The North American Project to Evaluate Soil Health Indicators (NAPESHM)

Indian Head Agricultural Research Foundation – Soil and Crop Management Seminar & AGM
February 5, 2020 Balgonie, Saskatchewan

Paul W. Tracy – Soil Health Institute

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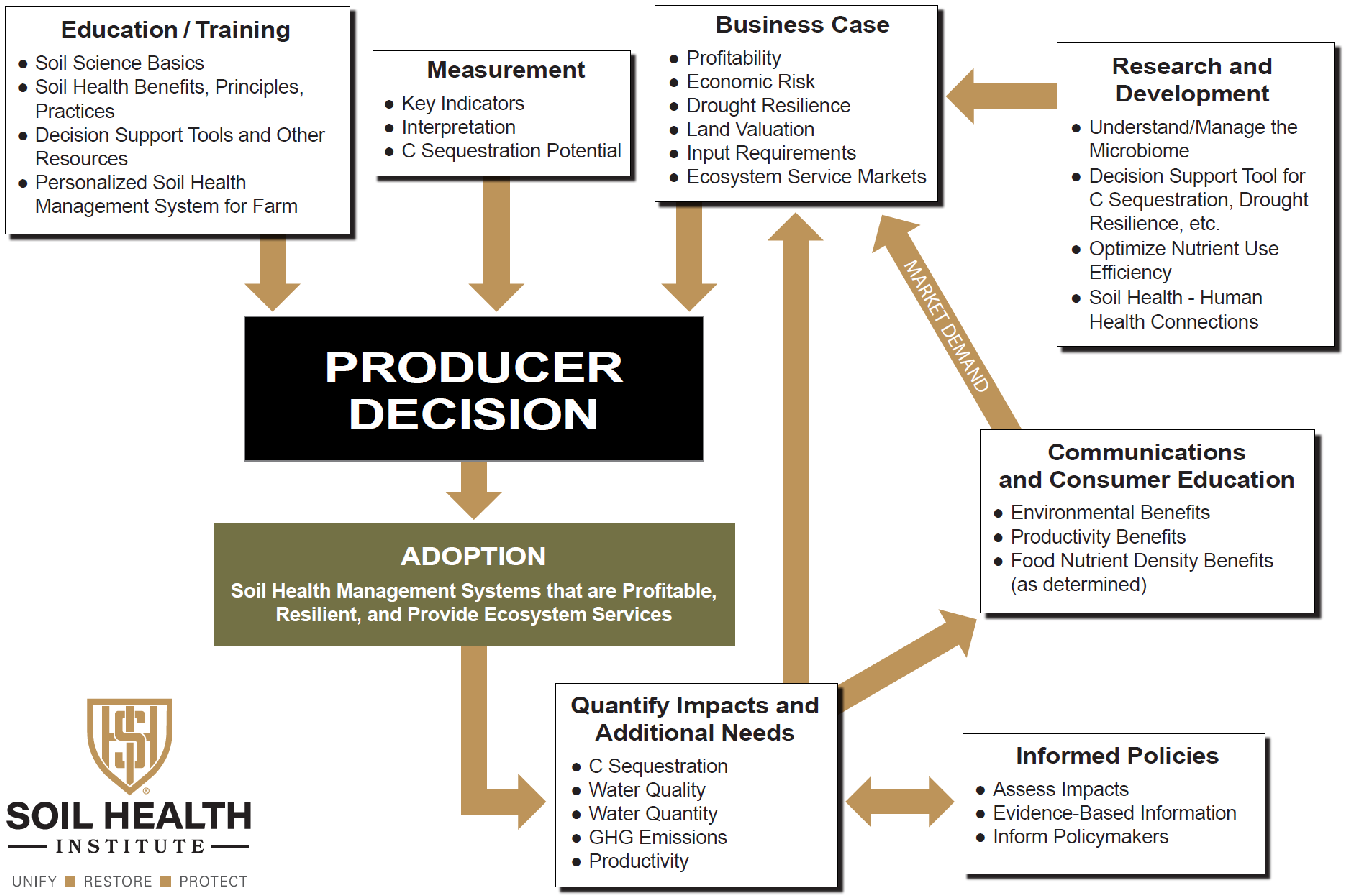
Comprehensive Strategy to Increase Adoption of Soil Health Management Systems

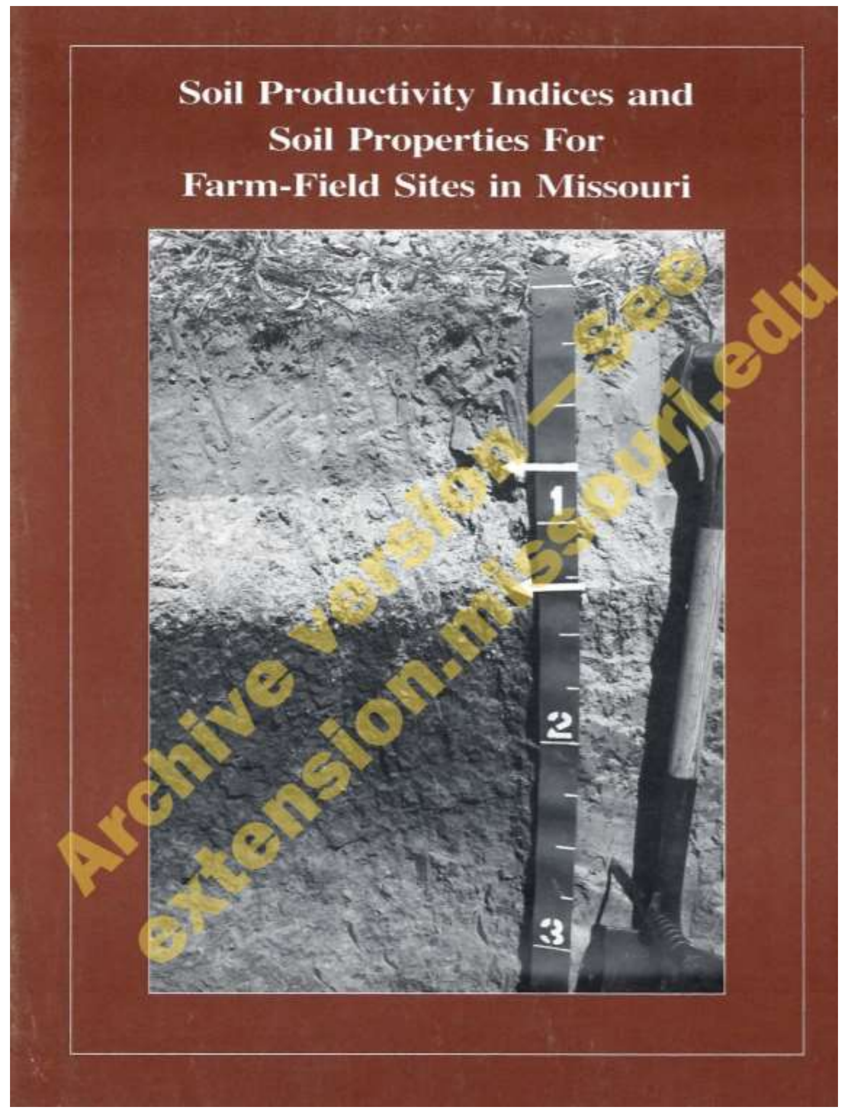


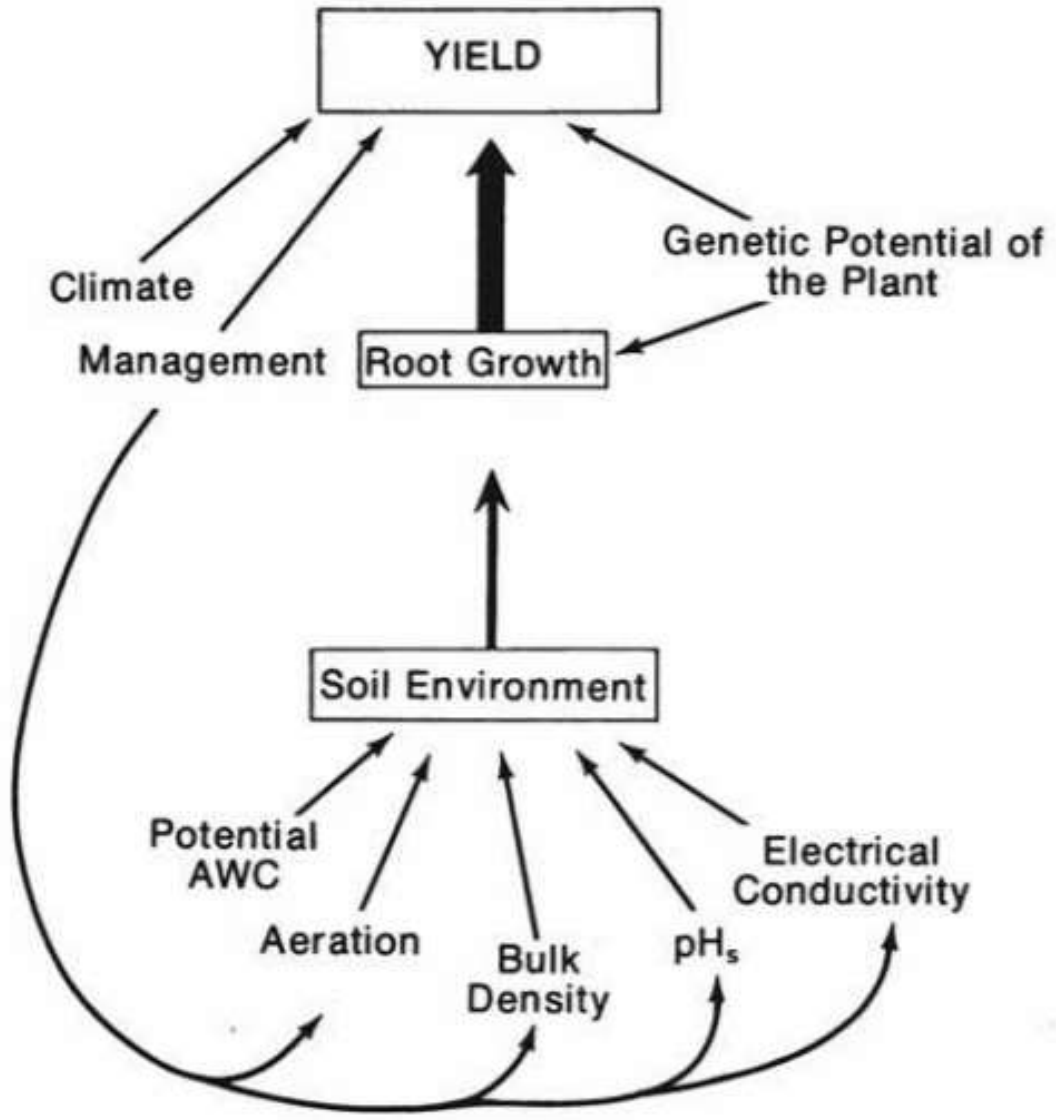
Our Team

Measurements & Indicators:

Traditional Soil Productivity Indices

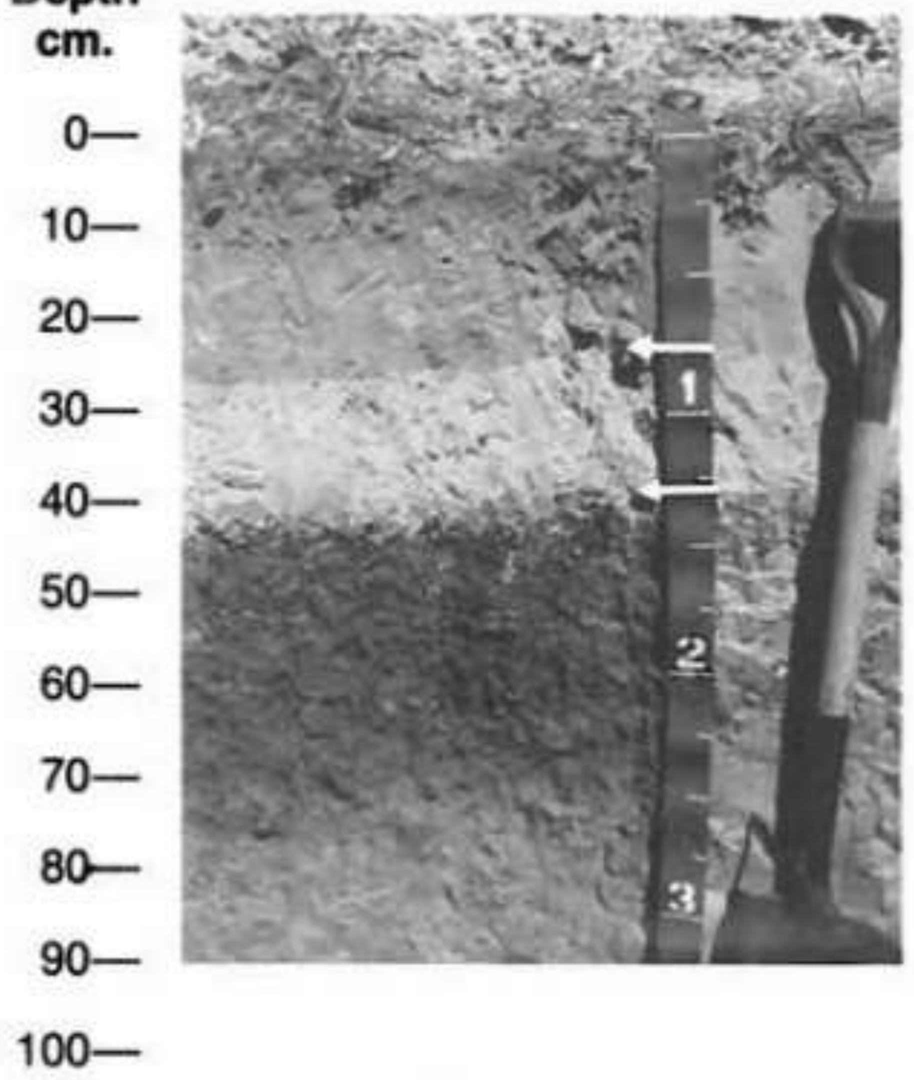
Does Productivity = Healthy?



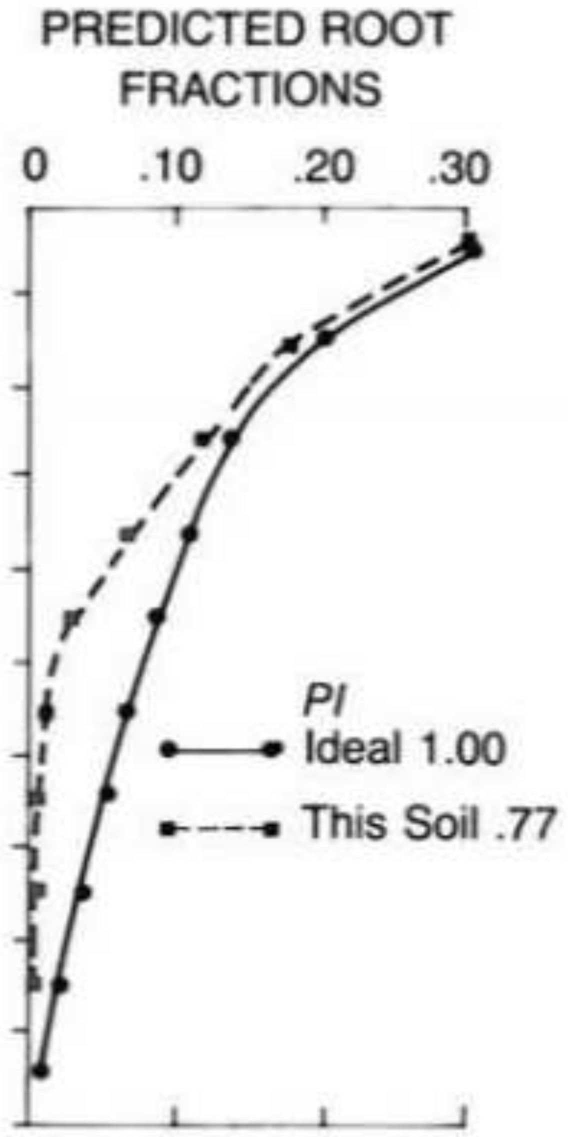


Scrivner, CL., B.L. Conkling and P.G. Koenig, 1985

Putnam Soil Series



SUFF. PAWC	x	SUFF. PHS	x	SUFF. DENS.	x	ROOT FRACT. IDEAL	=	ROOT FRACT. THIS SOIL
1.00		1.00		.98		.314		.308
1.00		1.00		.98		.196		.192
1.00		.88		1.00		.143		.126
1.00		.70		1.00		.108		.076
.30		.70		1.00		.082		.017
.30		.74		.99		.061		.013
.35		.88		.96		.044		.013
.55		.98		.90		.030		.015
.60		1.00		.89		.017		.009
.70		1.00		.89		.005		.003
						PI = 1.000		.772



Soil Health Indicators: Key Considerations

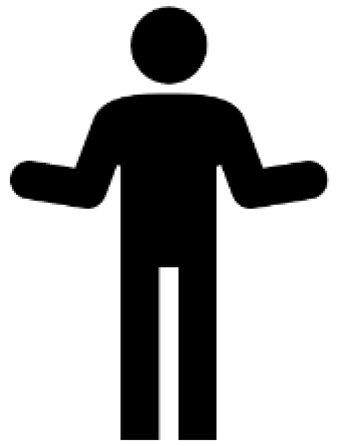
properties related to functions

inherent vs. management-sensitive properties

scale? how healthy is this soil? how heathy can we get it?

