How Reliably Can We Estimate Soil Test Values at Different Depths?

FRST Meeting – Feb 13, 2025

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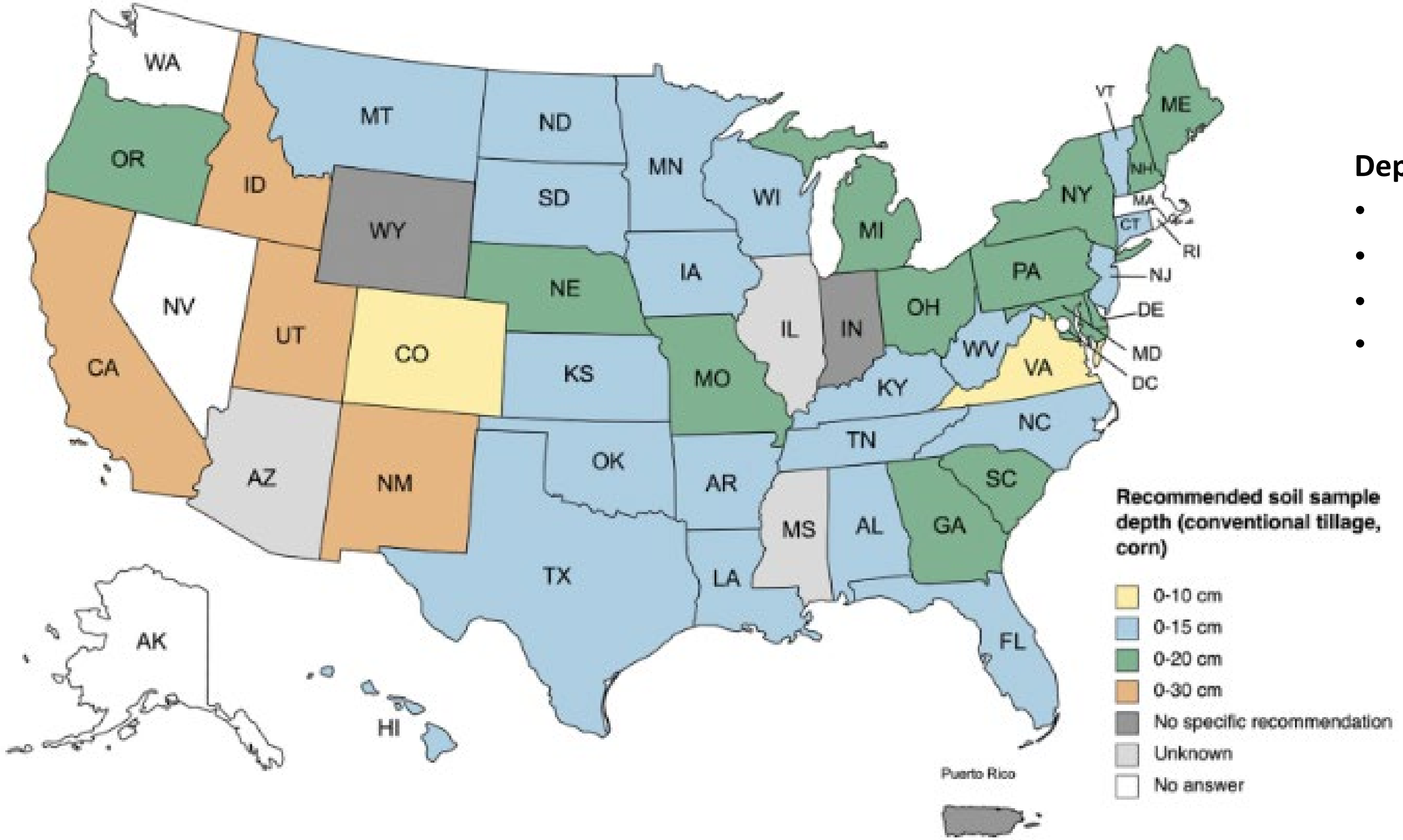
Soil Depths for LGU Fertilizer Rec Vary by State



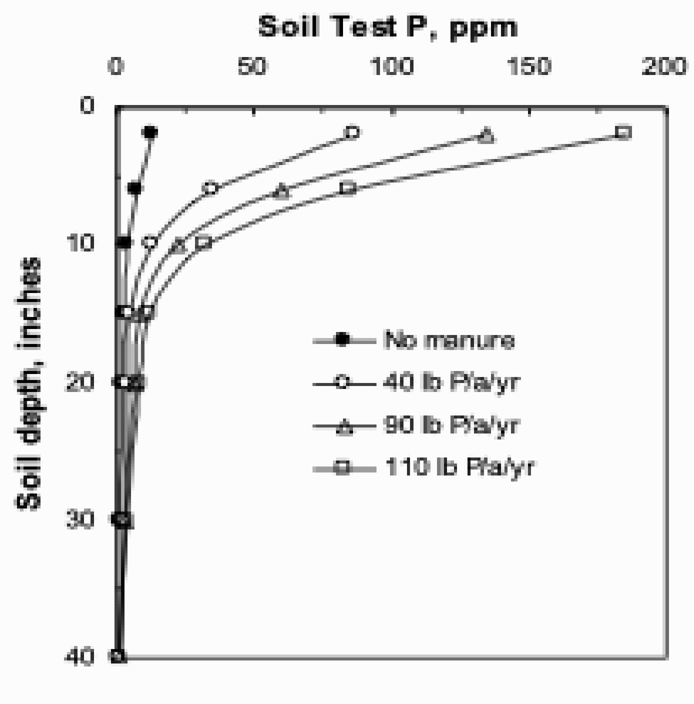
Depth Recs by State

- 0-10cm: 2 states (4%)
- 0-15cm: 21 states (41%)
- 0-20cm: 13 states (25%)
- 0-30cm: 4 states (8%)

Lyons et al., 2023. SSSAJ: doi.org/10.1002/saj2.20536

Soil Stratification

- Creates large uncertainty if sampling different depths
- How to aggregate crop response trials from studies with different depths?



Key Questions to Move Beyond State Boundaries

- How does geography, soil type, and management history impact soil stratification?
- Can we develop generalized equations to convert soil test values to a depth different than what was sampled?

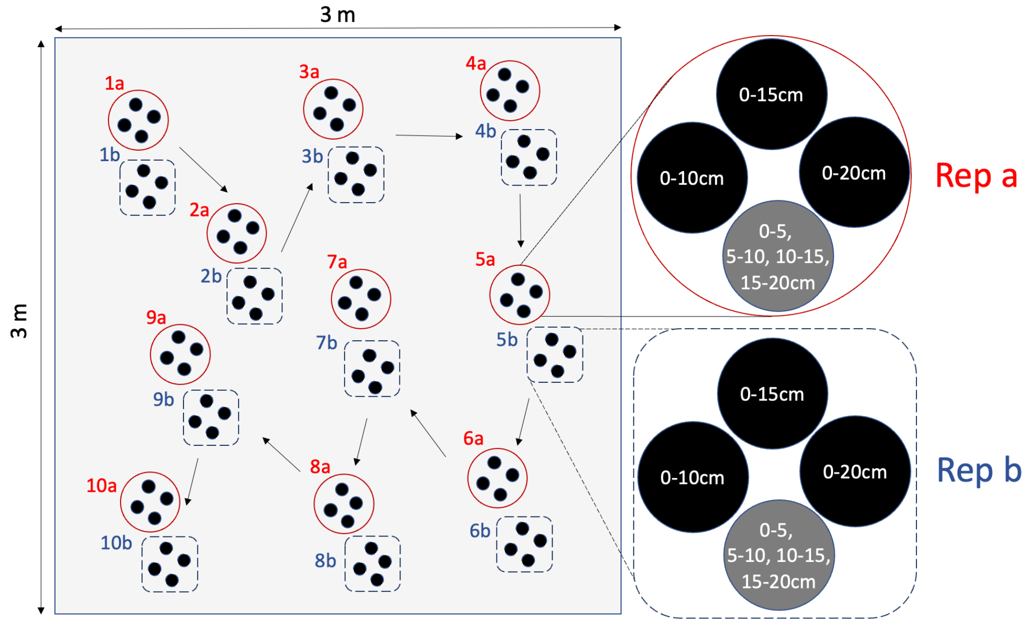
Site Selection

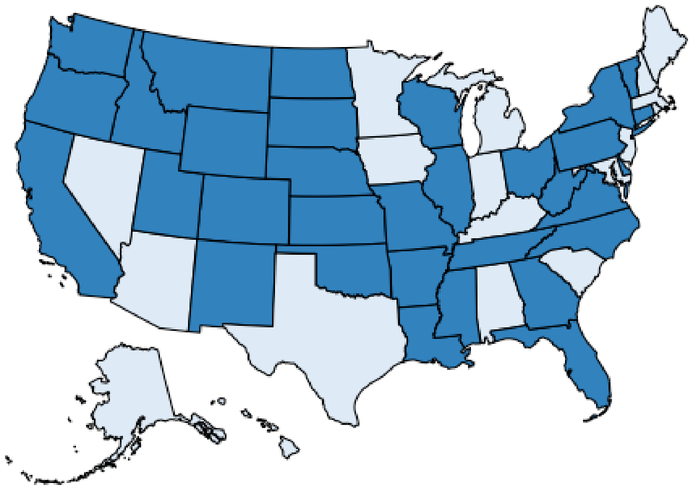
- Collaborators identified sites with different histories:
  - Tillage (n=99)
  - Fertilizer application (n=26)
  - Soil type (n=67)

- Each field
  - Soil sampled
  - Management survey to capture site history

Sampling Overview

- 197 fields sampled over 32 states
  - 2,936 soil samples
- 147 East fields
  - Full cores: 0-10, 0-15, 0-20cm
  - Incremental cores: 0-5, 5-10, 10-15, 15-20cm
- 50 West field
  - Full cores: 0-10, 0-15, 0-20, 0-30 cm
  - Incremental cores: 0-5, 5-10, 10-15, 15-20, 20-30cm
- Each soil sample replicated in field 2x





