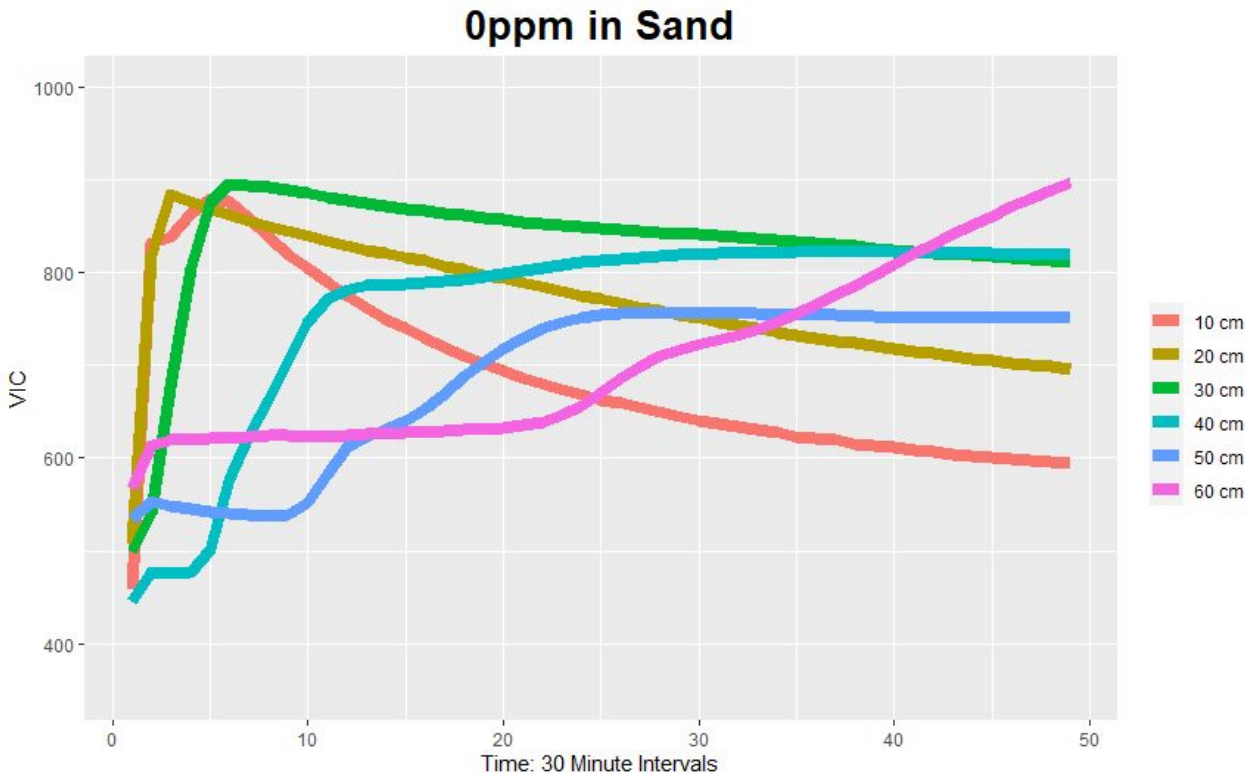


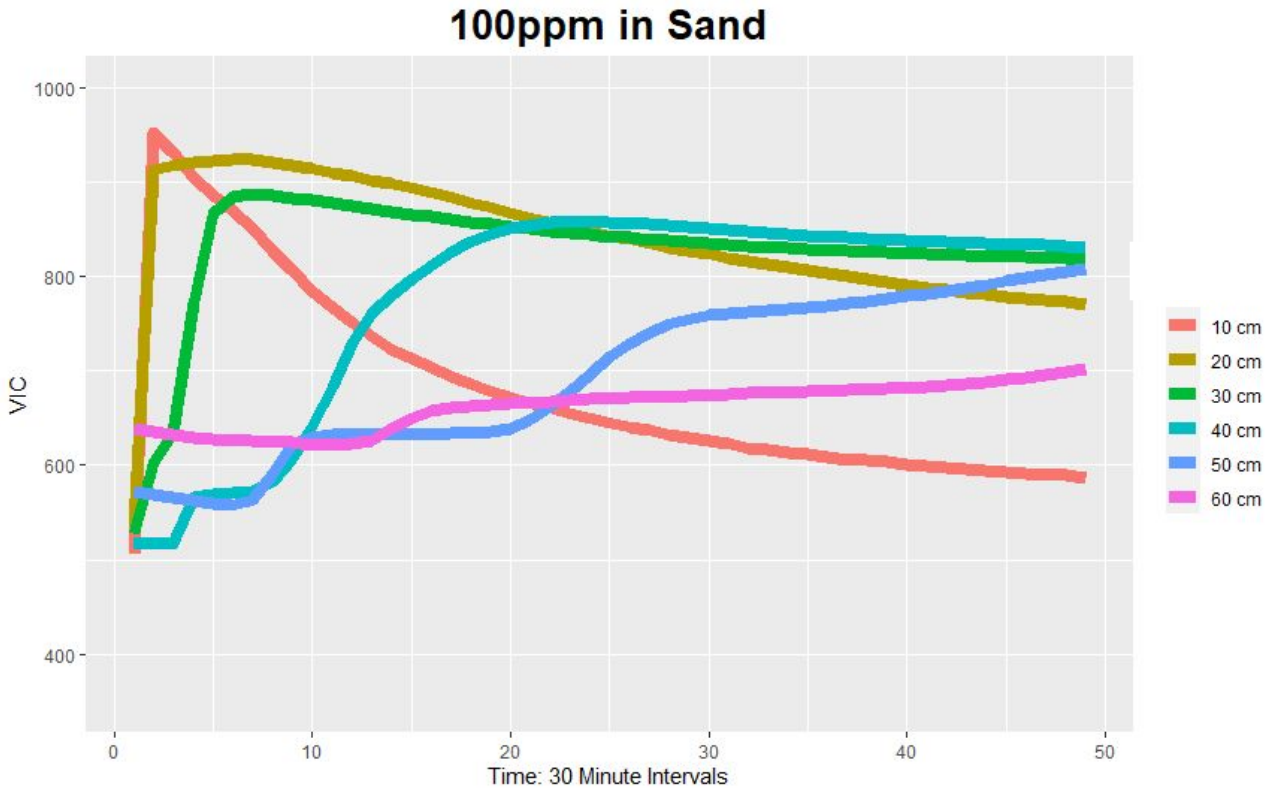
After 24 hours, the VIC measurements indicate that the highest levels of PO4 remain in the bottom 40cm of the soil profile, highest at 50 cm.



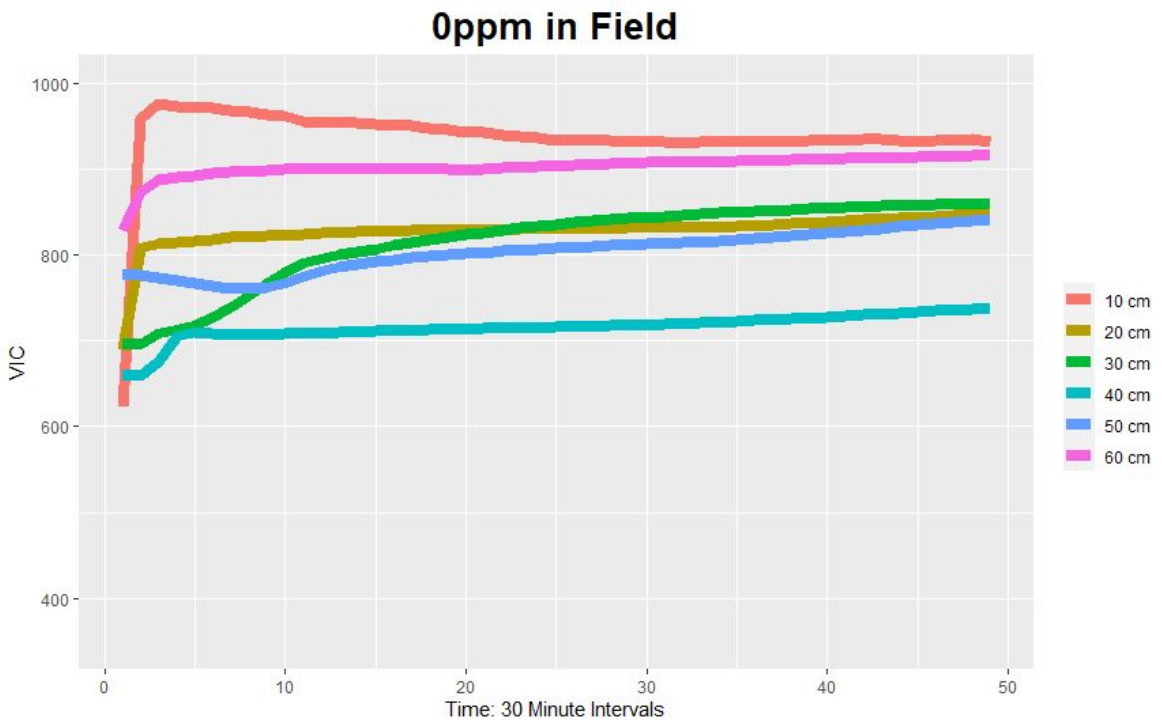


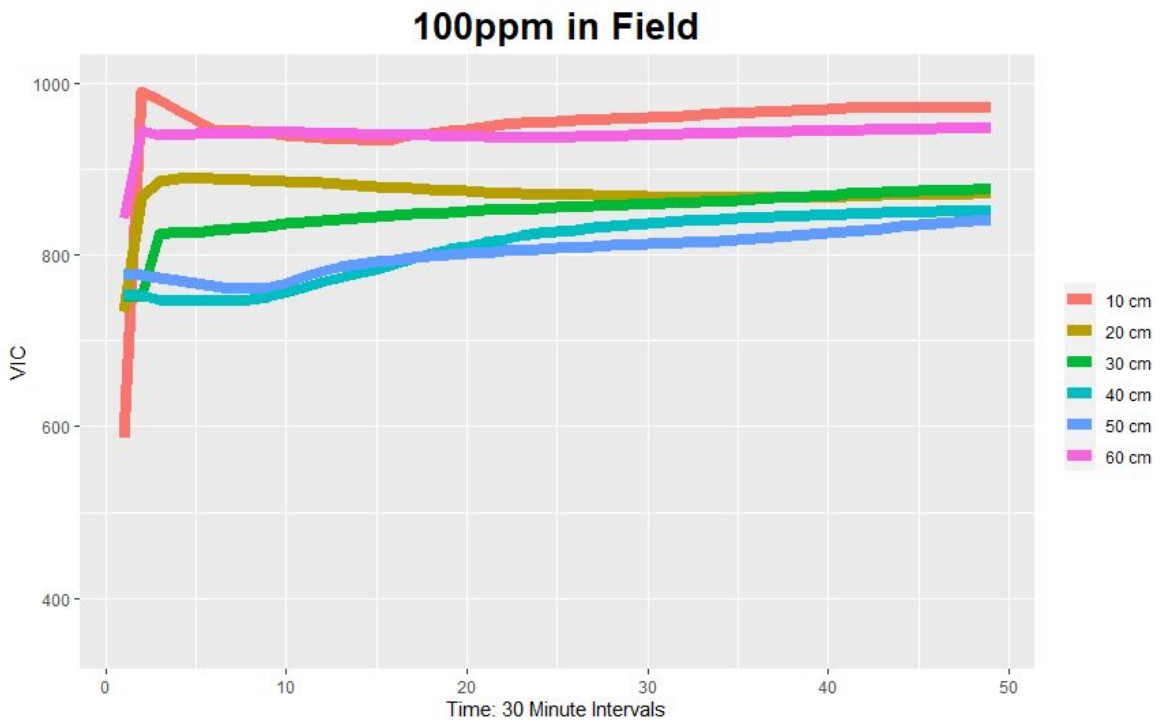
However, lab results contradict the conclusion drawn by the SM probes' VIC readings. The results reflected that PO4 generally did not leach below 30cm, remaining mostly within 10cm of the soil profile.





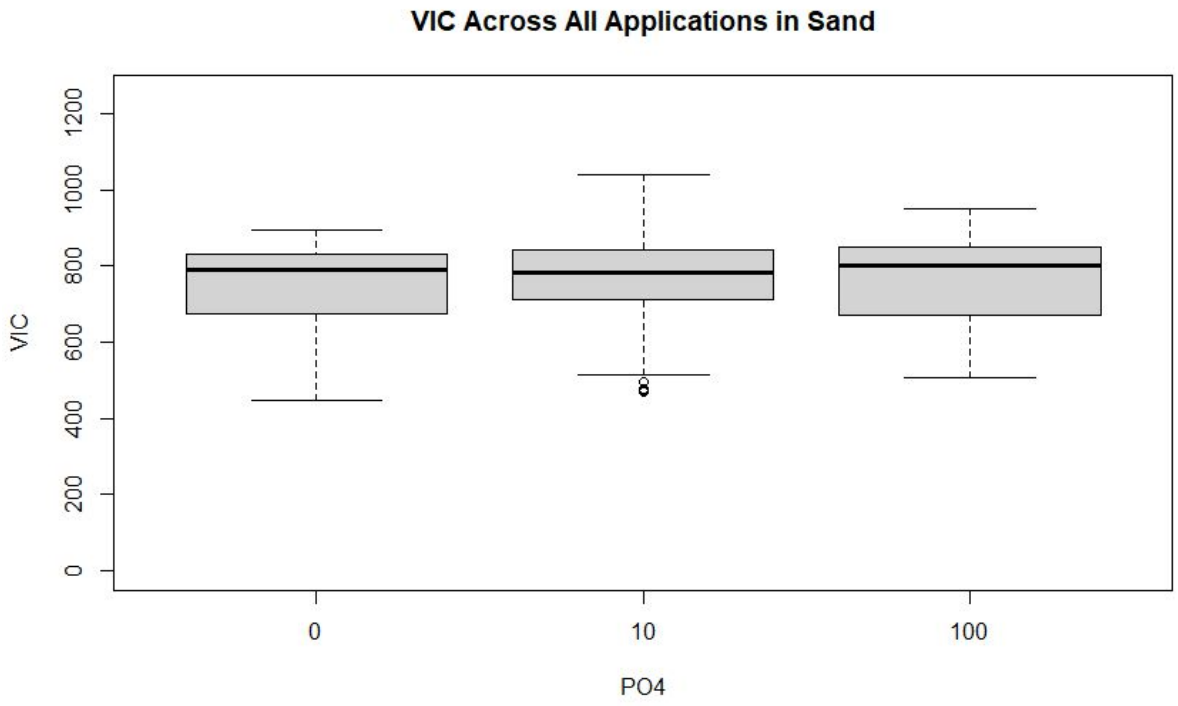
The only significant difference between the 0ppm and the 100ppm is at 60cm. The **0ppm** application had a significantly **HIGHER** VIC trend than the 100ppm.

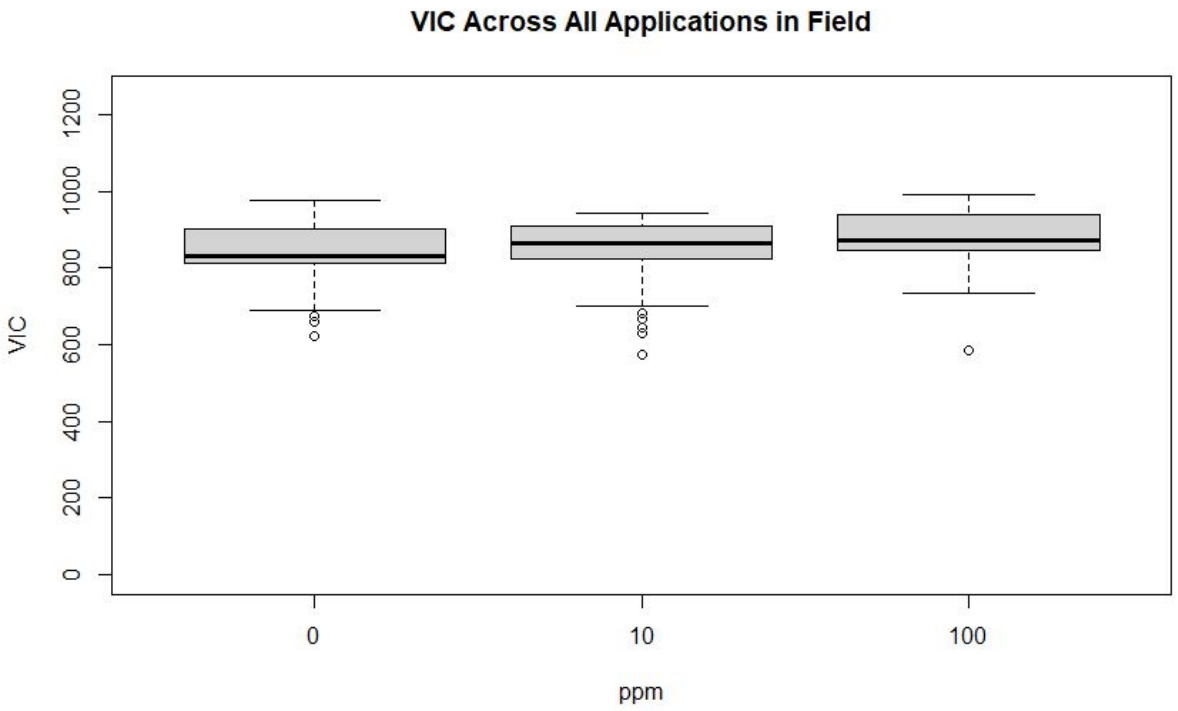




The only depth significantly different between treatments is 40cm. The 100ppm trial gave higher VIC recordings than the 0ppm.