Reference states

Poor	Good	Better	Best



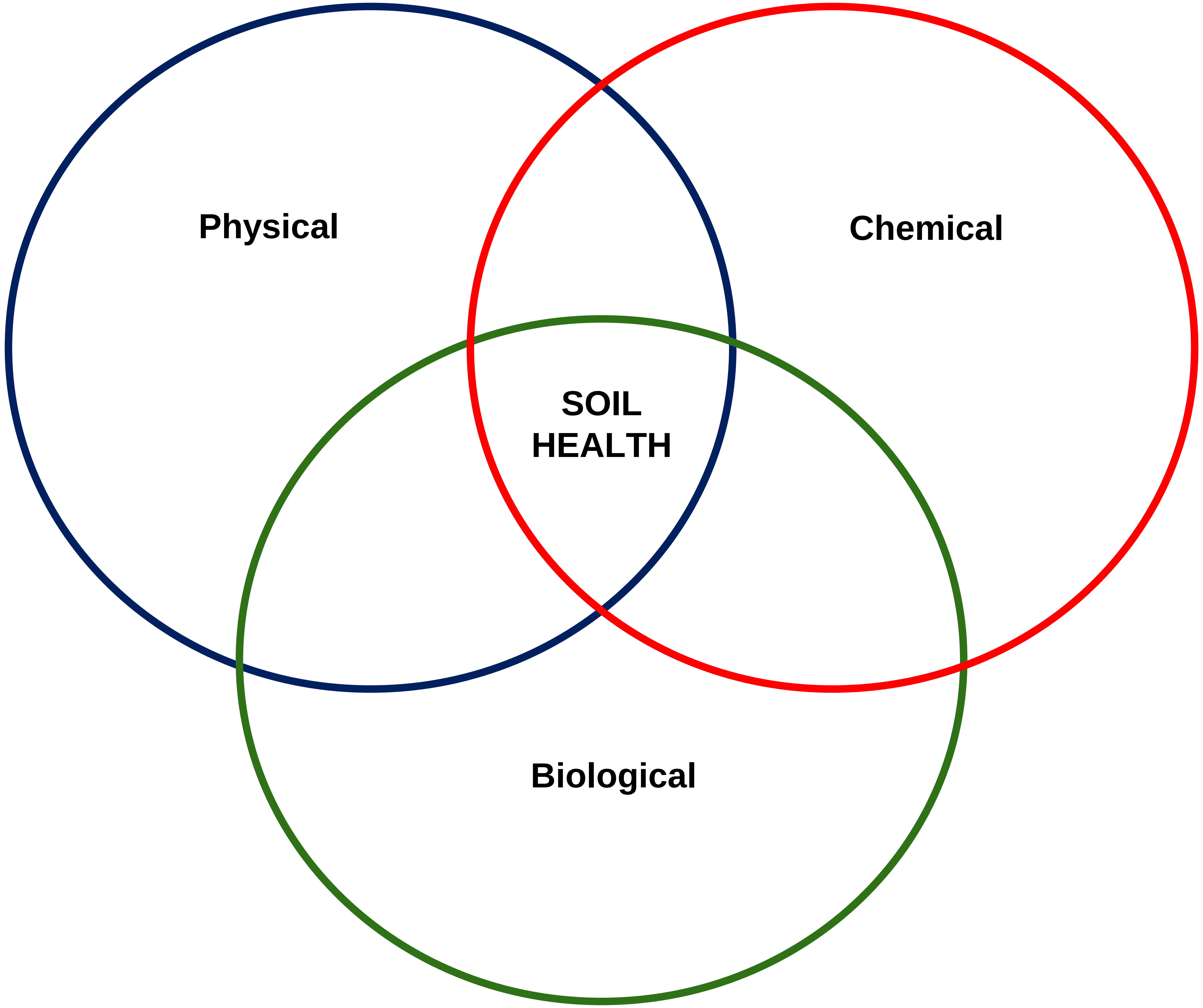
Soil Health Measurements: How do we Select Them?

Soil Health ~ fx (Inherent soil properties X management)

1. Inherent Soil Properties
   1. Clay Content
2. Soil Health Indicators
   1. Aggregate Stability
   2. Organic Carbon (Carbon Stock)
   3. Organic Carbon Fractions
   4. Structure
   5. Health Indexes (Haney, SMAF, Cornell)
3. Biomass or Plant Performance
   1. Evapotranspiration
   2. Roots growth and vigor (carbon, carbon , carbon)

Intact vs. processed
in situ vs. lab
cheap vs. expensive
quantitative vs. qualitative

Soil Health Measurements



Tier 1 Soil Health Indicators

Chemical/Biological Lab

pH
Electrical Conductivity
Cation Exchange Capacity
Percent Base Saturation

Organic Carbon
Short-Term C Mineralization
Total Nitrogen
Nitrogen Mineralization
Extractable P and K
Sec./Micro. (Ca, Mg, S, Fe, Zn, Cu, Mn)

Physical Lab/Field

Particle Size

Bulk Density
Water Stable Aggregation
Available Water Holding Capacity
Hydraulic Conductivity Surface
Crop Yield
Others

Tier 2 & 3 Soil Health Indicators Identified

- Sodium Adsorption Ratio
- Enzymes: B-Glucosidase, B-Glucosaminidase, Phosphatase, Arylsulfatase
- Soil Protein Index – Autoclave Citrate Extractable
- Active Carbon – Permanganate Oxidizable C
- Phospholipid Fatty Acid (PLFA)
- Ester-Linked Fatty Acid Methyl Ester (EL-FAME)
- Genomics
- Reflectance (visNIR)

Soil Ecosystem Services – Soil Health Indicator Needs

1) **Biomass Production** – Yield

2) **Carbon Cycling** – SOC, Short-term C mineralization, Permanganate Oxidaizable C (POXC), Enzymes, Protein Index (ACE), Phospholipid Fatty Acid (PLFA)

1) **Nutrient Cycling** – Total Nitrogen, N mineralization, P,K, Micronutrients, biological measures above

2) **Water Cycling** – Saturated Hydraulic Conductivity, Plant-Available Water, Bulk Density

Soil Health Indexes being considered

- **SMAF** – Soil Management Assessment Framework

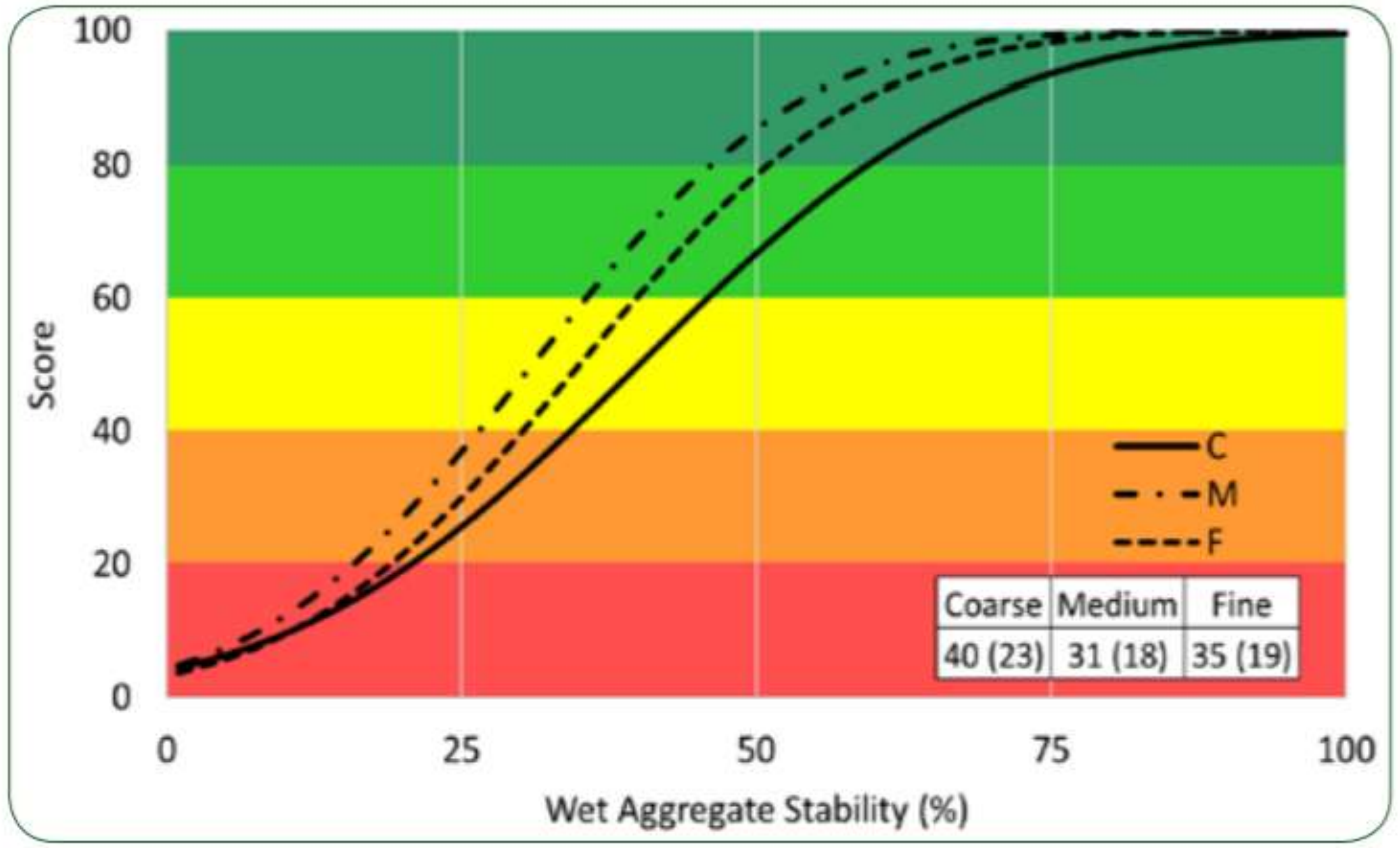
- **CASH** – Cornell's Comprehensive Assessment of Soil Health

- **Haney** Test

Comprehensive Assessment of Soil Health CASH

Standard Indicators:
Soil Texture
Available Water Holding Capacity
Surface and Subsurface hardness (penetrometer)
Wet Aggregate Stability (rainfall simulator)
Organic matter (LOI)
Soil Protein Index (ACE)
Soil Respiration (4-day CO_2 incubation)
Active Carbon (POXC)
Standard nutrient analysis (Modified Morgan)

Add-on Indicators:
Potentially mineralizable N (7-day incubation)
Root pathogen pressure (bioassay)
Heavy metal contamination (Modified Morgan)
Salinity and Sodicity (EC & Na)

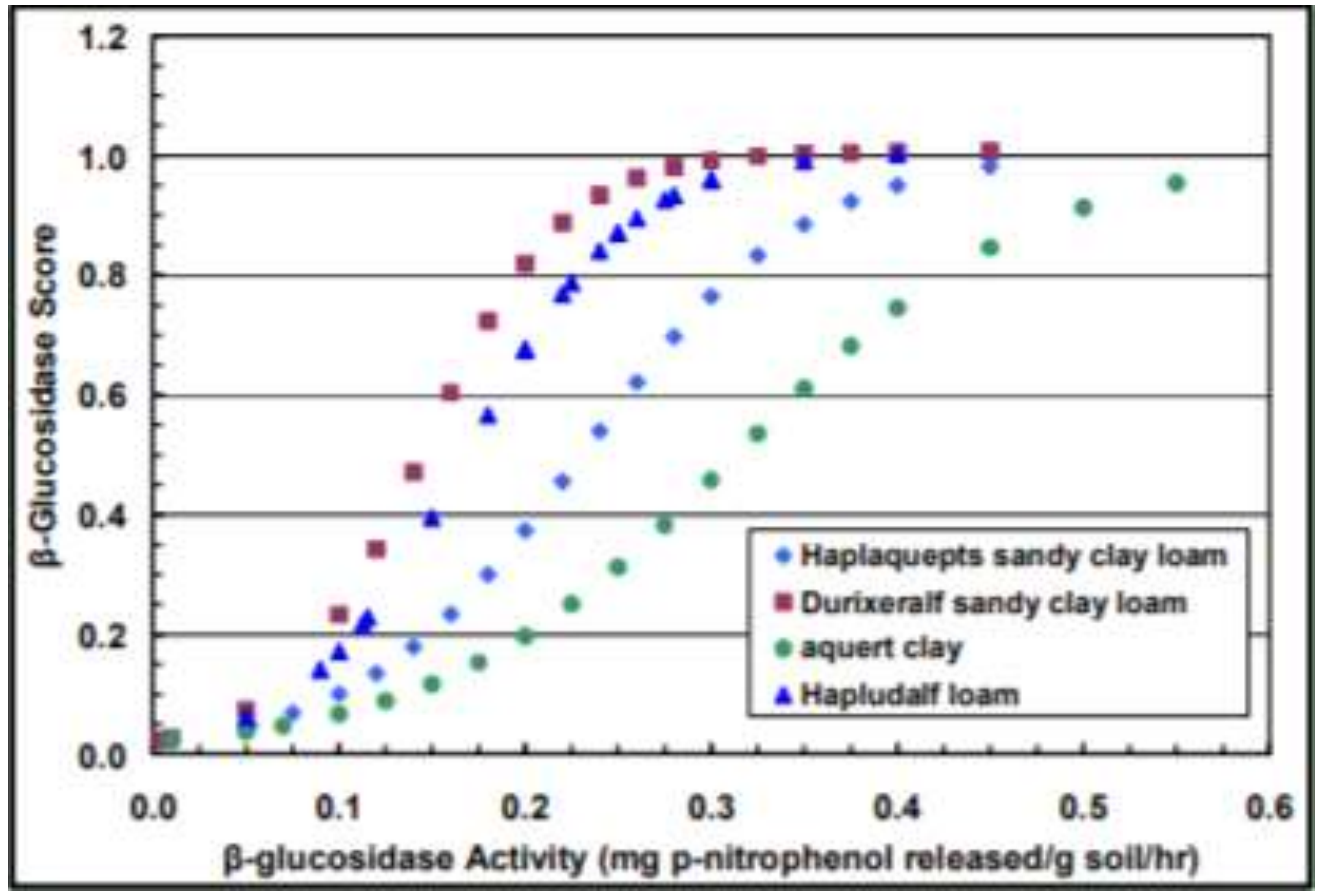


- Scoring functions based upon soil texture
- Scoring curves calculate percentile rating
- Output includes overall score (ave. scoring functions)
- individual indicators (targeted improvement)

http://www.css.cornell.edu/extension/soil-health/manual.pdf

Soil Management Assessment Framework SMAF

Wet Aggregate Stability
Bulk Density
Electrical Conductivity
pH
Sodium Adsorption Ratio
Extractable P
Extractable K
Soil Organic Carbon
Microbial Biomass Carbon (MBC)
Potentially Mineralizable N,
B-Glucosidase activity



-Utilizes soil taxonomy groups (soil suborders)
-Allows for soil and site-specific factors to be considered
-Designed for flexible improvements
-Equal weight assigned to each indicator analyzed

The Haney Test (Ward Laboratories)

Measurements

- Soil pH
- Soil soluble salts (EC)
- Soil organic matter (LOI)
- Total N
- Inorganic N (NO3+NH4), organic N
- Inorganic P + Organic P
- Soil Respiration (24-hour CO2-C)
- Water extractable organic C (WEOC) and organic N(WEOC)
- H3A Extractable NO3, NH4,Total P, Inorganic P, K, Zn, Fe, Mn, Cu, S, Ca, Mg, Na and Al

Purpose

-Provide nutrient and cover crop recommendations
-Provide a soil health score

Score calculated as (Soil Respiration/10) + (WEOC/50) + (WEON/10)

USDA NRCS Suite of Soil Health Indicators – Tech Note No. 450-03

Soil Health Indicator	Recommended Method
Routine Soil Test	Based primarily on state universities
Soil organic carbon (SOC)	Dry Combustion
Aggregation	ARS wet macroaggregate stability (MAS)
Short-term carbon mineralization	4-day respiration
Enzyme Activity (EA)	B-Glucosidase
	N-acetyl B-D-glucosaminidase
	Phosphomonoesterases
	Arlysulfatase
Readily Available Carbon Pool	Permanganate Oxidizable Carbon (POXC)
Available Organic N Pool	Autoclaved citrate extractable protein (ACE)
Phospholipid fatty Acid (PLFA)	PLFA

Correlating Soil Health Indicators – Looking for Opportunities to Improve Efficiencies and Cost

Example: Correlating visNIR and SMAF scoring functions

	Oven-dry soil	
SMAF score category	Direct	Indirect
Overall SMAF	0.82***	0.81***
Biological SMAF category	0.87***	0.88***
Organic C	0.94***	0.94***
β-glucosidase	0.92***	0.92***
Microbial biomass C	0.70***	0.80***
Mineralizable N	0.45***	0.53***
Physical SMAF category	NS†	NS
Bulk density	NS	0.28*
Water-filled pore space	0.35**	0.27*
Water-stable aggregates	NA	NA
Chemical SMAF category	0.52***	0.36*
pH	0.25*	0.71***
Electrical conductivity	0.63***	0.23*
Nutrient SMAF category	0.50***	0.45***
Extractable P	0.49***	0.75***
Extractable K	0.58***	0.51***

Veum, Sudduth, Kremer, Kitchen, 2014. Soil Sci. Soc. Am. J. 79:637–649

How can we use Measurements to Efficiently Account for Spatial Variability?