Laboratory Analysis

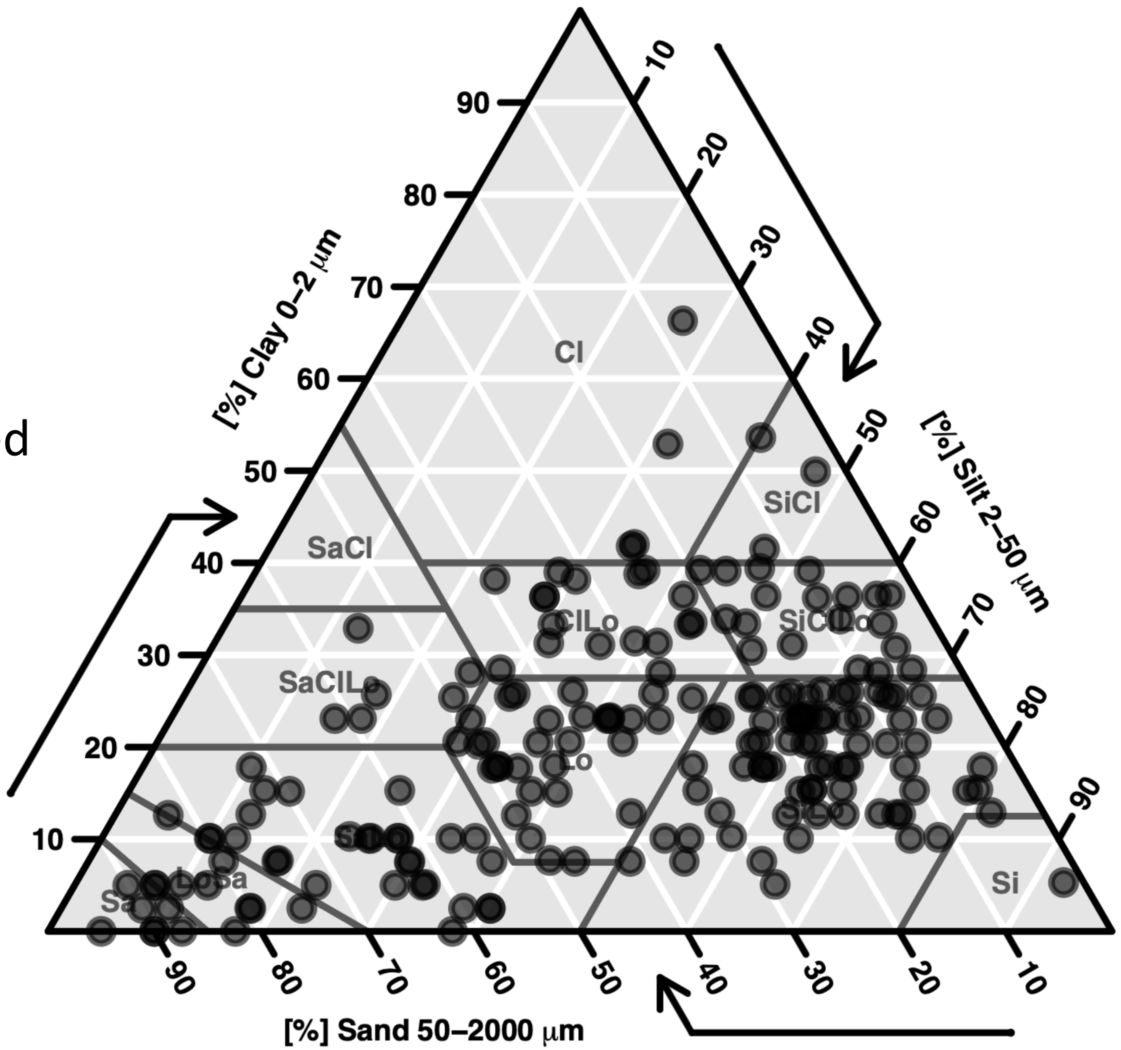
- All soils ➔
  - Penn State Analytical Lab – pH, OM (LOI), Mehlich-3 extractable nutrients
  - Univ of Arkansas – soil texture (per site basis, 0-20cm)
- Soils from NE ➔
  - Univ of Maine – Modified Morgan extractable nutrients
- Soils with pH > 7.2 & West of Mississippi River ➔
  - Kansas State Univ – Olsen P

Cropping Systems Sampled

Crop Type	Crops Included	Fields (%)
Corn	Grain, silage, sweet	34.4
Soybean		19.0
Small grain	Winter and spring wheat, triticale, oats, barley	14.0
Forage	Alfalfa, grass hay, mixed species	12.6
Fallow or no crop		8.1
Fiber	Cotton, hemp	3.1
Vegetable	Tomatoes, potatoes, brassicas, sugarbeet, chile	3.5
Other grain, pulse or oilseed	Rice, sorghum, millet, dry beans, canola, sunflower	3.5
Specialty, other	Peanut, peach	2.1

Soil Textural Distribution

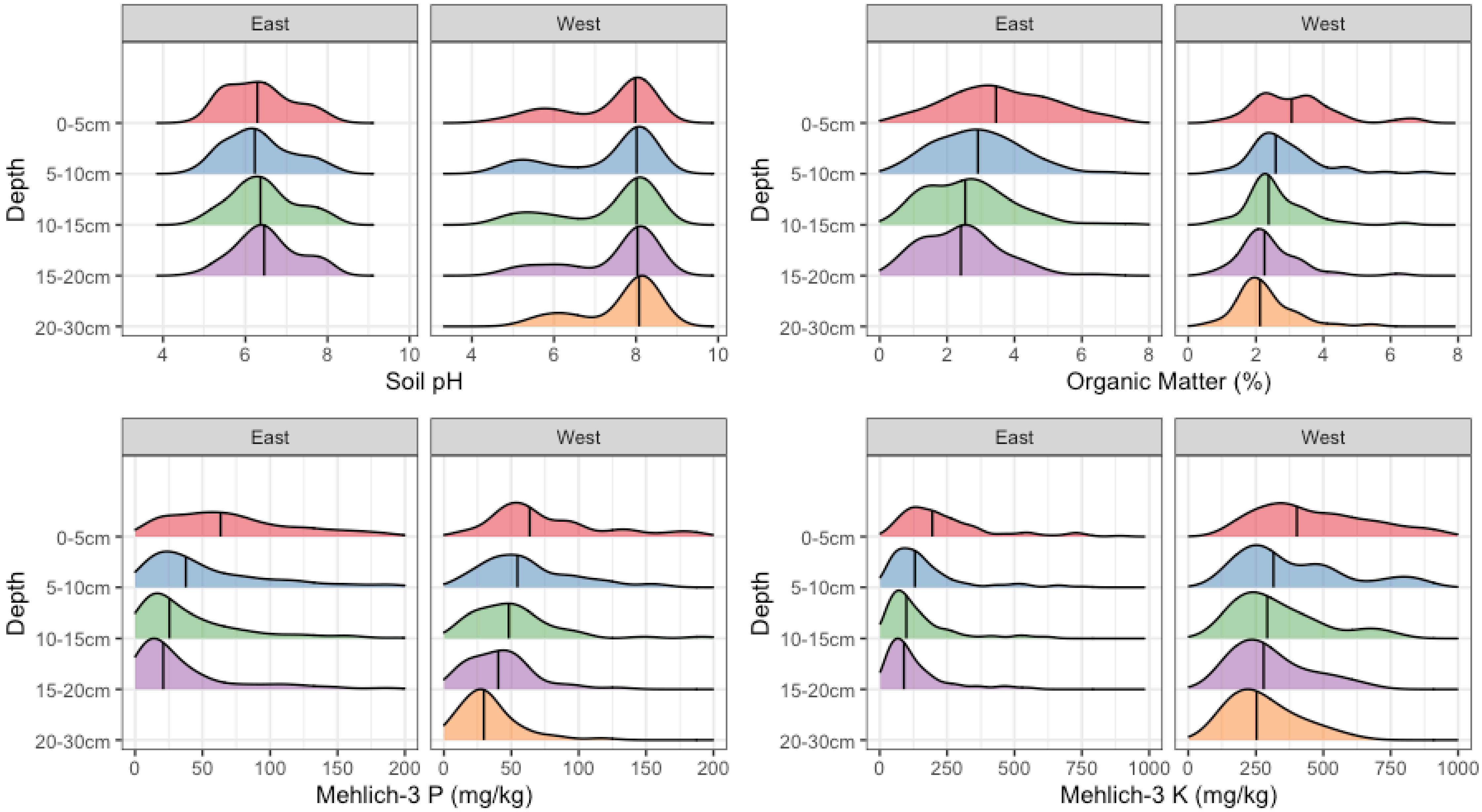
11 out of 12 soil texture classifications represented



Number of Fields

- Coarse = 45
- Medium = 109
- Fine = 43

Soil Distributions



Stratification Ratios = SRs = 0-5cm/15-20cm

Variable	Min	5th	25th	50th	75th	95th	Max
pH	0.7	0.8	0.9	1.0	1.0	1.1	1.4
Organic Matter	0.5	1.0	1.2	1.4	1.8	3.0	11.6
Mehlich-3 P	0.6	1.0	1.3	2.3	3.9	10.9	34.2
Mod-Morgan P (col)	0.5	0.8	1.0	2.1	3.4	5.2	7.3
Olsen P	0.4	0.8	1.4	3.0	5.5	11.5	23.1
Mehlich-3 K	0.7	1.0	1.4	1.8	2.6	4.3	7.3

** Soil properties that were most stratified are extractable P, K and Zn

** 4 variables we're focusing on: pH < OM < M3K < M3P

Question #1:

How does geography, soil type, and management history impact soil stratification?

Exploring Trends with Soil Stratification

1. Geography
2. Soil Properties
3. Management

Simple Approach:

1) Average sites by various factors and look at trends with SRs (stratification ratios) between factors
2) Run ANOVAs to see if there are differences between factors ($P < 0.05$)

