ILLINOIS
Crop Sciences
COLLEGE OF AGRICULTURAL, CONSUMER
& ENVIRONMENTAL SCIENCES

2026 ALTA Winter Workshop

Transitioning from Water pH to Buffer pH-based Liming Recommendations

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Alternate title:
What value does a buffer pH-based liming recommendation need to provide to warrant adoption in Illinois?

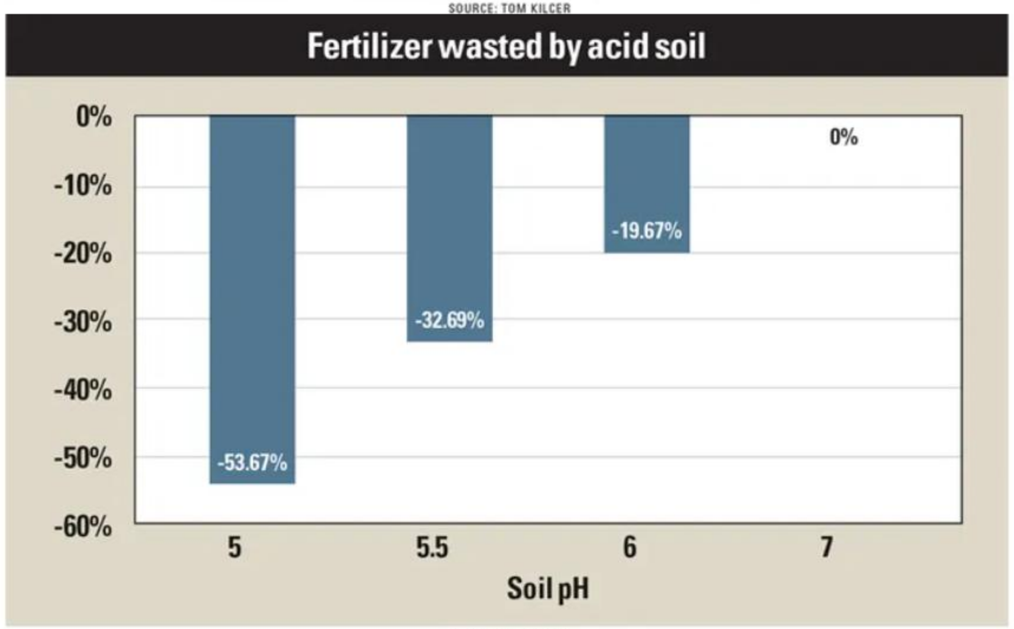
Audience Feedback

- Use the QR code or meeting ID to respond or submit comments/questions (they will be cataloged).
- #2016728
- https://app.sli.do/event/eaqaQcouatJf446Ufh3nRN

Messaging to support liming is not always supported with correct data

Soil pH	Nitrogen efficiency	Phosphorus efficiency	Potassium efficiency
7.0	100%	100%	100%
6.0	89%	52%	100%
5.5	77%	48%	77%

SOURCE: TOM KILCER



SOURCE: TOM KILCER

https://www.farmprogress.com/crop-protection/2-ways-to-stave-off-high-fertilizer-prices

HOW SOIL pH AFFECTS FERTILIZER EFFICIENCY

Soil pH	Nutrient Availability			Fertilizer Efficiency
	Nitrogen	Phosphate	Potash	
7.0	100%	100%	100%	100%
6.0	89%	52%	100%	80%
5.5	77%	48%	77%	67%
5.0	53%	34%	52%	46%
4.5	30%	23$	33%	29%

https://www.agriculture.com/crops/soil-health/soil-ph-keys-soil-fertility

Wasted (Unavailable)