To evaluate movement of fertilizers in the soil, the company also recommended assessing all the values in a period of time as a whole.

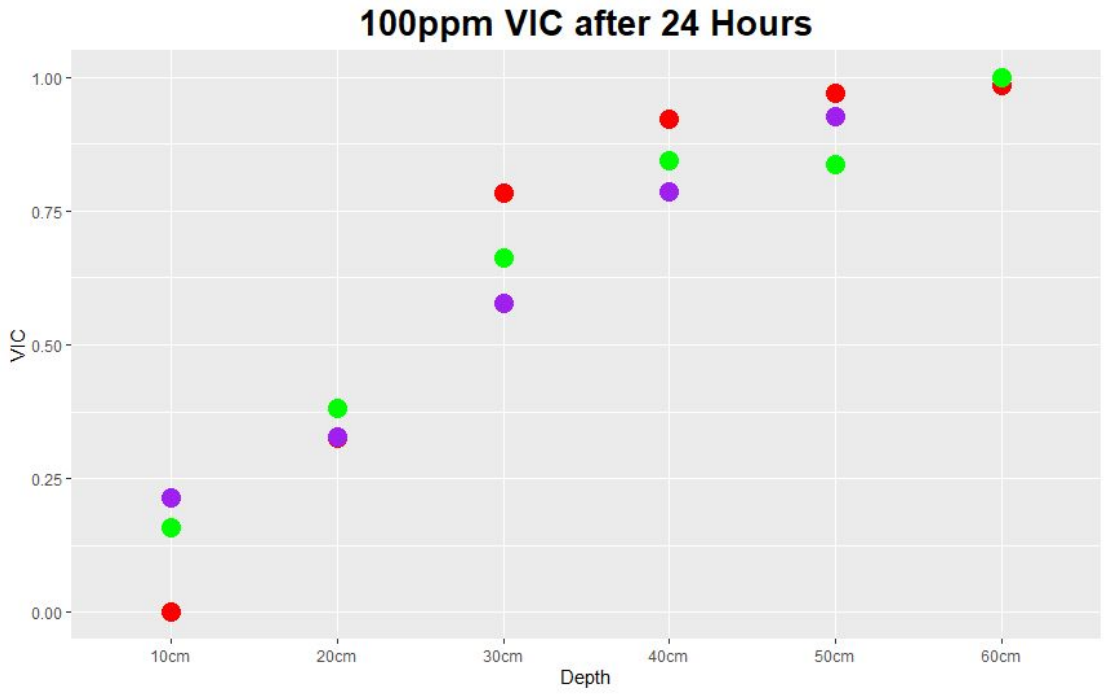


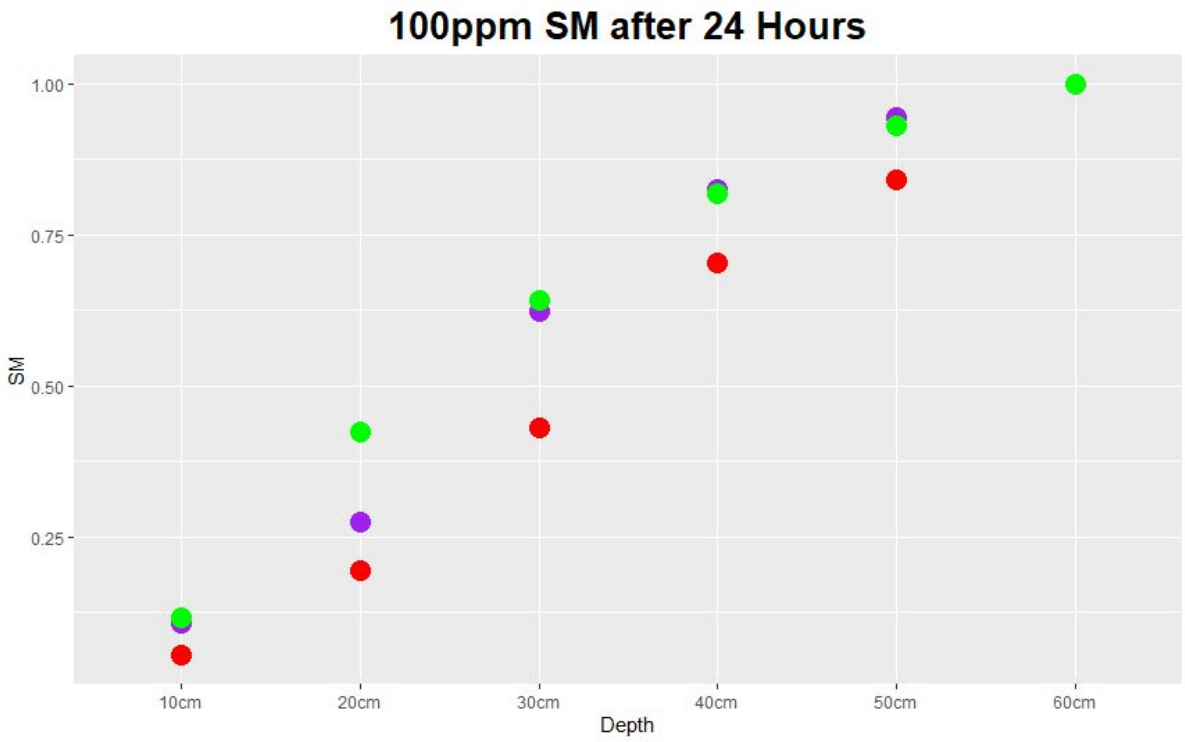


The one-way ANOVA analysis indicates that there is ***no significant difference in VIC readings*** across the treatments in both sand and field cores.

What's Going On?

High Correlation Between SM and VIC



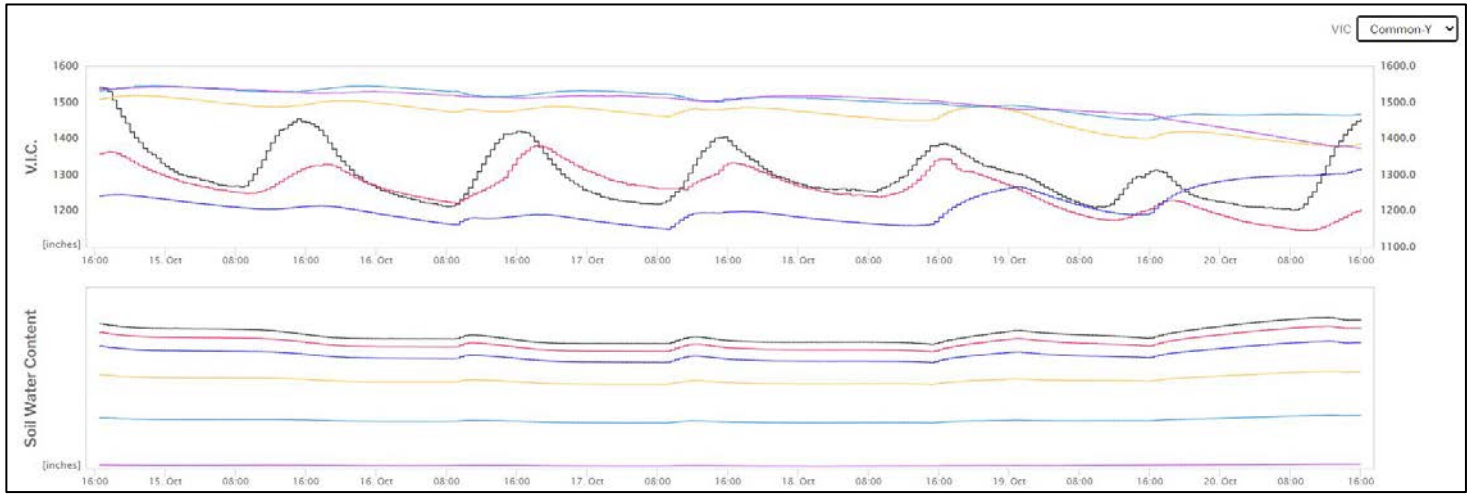


The influence of SM is too high and must be removed from the VIC readings.

Future Work

1) Separate the influence of SM from VIC.

2) Improve visualization platforms available to growers for more practical utilization of VIC data.



3) Use field data from currently installed sensors to further assess P and overall nutrient management.

4) Further P sensor development should be incorporated into these probes to accelerate implementation.

Acknowledgements

Guzmán Smart Irrigation and Hydrology Lab, IRREC UF IFAS

- Dr. Sandra M. Guzmán
- Daniel Y. Palacios Linares

Randy Burton, IRREC UF IFAS Farm Supervisor

Indian River Research and Education Center

STEPS

UF ANSERV Labs

BMP Logic, Technical Assistance

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Questions?

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Avoiding phosphorus losses while optimizing yield: Fertilizer Recommendation Support Tool (FRST)

Sustainable Phosphorus Summit – November 3, 2022

Sarah E. Lyons

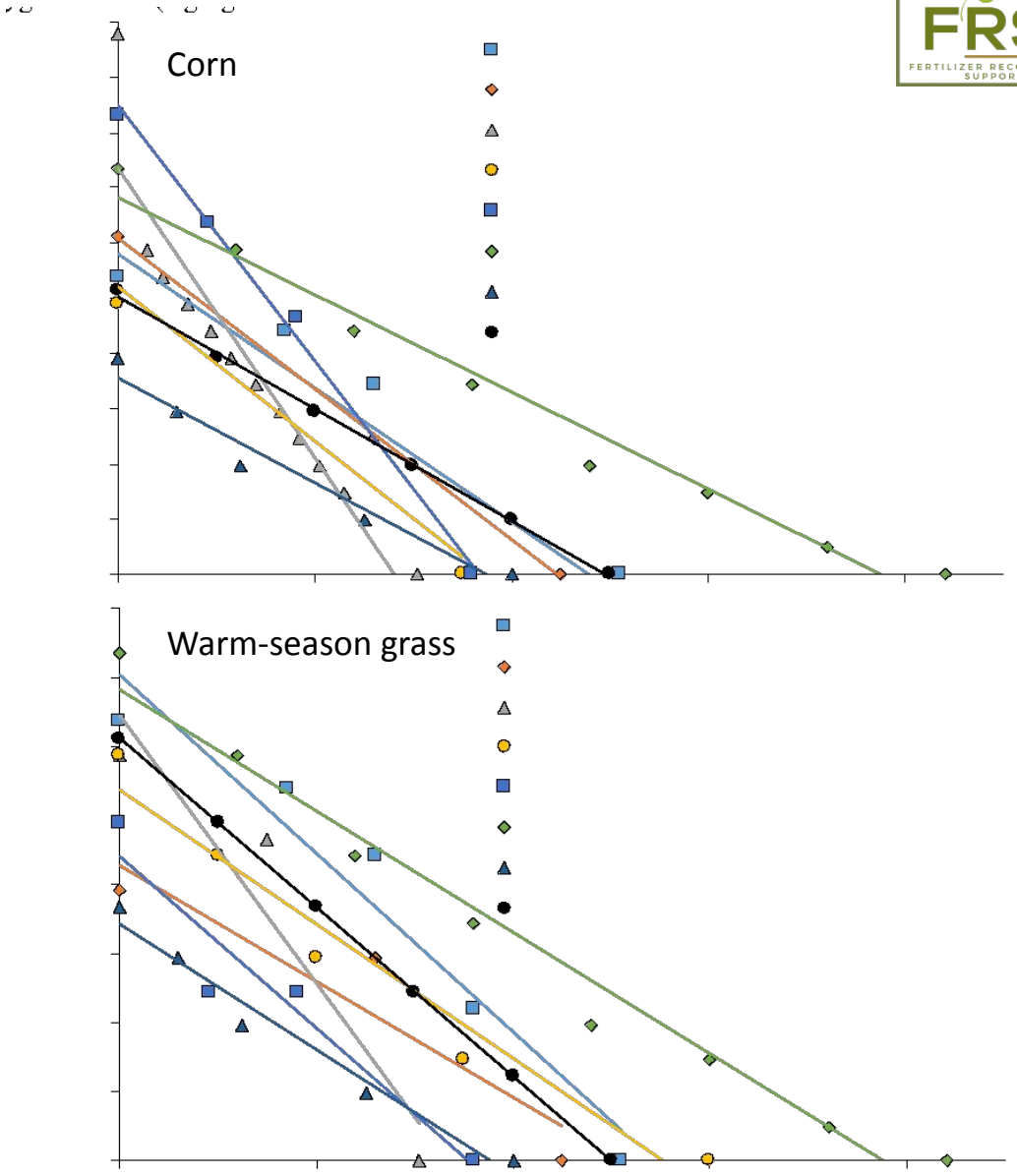
Deanna Osmond, Nathan Slaton, John Spargo, Pete Kleinman, Austin Pearce, and Greg Buol

FRST

FERTILIZER RECOMMENDATION SUPPORT TOOL

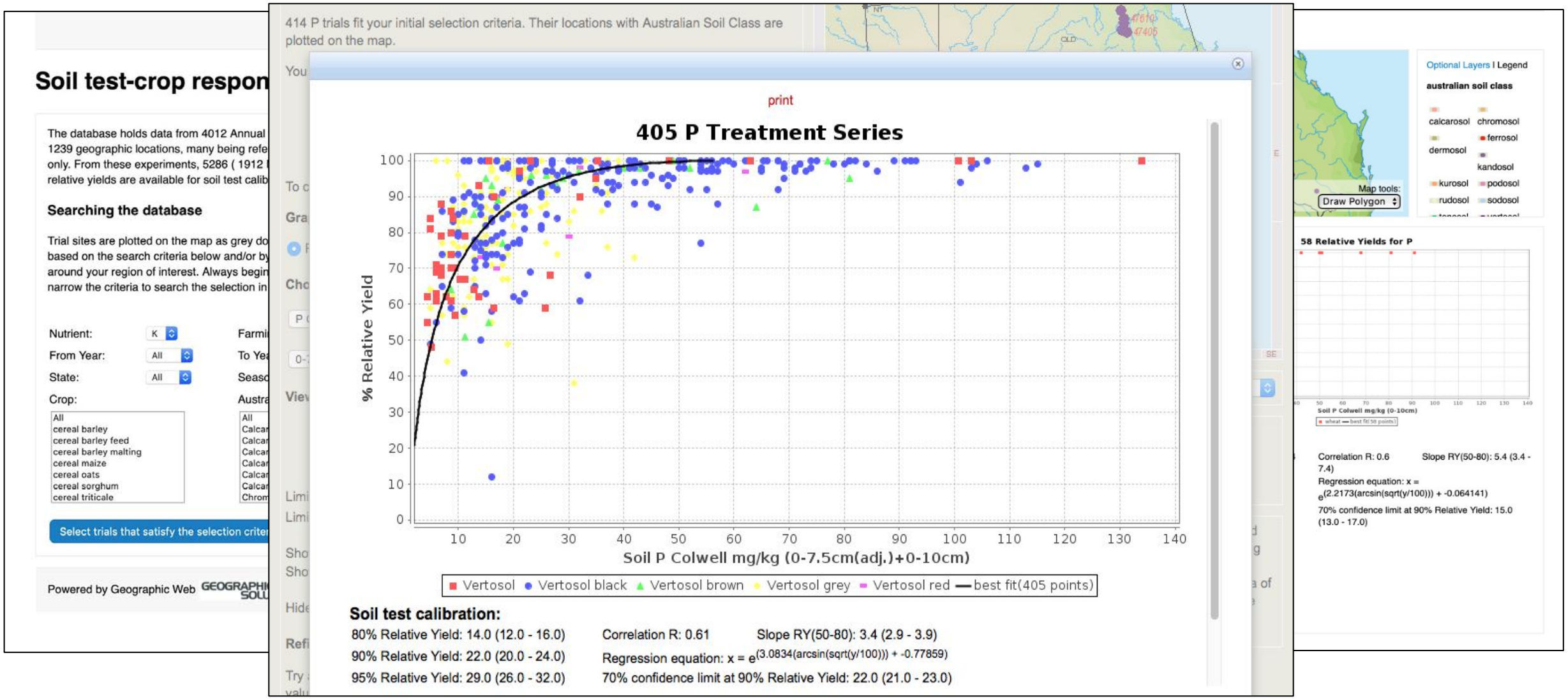
The Need for FRST

- 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



Fertilizer P rate recommendations based on soil test P

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 searchable tool that provides soil test correlation and calibration graphs with statistical confidence intervals for the area of interest (general users)
2. 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 University
Leo Deiss	Ohio State University
Jagman Dhillon	Mississippi State University
Gerson Drescher	University of Arkansas
Bhupinder Farmaha	Clemson University
Joshua Faulkner	University of Vermont
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
Clain Jones	Montana State University
John Jones	University of Wisconsin
Daniel Kaiser	University of Minnesota
Quirine Ketterings	Cornell University
Gene Kim	USDA-NRCS
Pete Kleinman	USDA-ARS
Greg LaBarge	Ohio State University
Gabe LaHue	Washington State University
Jay Lessl	University of Georgia
Sarah Lyons	North Carolina State Univ.
Rory Maguire	Virginia Tech 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
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
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Mark Reiter	Virginia Tech University
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Andrew Sharpley *	University of Arkansas
Amy Shober	University of Delaware
Frank Sikora	University of Kentucky
Henry 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
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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
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Oklahoma State University
UTIA Institute of Agriculture The University of Tennessee
Virginia Tech
Colorado State University
UofA Division of Agriculture Research & Extension University of Arkansas System
USDA NRCS United States Department of Agriculture Natural Resources Conservation Service
USDA ARS United States Department of Agriculture Agricultural Research Service
Mississippi State University
NC State University
ECU
UC Davis University of California
Texas A&M University
FSA Farm Service Agency
FAR Foundation for Agronomic Research
Plant Nutrition Canada
Auburn University
Clemson University
NM State
LSU Louisiana State University
UPR Recinto Universitario de Mayagüez
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FRST Project: Step-wise activities