Exploring Trends with Soil Stratification

1. Geography

a. State
b. Territory
c. Region
d. Division

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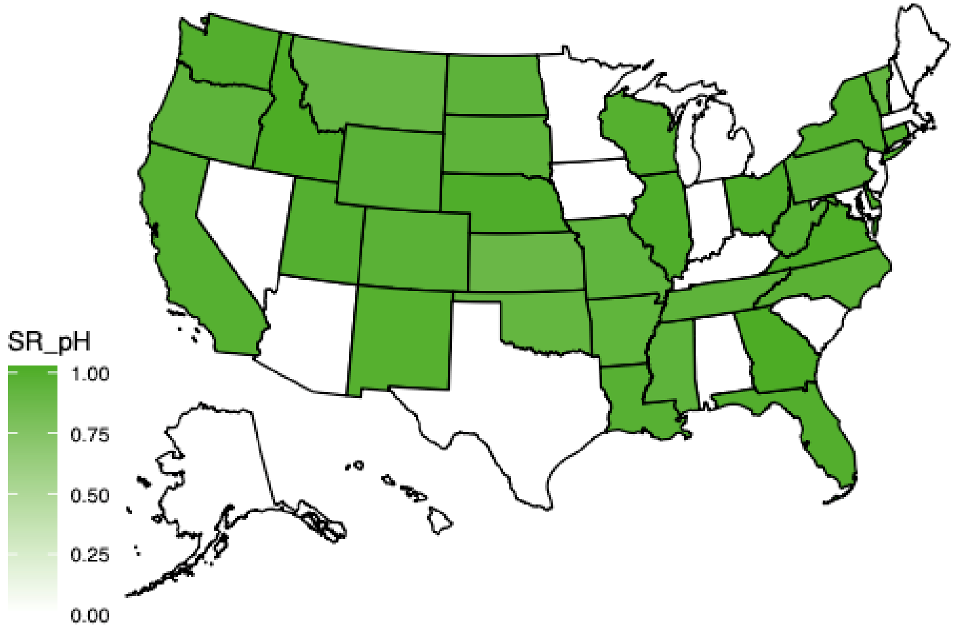
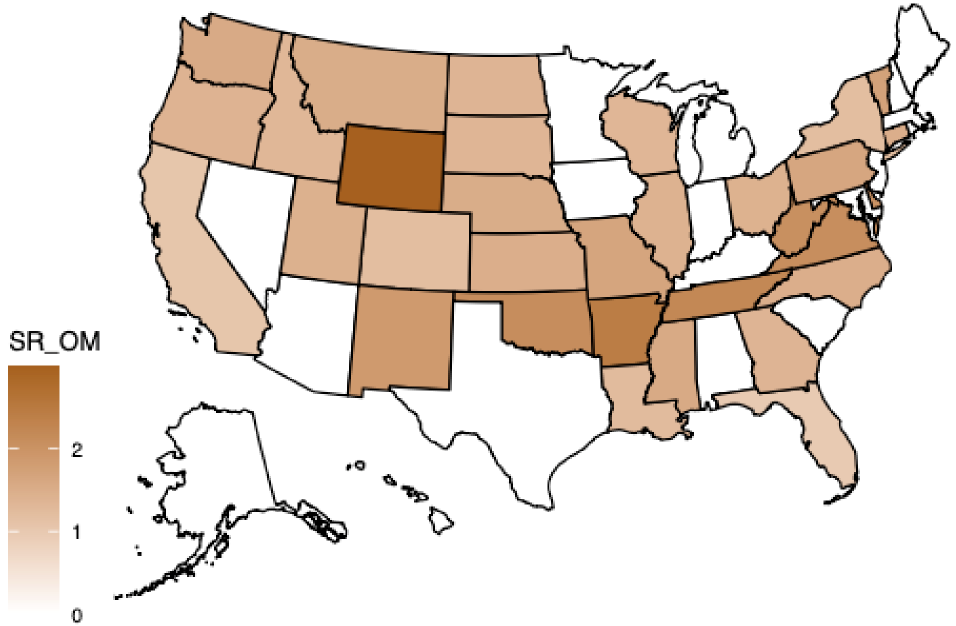
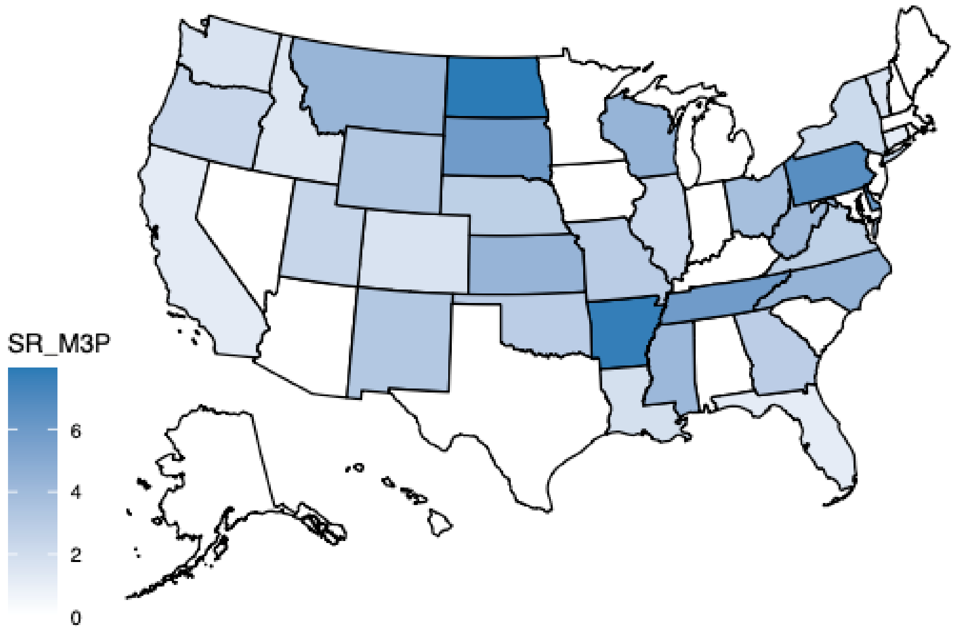
pH Stratification Ratios