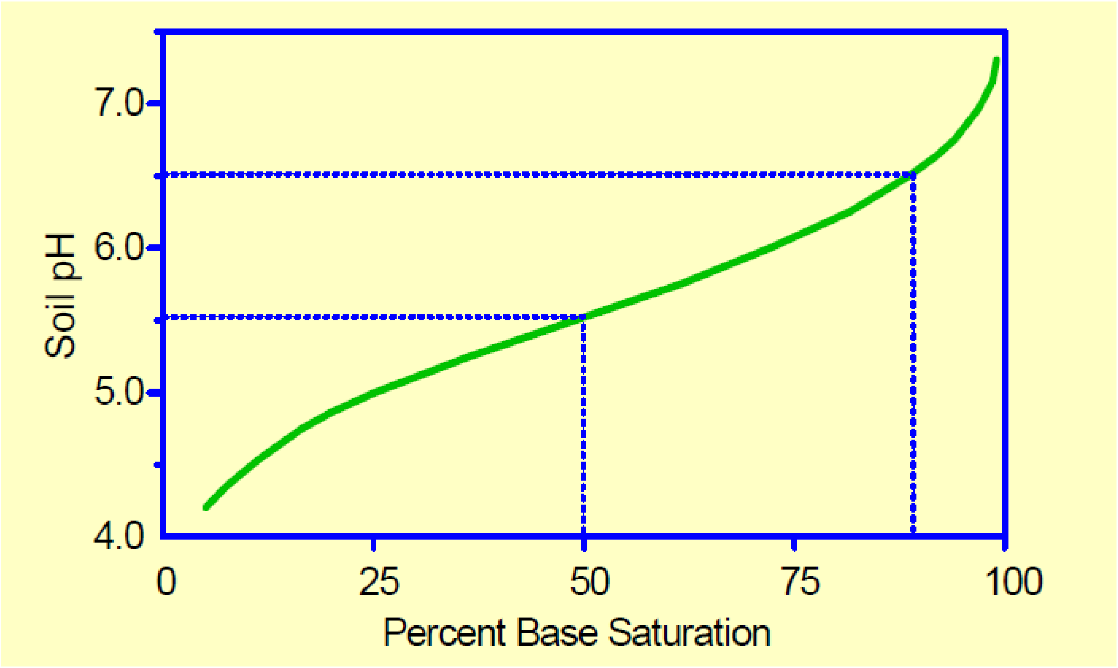
pH	Nitrogen (N)	Phosphorus (P)	Potassium (K)
6.5	0%	0%	0%
6.0	11%	48%	0%
5.5	23%	52%	23%
5.0	47%	66%	48%
4.5	70%	77%	67%

Table: Farm Journal • Source: Iowa State University • Get the data • Created with Datawrapper

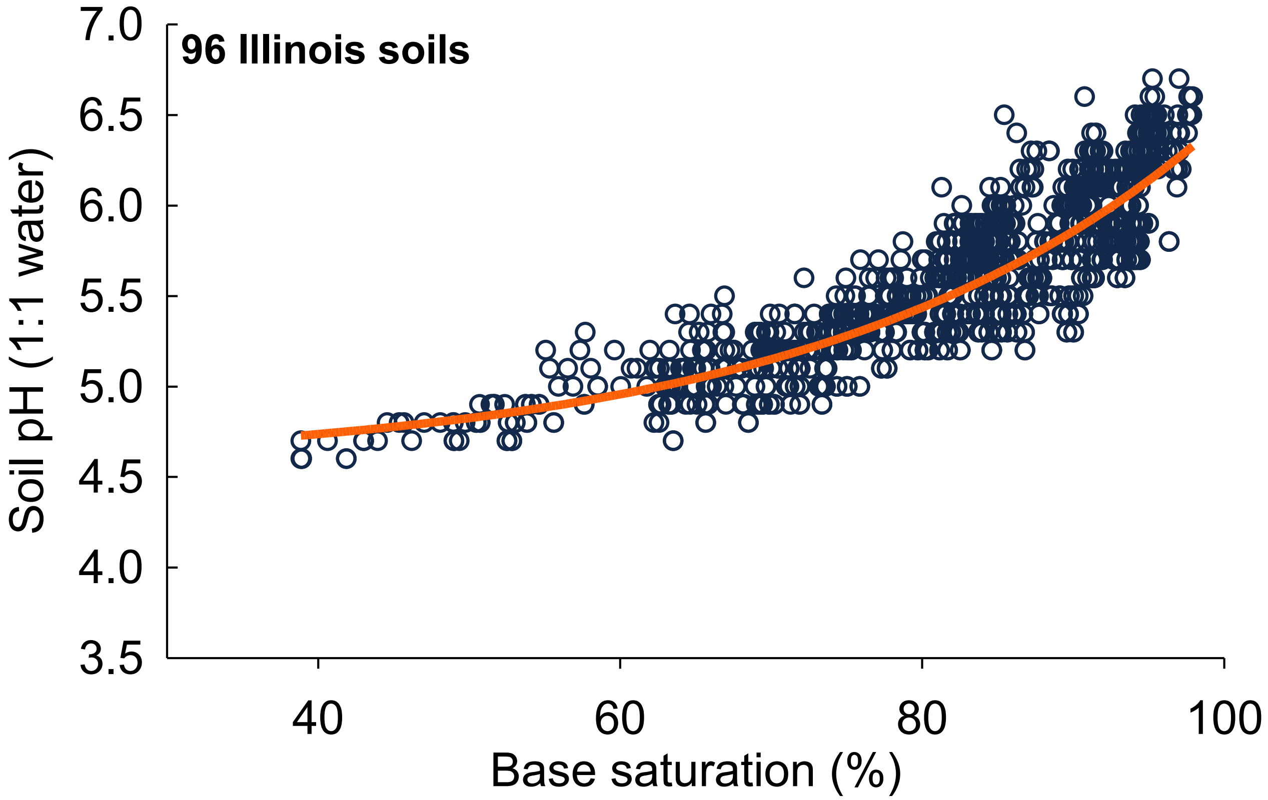
https://www.agweb.com/news/crops/farm-journal-test-plots/can-you-cut-fertilizer-expenses