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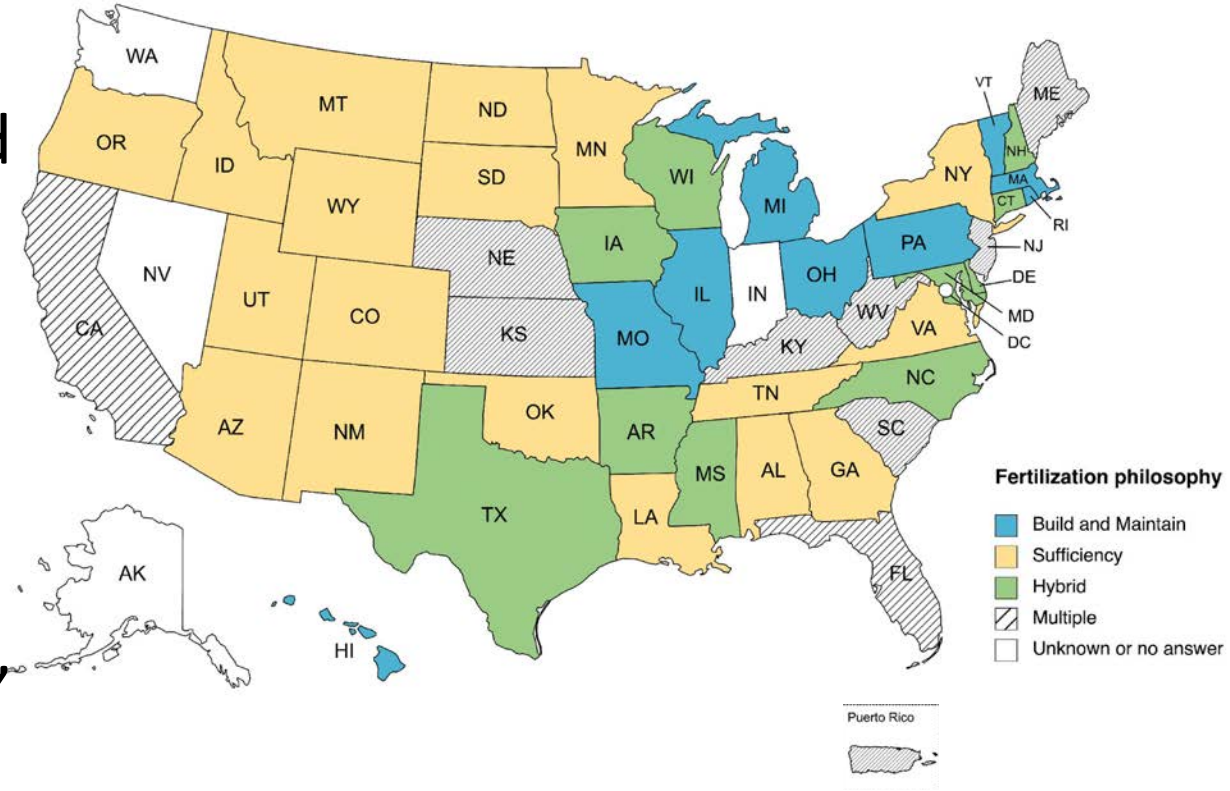
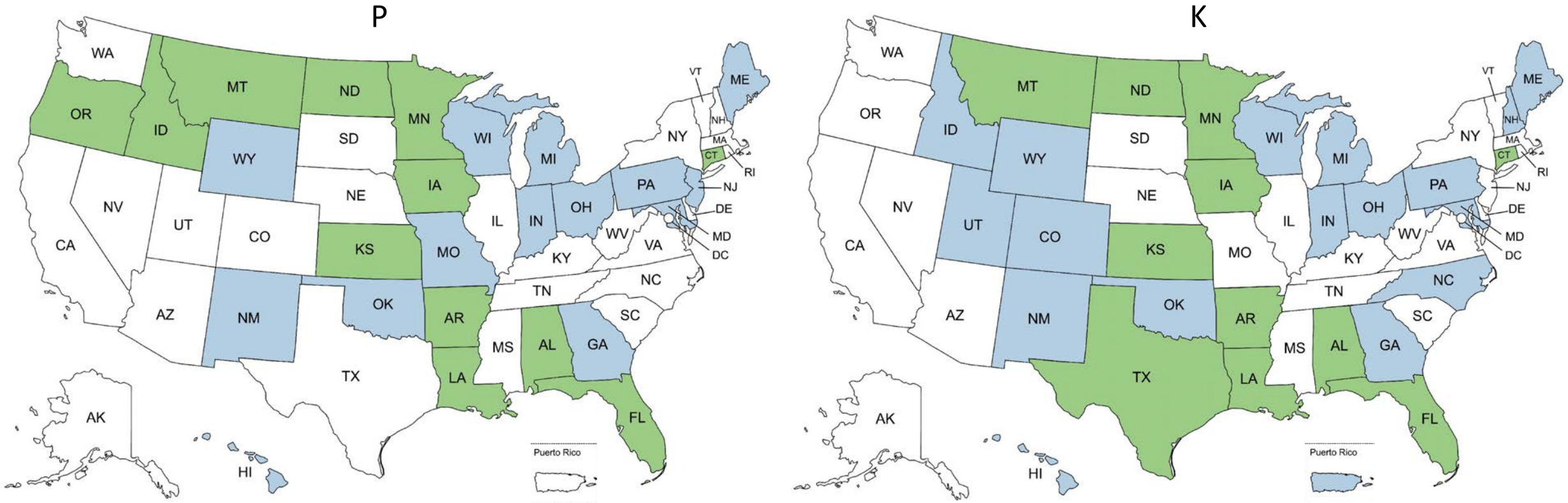
National Land Grant University Soil Fertility Survey

- 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)



National Land Grant University Soil Fertility Survey

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



2002 or later

2001 or earlier

Unknown or no answer

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Minimum Dataset for Correlation and Calibration Trials

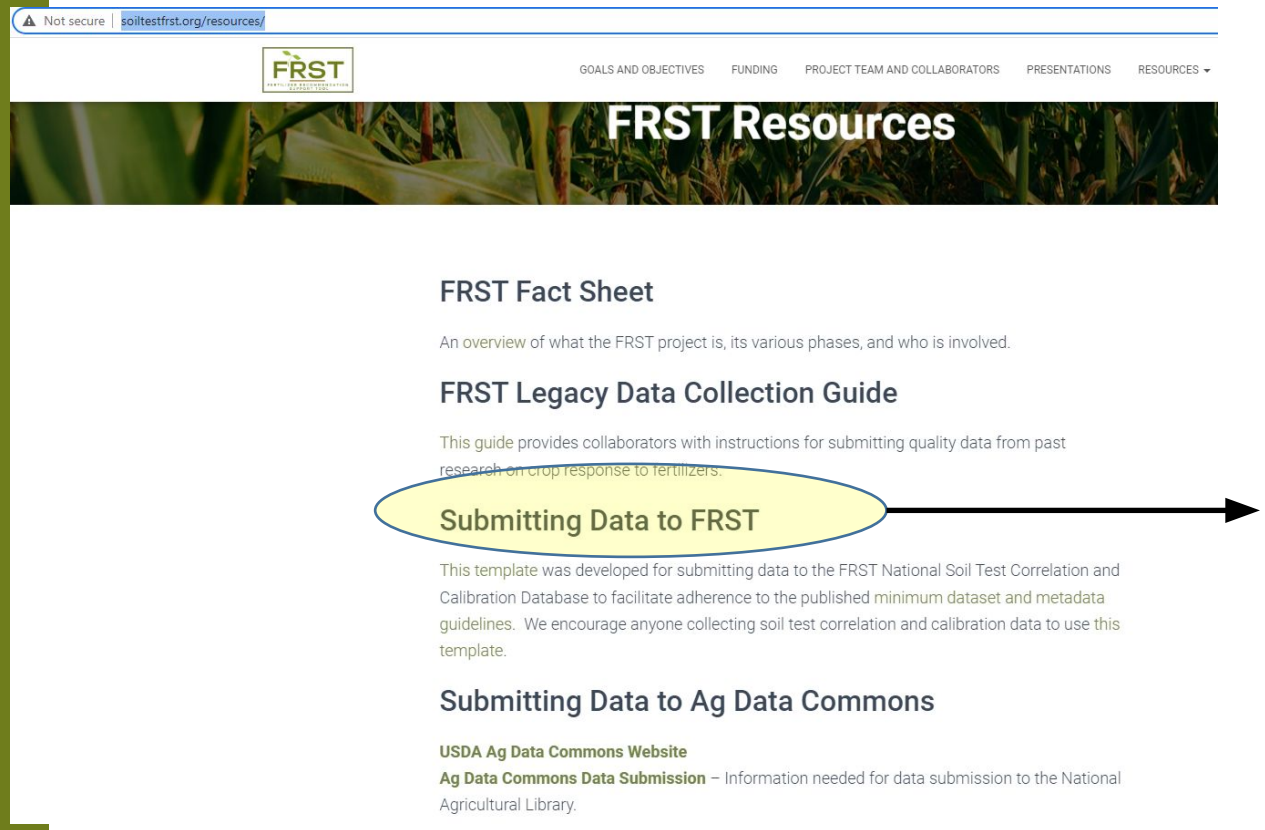
Category	Required data	Recommended data
Soil sample collection and processing metadata	9	5
Soil chemical and physical properties	6	19
Crop, soil, and nutrient management metadata	26	17
Experimental design and statistical analysis	8	9

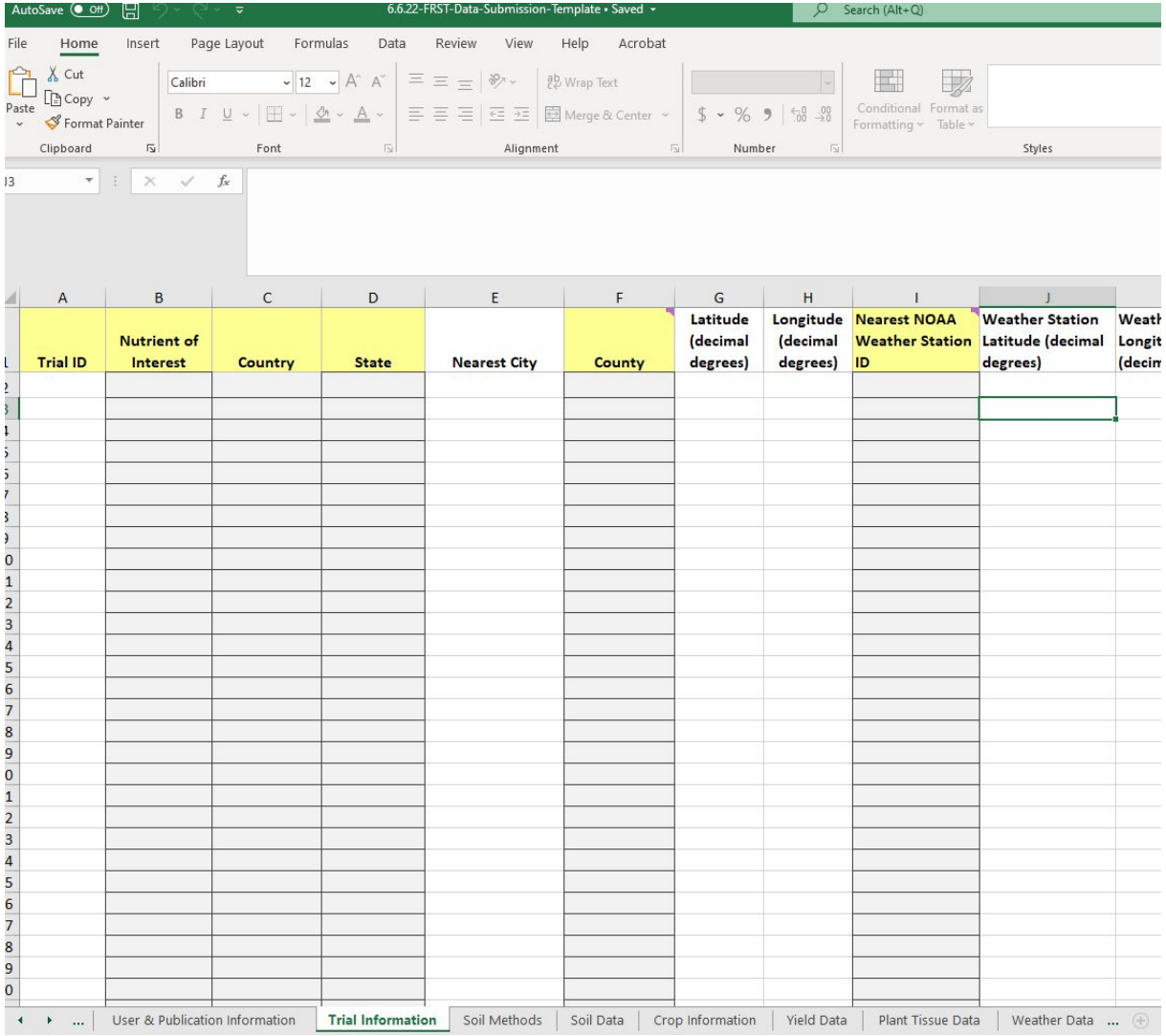
Soil Sci. Soc. America J. (2022) 86:19-33
DOI: 10.1002/saj2.20338

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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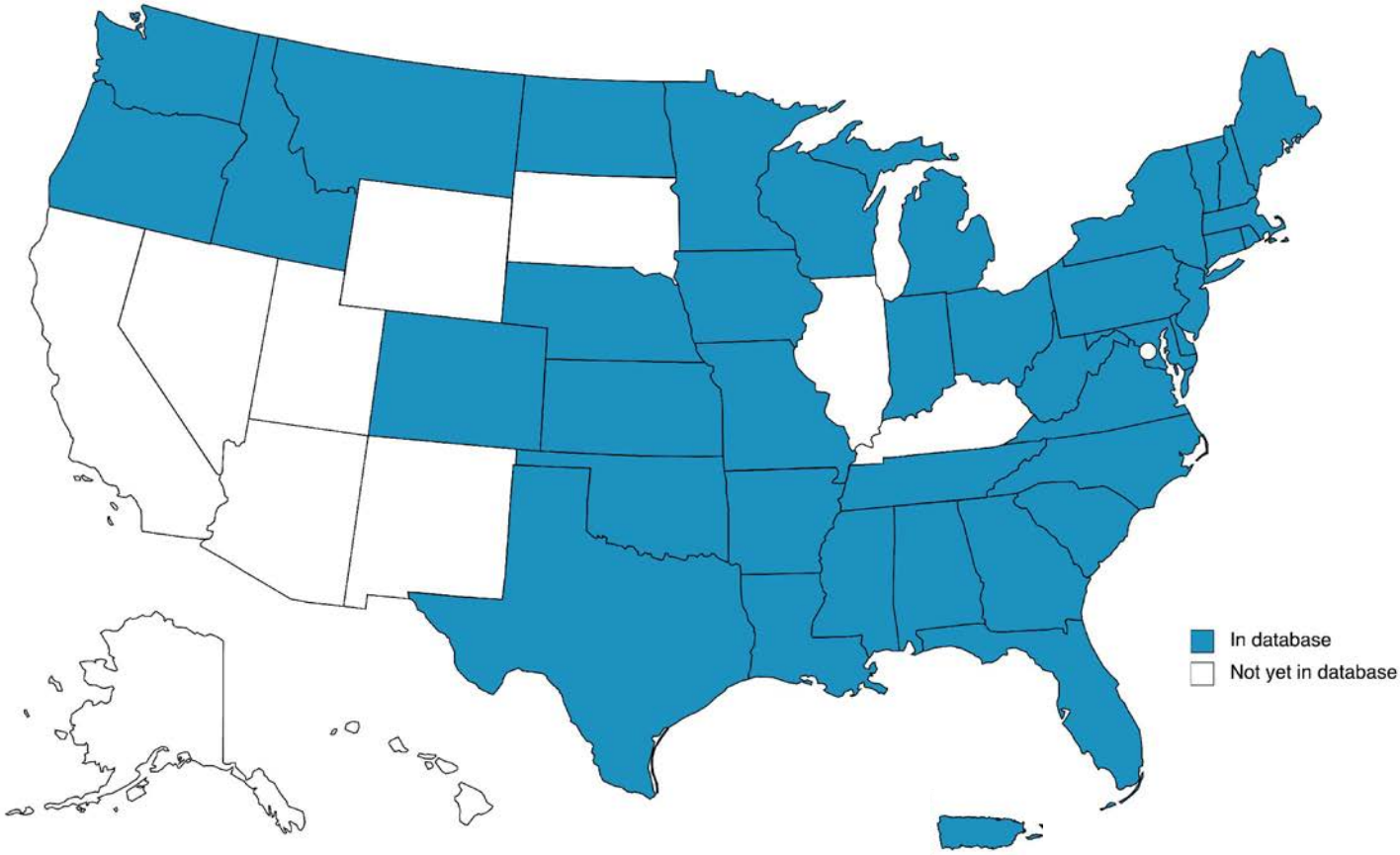
FRST Legacy Database

- 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

States Currently Represented by the FRST Database



FRST Legacy Database Summary

Trials	1,332	Years	1949 - 2021
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, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NY, OH, OK, OR, PA, PR, RI, SC, TN, TX, 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.