Surfing

High resolution surface (x,y) mapping

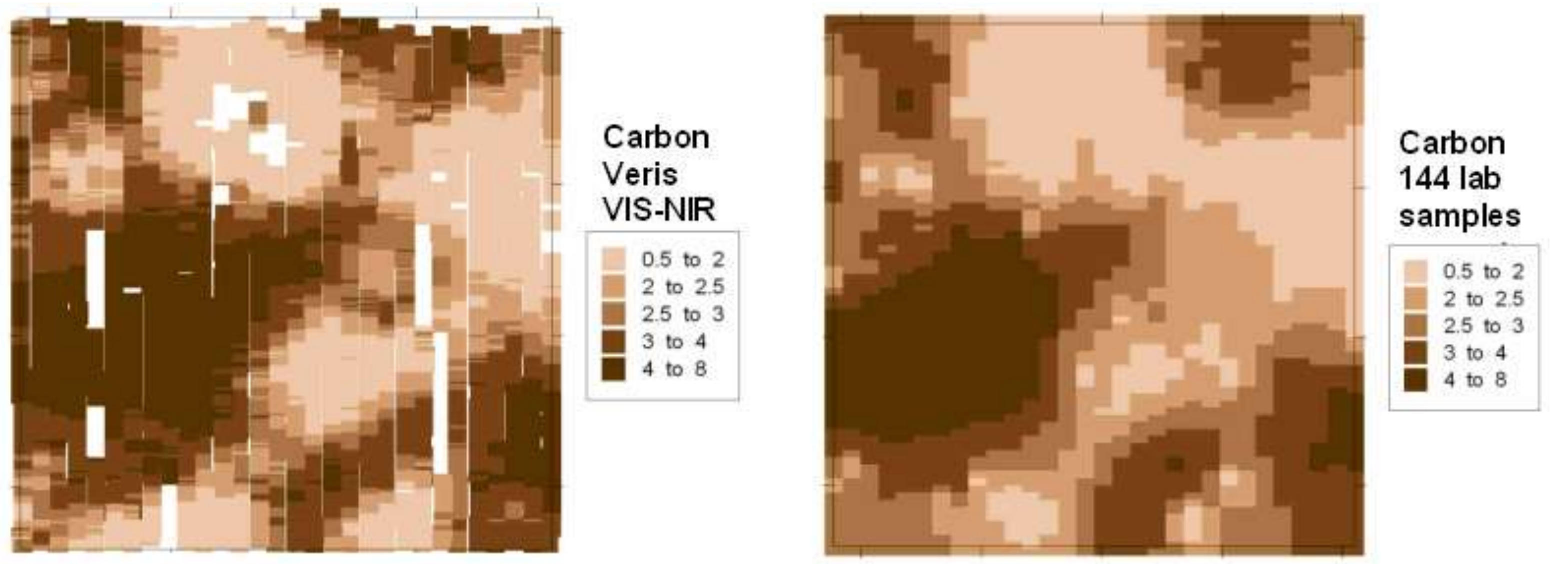
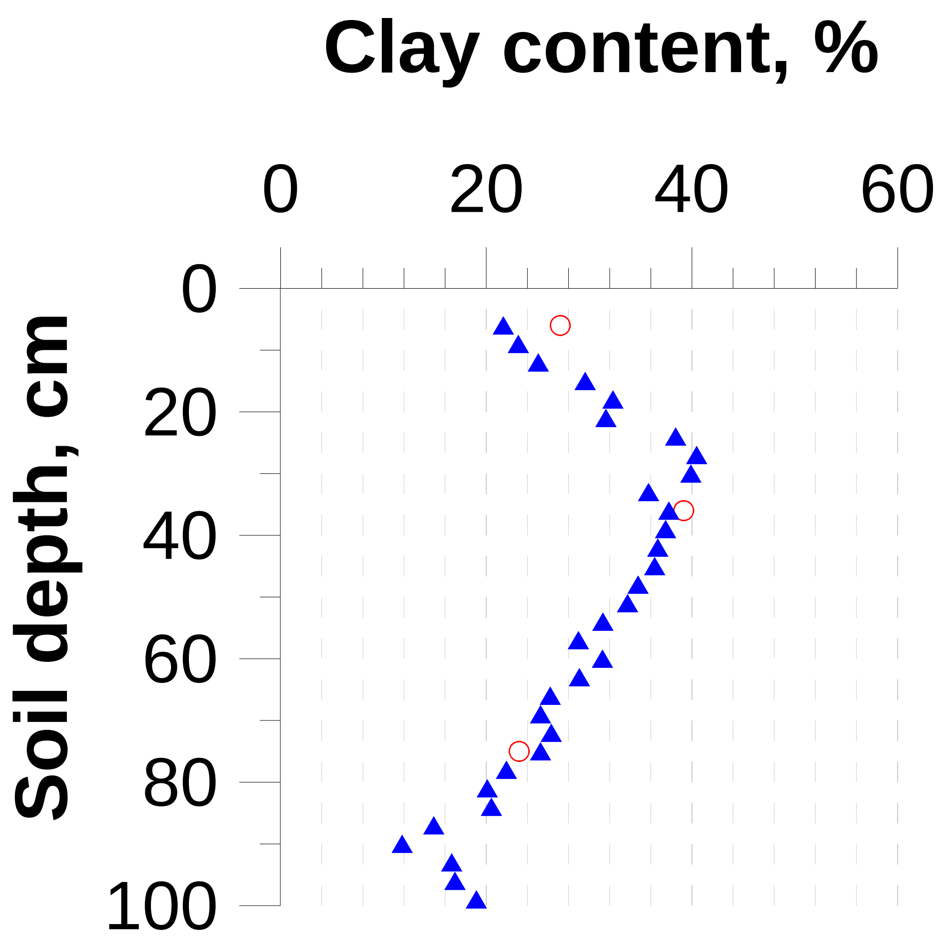


Image from Veris Technologies

e.g. Christy, 2008; Bricklemyer and Brown 2010

Diving

High resolution profile mapping (z)



e.g. Ackerson et al. Geoderma

North American Project to Evaluate Soil Health Measurements (NAPESHM)

GOAL: Identify most effective indicators of soil health

APPROACH: Evaluate soil health indicators on long-term agricultural research sites

Funders:

General Mills

FFAR

Partners:

Soil Health Partnership

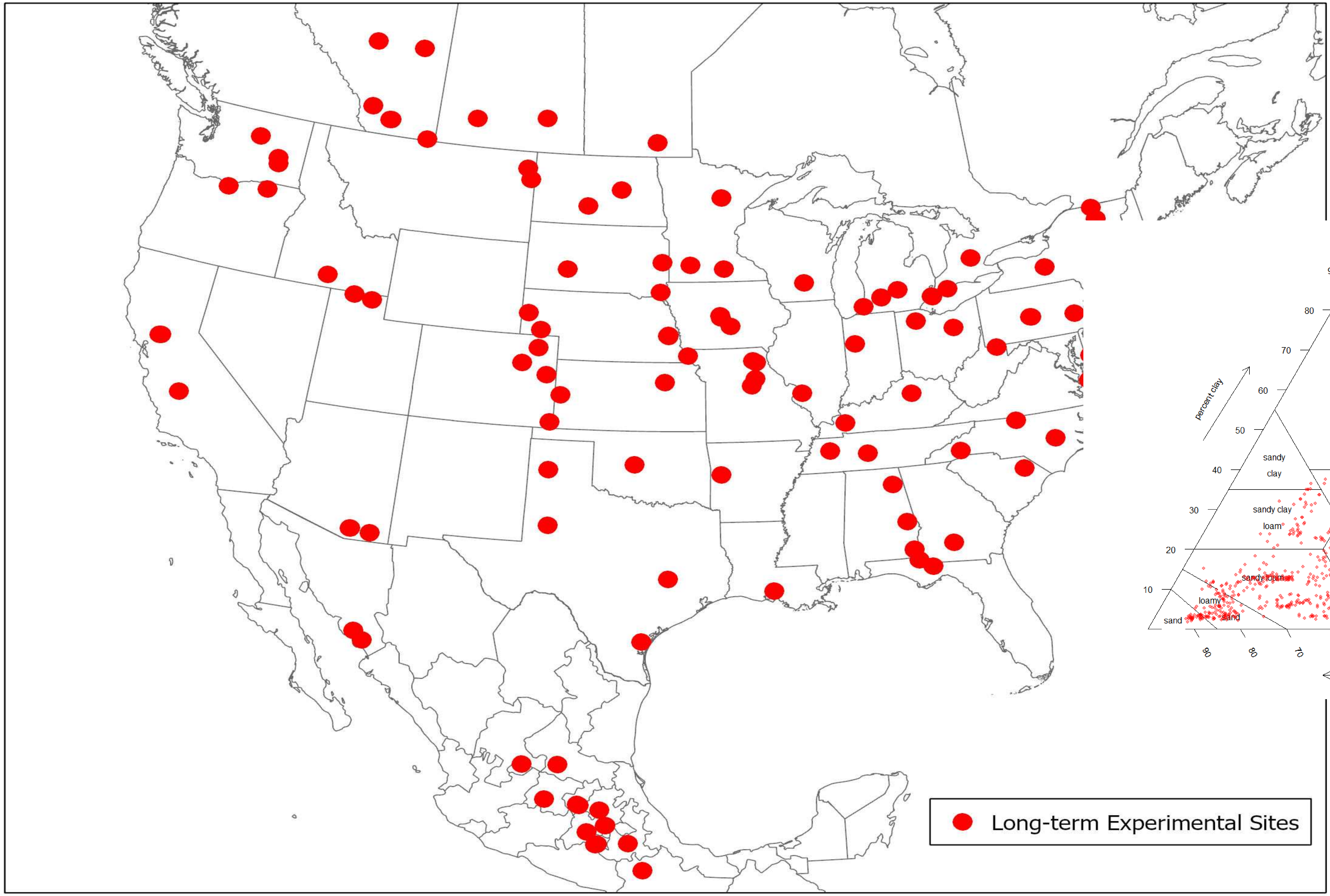
The Nature Conservancy

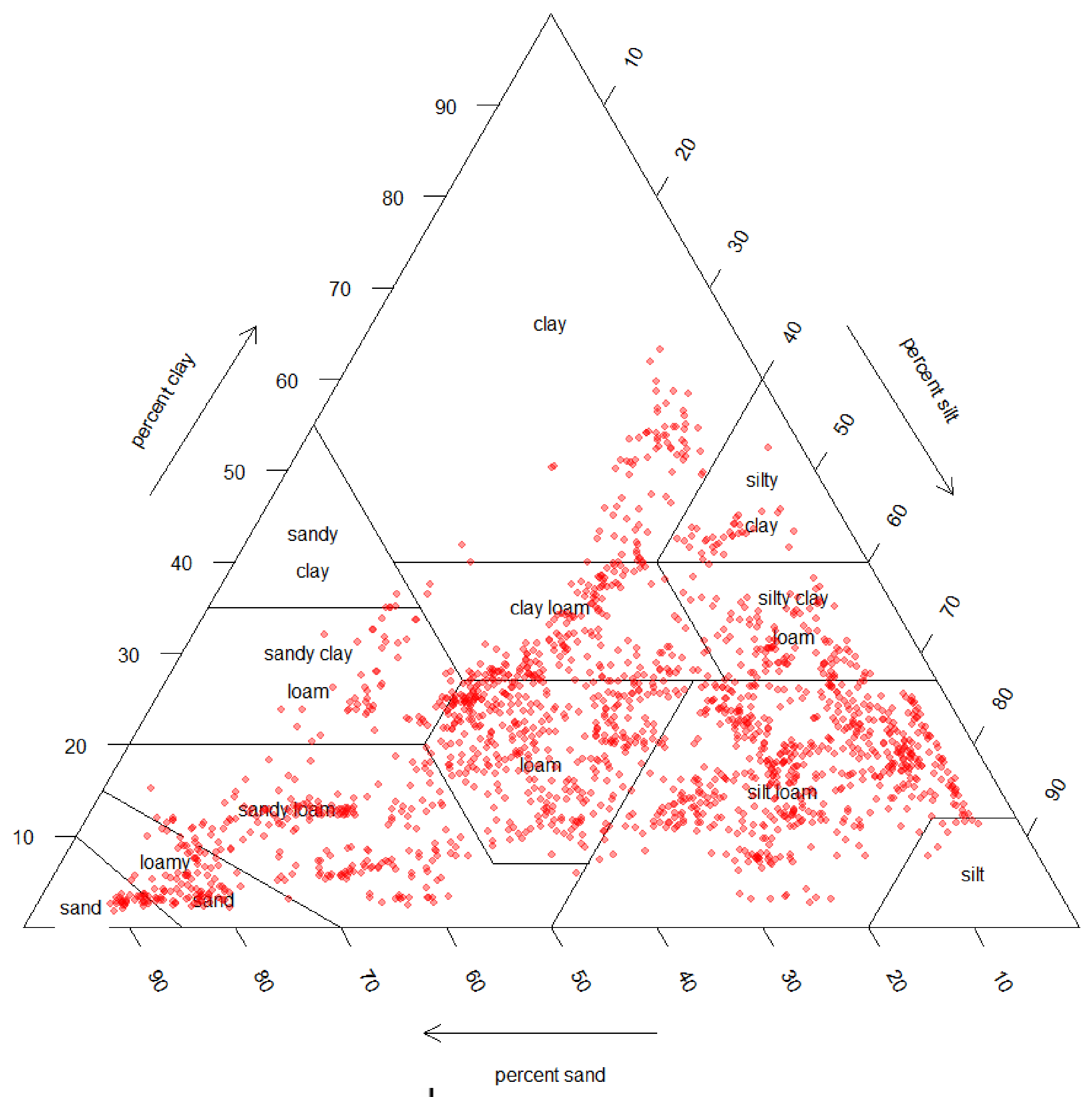
Many universities, USDA, AAFC, CIMMYT

NAPESHM

- Identified & published Tier 1, 2, 3 indicators or measurements (31)
- Technical panel selected methods for evaluating each indicator
- Issued RFA for long-term site applications; Technical Panel selected 124 long-term agricultural research sites/partners
- Hired team of 8 Ph.D. scientists (positioned across N. America)
- Issued RFA for Labs; Selected labs for analyses
- Held 2-day planning workshop for participating scientists
- Developed & distributed Data Management Plan
- Soils sampled 2019; Data interpretation/publication 2020+

NAPESHM Long-Term Research Sites (124)





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NAPESHM – Interesting Preliminary Results