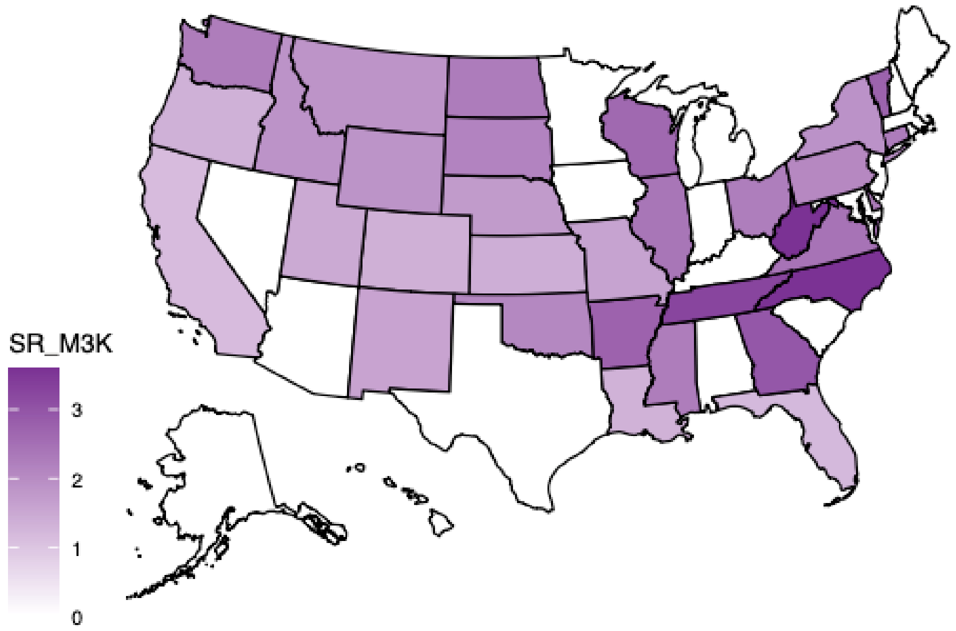
OM Stratification Ratios



M3−P Stratification Ratios



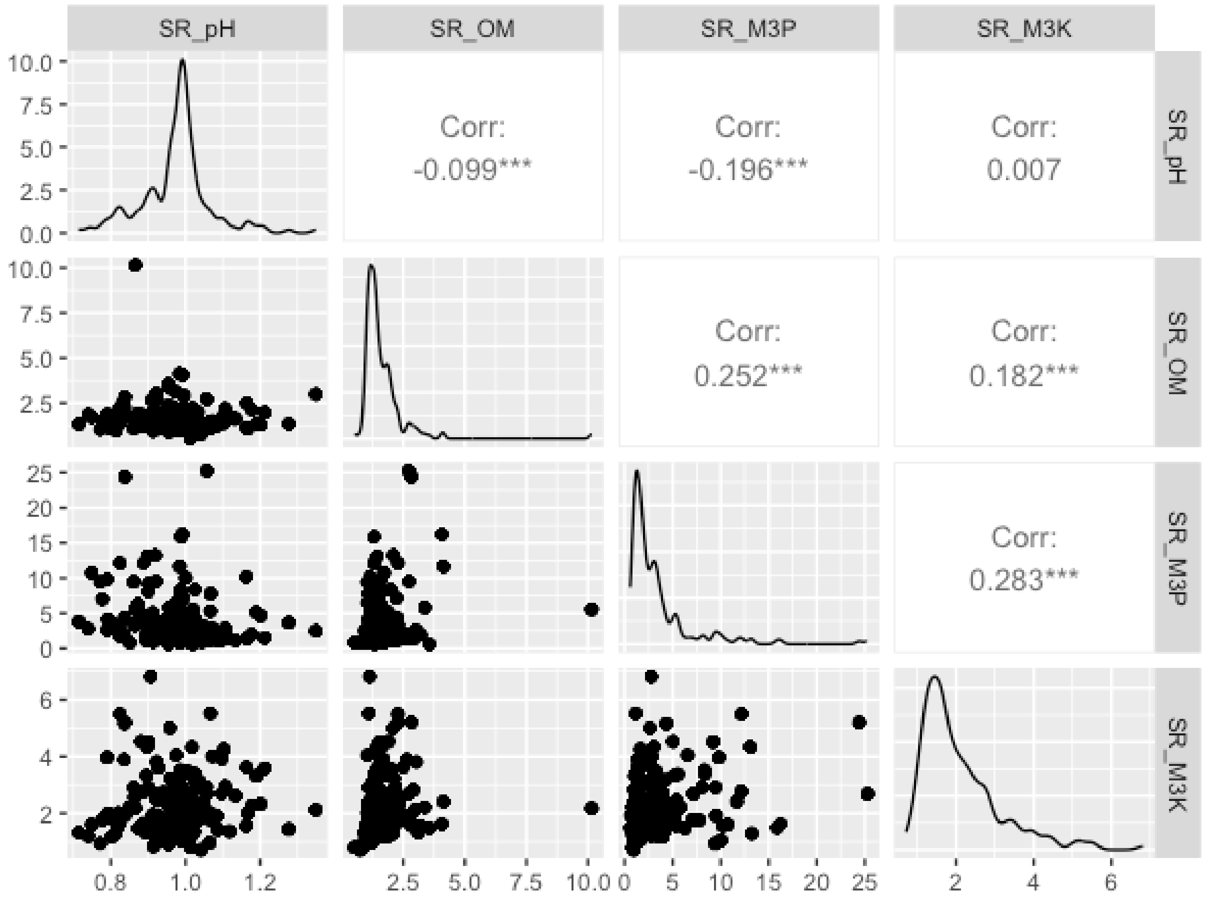
M3−K Stratification Ratios



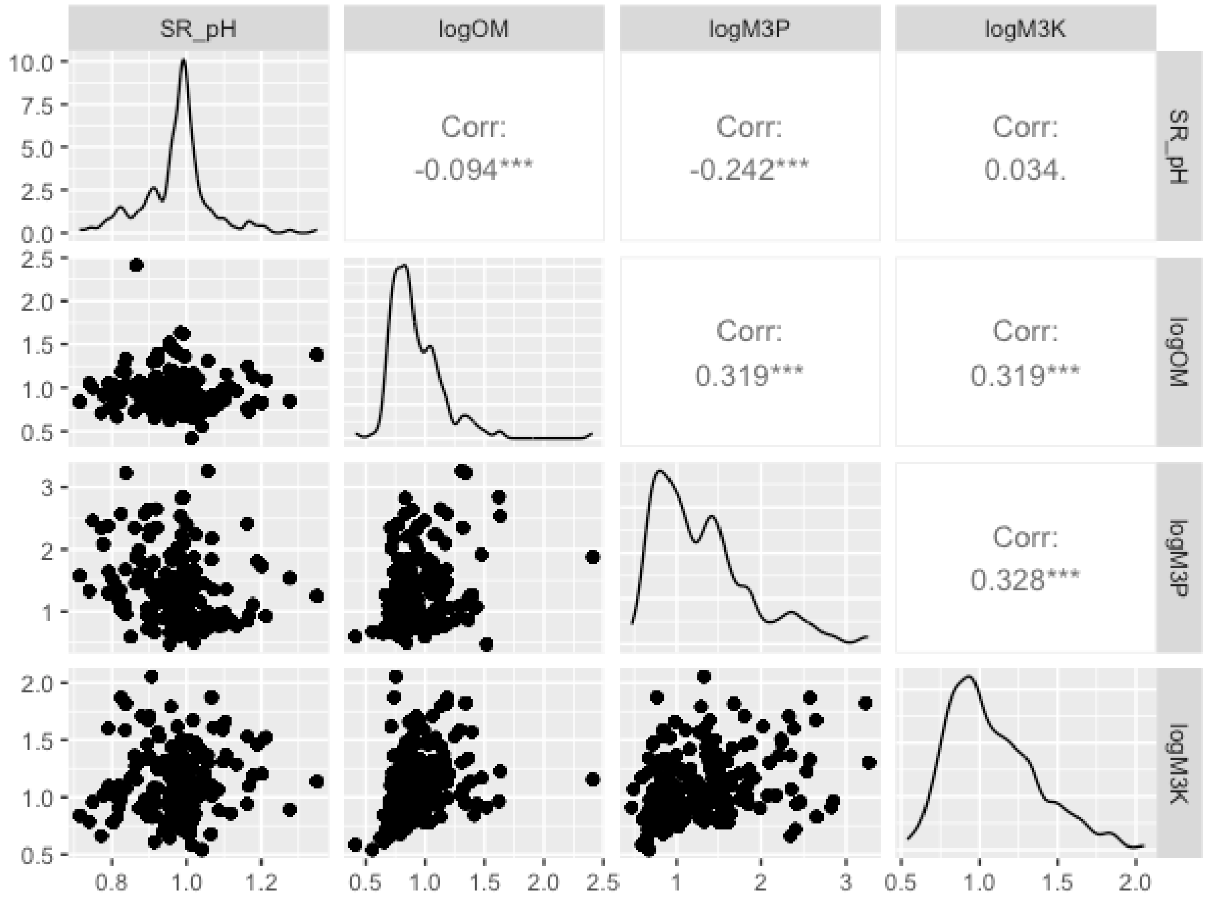
Degree of stratification in a field is inconsistent across soil properties

(weak correlations of SRs b/n pH, OM, M3P, M3K)

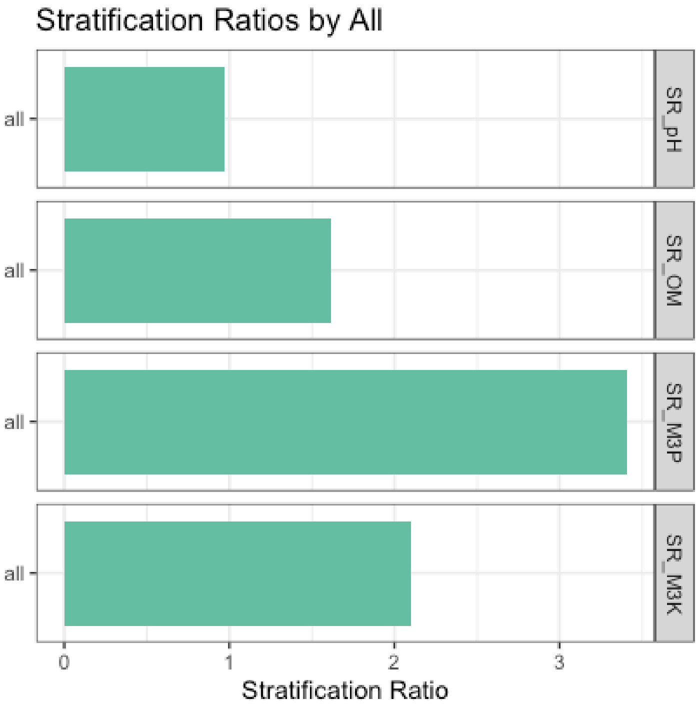
Correlations of SRs (Raw Data)

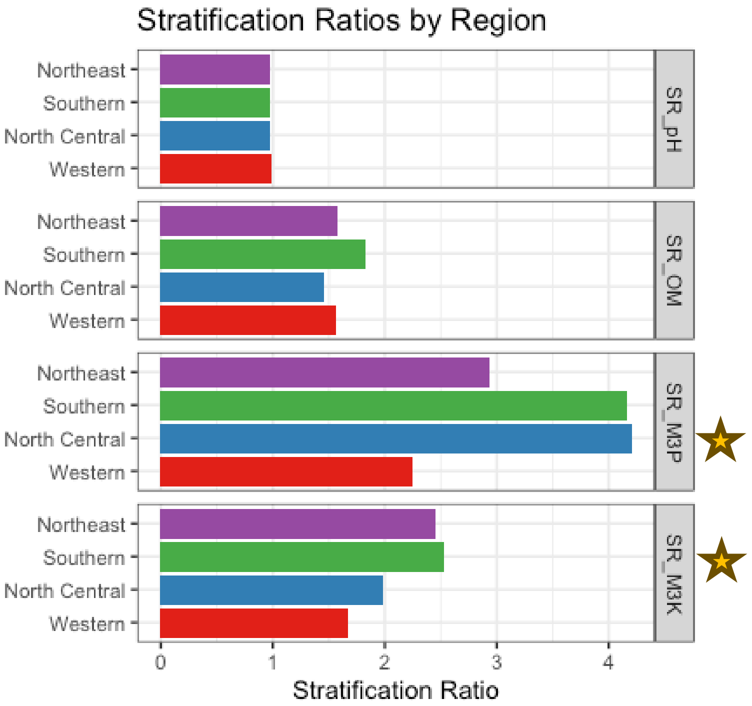


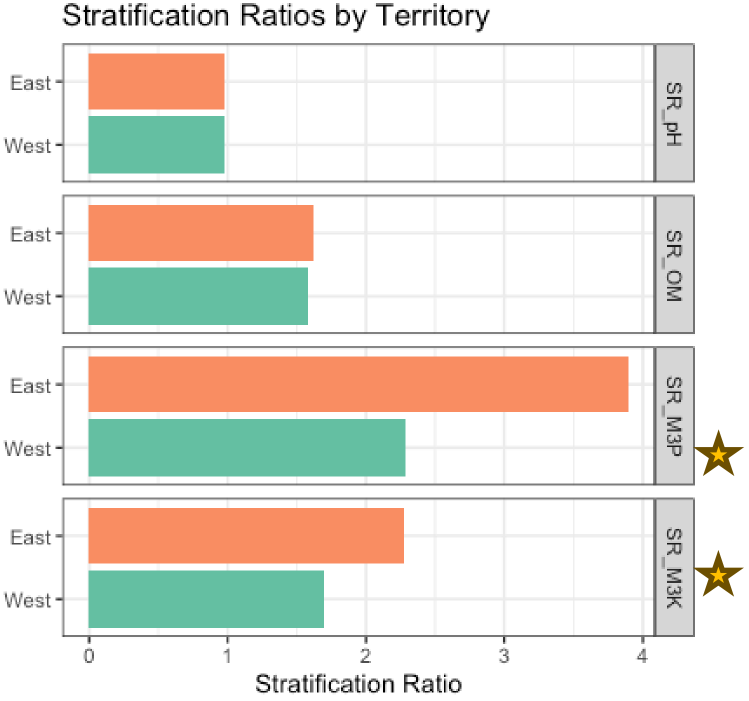
Correlations of SRs (OM, M3P, M3K log-transformed)