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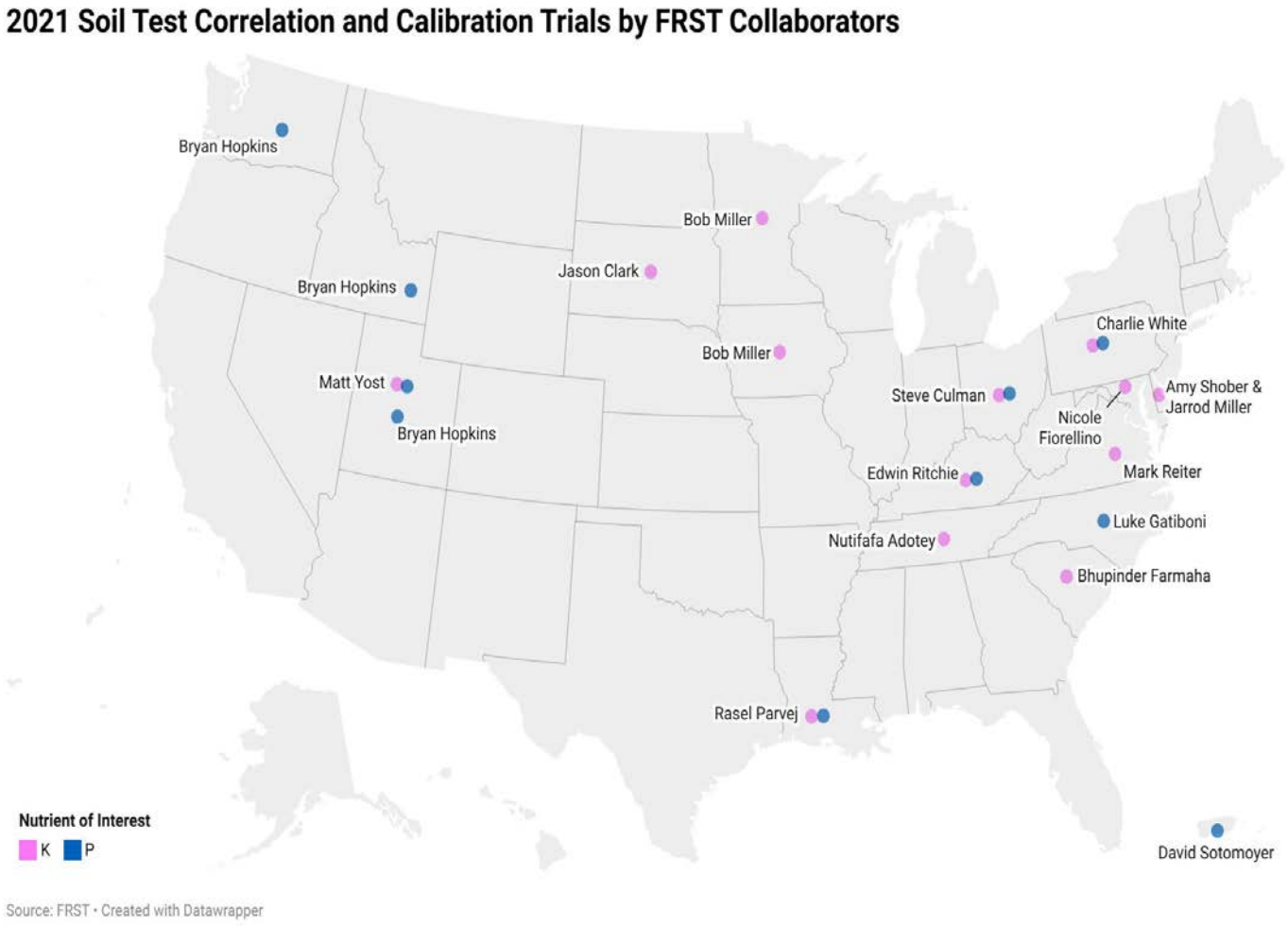
Collaborator (State-level) Soil Test Correlation and Calibration Trials (2021)

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



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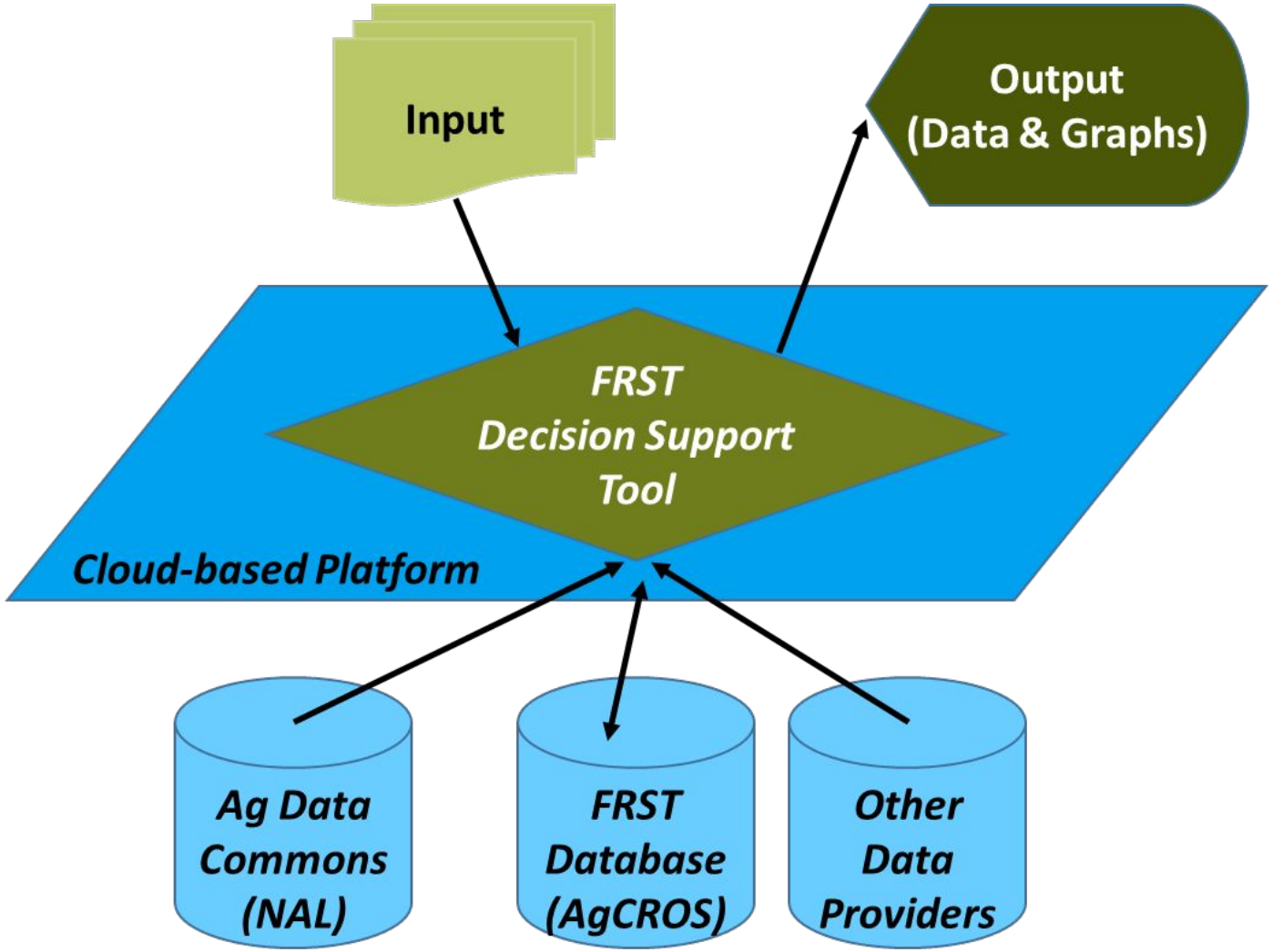
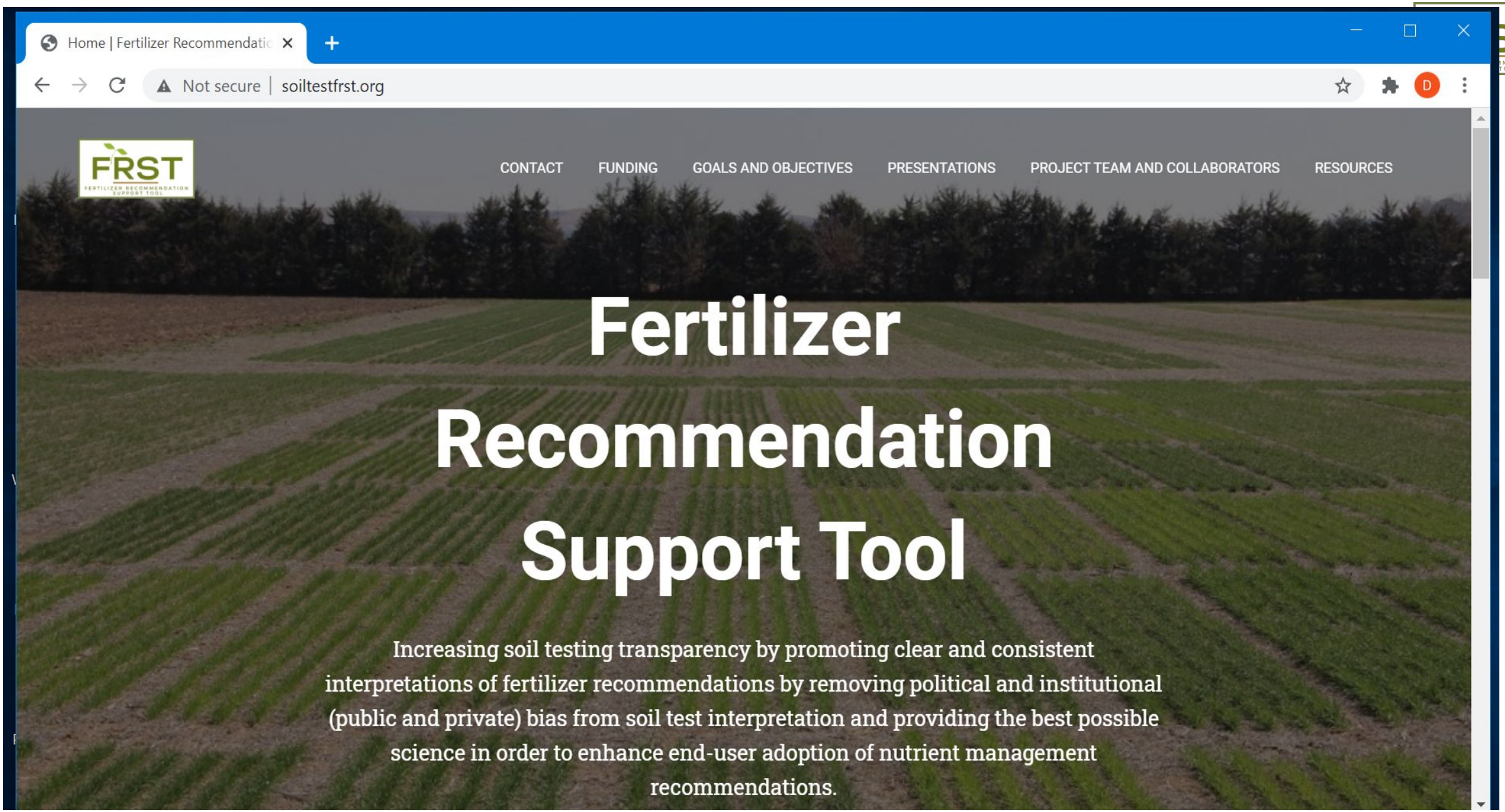
FRST Decision Support Tool

Principles of model development:

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





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Have data to contribute?
Contact: selyons@ncsu.edu

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2022 Sustainable Phosphorus Summit

Transformation of Soluble Phosphate within Manure to a Less Soluble Calcium Phosphate Solid with Cement from Waste Concrete

Tian Zhao

Ph.D. Candidate

Mining and Materials Engineering, McGill University

Montreal, Quebec, Canada

Supervisor: Prof. Sidney Omelon

2022 Nov

Image credit: Alena Demidyuk / Shutterstock.com

Outline

Algae bloom in Montreal July 29, 2012.

- *Project Background*
- *Design of Experiments (DoE)*
- *Greenhouse Experiment*
- *Results and Discussion*
- *Conclusions*

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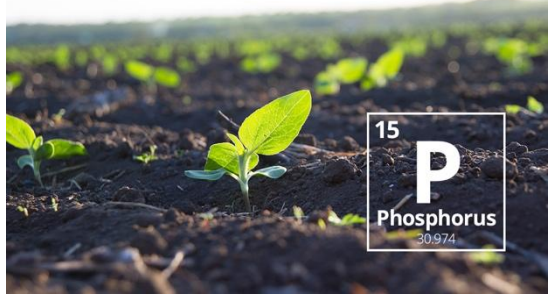
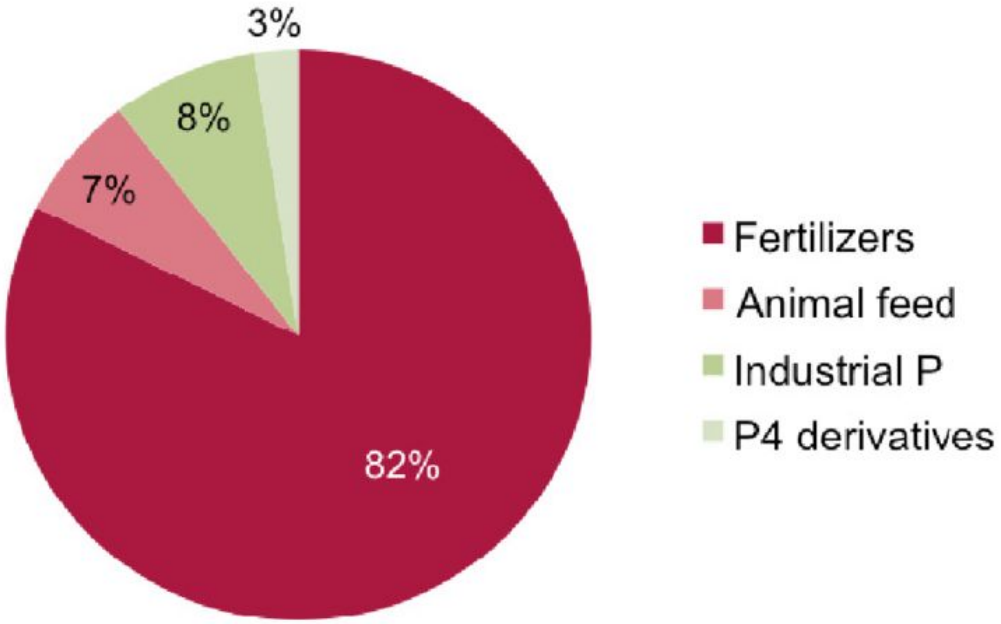
Background



Phosphorus (P) is an essential non-renewable resource



Breakdown of phosphorus end uses

- Manure is a P fertilizer source.
- High manure production requires disposal.
- The manure **N/P ratio** is usually smaller than the plant uptake ratio
- This uptake imbalance may cause **nonpoint P runoff.**

Schroder, J. & Cordell, Dana & Smit, A. & Rosemarin, Arno. (2010). Sustainable use of phosphorus : EU tender ENV.B1/ETU/2009/0025. Biosystems Engineering - BIOSYST ENG.