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Saturated Hydraulic Conductivity (Ksat) NAPESHM Project Selected: Saturo (Meter Group, Inc)

-Manufactured by Meter Group, Inc

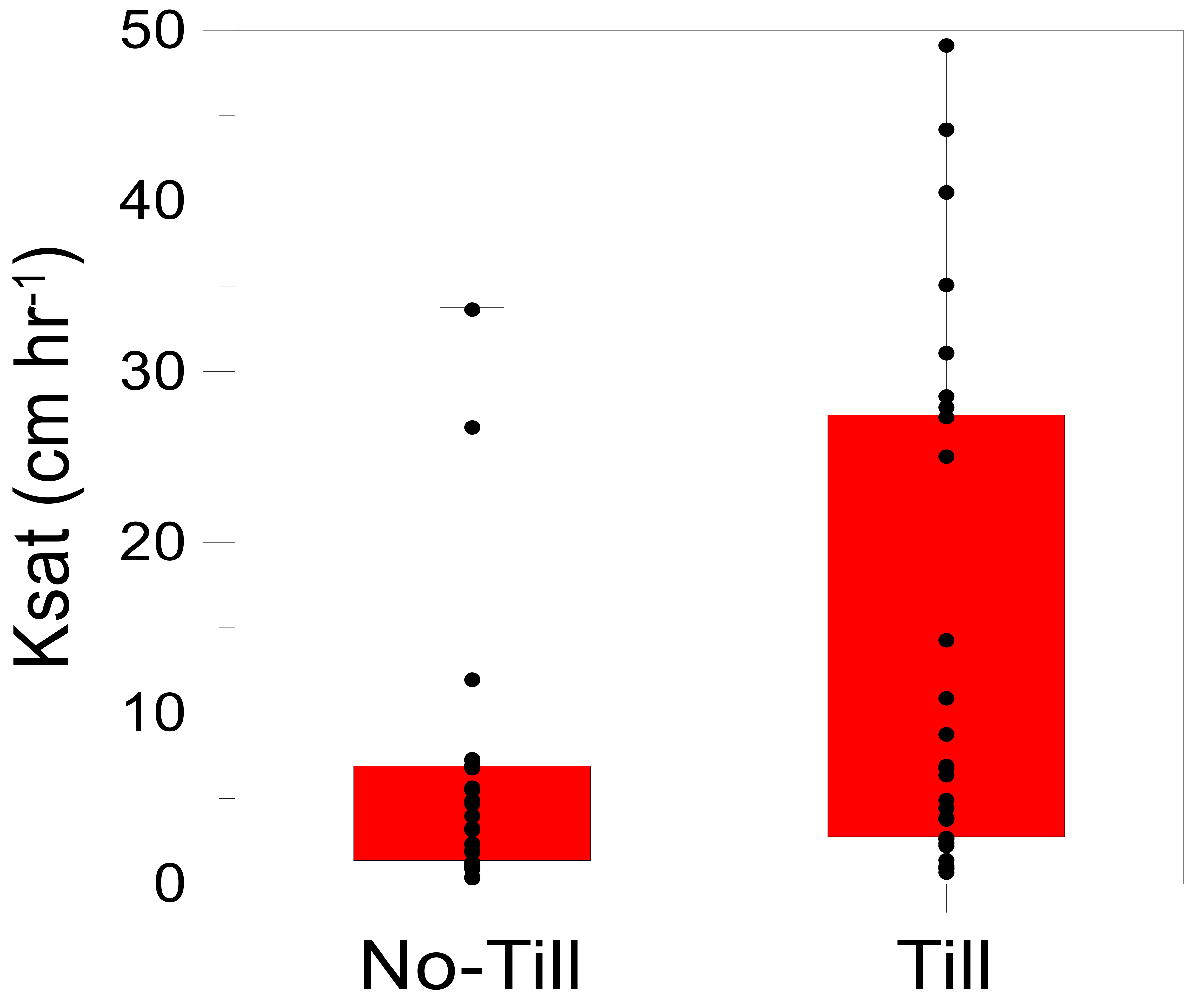
-Performed in the field

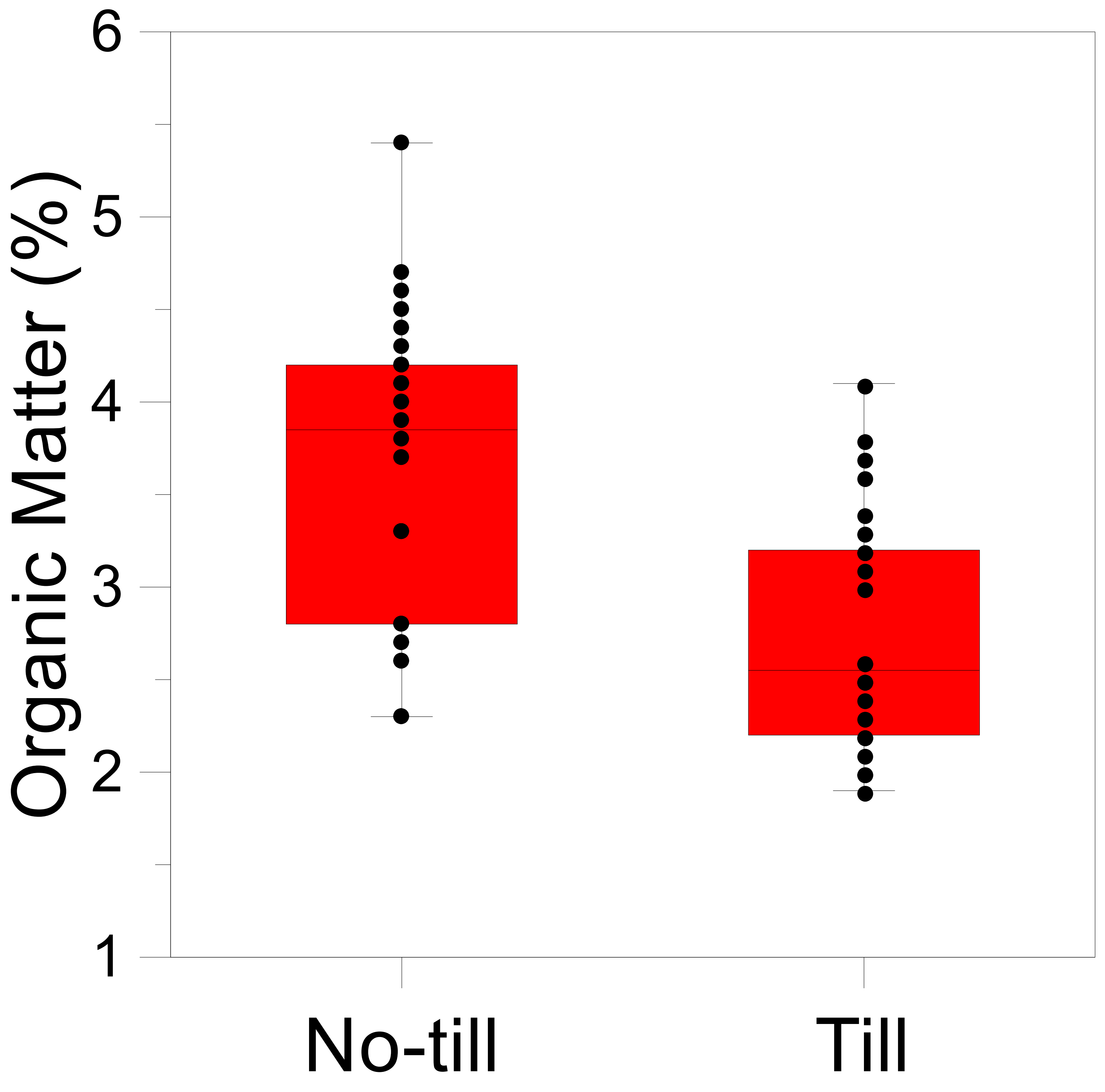
-Automated tool

-Utilizes multiple pressure heads to correct for three-dimensional flow

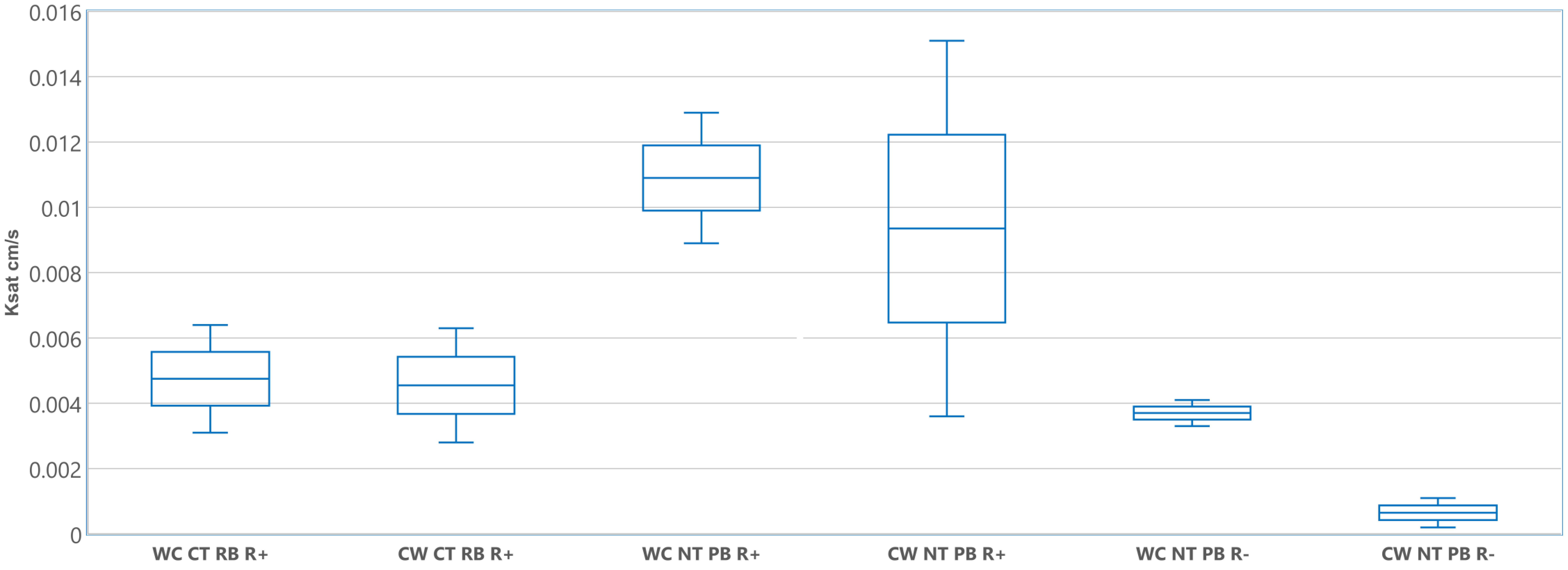
-No post-processing required

Illinois, Missouri, 2 Kentucky



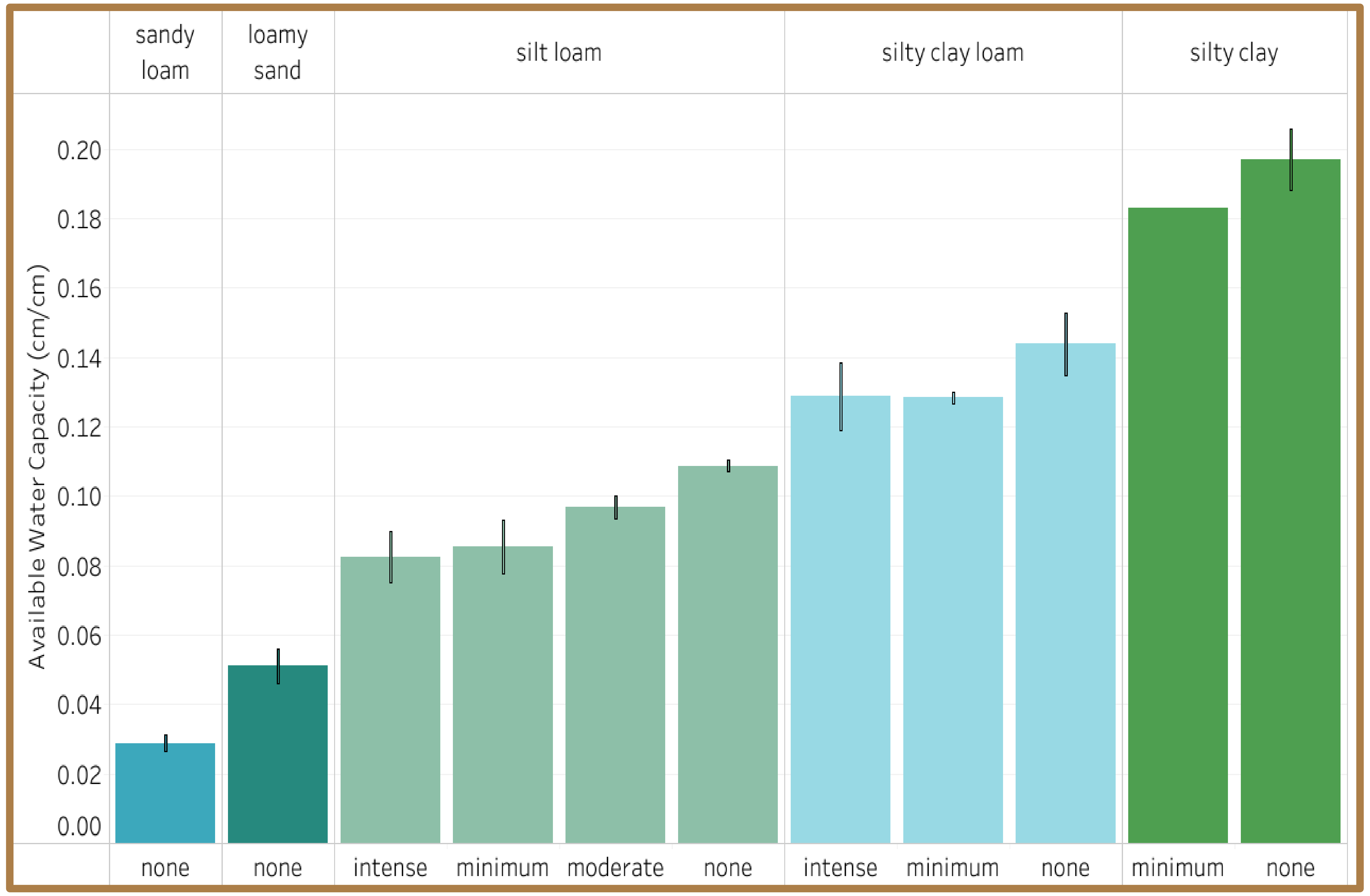


Saturated Hydraulic Conductivity – Texcoco, Mexico Site 2

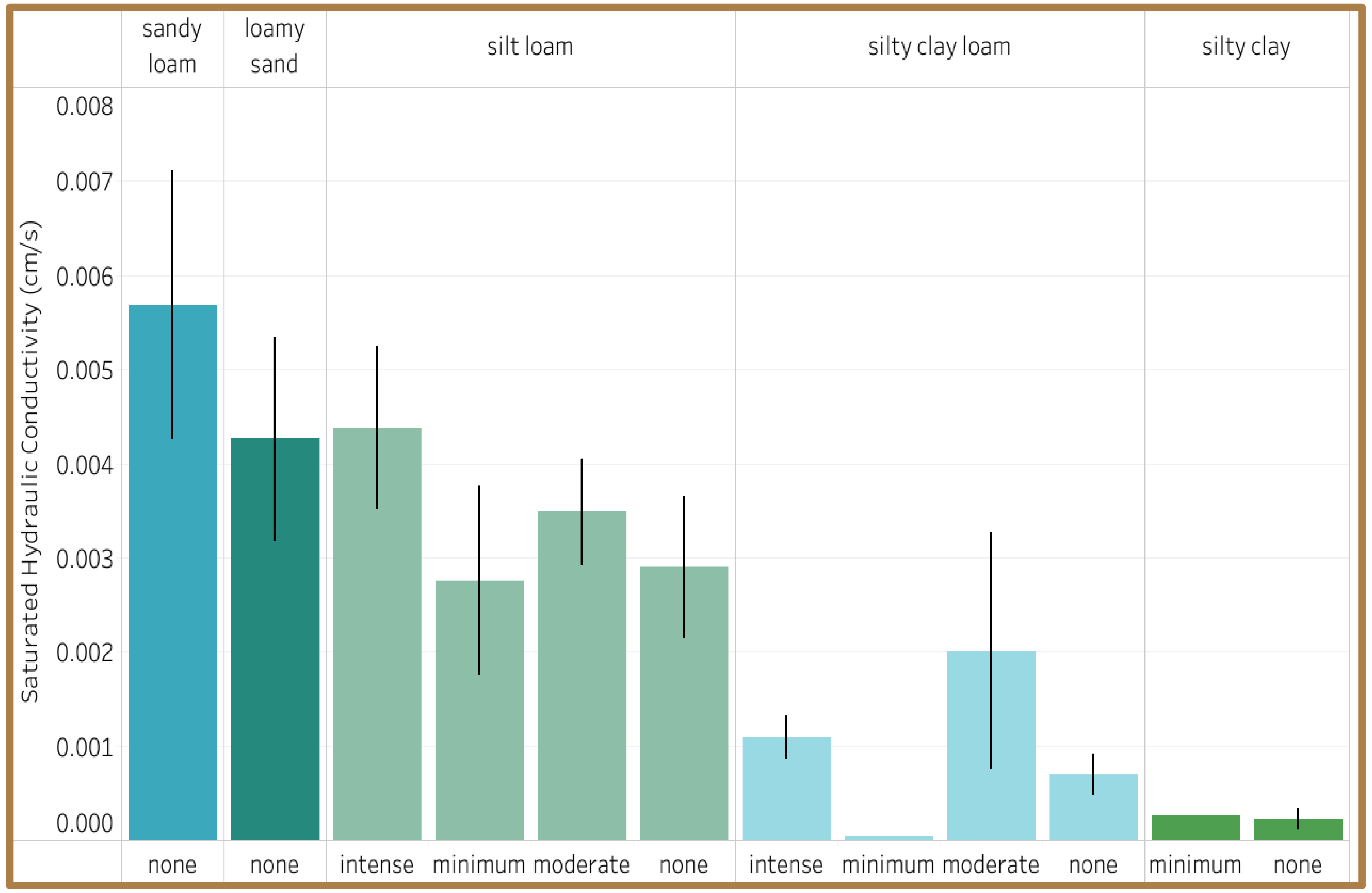


WC= Wheat/Corn, CW = Corn/Wheat, CT=Conventional till, NT = No-till, RB = Raised Seedbed, PB = Permanent Seedbed, R+ = Residue Retained, R- = Residue Removed