Certainly some principles do hold up.

Expected “textbook” Relationship between pH and BS%



Sawyer (2020)

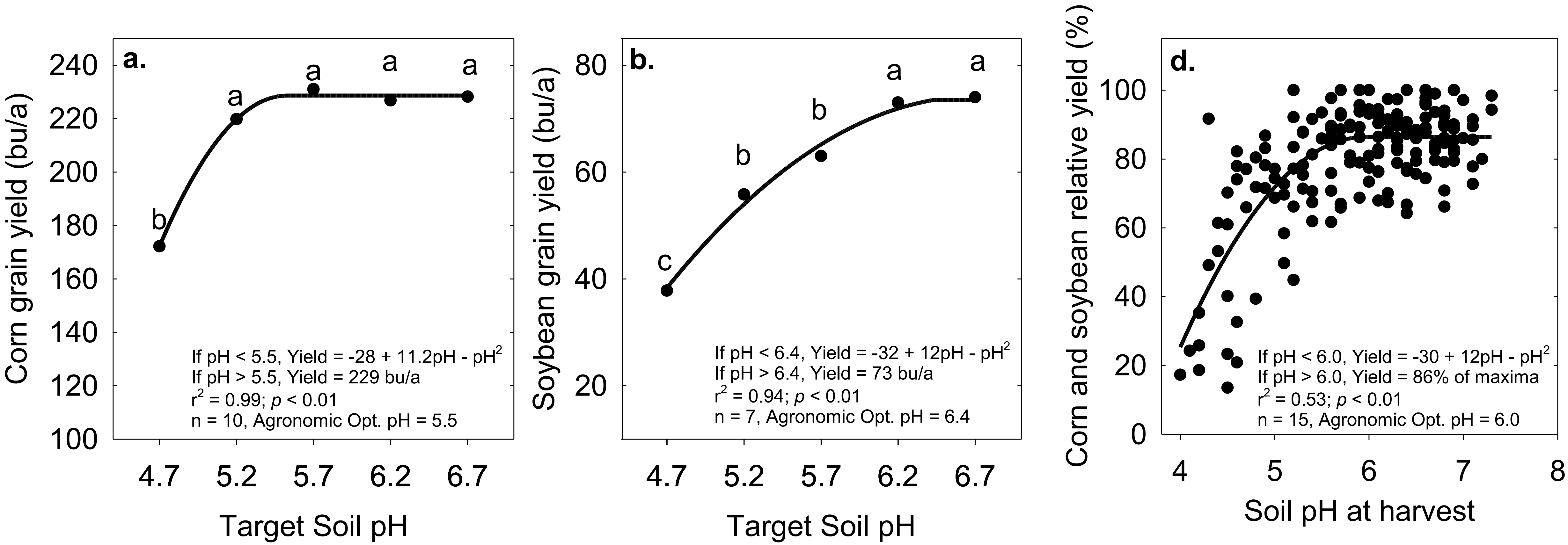


Jones (2025)

We know pH is important, but rarely have recent data to explain why...