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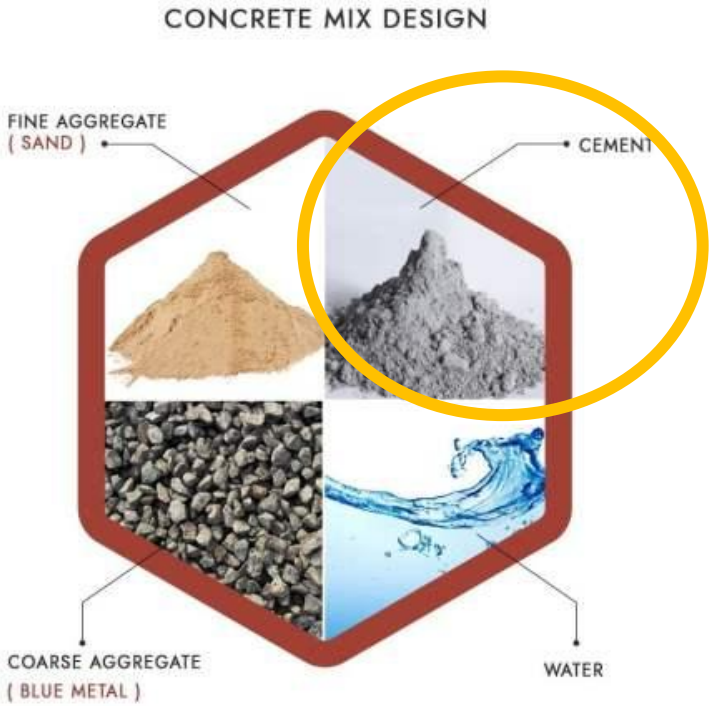
Project Goal

Reduce soluble inorganic P concentration in dairy cattle manure.

P solubility is reduced by addition of the cement fraction of <u>waste concrete powder</u> to form a less soluble calcium phosphate (Ca-P) product, which has slow-release P-fertilizer potential.



The waste concrete is from Turcot interchange project in Montreal

https://theconstructor.org/concrete/beginners-guide-concrete-mixes/45944/

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P Solubility Reduction Mechanism(s)

Reactive adsorption (Chemisorption):

Phosphate ions diffuse and react with calcium and alkaline-rich hydraulic lime on the surface of the concrete powder

and/or

Precipitation:

The released inorganic orthophosphate (o-Pi) ions in aqueous solution precipitate with Ca^{2+} ions dissolved from the hydraulic lime from the waste cement under supersaturation conditions for apatite.

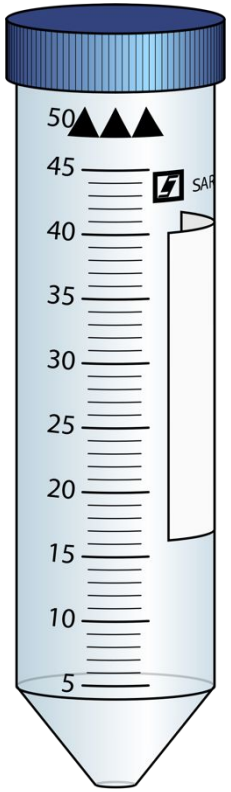
Experimental Method

Inorganic P release → P reaction with waste cement → Soluble o-Pi reduction evaluation

Fresh manure mixed with different water ratios at room temperature.
Soluble o-Pi dissolved.

Ground waste concrete powder mixed at different manure-water ratios.

o-Pi concentration was measured by colorimetric assay.

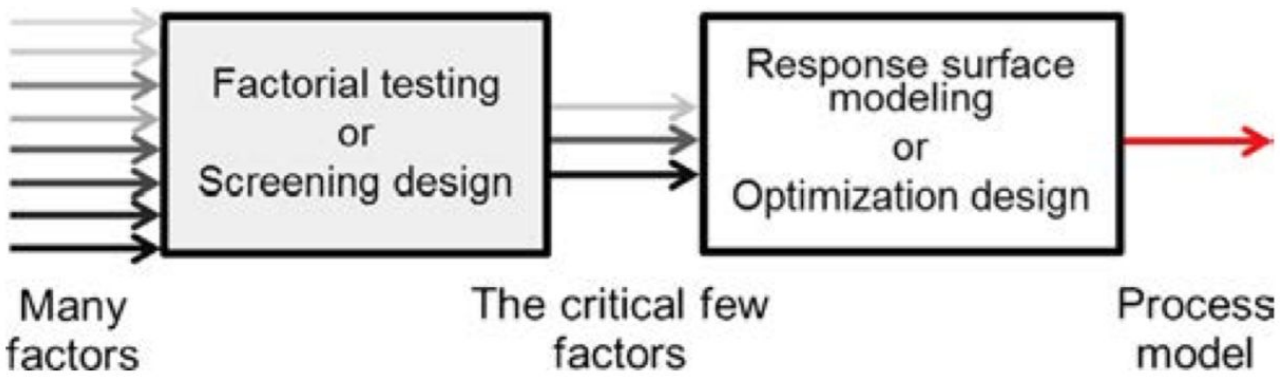


After the process, the supernatants were discarded, and the “treated product” pellet was collected and dried at 120 ˚C.
Design of Experiments was used to asses the effect of the experiment variables.

*o-Pi inorganic orthophosphate

Design of Experiment (DoE)

DOE (Design of Experiment) is a mathematical method for planning and conducting scientific experiments to investigate the relationships between the **factors (variables)** and **responses (results).**



Multiple input factors are considered and controlled simultaneously to ensure that the effects on the output responses are causal and statistically significant.

Ronald Fisher

McGill

Design of Experiment (DoE) with Minitab® 18

Identification of the critical factors in soluble o-Pi reduction

2 level, 5-factor fractional factorial design (replicates: 2)

Variables	Low	High
Water to manure ratio (w/w) (W:M)	1	4
Concrete particle size (µm)	425	1160
Concrete to manure ratio (w/w) (C: M)	0.2	0.8
Agitation (100 rpm) during precipitation (yes/no), categorical variable		
P release process before precipitation (yes/no), categorical variable		

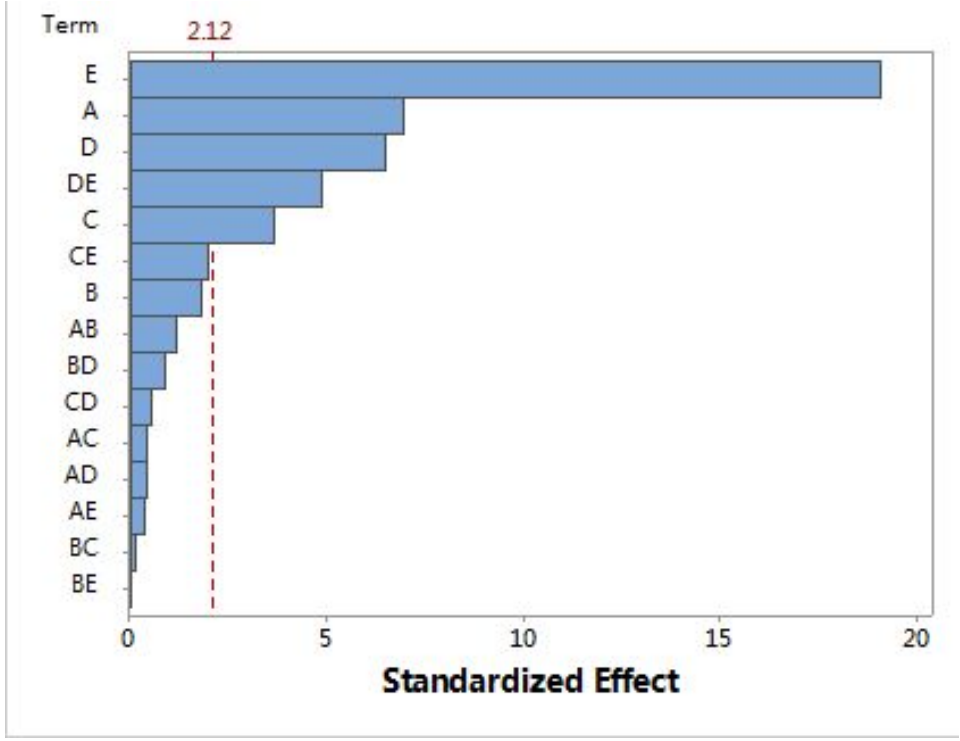
Responses:

1. Dissolved o-Pi mass (g) reduced per unit mass of manure (% TP reduction)
2. Supernatant soluble o-Pi concentration reduction (% o-Pi concentration reduction)

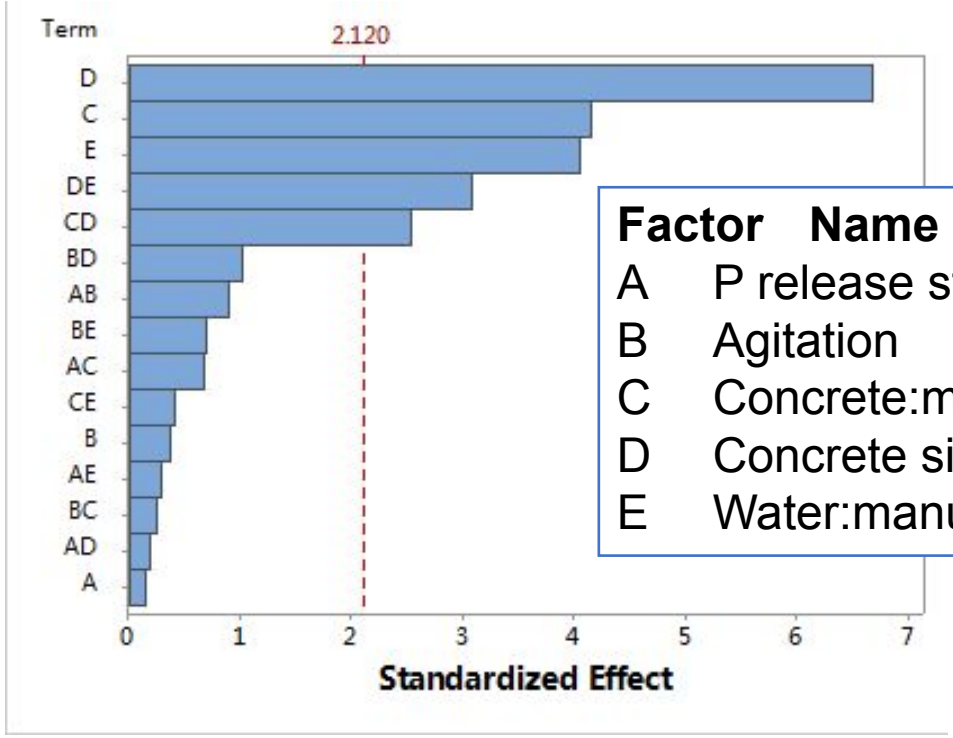
DoE Results – Pareto Charts

The Pareto chart shows the significance of each variable effect.
A variable is considered significant if exceed the threshold value.
The threshold value depends on the number of parameters.

Dissolved o-Pi mass (g) reduced per unit mass of manure (%)

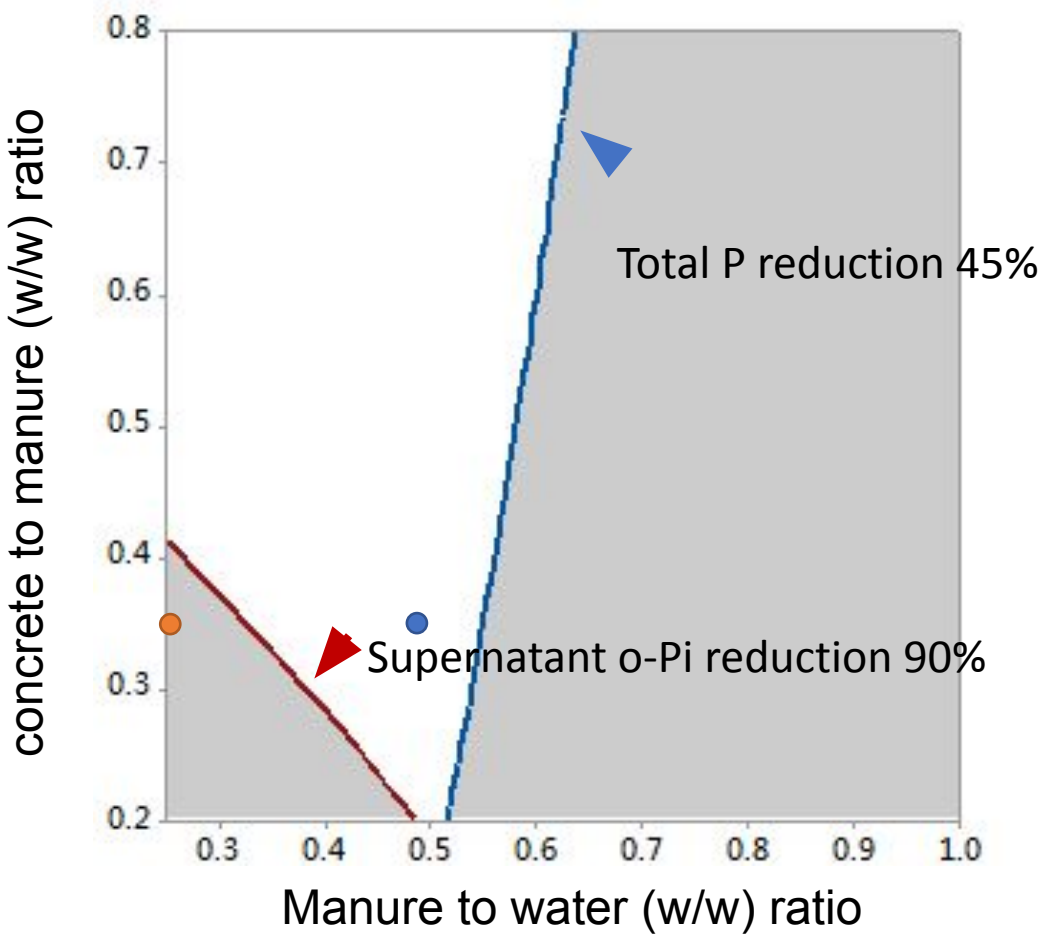


Supernatant soluble o-Pi concentration reduction (%)



Factor	Name
A	P release step
B	Agitation
C	Concrete:manure
D	Concrete size (μm)
E	Water:manure

DoE Results - Overlap Contour Plot of W:M and C:M



- Product 1 (0.5 W:M ratio, 0.35 C:M ratio)
- Product 2 (0.25 W:M ratio, 0.35 C:M ratio)

M:W - Manure to water ratio (w/w)
C:M - Concrete powder to manure ratio (w/w)

Responses:
Total dissolved P reduction (blue line)
o-Pi concentration reduction (red line)

Factors held constant:

- P releasing step: yes
- Agitation: no
- Concrete size: 650 μm

Greenhouse Experiments

- 3 L pot tests with spring wheat, 3 repeats per group
- *Sample groups:* Blank, mineral P, dried manure only, concrete only, 2 manure-concrete products
- Mixed P-free soil (sand, sphagnum moss)
- P source for the plants were from the **manure products** or **mineral P fertilizer**
- Other nutrients were sufficient and constant.
- Spring wheat grew for 8 weeks.
- Data: Soil P bioavailability - Mehlich 3 extraction. Plant P uptake – digestion and ICP-OES analysis.