Preliminary NAPESHM Soil Texture x Soil Disturbance affect on Available Soil Water Holding Capacity and Soil Saturated Hydraulic Conductivity – Cappellazzi, 2019



Available water capacity by textural class and tillage intensity for delivered data. Note strong relationship by texture with slight variation by tillage. 163 samples, bars represent standard error.



Saturated hydraulic conductivity by textural class and tillage intensity for delivered data. Note inverse relationship to water holding capacity. 141 samples, bars represent standard error.

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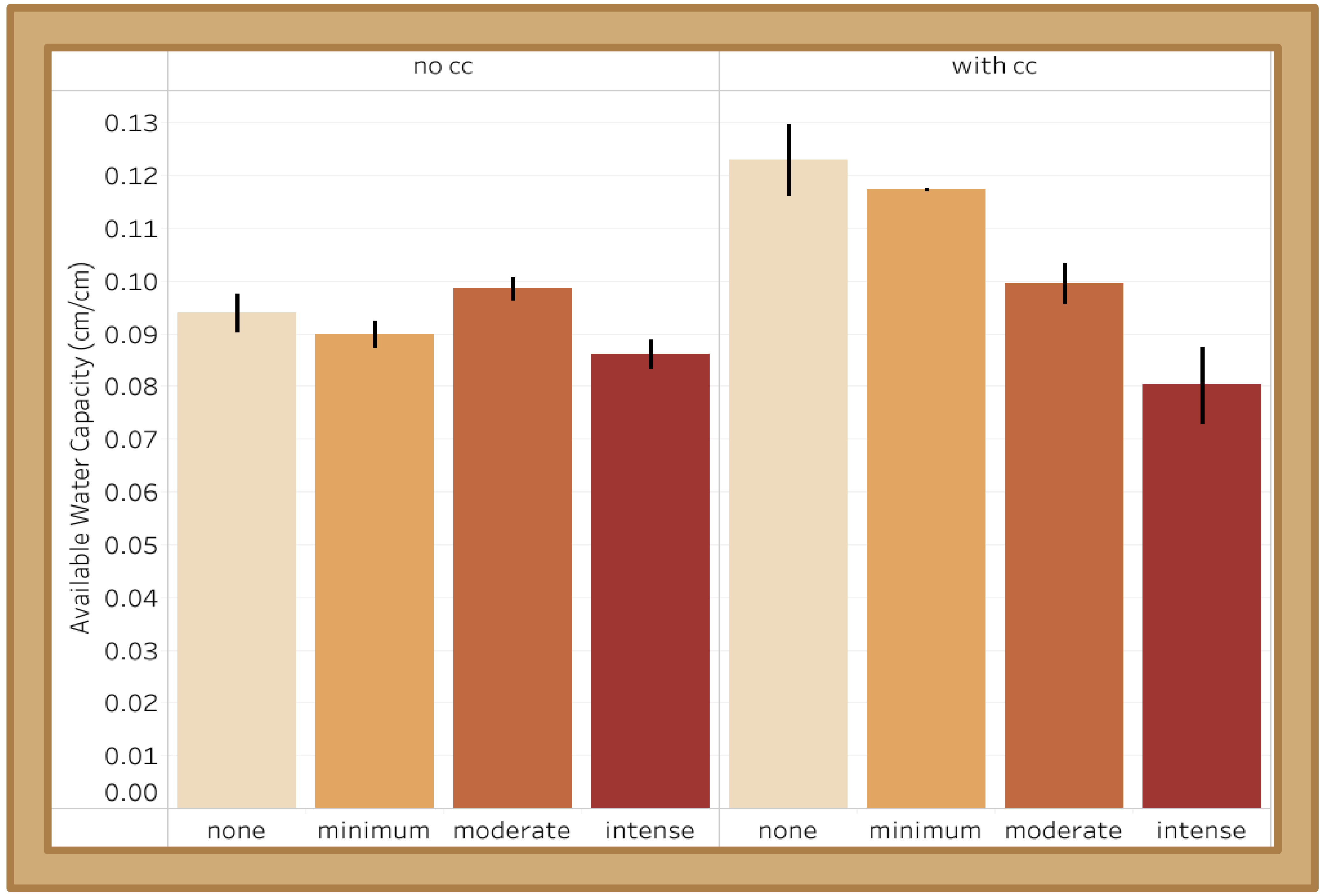
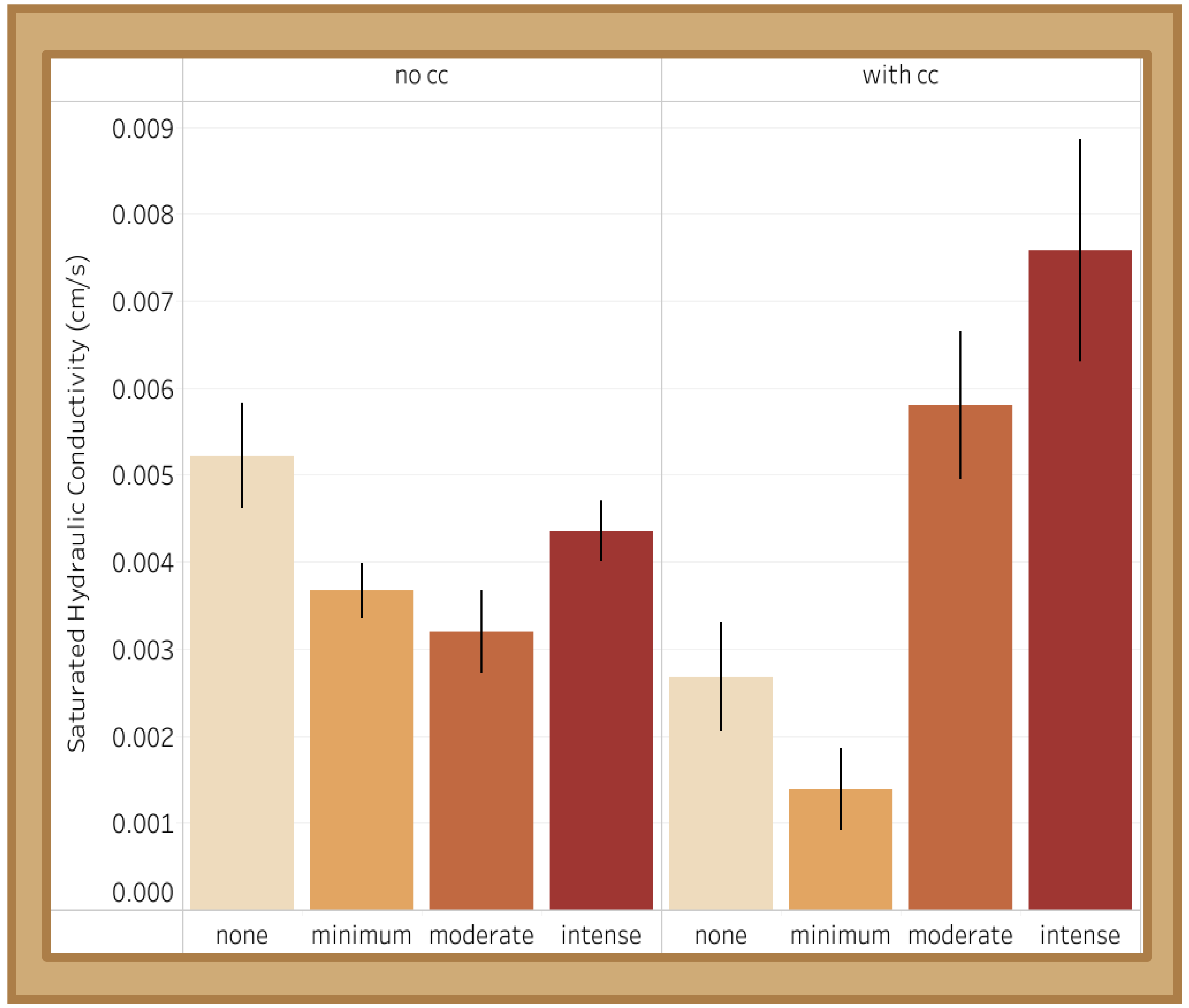
Preliminary NAPESHM Cover Crop x Soil Disturbance affect on Available Soil Water Holding Capacity and Soil Saturated Hydraulic Conductivity – Cappellazzi, 2019



Available water capacity by cover crop and tillage intensity. Note AWC relationship to tillage with cover crop. 1053 samples, bars represent standard error.



Saturated hydraulic conductivity by cover crop and tillage intensity. Note inverse relationship to AWC and interaction with and without cover crops. 892 samples, bars represent standard error.

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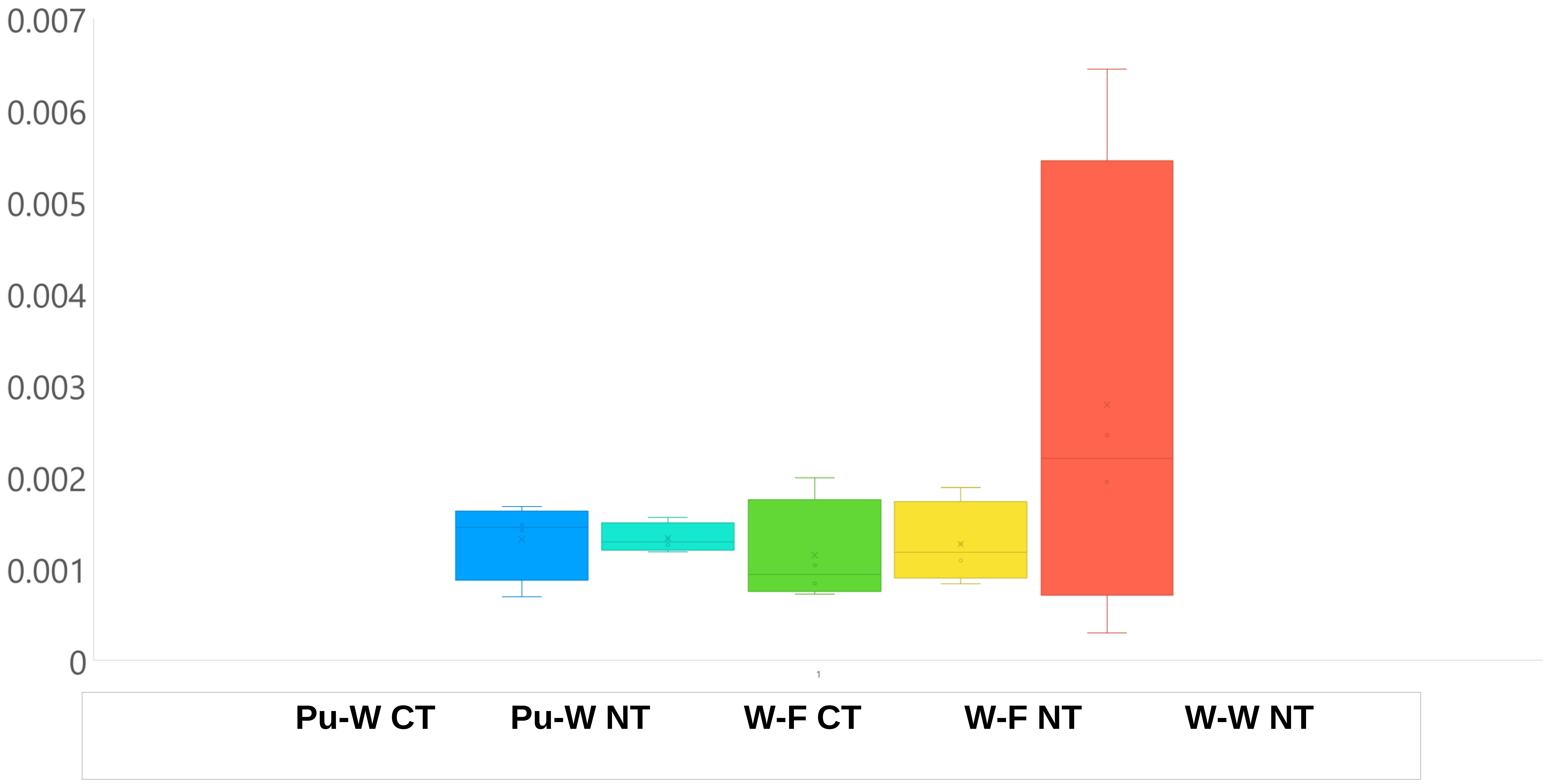
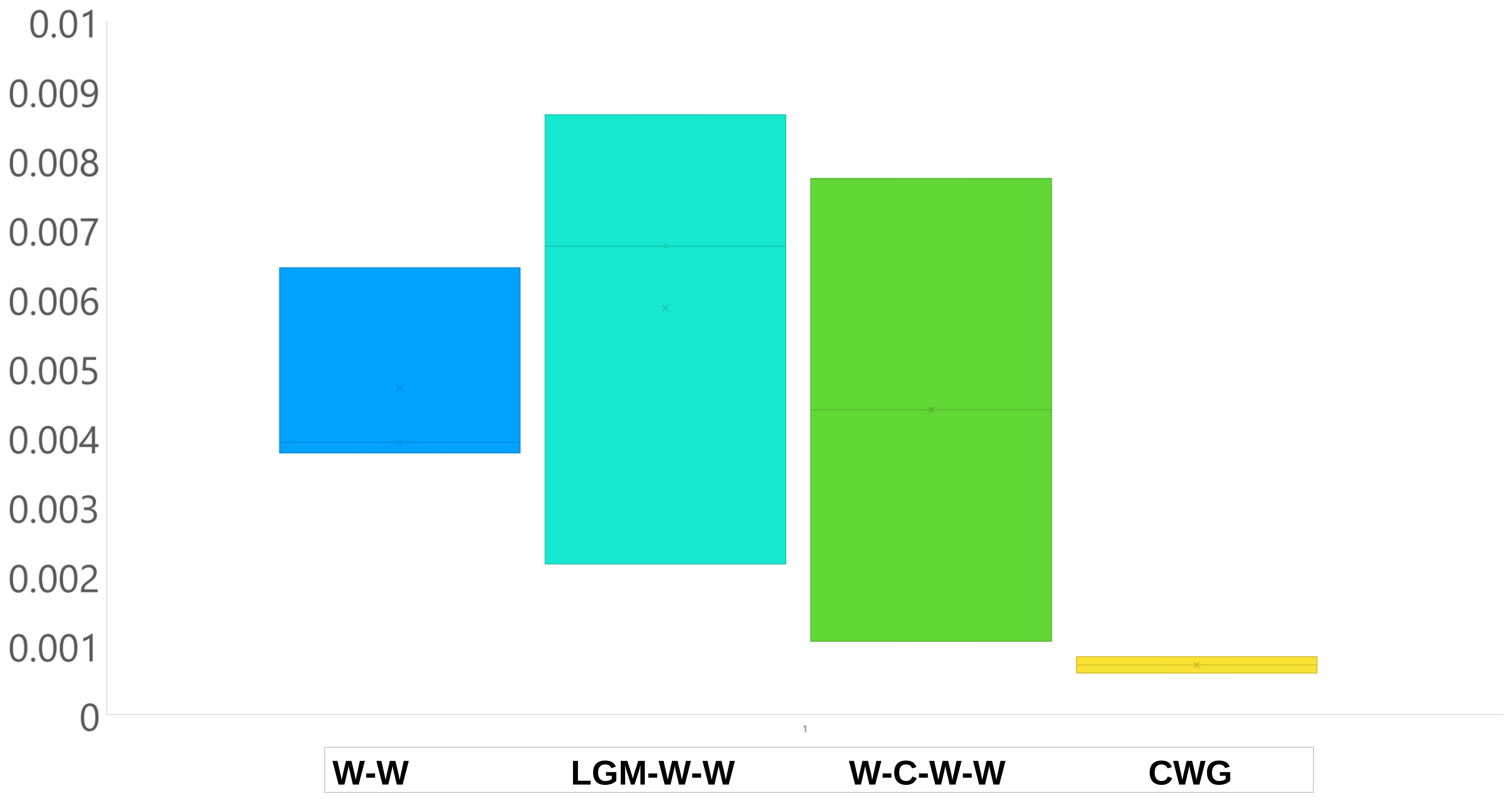
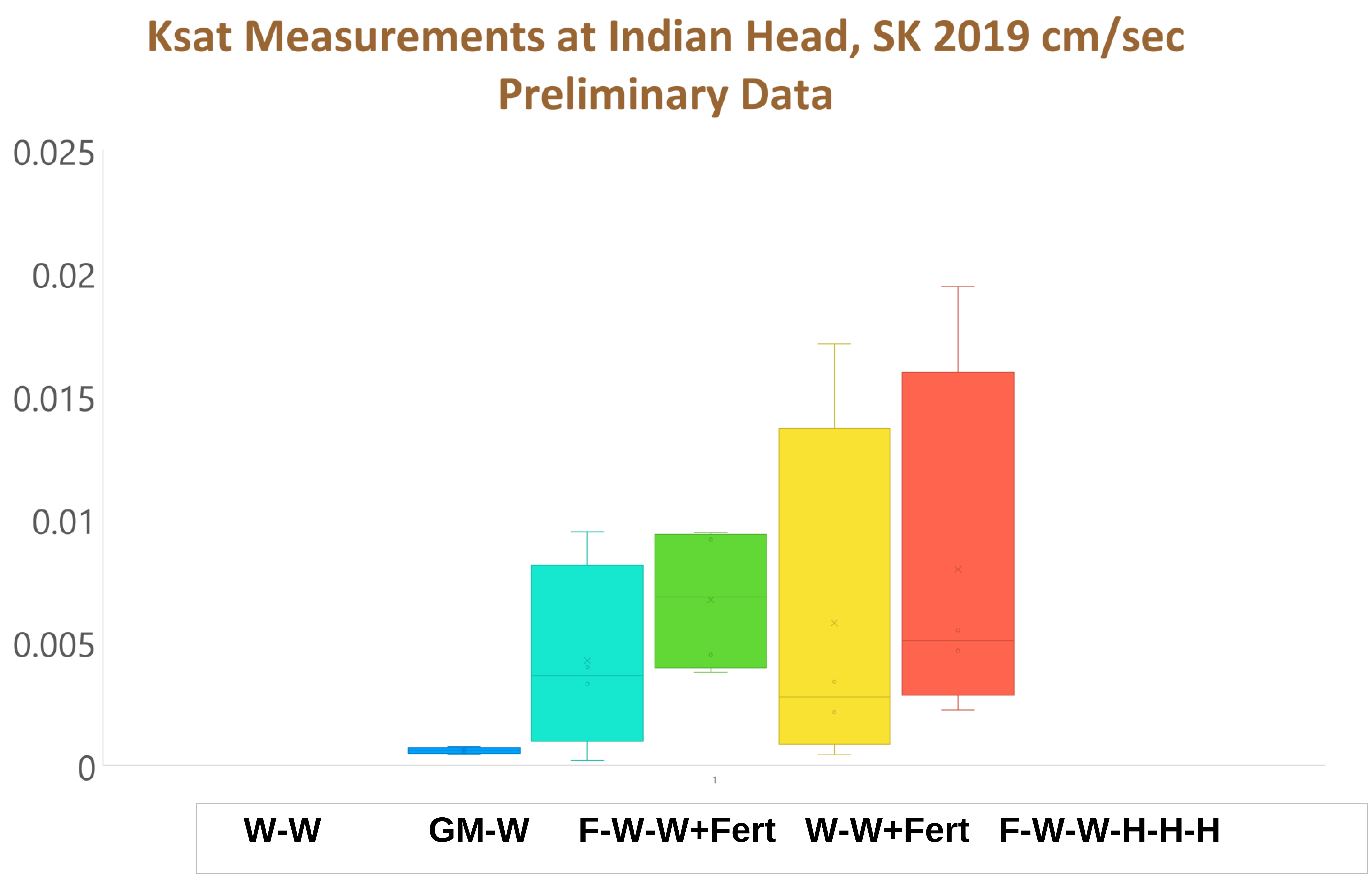
Ksat Measurements at Swift Current OMC Study 2019 (cm/sec) Preliminary Data