Long-term soil pH & crop yield trends

2003-2024; sandy loam soil texture



Study started by Keith Kelling (retired Soil Fertility Specialist) ~2003

Soil (water) pH trends in lower 48 states

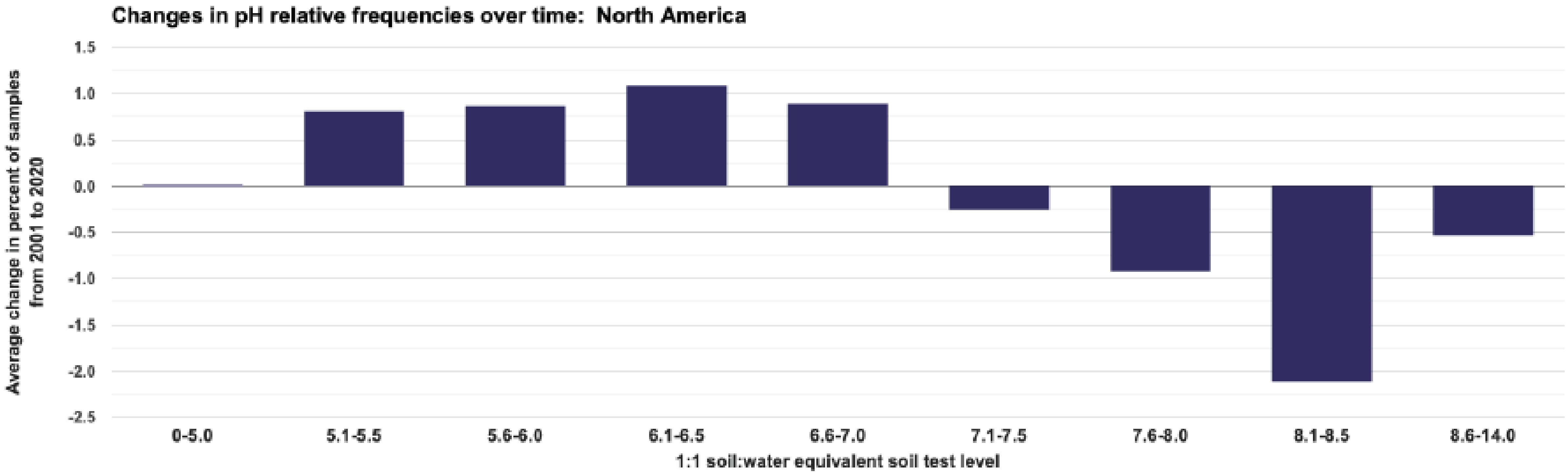


Figure 13. Average change in pH soil test levels from 2001-2020.

2020 North American Soil Test Summary

Two main points regarding state-to-state variability of recommendations

- Lime committee of Fertilizer Recommendation Support Tool conducted a state recommendation survey 2022-2023.
- Each state sent 6 soils and asked to respond with LR method and recommendation.
- Assumed 6.5 target pH, 100% ENV
- Results showed LARGE range

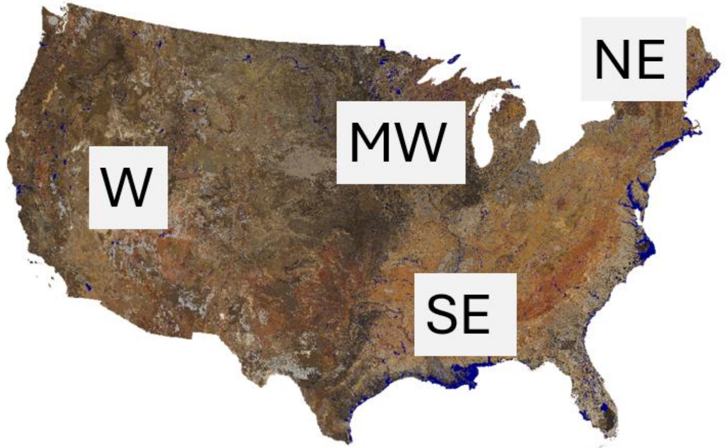
Soil Science Society of America Journal
SSSA Soil Science Society of America
REVIEW | Open Access