Spring wheat

McGill Macdonald Campus greenhouse

McGill

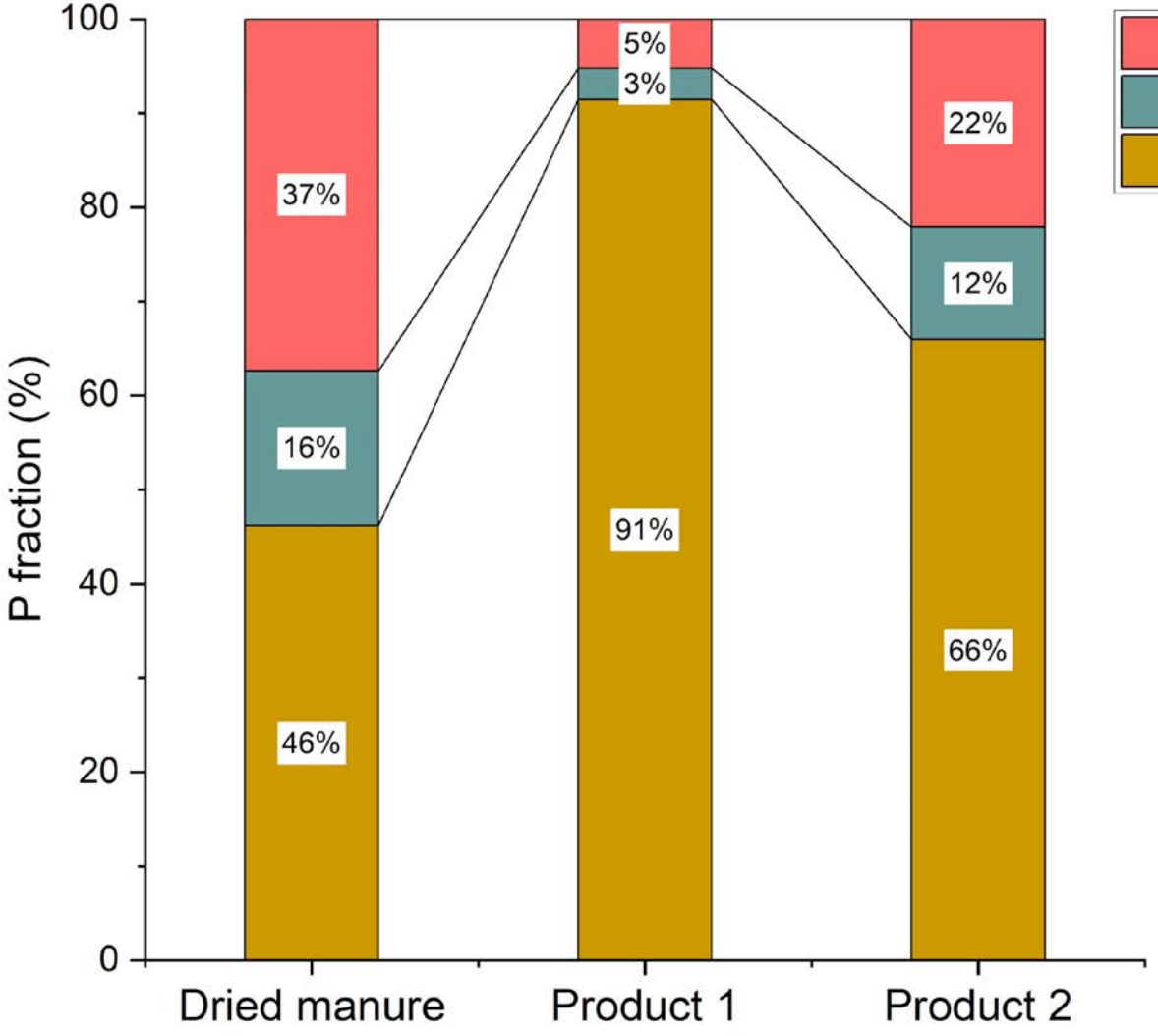
Greenhouse Experimental Design

Group	P application (mg total P /kg soil)	Details
Standard ladder with mineral P fertilizer		
Sample controls: dried manure or concrete		
Concrete-treated manure products		

Greenhouse Experimental Design

Group	P application (mg total P /kg soil)	Details
Blank	0	No P fertilizer addition
7.5-minP	7.5	$Ca(HPO_4)\cdot 2H_2O$ as **min**eral P fertilizer
15-minP	15	
30-minP	30	
Control: Dried Manure	**30**	Equivalent total P in dried manure
Control: Concrete with 15minP	15	5x the concrete added to treated manure products P as $Ca(HPO_4)\cdot 2H_2O$
Product 1 (0.5 M:W, 0.35 C:M)	30	Equivalent total P in the product
Product 2 (0.25 M:W, 0.35 C:M)	30	

Results – Manure Product P species



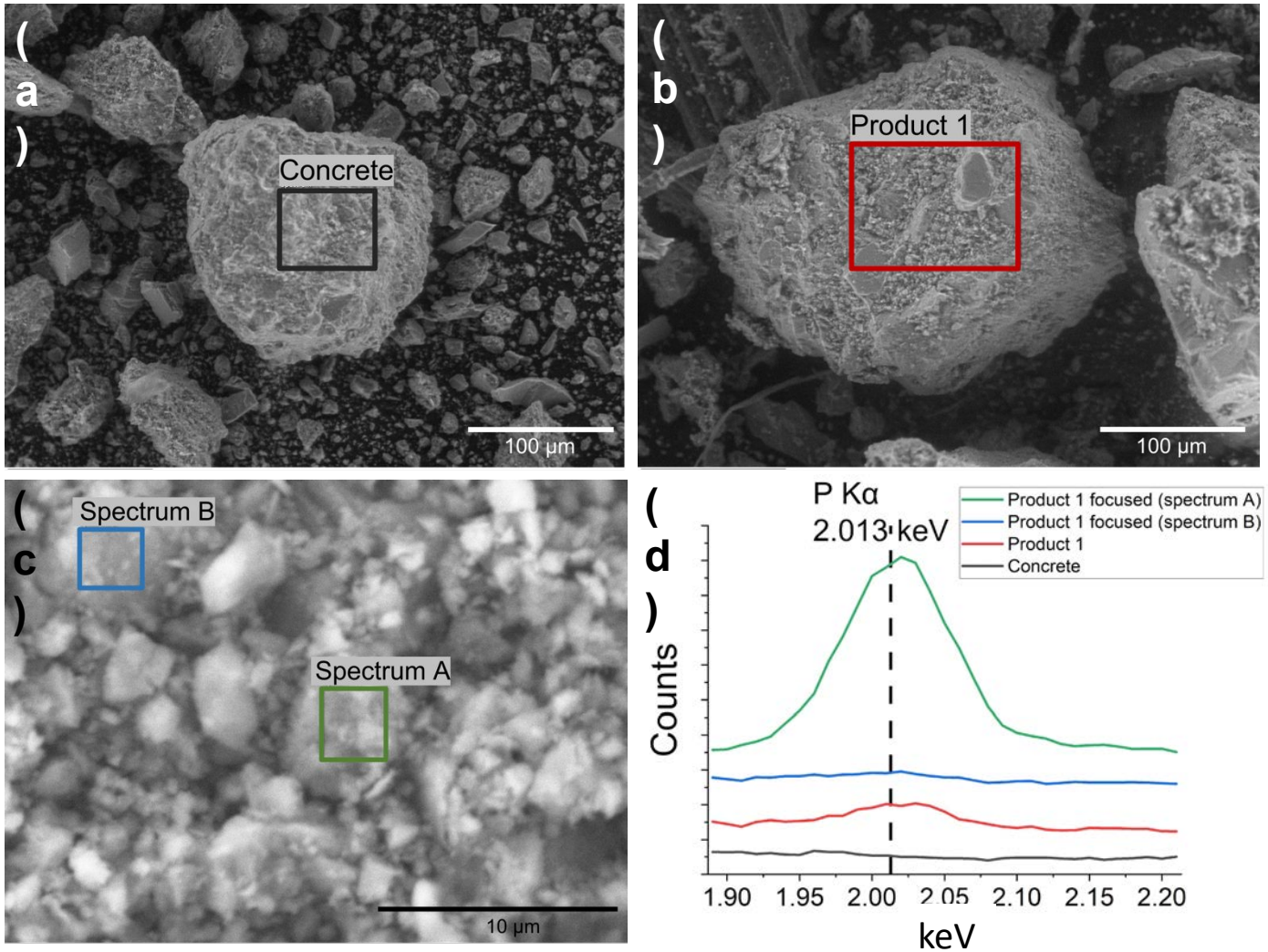
OP (Organic phosphorus)
NAIP (Non-apatite inorganic phosphorus)
AP (Apatite phosphorus)

- Phosphorus fractions were determined by the serial extraction method proposed by Pardo.
- The percentage of **apatite-type phosphorus increased** after the concrete treatment.

Product 1 (0.5 W:M ratio, 0.35 C:M ratio)
Product 2 (0.25 W:M ratio, 0.35 C:M ratio)

Pardo, P., Rauret, G., & López-Sánchez, J. F. n. (2004). Shortened screening method for phosphorus fractionation in sediments: a complementary approach to the standards, measurements and testing harmonised protocol. *Analytica Chimica Acta, 508*(2), 201-206.

Energy Dispersive X-ray Spectroscopy (EDS) Result



- Peak intensity indicates the P quantity.
- P content (red) in Product 1 had a slight increase compared to the concrete powder.
- The P amount in Product 1 was not homogeneously distributed.

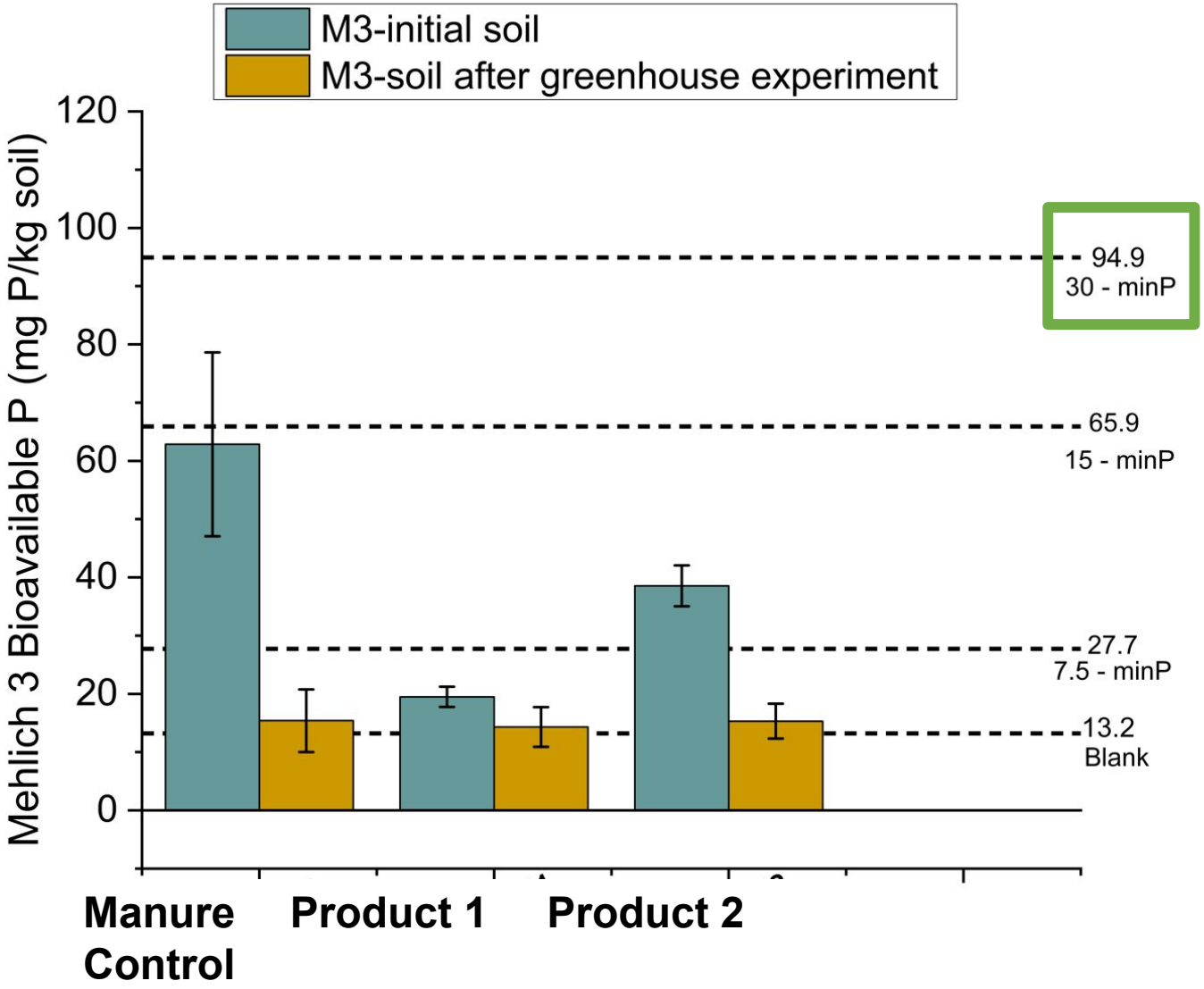
Mehlich 3 (M3) Extraction

Initial soil

- Dried manure (**30** mg P/kg soil) had reduced M3-extractible P (bars) than mineral P (**30** mg P/kg soil, dashed lines).
- Manure-concrete products (**30** mg P/kg soil) had reduced M3-extratible P than dried manure.

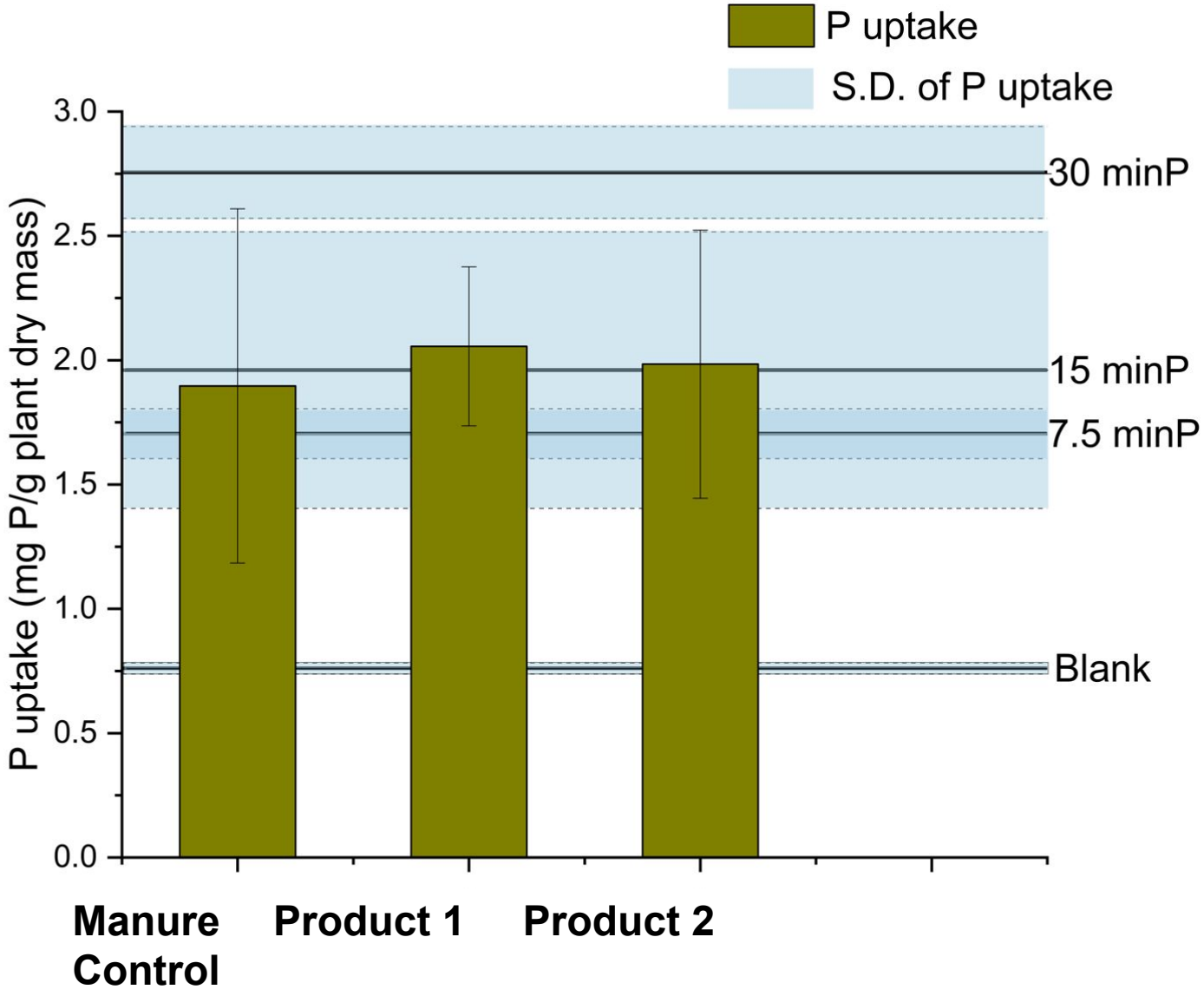
Post-greenhouse test soil

- All groups had similar M3-extractible P.



Product 1(0.5 W:M ratio, 0.35 C:M ratio)
Product 2 (0.25 W:M ratio, 0.35 C:M ratio)

Plant Phosphorus Uptake



- The final P uptake amounts were similar for the dried manure (bars) and treated manure product (bars) with a total P of **30** mg P/kg soil
- The P-uptakes for all manure-containing groups were lower than the **min**eral P at the same application concentration (30 minP, solid line)

Product 1(0.5 M:W ratio, 0.35 C:M ratio)
Product 2 (0.25 M:W ratio, 0.35 C:M ratio)
M:W manure to water (w/w)
C:M concrete powder to manure (w/w)

Soil pH and Heavy Metal Concentration

- The soil pH ranged from 6.4-6.9, except for a cement-only control (7.4).
- Quebec Criterion A regulations were not exceeded for Cd, Cu, Ni, Pb, or Zn.