Ksat Measurements at Swift Current, SK Rotation Study 2019 cm/sec Preliminary Data




Ksat Measurements at Indian Head, SK 2019 cm/sec
Preliminary Data
0.025
0.02
0.015
0.01
0.005
0
1
W-W
GM-W
F-W-W+Fert
W-W+Fert
F-W-W-H-H-H

Aggregate Stability as a Soil Health Indicator

Water & air movement
C storage
Erosion potential
Crop productivity
Sensitive to management & inherent properties
Soil disturbance
Cover cropping
Clay content


Photo courtesy of Kade Flynn

Aggregate Stability Methods – NAPESHM evaluated Four

Wet sieve procedure (Kemper and Roseneau, 1986)

SLAKES test

Water slaking image recognition (Fajardo, et al., 2016)

Sprinkle infiltrometer (Wet Aggregate Stability test)
(Schindelbeck et al., 2016)

Soil stability

Combination of wet and dry sieving at multiple sieve sizes (Franzluebbers et al., 2000)

SLAKES: an app for aggregate stability

- developed at the University of Sydney, Australia
  - based on methodology in Fajardo et al., 2016
- stability at 10 min
  - *stab-10*= $\frac{initial\ area}{final\ area}$
  - larger stab-10 = more stable
  - smaller stab-10 = less stable

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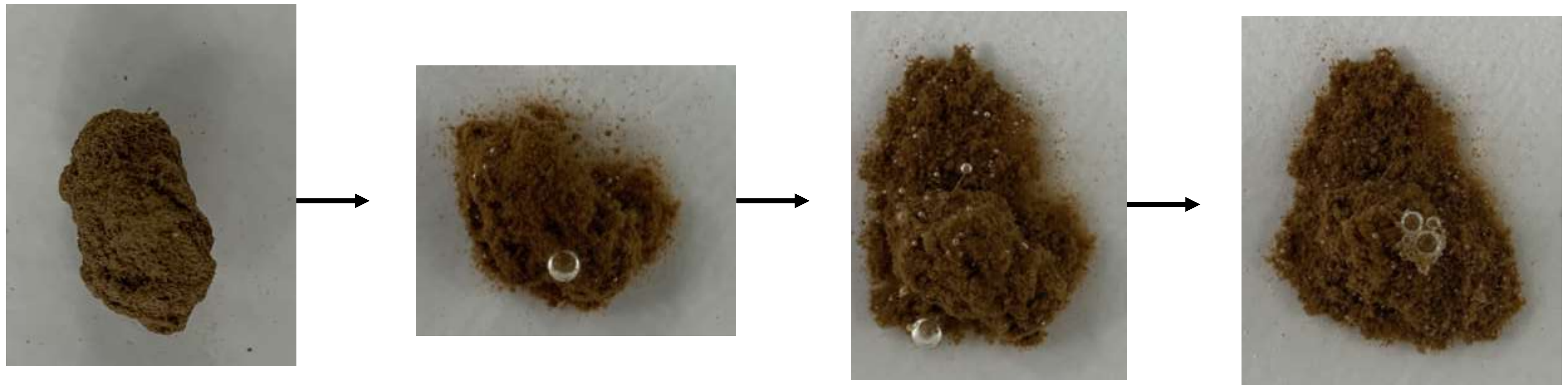

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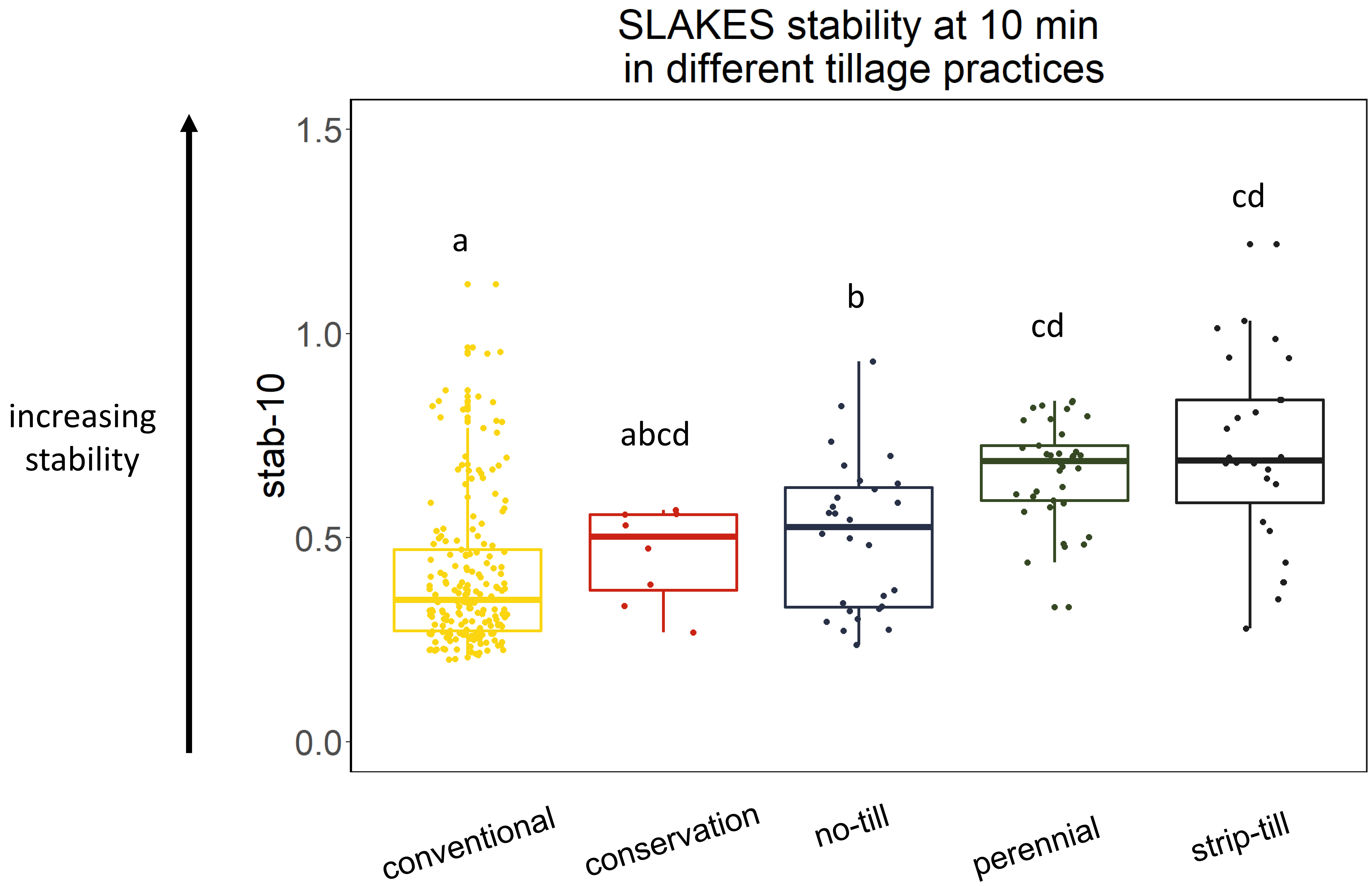
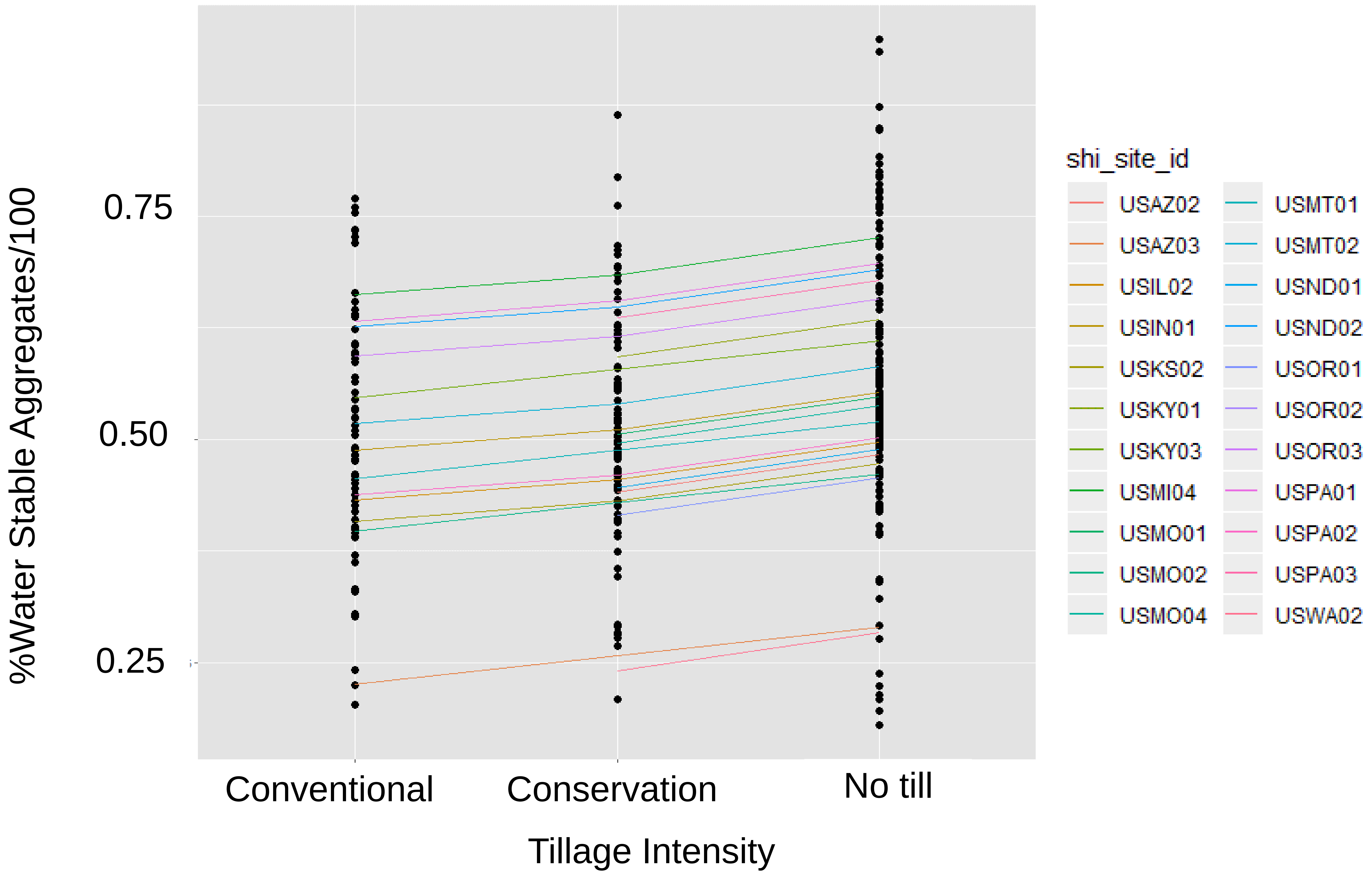
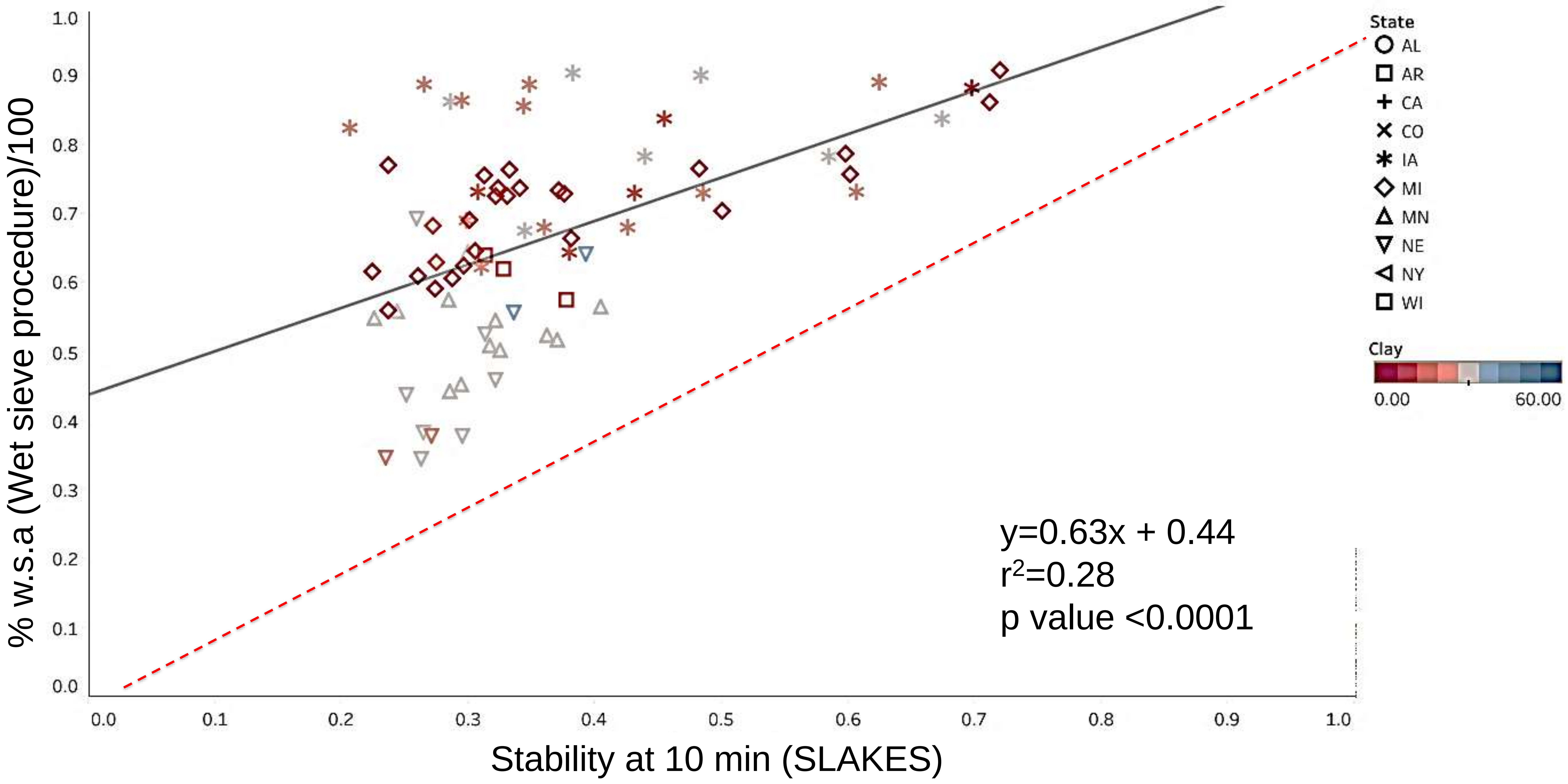