Assessment of soil pH and lime requirement methods and recommended lime rates for six reference soils across US land grant institutions

John D. Jones, Robert O. Miller, John T. Spargo, Frank J. Sikora, Manbir K. Rakkar, Nathan A. Slaton, Deanna L. Osmond

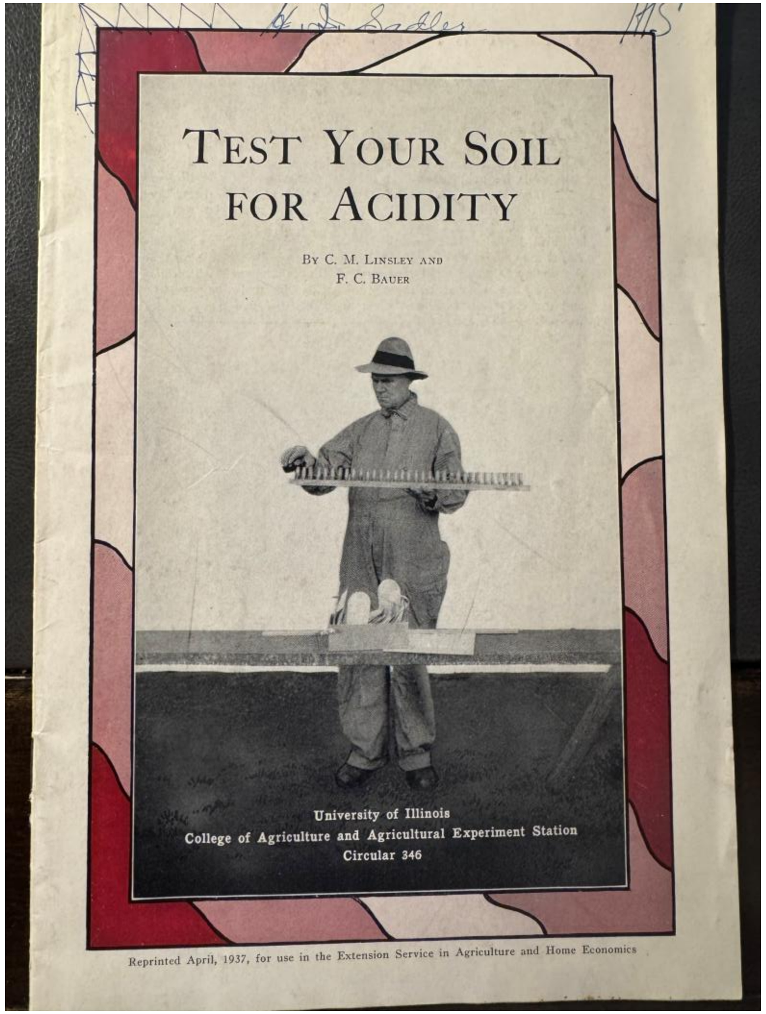
Soil pH methods

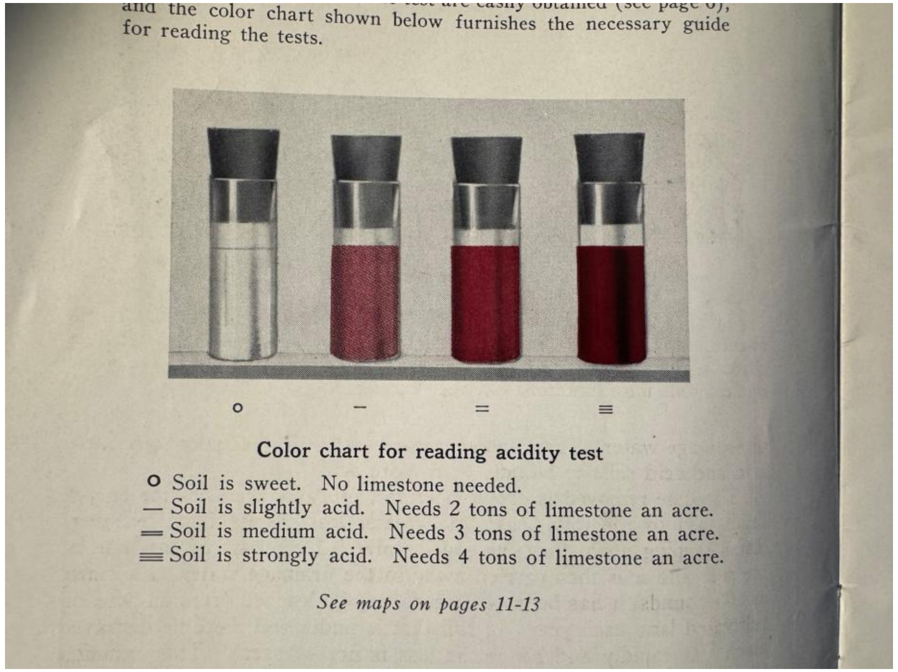
1. 1:1 H_2O (SE, NE, MW, W)
2. 1:1 0.01M $CaCl_2$ (SE, MW)
3. Saturated Paste (W)
4. 1:2 0.01M $CaCl_2$ (MW)
5. 1:1 1.0N KCl (SE)
6. 1:2 H_2O (W)
7. 1:5 H_2O



Adapted from Miller, 2020

Quick ‘tests’ for liming predated buffer pH use




and the color chart shown below furnishes the necessary guide for reading the tests.