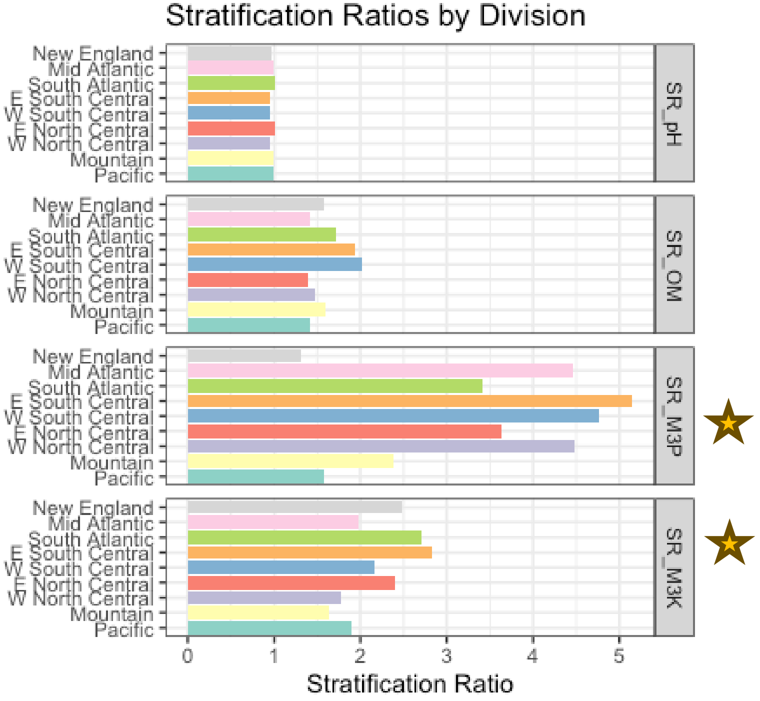


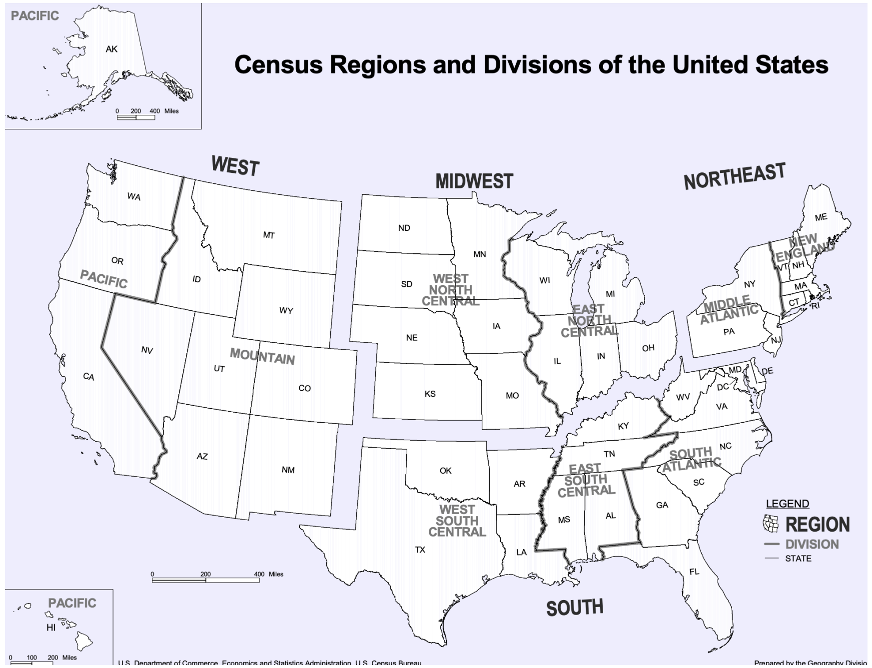
Stratification Ratios by Geography







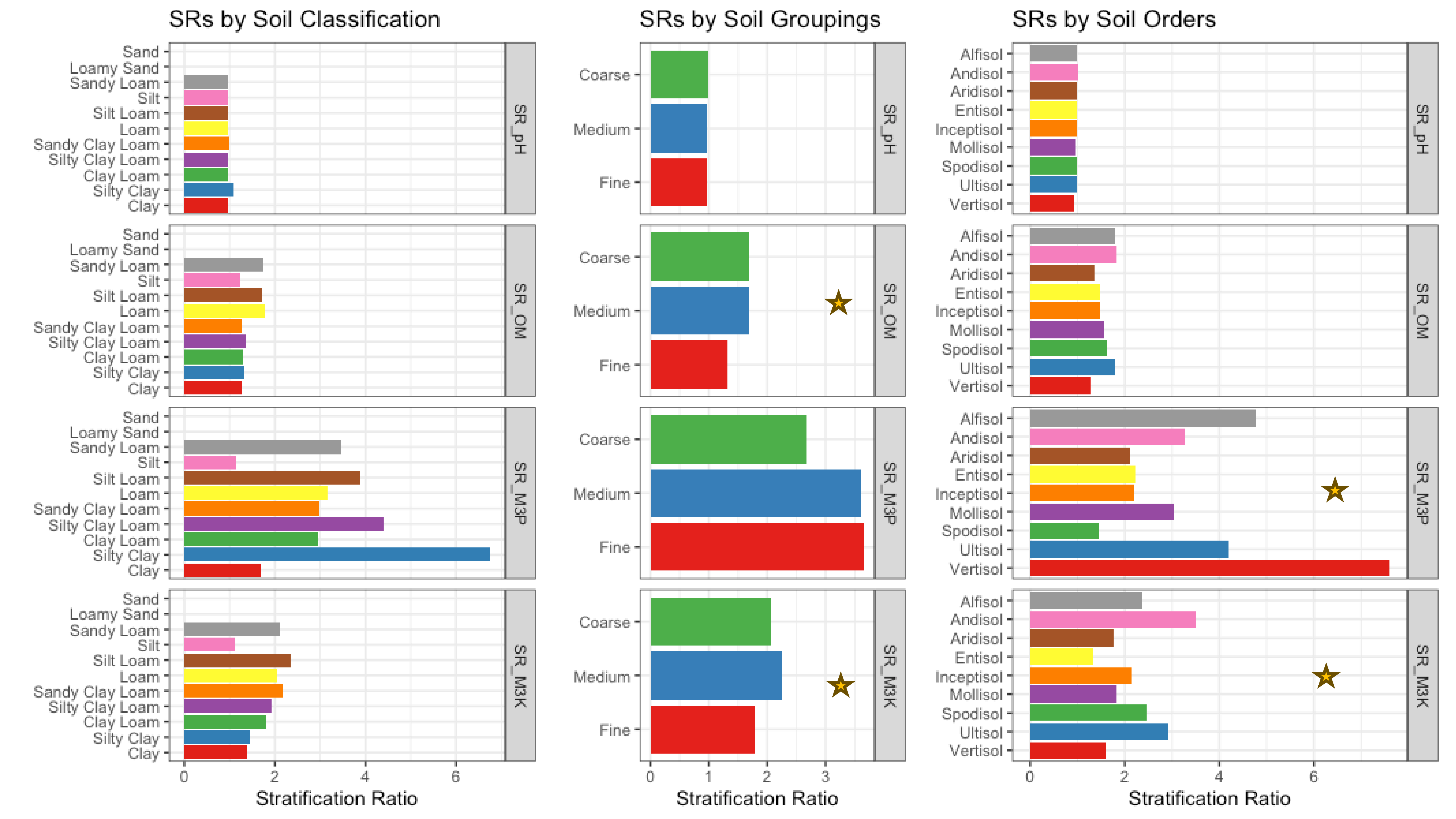




Exploring Trends with Soil Stratification

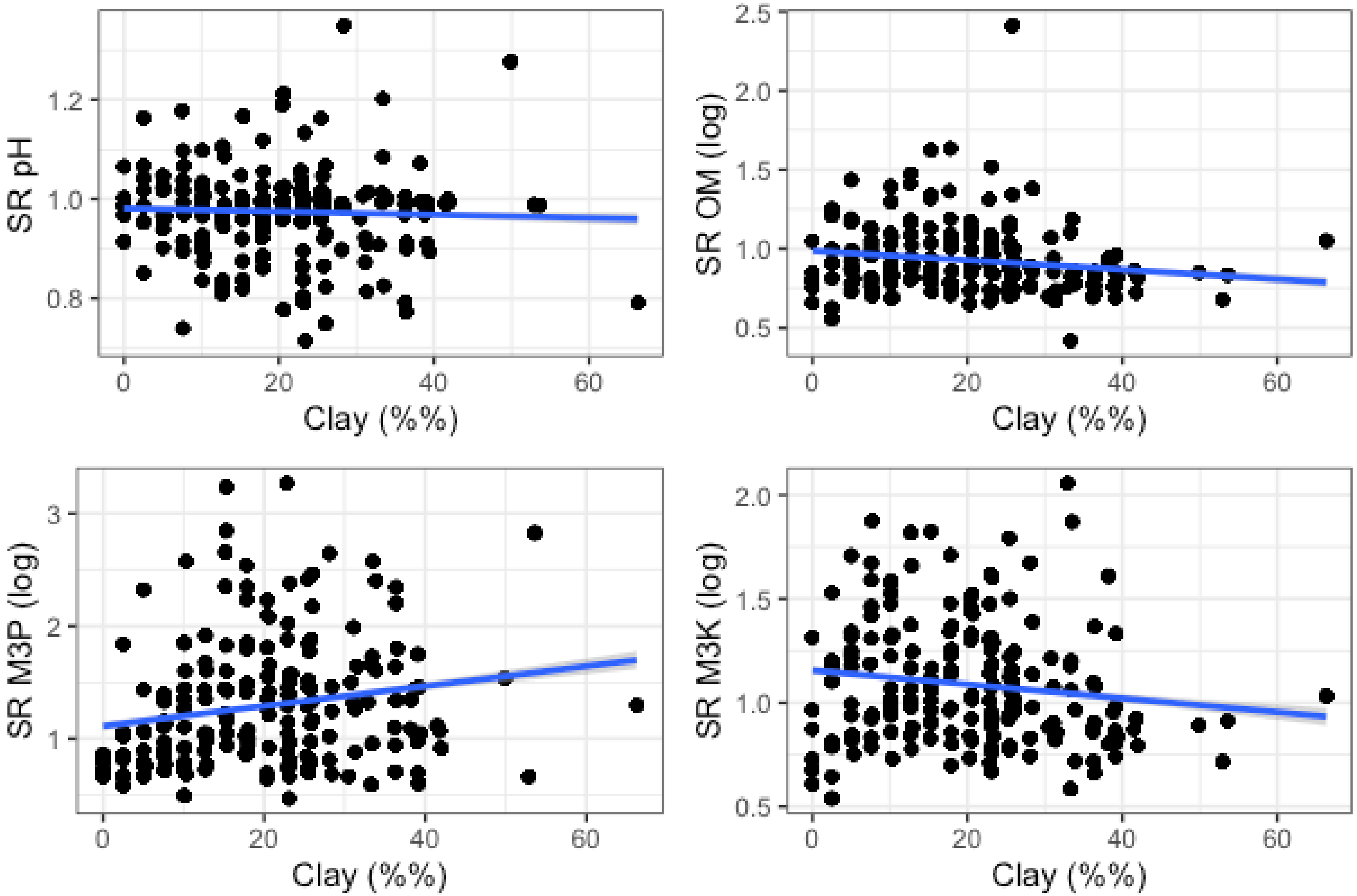
2. Soil Properties

a. Soil Textural Classifications
b. Soil Textural Groupings
c. Soil Order
d. % Clay



SRs by Soil Classification
SRs by Soil Groupings
SRs by Soil Orders
Sand
Loamy Sand
Sandy Loam
Silt
Silt Loam
Loam
Sandy Clay Loam
Silty Clay Loam
Clay Loam
Silty Clay
Clay
Coarse
Medium
Fine
Alfisol
Andisol
Aridisol
Entisol
Inceptisol
Mollisol
Spodisol
Ultisol
Vertisol
SR_pH
SR_OM
SR_M3P
SR_M3K
0
2
4
6
0
1
2
3
Stratification Ratio