- lowest stability in conventional
- highest stability in perennial grass and strip-till
- tillage, cover crop as fixed effect; location as random effect
- $p < 0.0001$
- tukey's $\alpha = 0.1$

Aggregate Stability - Wet sieve



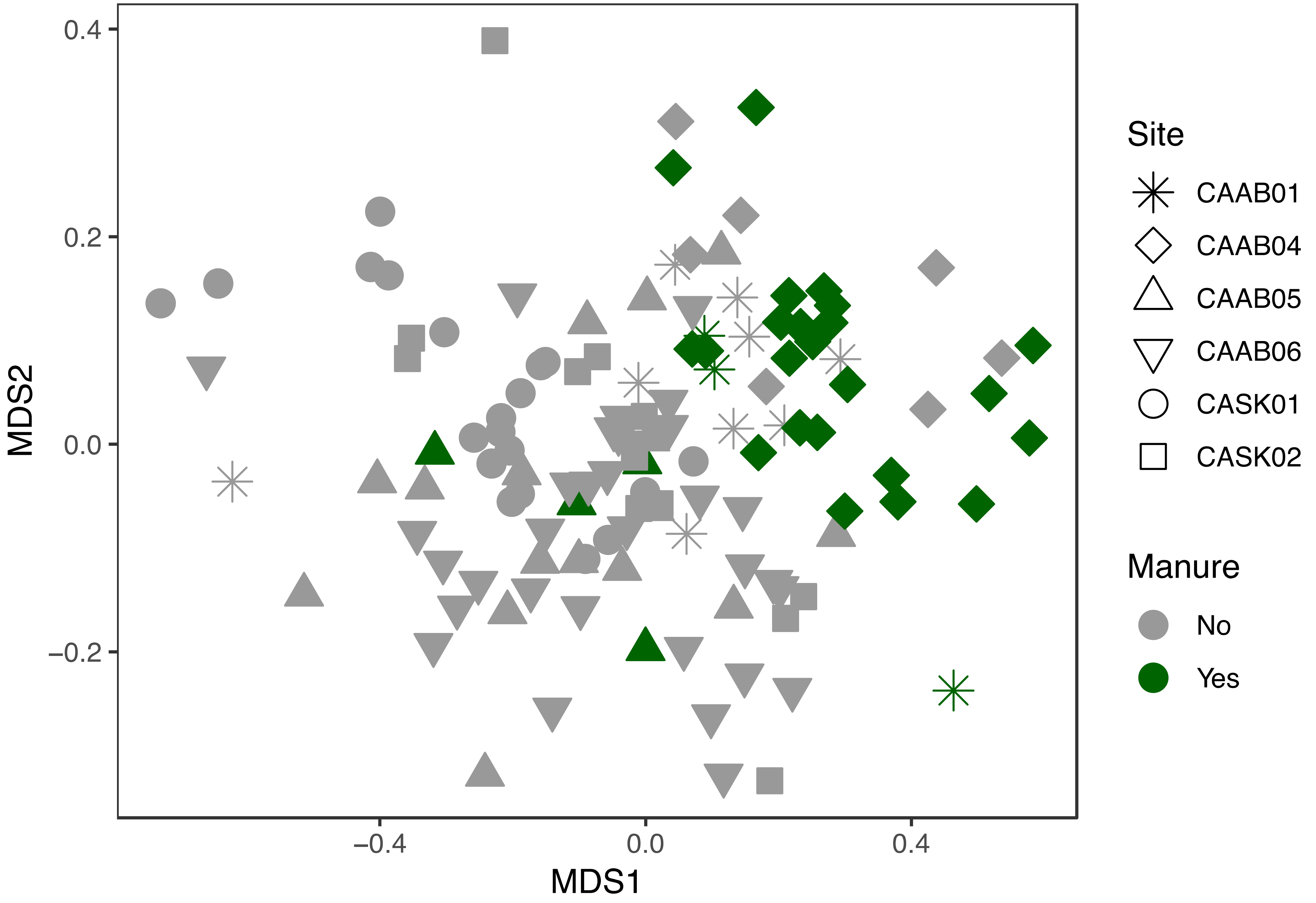
Aggregate Stability: SLAKES vs Wet Sieve



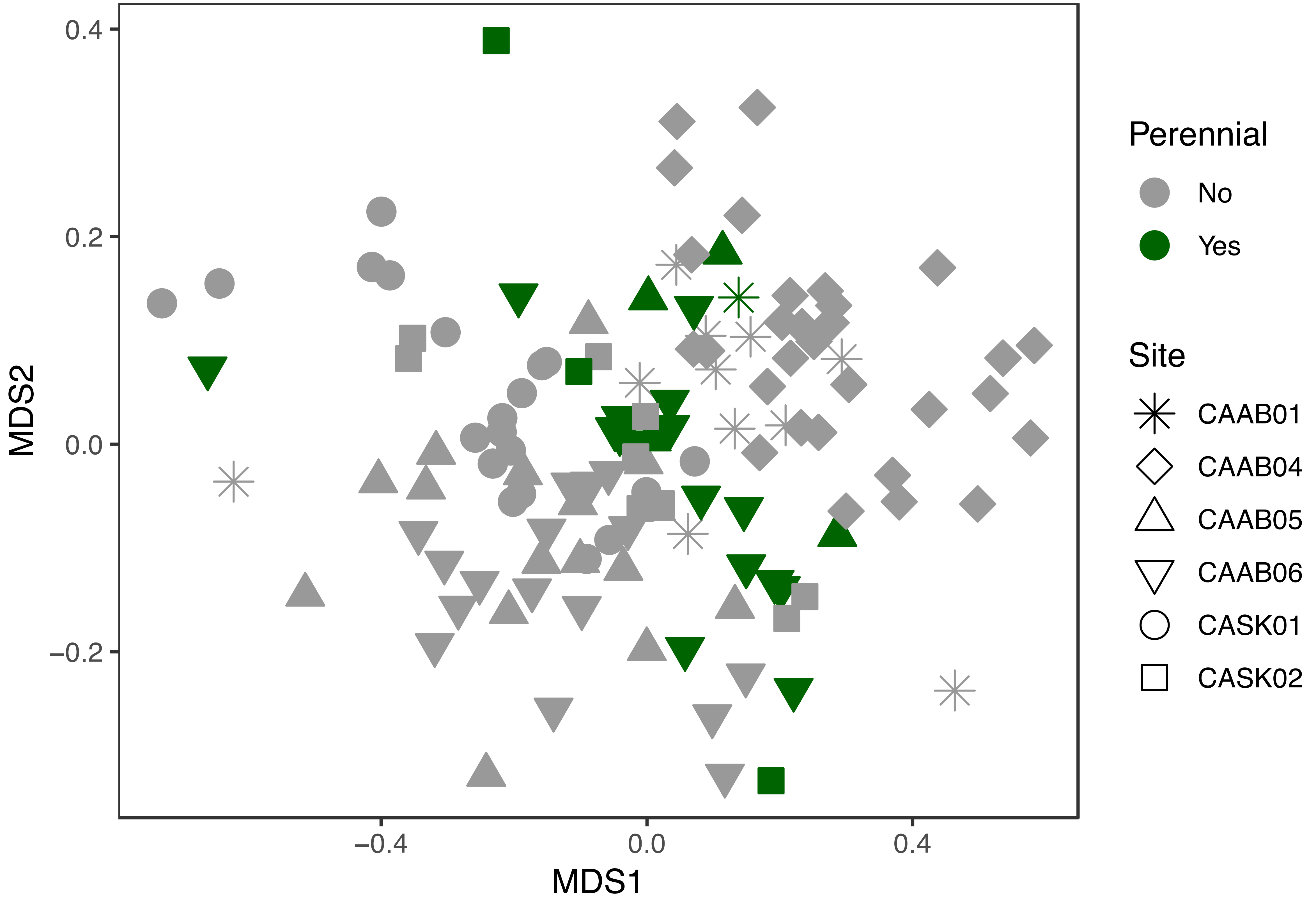
Understanding the Soil Microbiome:
Pathogen Suppression, Nutrient Cycling, Cseq

PLFA Separations based upon Management – 6 sites in Canada

Management – Amendment - Manure



Management – Cover crop - Grass

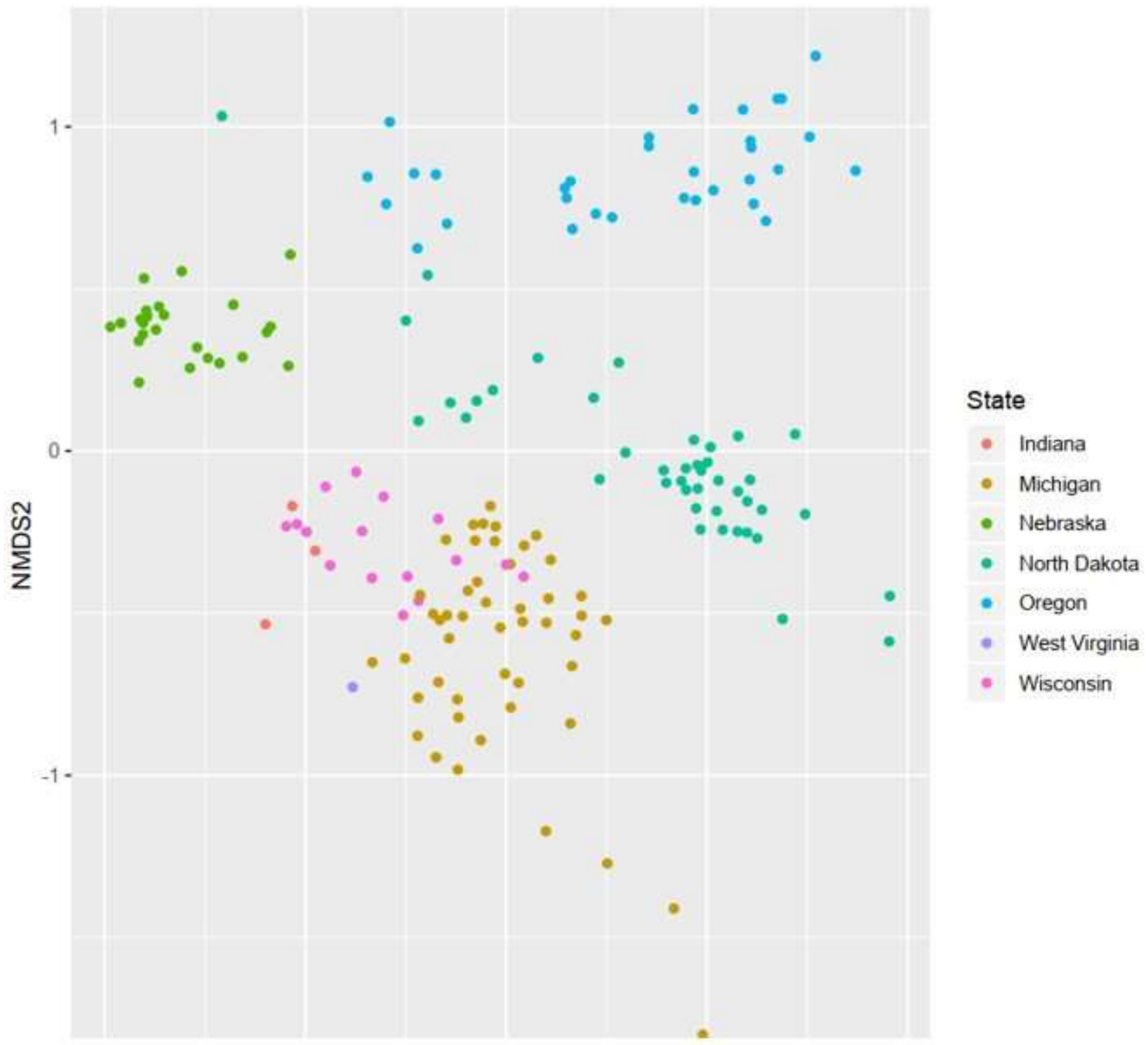


NAPESHM: Genomics Results Across Locations from a few Sites

Amplicon Sequencing

Address spatial heterogeneity
- **Spatial and Temporal Influences**
- **Intrinsic soil properties**
- **Other natural influences**