Soil pH

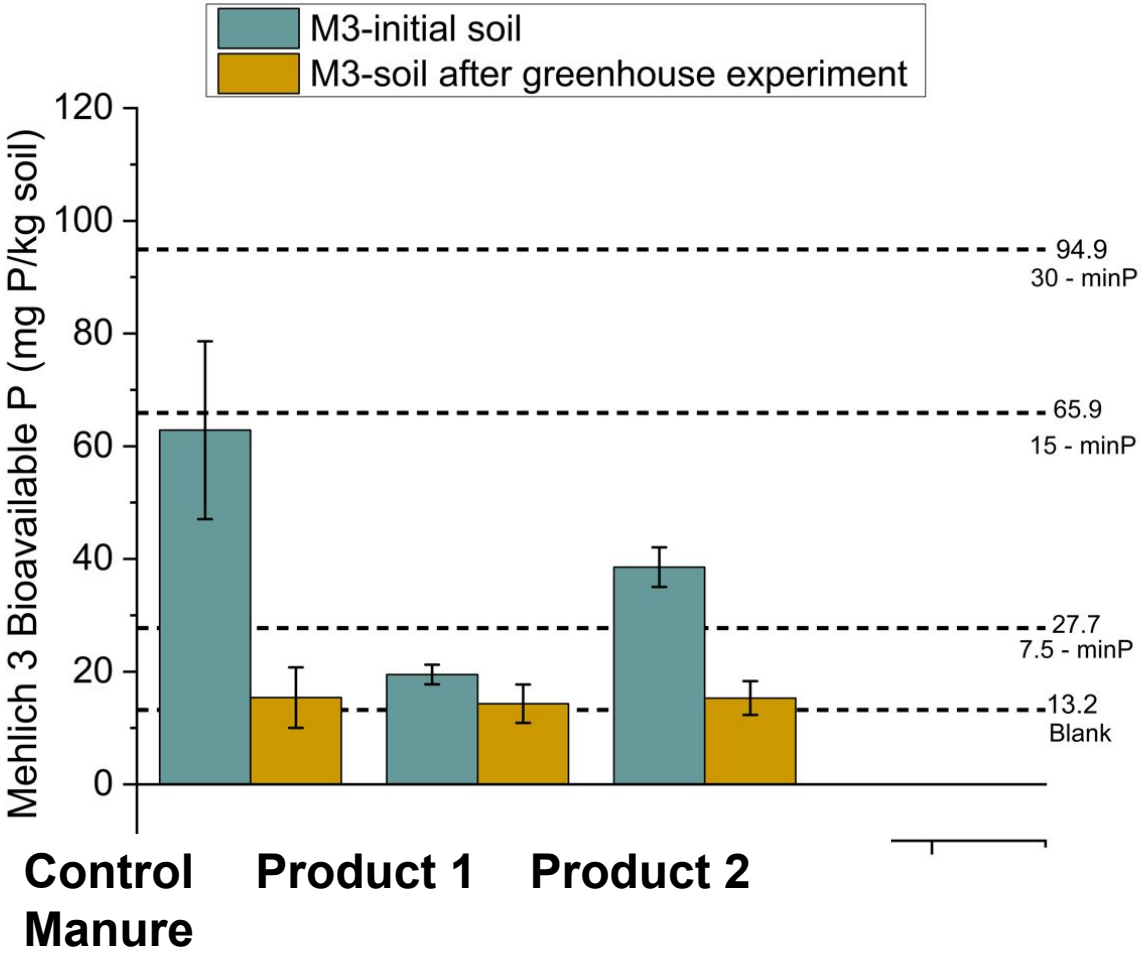
Sample	pH
Blank	6.46±0.10
7.5-minP	6.51±0.11
15-minP	6.44±0.15
30-minP	6.72±0.08
Control: Dried Manure	6.57±0.23
Control: Concrete-15minP	7.37±0.11
Product 1	6.89±0.12
Product 2	6.84±0.13

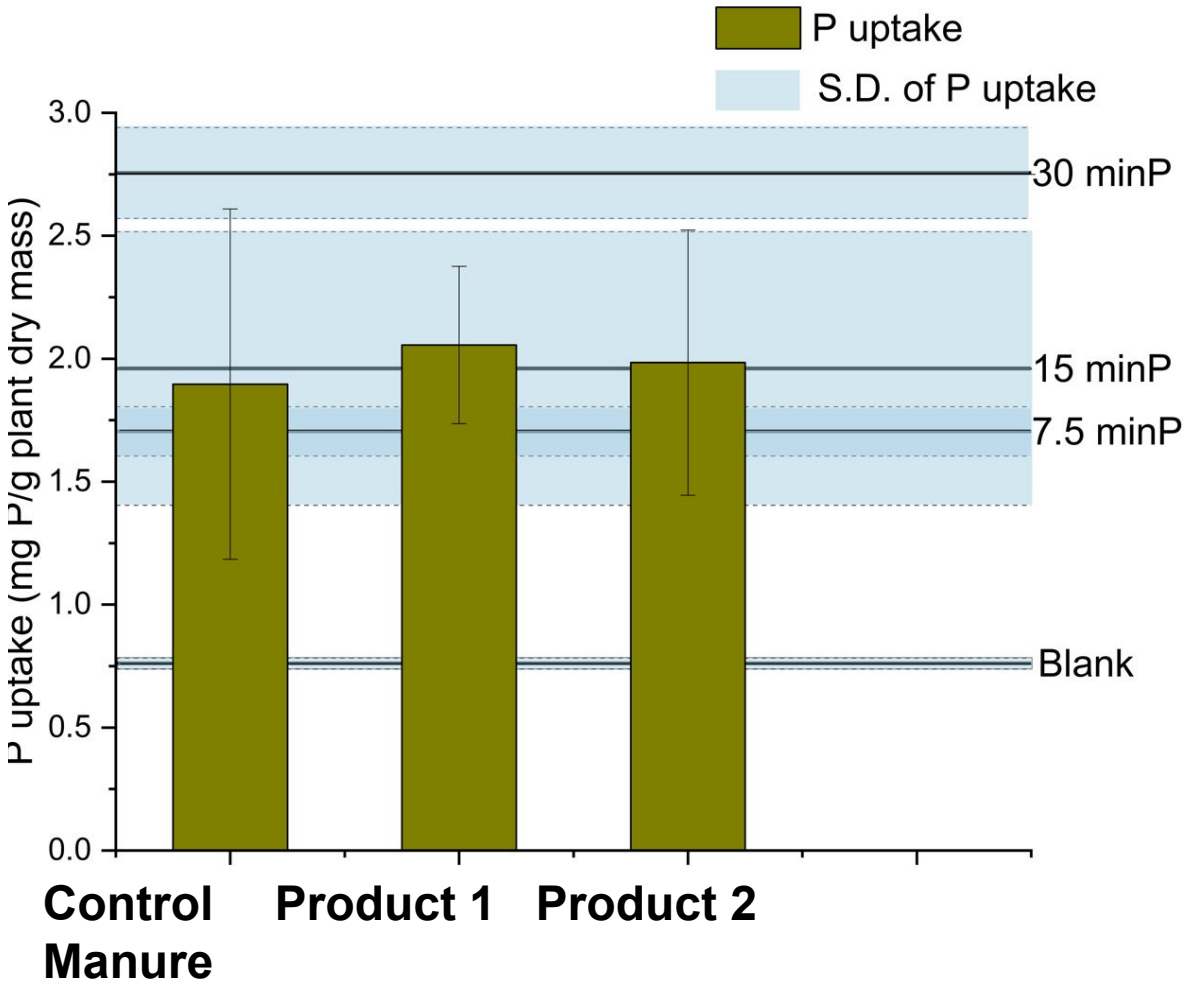
Soil heavy metal (mg element/kg soil)

Samples	Cd	Cu	Ni	Pb	Zn
Blank	0.62	11.82	4.36	2.70	19.07
Control: Concrete-15minP	0.62	16.57	4.35	5.17	0.00
Control: Dried Manure	0.62	11.41	3.94	2.49	28.00
Product 1	0	10.35	3.73	1.66	1.45
Product 2	0.41	10.36	3.73	1.24	0.62
Criterion A – Low *	**1.5**	**40**	**50**	**50**	**110**

*Generic criteria by Quebec's Ministry of Sustainable Development, Environment and Parks (MDDEP) to determine the degree of soil contamination.

Summary: Greenhouse Experimental Results





The P fertilizer efficiency of waste concrete-treated manure was not statistically significant than manure, and demonstrated a reduced o-Pi runoff risk.

Conclusions

- The proposed process for reduction of soluble o-Pi in manure with the addition of cement obtained from crushed waste concrete powder is feasible.
- The soluble o-Pi in manure decreased while the P uptake by spring wheat sprouts was unchanged. This reduces the P runoff risk.
- DoE is a powerful tool to determine the significant parameters and optimal conditions for the reduction of soluble o-Pi in manure with the addition of cement from waste concrete.
- The mechanism of the soluble o-Pi reduction process in manure by waste cement addition needs further investigation.

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Thank you!

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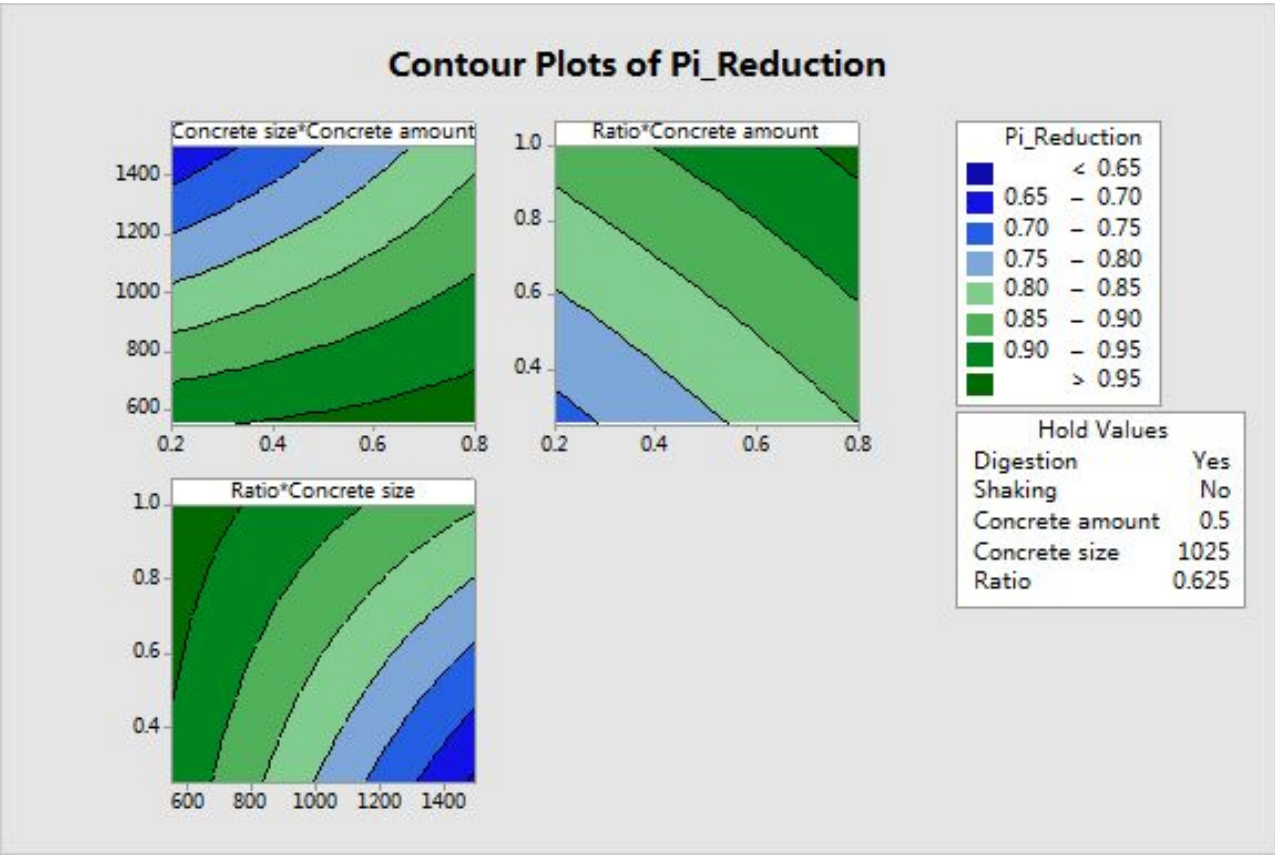
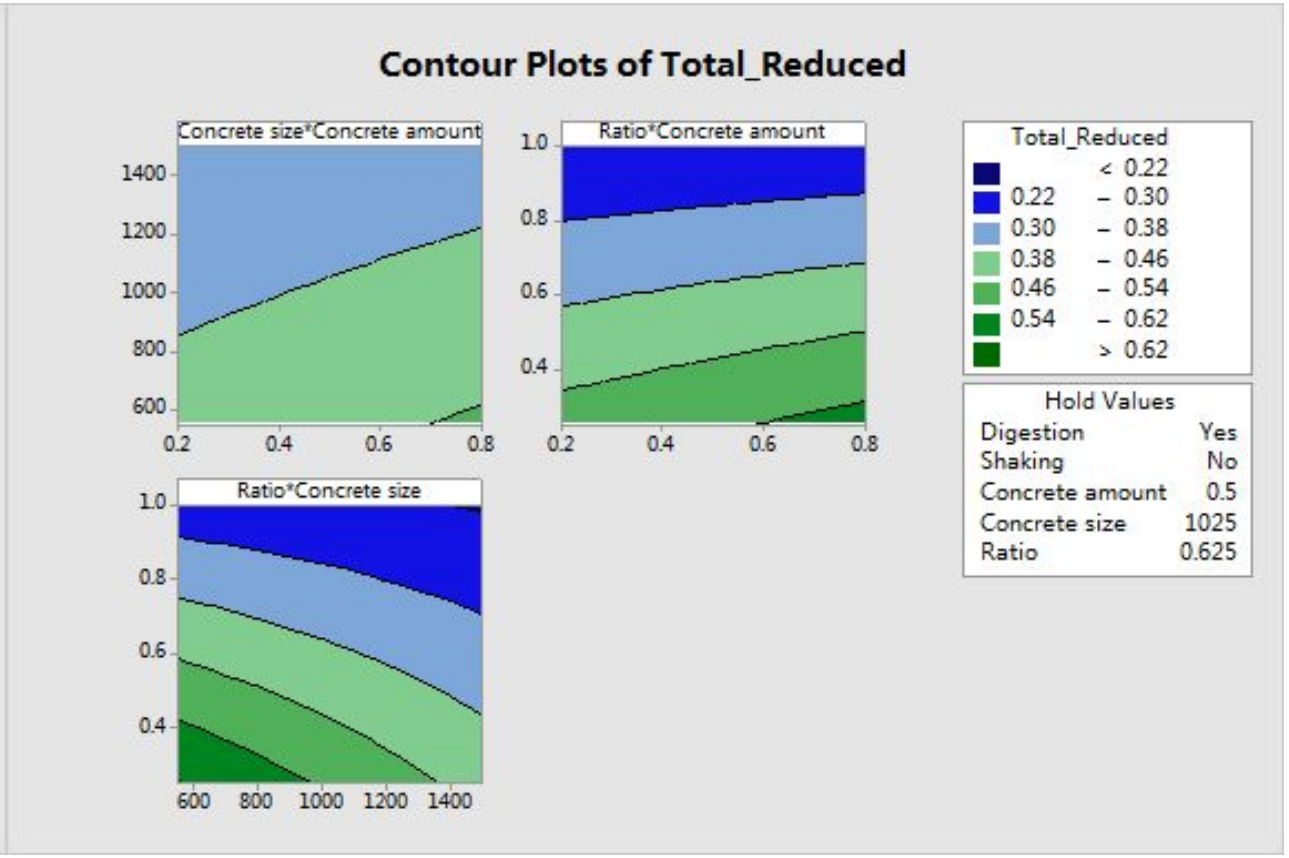
Design Table (randomized)

Run	Blk	A	B	C	D	E
1	1	+	-	-	+	+
2	1	-	+	+	-	+
3	1	-	+	+	+	-
4	1	+	-	+	+	-
5	1	+	-	-	+	+
6	1	-	-	-	-	+
7	1	+	+	+	+	+
8	1	+	-	-	-	-
9	1	+	-	+	-	+
10	1	-	-	-	-	+
11	1	-	+	+	-	+
12	1	-	+	-	-	-
13	1	-	-	+	-	-
14	1	+	-	+	-	+
15	1	+	-	-	-	-
16	1	-	+	-	+	+
17	1	+	+	-	+	-
18	1	+	+	-	-	+
19	1	+	+	+	-	-
20	1	-	-	+	+	+
21	1	-	-	-	+	-
22	1	+	-	+	+	-
23	1	-	+	-	-	-
24	1	-	-	+	+	+
25	1	-	-	-	+	-
26	1	+	+	+	+	+
27	1	+	+	-	-	+
28	1	-	-	+	-	-
29	1	-	+	+	+	-
30	1	+	+	-	+	-
31	1	+	+	+	-	-
32	1	-	+	-	+	+

DoE Results – Contour Plots





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DoE with Minitab® 18

To determine the optimal conditions for partial phosphate release

P release

2 level 3-factor central composite design in response surface methodology

Variables	Low	High
Time (days)	1	9
Manure to water ratio (w/w)	0.25	1
Temperature is a categorical variable in this study due to experimental condition limitation, 2 temperature (20 C and 60 C) was evaluated.		