Influence of Clay on Stratification Ratios

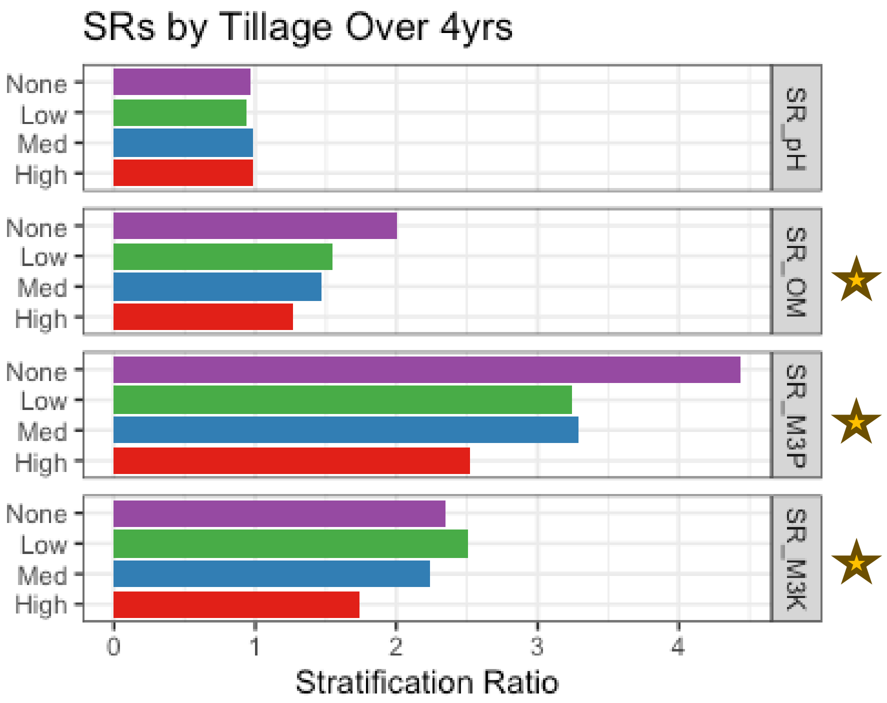


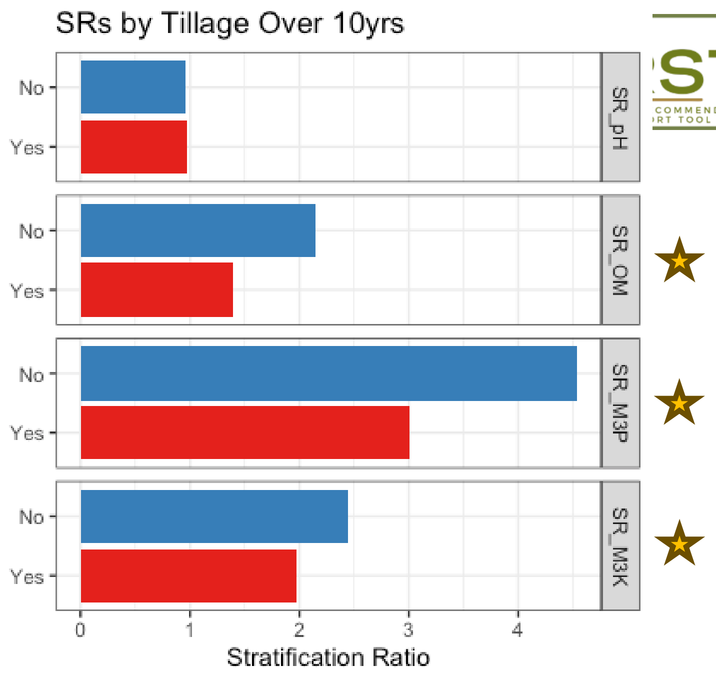
Exploring Trends with Soil Stratification

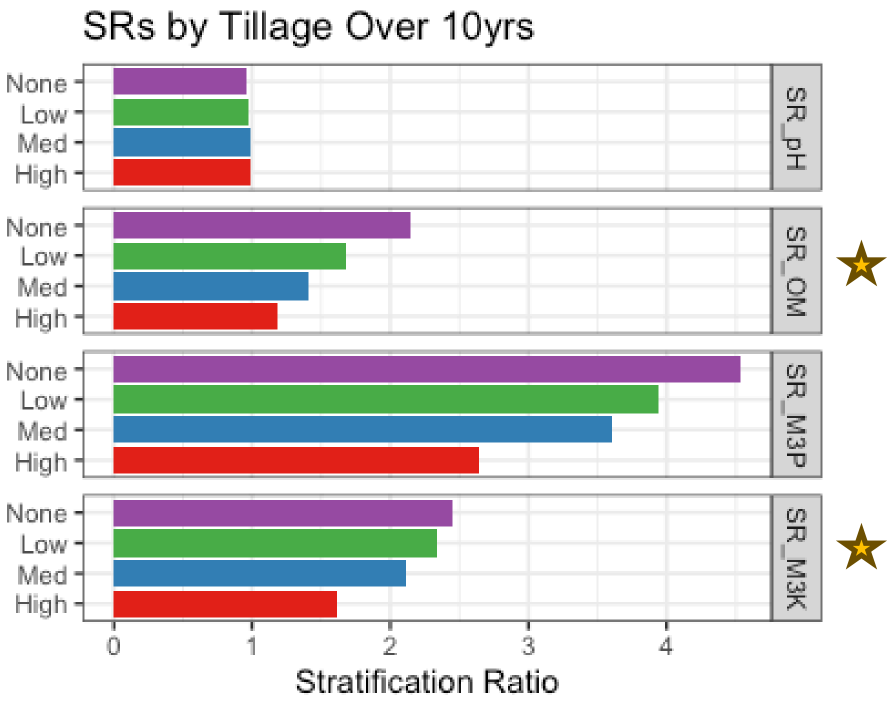
2. Management

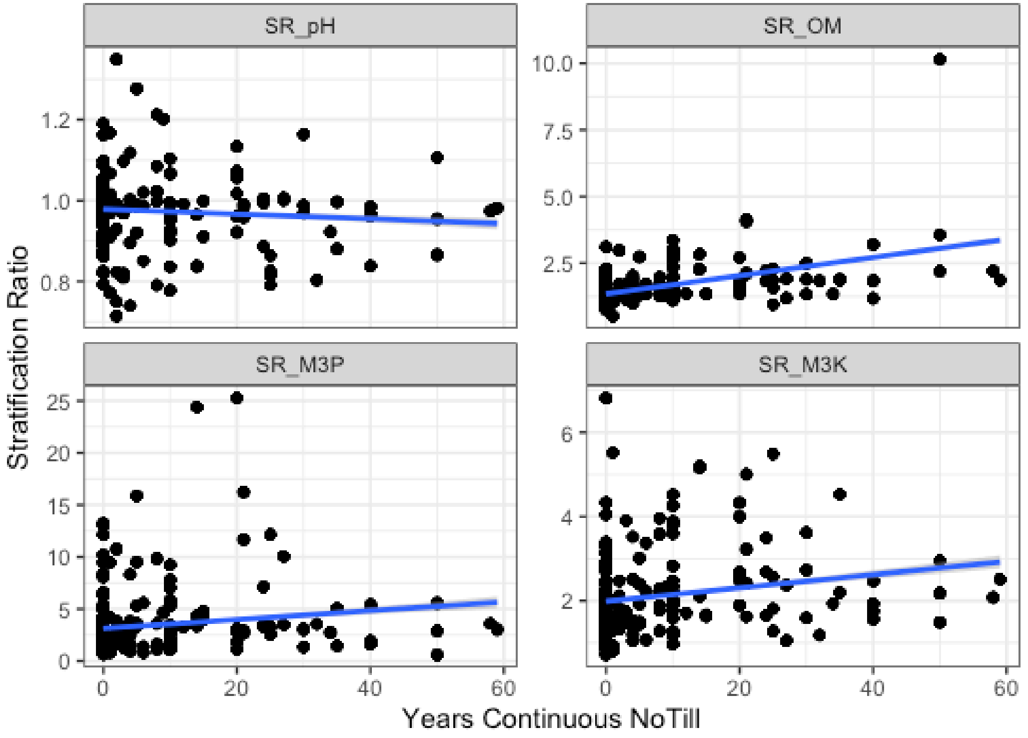
a. Tillage
b. NPK Fertilization, Lime
c. Perennials, Cover Crops, Manure