- **Will this become a useful soil health indicator moving forward?**



NAPESHM: Genomics results based upon land management

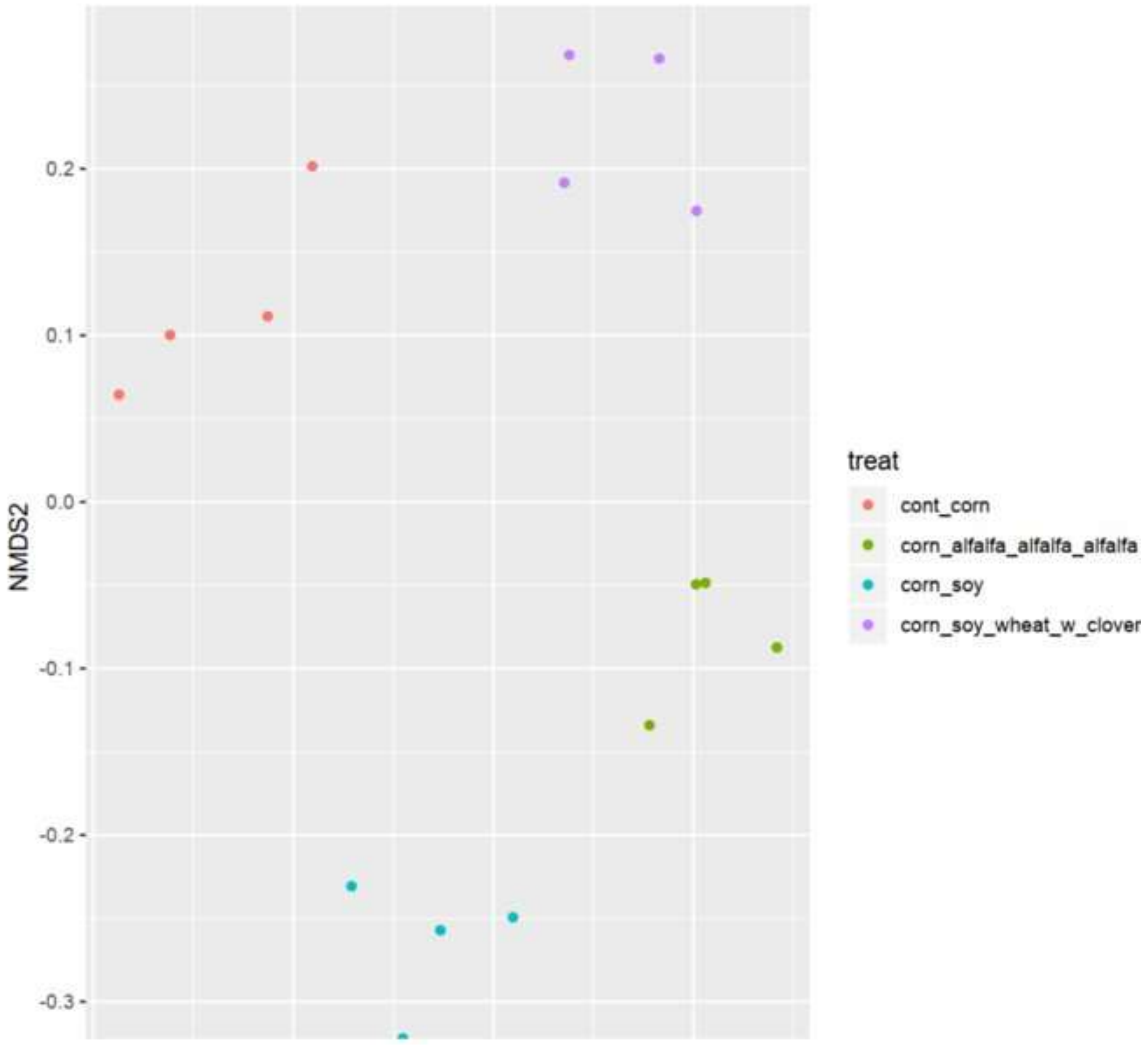
Amplicon Sequencing

Response to management factors across total data set and geographic zones

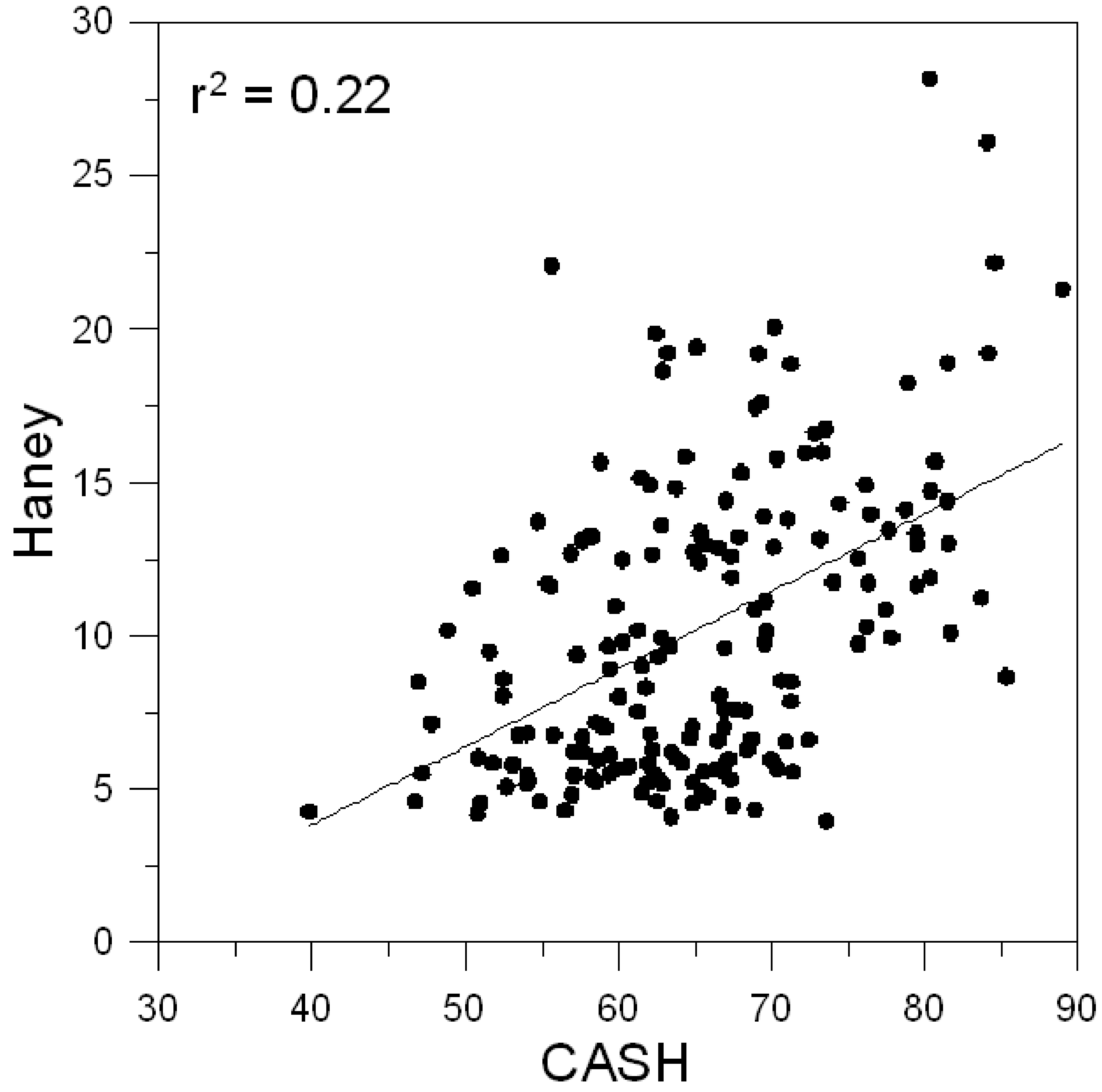
- **Crop rotations**
- **Tillage**
- **Cover Crops**
- **Rangeland Groupings**
- **Fertilizer Quantity/Quality**

The depth of analyses determined by preliminary data assessments

Example from preliminary NAPESHM data

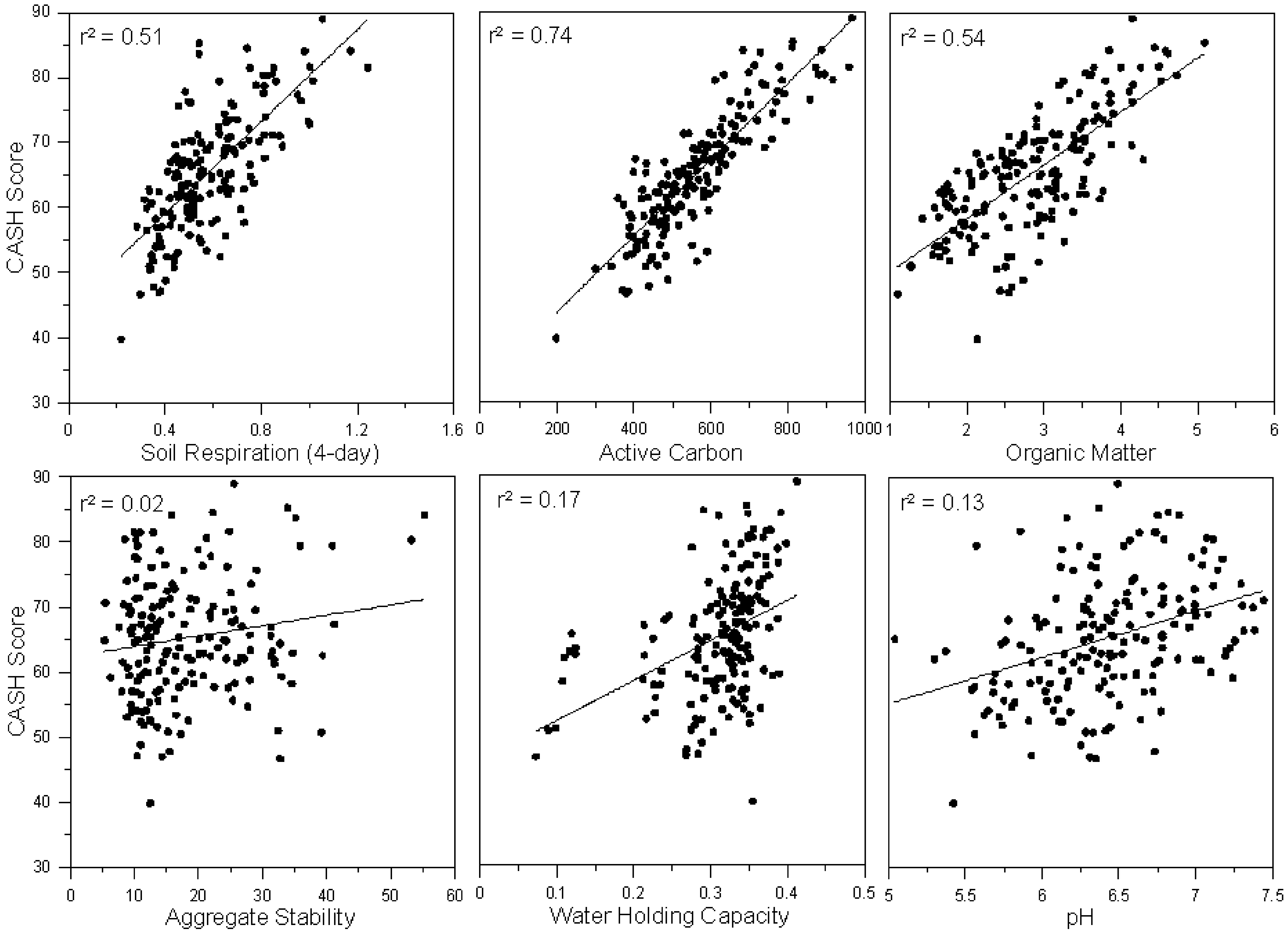


NAPESHM: First 200 samples: Comparison of Index's Haney/SMAF Scores



Note: Missouri Sites Included
When complete = 2000+ samples from across North America

NAPESHM: First 200 samples: Comparison of selected CASH functions to overall Cash Score



Note: When complete = 2000+ samples from across North America

Summary of Soil Health Measurements – Paul's Perspective

1) Much work has been done over the past 30 years

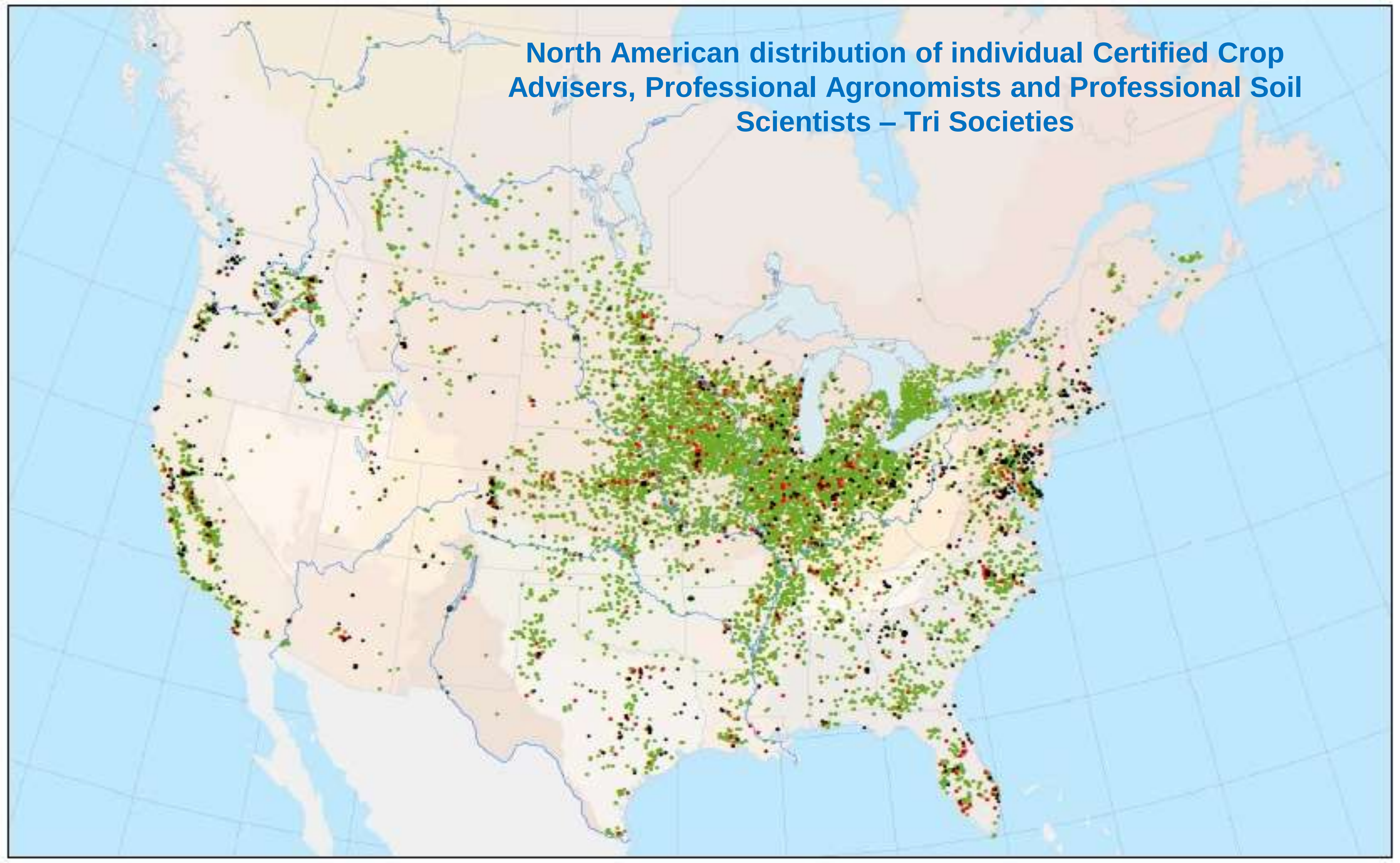
2) We need standardization and uniformity with measurements and with soil health index programs

3) Intrinsic soil properties and local environments may mask the effect of management on many soil health measurements. However, several soil health indicators were greatly affected by management, especially within similar geographies and soils

4) Exciting new strategies of measuring soil health are being developed and the NAPESHM project is contribution to that effort. We are very excited about initial results and look forward to interpreting the data set.

What role do crop advisers and land managers play in soil health?

- Continue to make defendable rec's
- Utilize client trust
- Keep learning
  - Measurements
  - Programs
  - Opportunities
- Initiate activity and new partnerships
- Lead the conversation – you have much to offer!



Summary Soil Health Crop Advising – Paul's Perspective

1) Agribusiness and crop advising is a vital link in providing highly productive & sustainable agroecosystems. Always have – Always will!

2) Soil health enhancing practices are required in today's agriculture.

3) Non-agriculture-based segments of society will continue to look to us to lead the way. A golden opportunity to promote our value.

4) Economic opportunities centered around soil health are out there for those who seek them.

5) Partnerships will be required as we move forward

Thanks