Waste concrete XRD and XRF

Component	Al_2O_3	SiO_2	SO_3	K_2O	CaO	TiO_2	Fe_2O_3
Wt %	5%	20%	2%	2%	66%	1%	5%

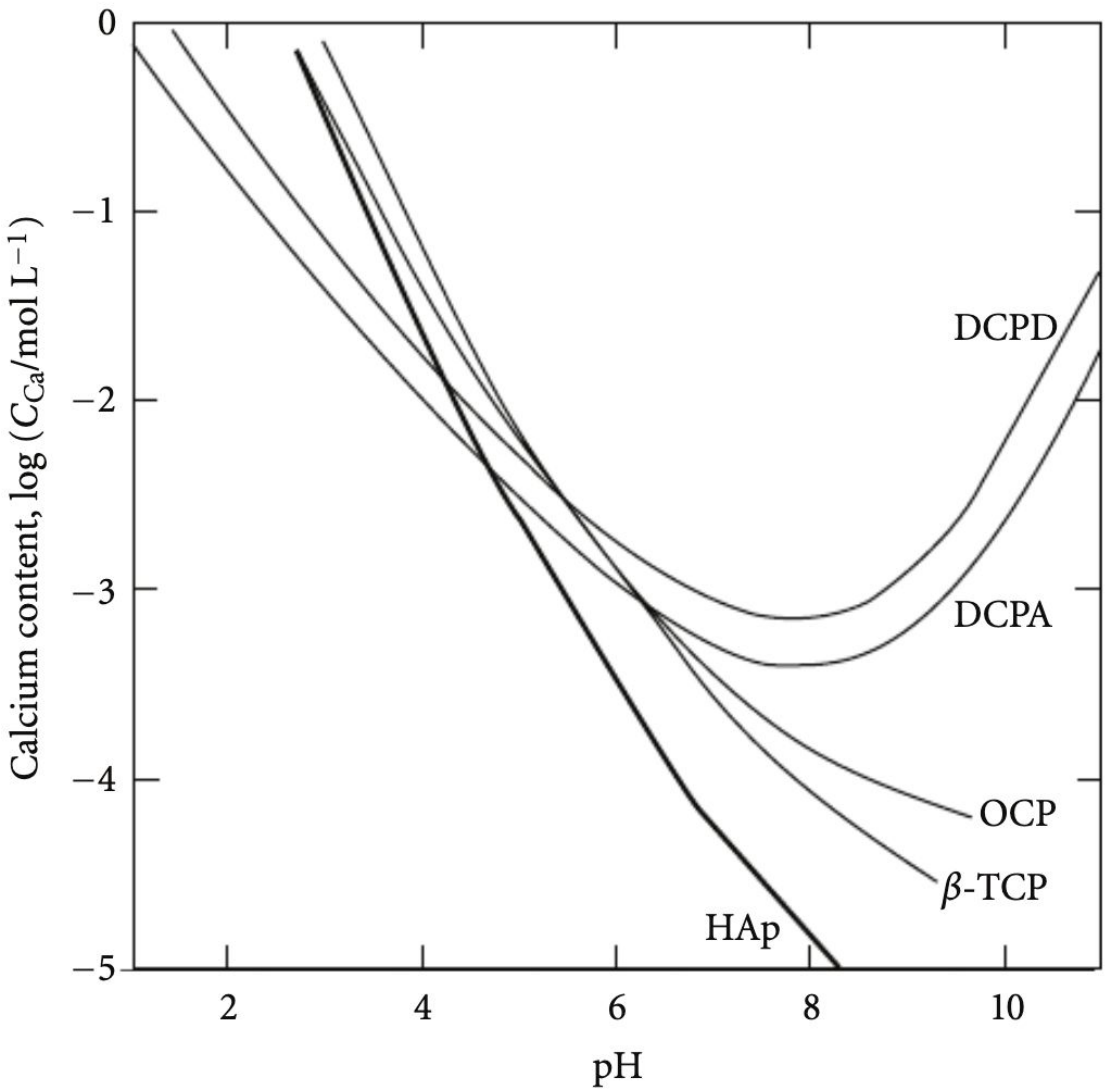
Chemisorption

- Combination of chemical reaction and adsorption; often irreversible (covalent/ionic bond)

P chemisorption on waste concrete surface

- The chemisorption in this case is affected by pH.
- On the surface of CaO-containing sorbents ($Ca(OH)_2$ in aqueous solution), low solubility metal–phosphate complexes (Ca-P) formed.

Precipitation

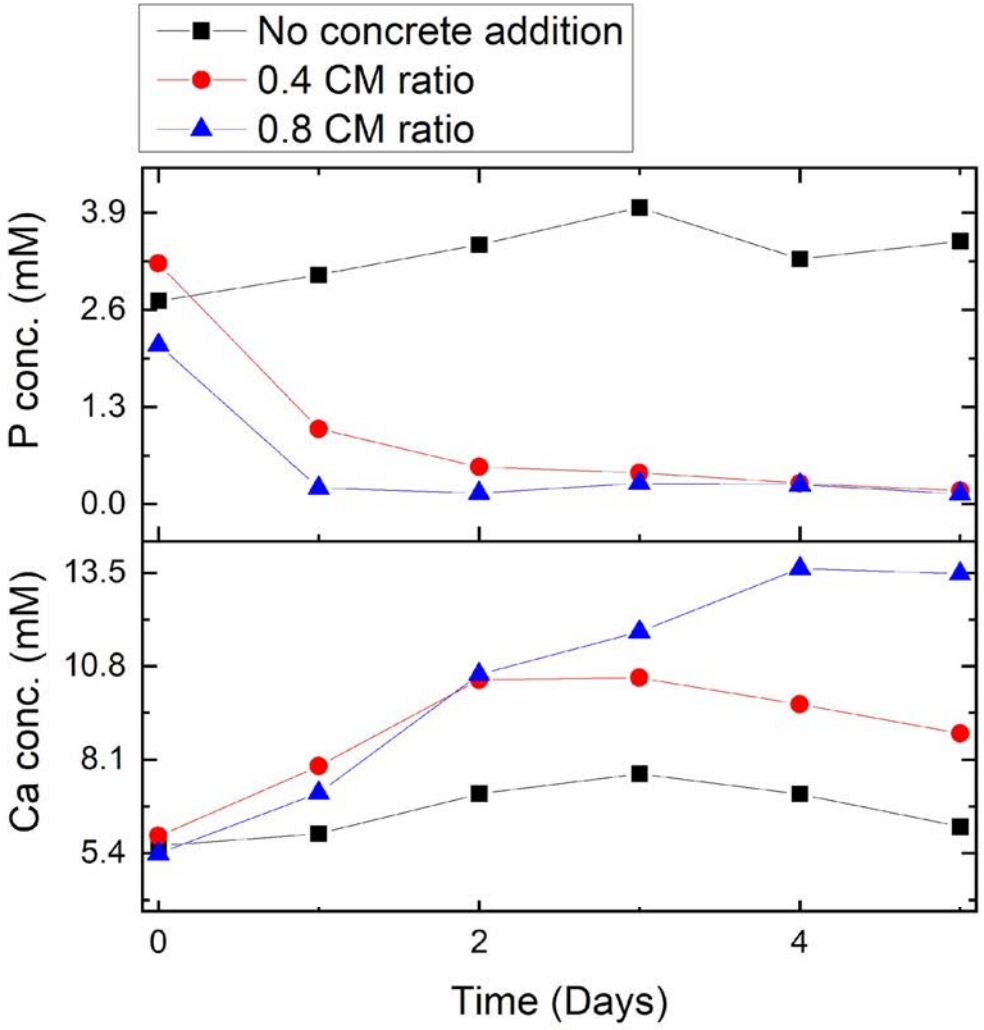


Supersaturation is the driving force for precipitation.

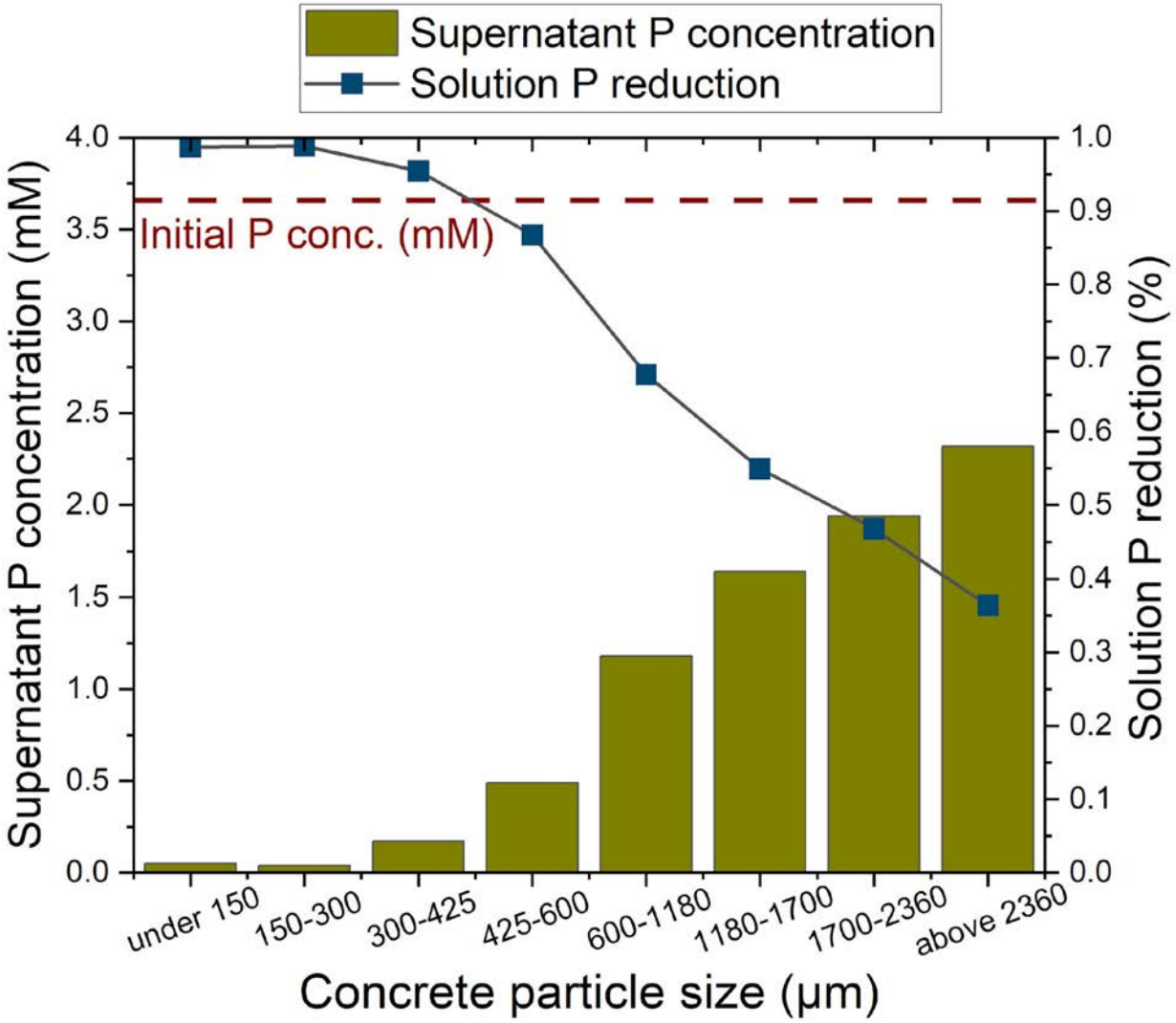
- Solubility curves of calcium orthophosphoric compounds at 37◦C, depending on pH in aqueous solution.
- HAp: hydroxyapatite (Ca10(PO4)6(OH)2)
- TCP: calcium phosphate (Ca3(PO4)2)
- OCP: octacalcium phosphate (Ca8H2(PO4)65H2O),
- DCPA: dicalcium phosphate anhydrous (CaHPO4)
- DCPD: dicalcium phosphate dihydrate (CaHPO42H2O).

"Chapter 1 - General Chemistry of the Calcium Orthophosphates," in *Studies in Inorganic Chemistry*, vol. 18, J. C. Elliott Ed.: Elsevier, 1994, pp. 1-62.

Results – manure concrete supernatant P reduction

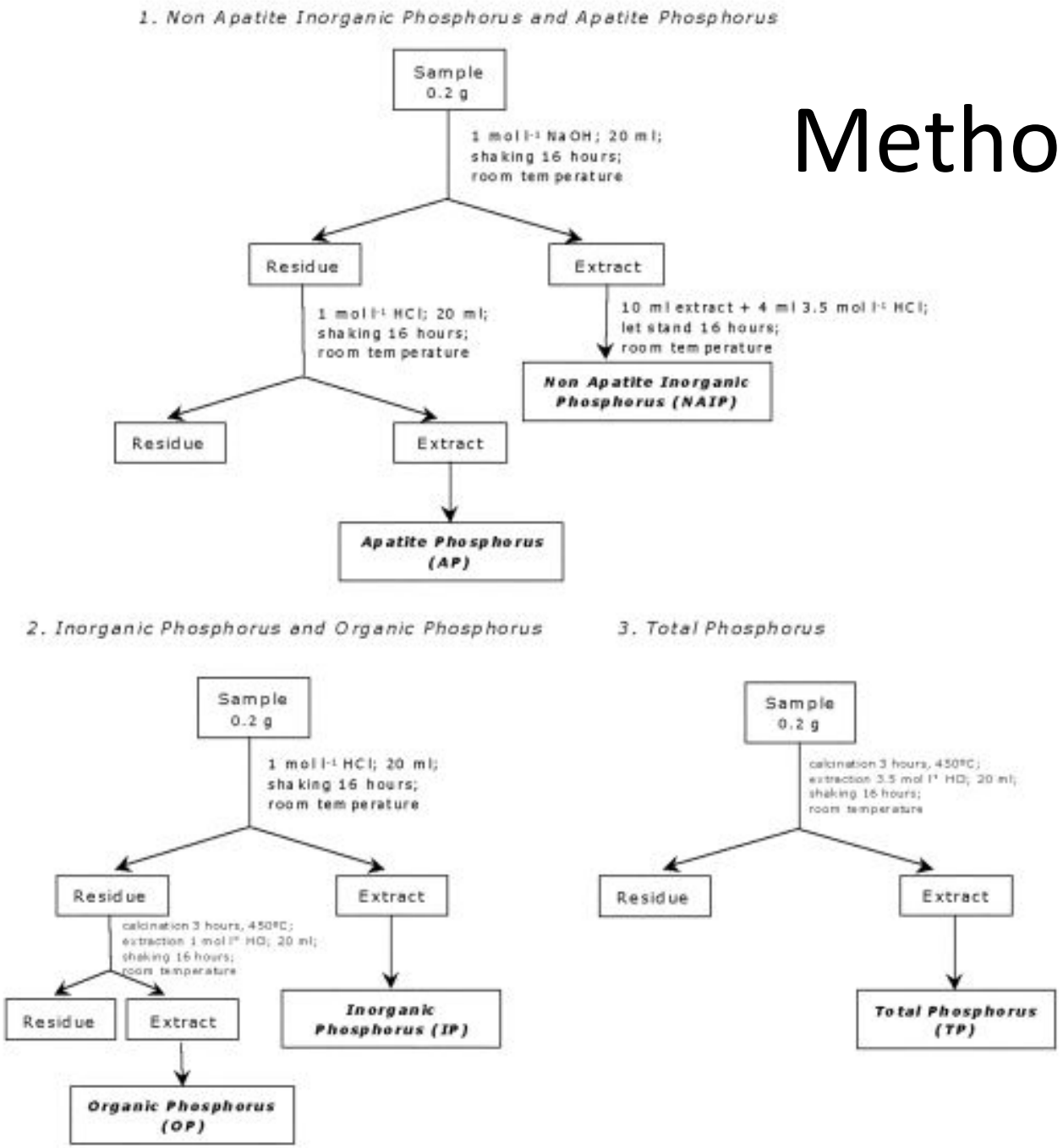


Determine the concrete particle size



Method for P fraction

Fig. 1 Flow chart of the SMT protocol



Pardo P, López-Sánchez JF, Rauret G. Relationships between phosphorus fractionation and major components in sediments using the SMT harmonised extraction procedure. Anal Bioanal Chem. 2003 May;376(2):248-54. doi: 10.1007/s00216-003-1897-y. Epub 2003 Apr 12. PMID: 12692704.