SRs by Tillage Practices

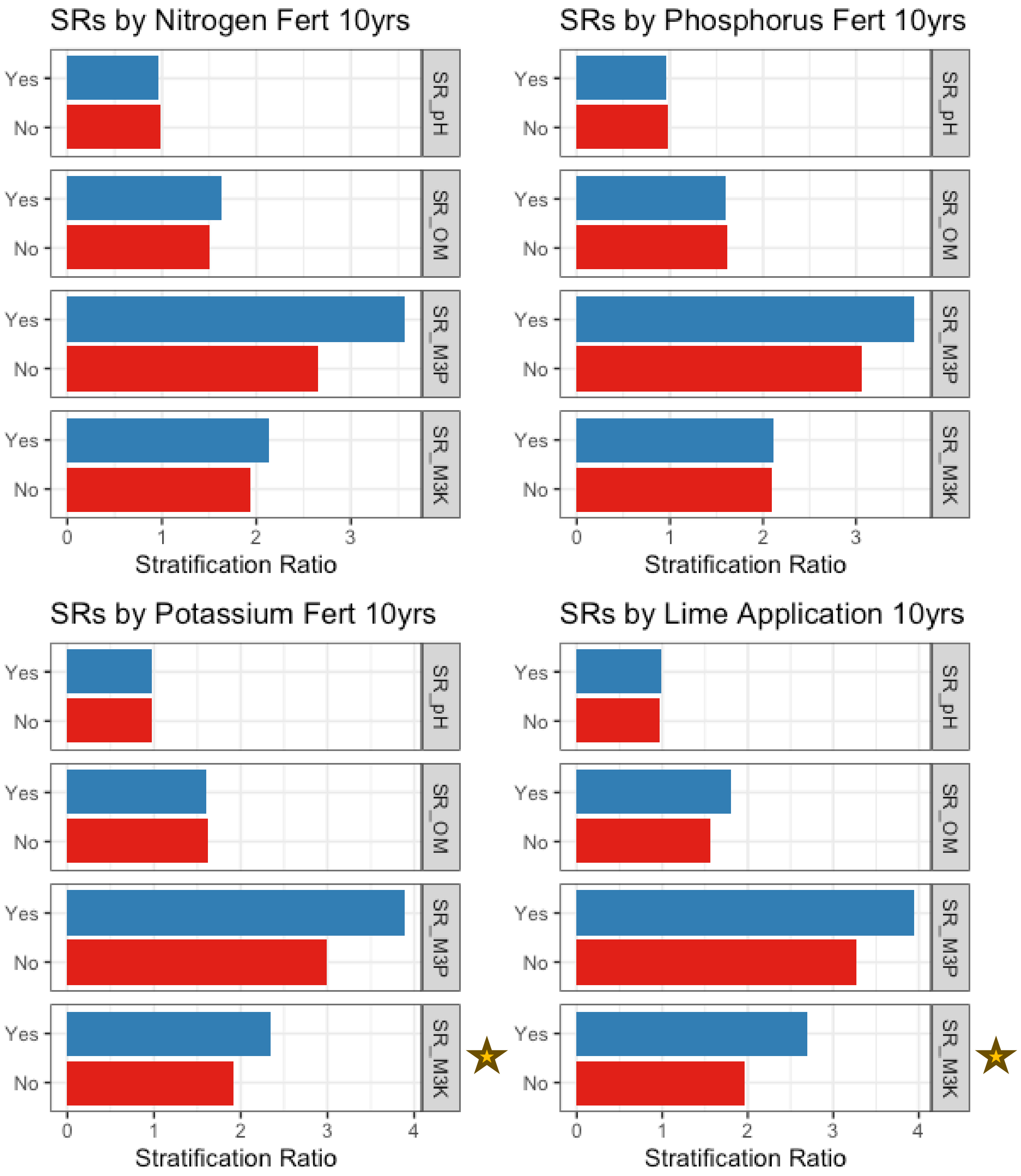




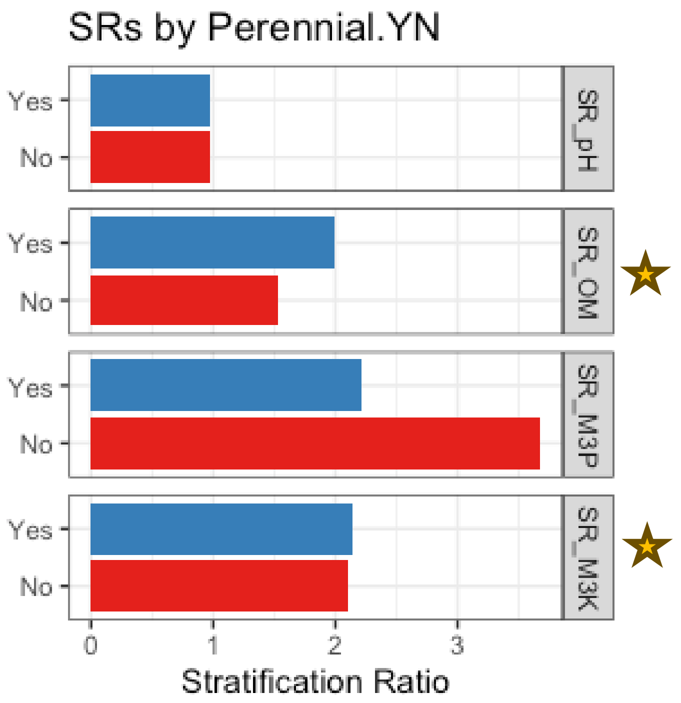


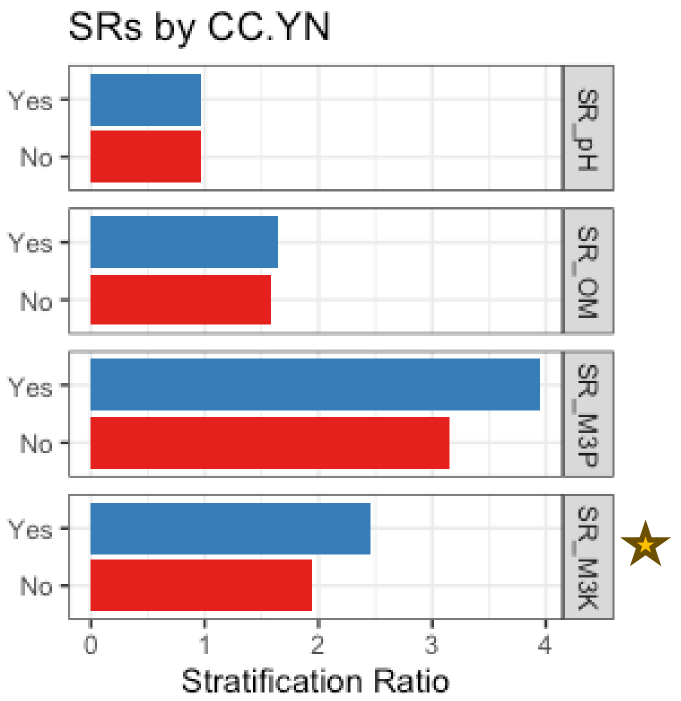


SRs by Fertilizer Practices

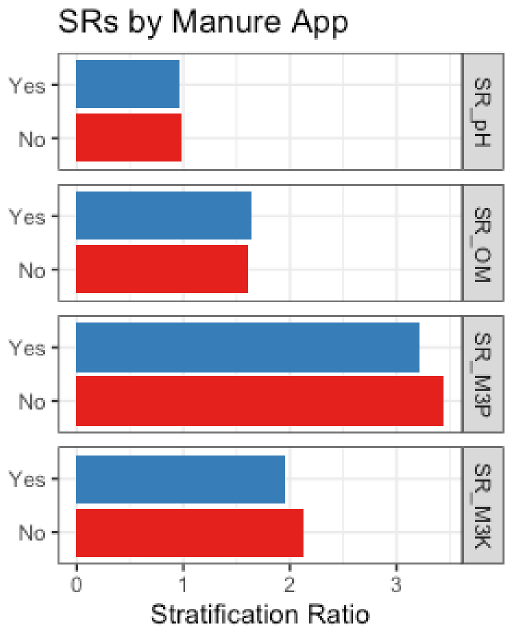


Perennials, Cover Crops, Manure





SRs by Manure Application



Drivers of Soil Stratification Summary

- SRs b/n pH, OM, M3P, M3K within a field were poorly correlated
- Geography
  - Eastern soils more stratified with P and K than Western soils
- Soil Texture
  - Fine soils < SRs than Coarse and Med with OM and M3K
  - Soil Orders impacted SRs in P, K

- Management
  - Tillage: impacted SRs in OM, M3P, M3K
  - Fertilizer: trends with P and K, only significant with K
  - Manure: no trends
  - Perennials and CCs for 4 yrs: OM and M3K

How do we get at drivers of soil stratification?

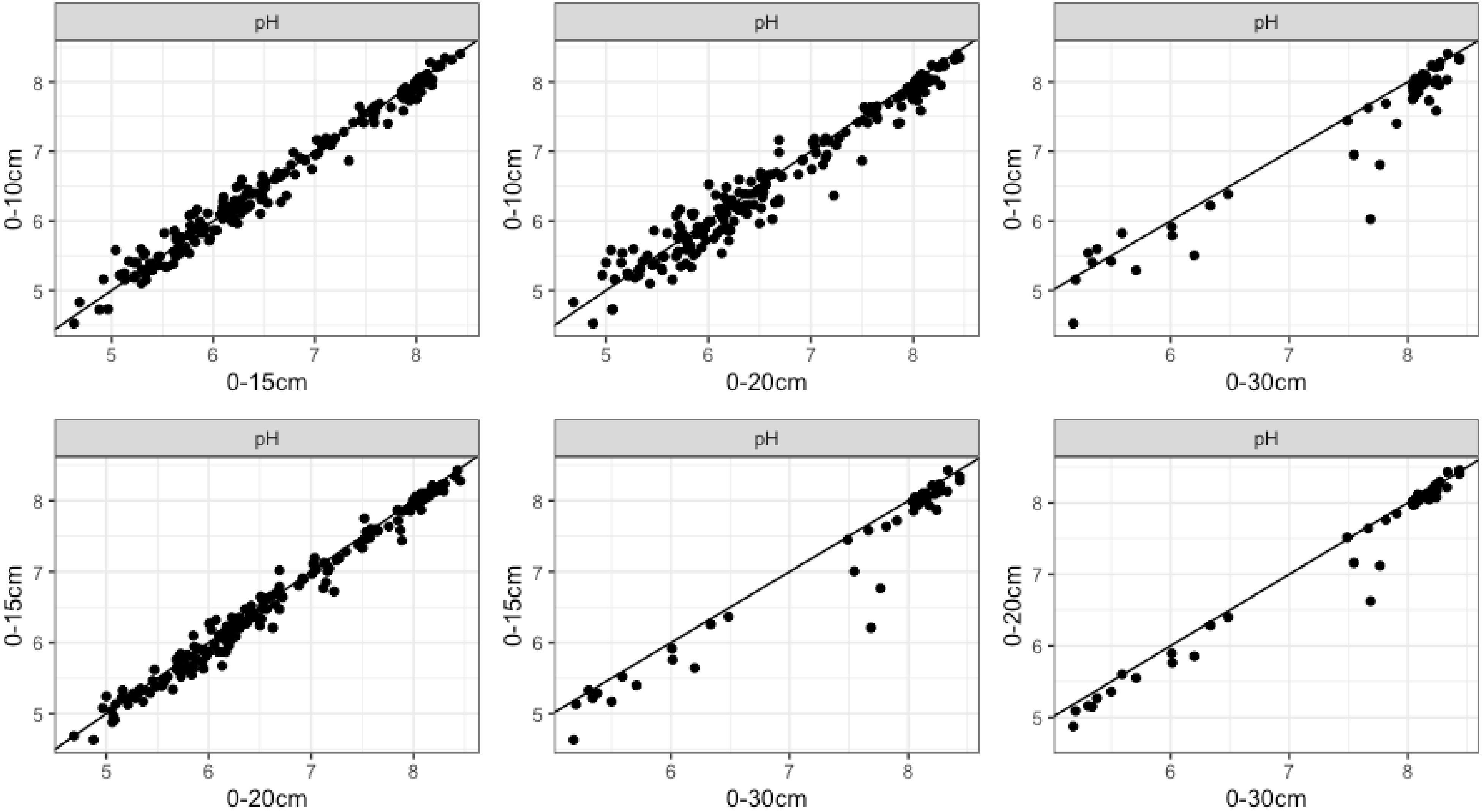
How do we tease apart these relationships and quantify relative effects of factors driving stratification?

- Showing relationships with past management
  - Numeric variables = weak relationships
  - Discrete variables = clearer trends
- F-statistics with ANOVAs as a relativized metric of effect size?
- T-statistics with MLR?
- Other ideas??

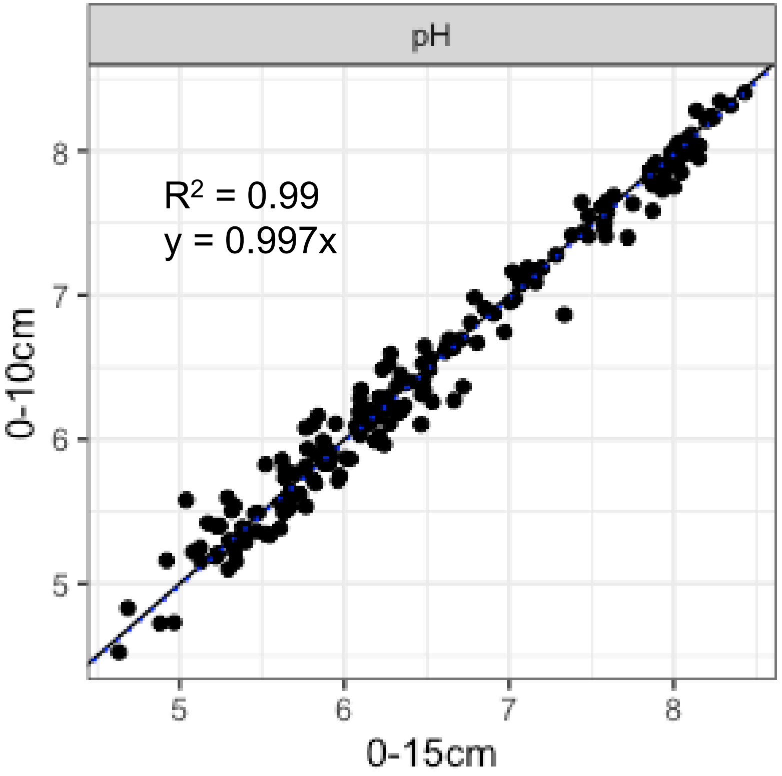
Question #2:

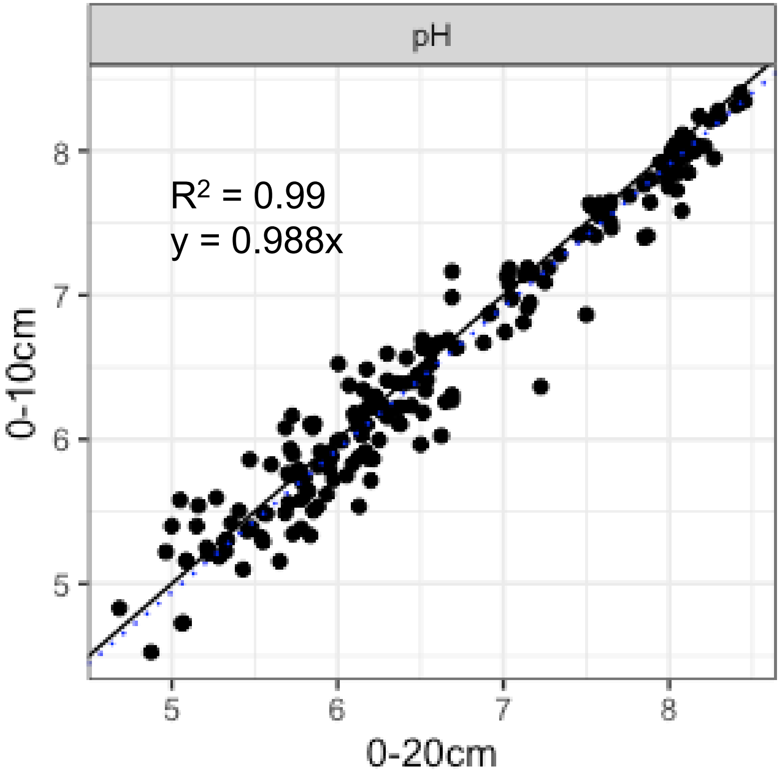
Can we develop generalized equations to convert soil test values to a depth different than what was sampled?

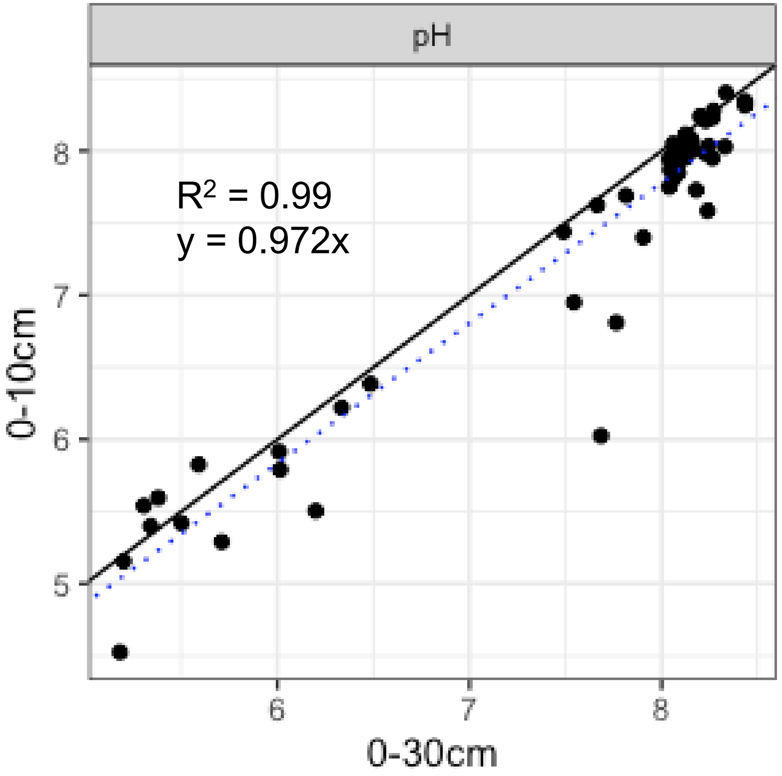
Soil pH – Full cores



Soil pH


pH
R² = 0.99
y = 0.997x
0-10cm
0-15cm
5
6
7
8


pH
R² = 0.99
y = 0.988x
0-10cm
0-20cm
5
6
7
8


pH
R² = 0.99
y = 0.972x
0-10cm
0-30cm
5
6
7
8

Standard Major Axis Regression

Variable	depths	Intercept	Slope	r2	pval	slope.r	slope.p
pH	x10.15	0.094	0.983	0.965	0.000	-0.089	0.079
pH	x10.20	0.046	0.982	0.938	0.000	-0.070	0.165
pH	x10.30	-0.348	1.019	0.899	0.000	0.056	0.586
pH	x15.20	-0.051	0.999	0.973	0.000	-0.005	0.914
pH	x15.30	-0.610	1.057	0.941	0.000	0.217	0.034
pH	x20.30	-0.515	1.055	0.970	0.000	0.290	0.004
OM	x10.15	-0.159	1.136	0.925	0.000	0.408	0.000
OM	x10.20	-0.202	1.204	0.863	0.000	0.425	0.000
OM	x10.30	-1.456	1.780	0.733	0.000	0.710	0.000
OM	x15.20	-0.016	1.053	0.948	0.000	0.215	0.000
OM	x15.30	-0.266	1.215	0.890	0.000	0.486	0.000
OM	x20.30	0.006	1.084	0.917	0.000	0.260	0.010
M3P	x10.15	6.295	1.027	0.977	0.000	0.169	0.001
M3P	x10.20	11.644	1.053	0.953	0.000	0.228	0.000
M3P	x10.30	-8.300	1.636	0.698	0.000	0.615	0.000
M3P	x15.20	5.332	1.024	0.986	0.000	0.195	0.000
M3P	x15.30	-3.552	1.394	0.861	0.000	0.645	0.000
M3P	x20.30	1.961	1.148	0.924	0.000	0.435	0.000
M3K	x10.15	7.852	1.075	0.968	0.000	0.370	0.000
M3K	x10.20	11.153	1.152	0.948	0.000	0.519	0.000
M3K	x10.30	-13.583	1.354	0.844	0.000	0.583	0.000
M3K	x15.20	3.551	1.069	0.982	0.000	0.446	0.000
M3K	x15.30	-9.130	1.218	0.939	0.000	0.614	0.000
M3K	x20.30	-14.258	1.146	0.963	0.000	0.571	0.000

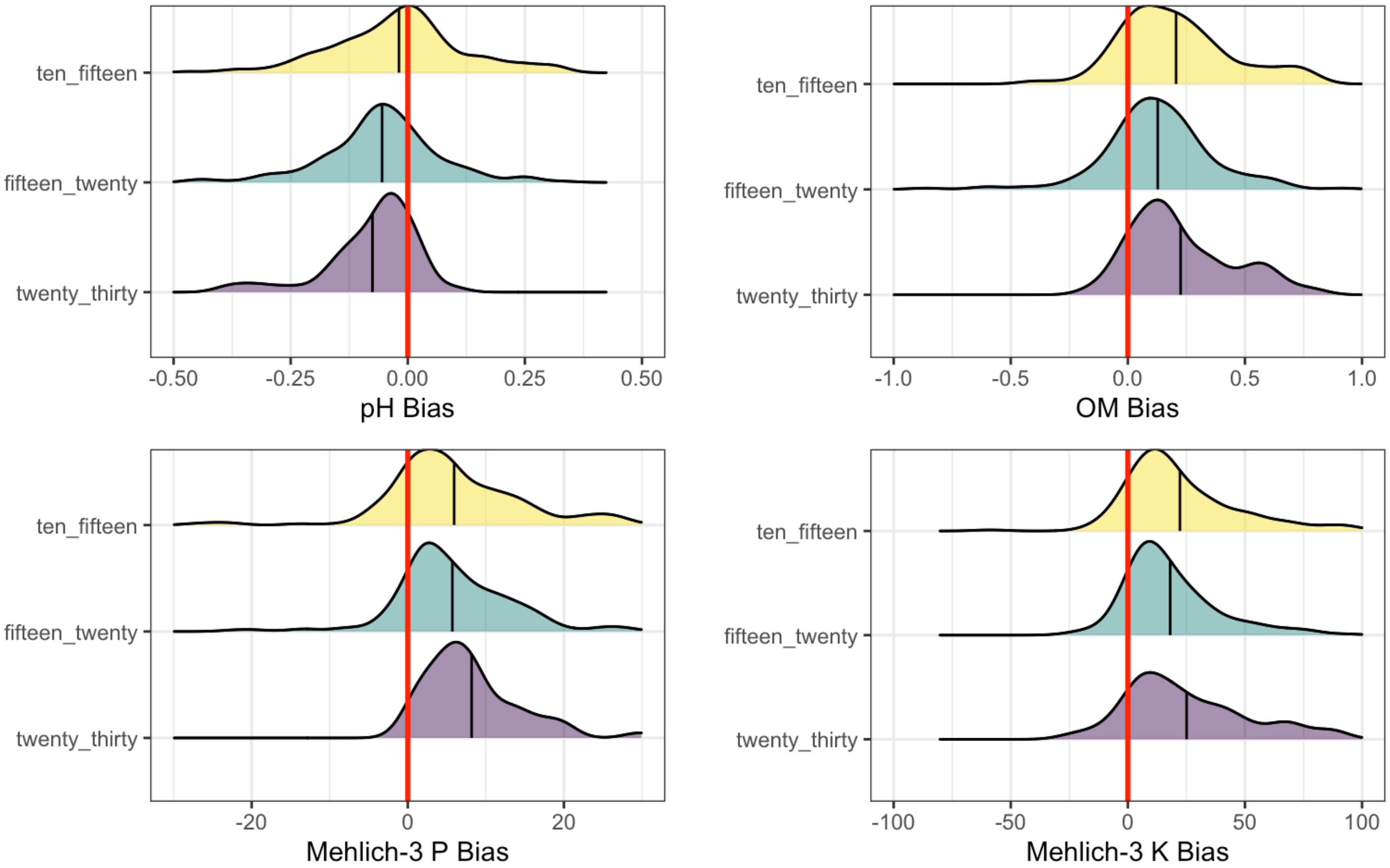
Agreement and Tolerance Tests

- Developed in medical field to compare agreement of two test with different methodologies

- Requires setting agreement/tolerance limits a priori
  - What are they for this context??

- Calculates Bias → average (test_a – test_b)

Distributions of Bias (shallow – deeper depth)



Next Steps to Contemplate

- Conversion equations are possible, but might not be appropriate
  - Stratification uncertainty if measurements aren't made
- Appropriateness and value of local vs. global conversion factors?
  - How to decide?
- SRs only ➔ 0-5cm/15-20cm, other depths possible