o — = ≡

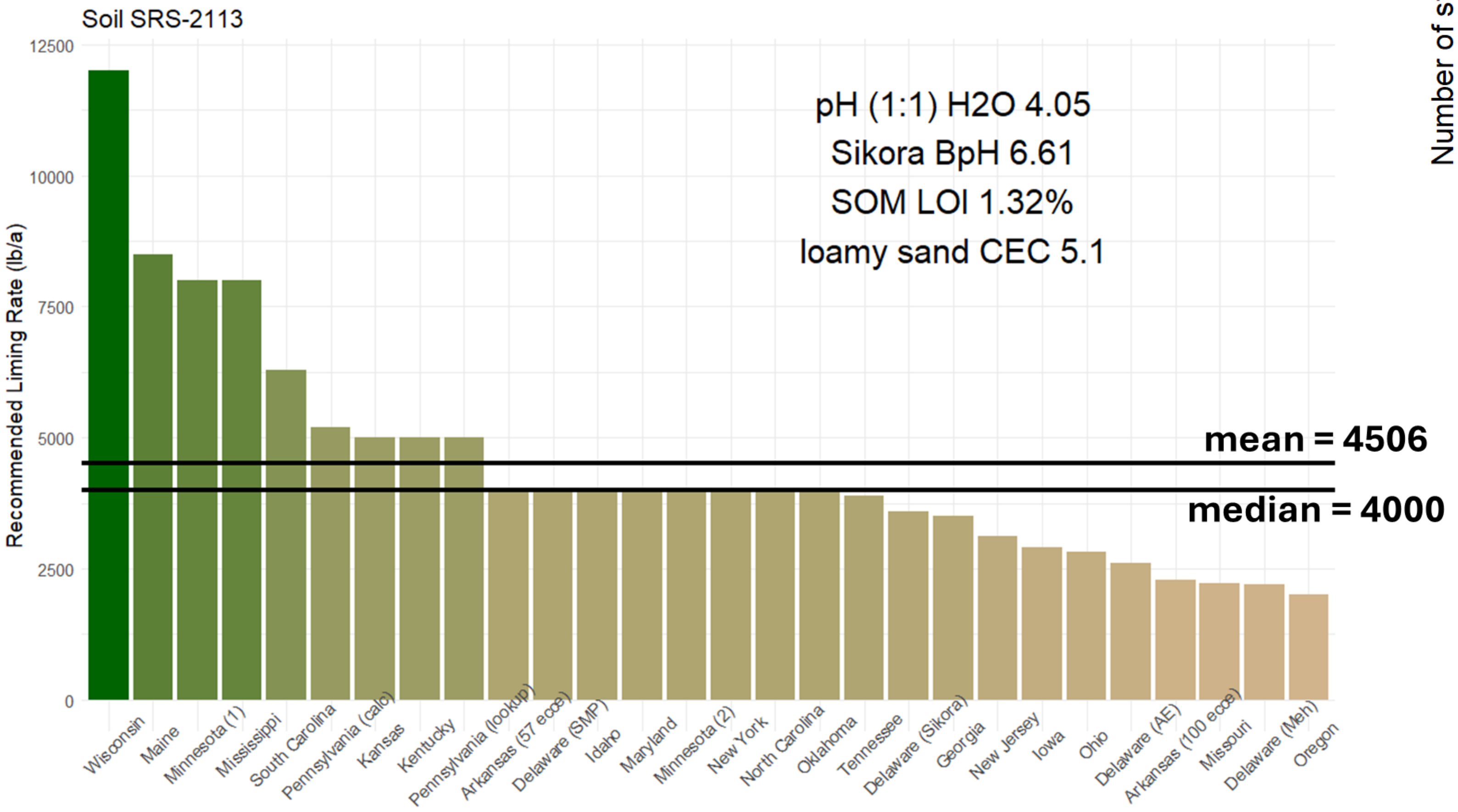
Color chart for reading acidity test

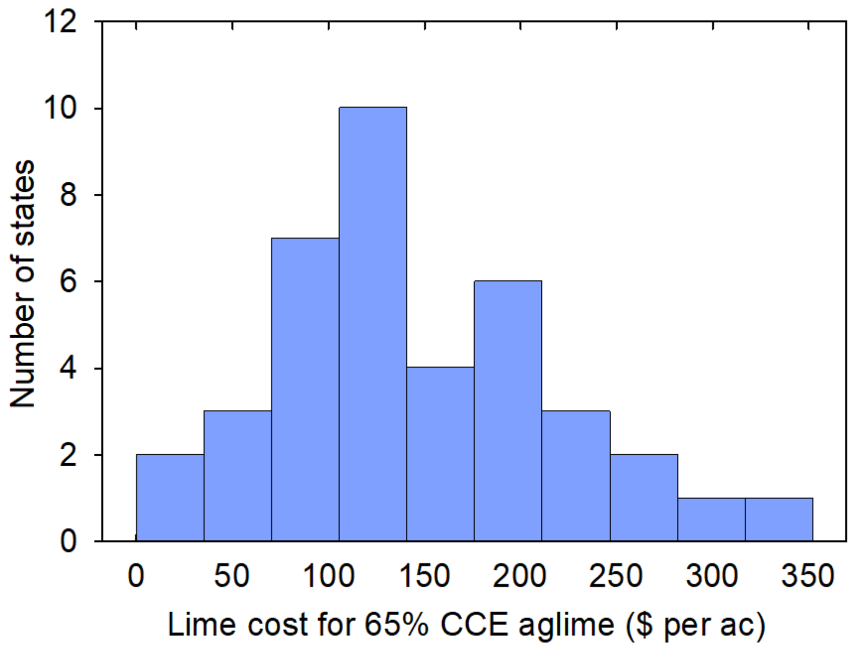
o Soil is sweet. No limestone needed.
— Soil is slightly acid. Needs 2 tons of limestone an acre.
= Soil is medium acid. Needs 3 tons of limestone an acre.
≡ Soil is strongly acid. Needs 4 tons of limestone an acre.

See maps on pages 11-13

Large variation in state recommendations

one soil shown below



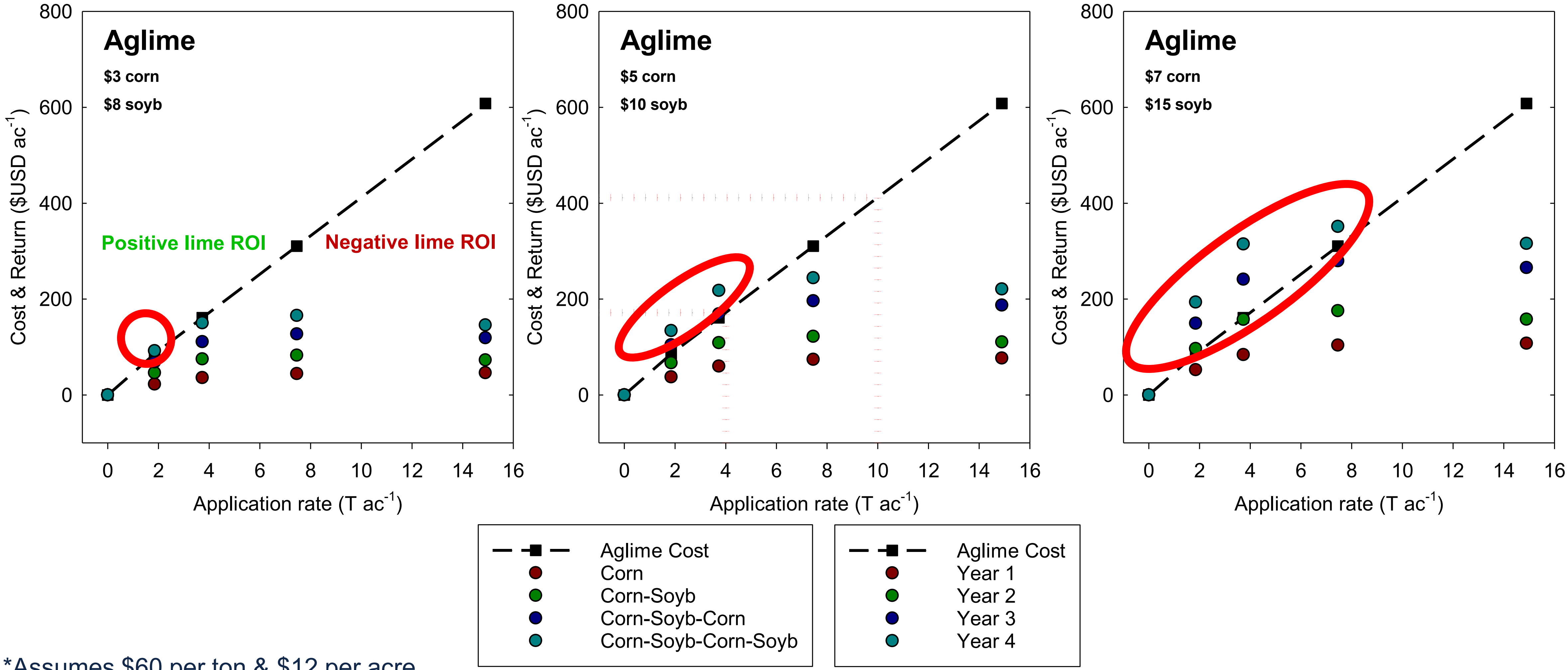


Major economic implications

Jones et al., 2025

Economics of Liming Example – Aglime

Aggregation of IA & WI lime response data



*Assumes $60 per ton & $12 per acre tillage/incorporation

Jones and Mallarino (unpublished)

TABLE 2. Median soil test phosphorus, potassium, soil pH, and soil organic matter levels for the U.S. and the North-Central region and its states from 2001 to 2020.

Year	CONUS[a]	North Central	IL	IN	IA	KS	MI	MN	MO	NE	ND	OH	SD	WI
	Phosphorus (Bray-1 equivalent, ppm)													
2001	27	26	36	33	25	20	50	16	17	21	10	28	11	41
2005	31	27	36	29	25	21	49	18	18	22	11	25	14	39
2010	24	22	26	26	22	18	42	18	16	18	11	24	13	26
2015	26	23	25	24	25	21	37	21	20	21	11	21	15	27
2020	23	21	23	23	24	18	37	21	18	21	13	19	16	28
	Potassium (ammonium acetate equivalent, ppm)													
2001	154	161	150	130	153	331	129	159	147	373	275	151	279	111
2005	155	177	178	145	173	295	149	156	150	364	265	169	269	126
2010	152	164	179	130	161	274	131	160	144	340	236	145	247	133
2015	150	172	164	134	189	208	129	165	144	306	247	145	241	141
2020	141	155	155	131	180	211	125	166	131	285	247	134	213	117
	Soil pH													
2001	7.0	6.6	6.3	6.3	6.4	6.8	6.5	6.9	6.2	6.3	7.5	6.3	6.9	6.6
2005	7.0	6.6	6.3	6.4	6.4	6.8	6.7	7.0	6.3	6.4	7.5	6.3	7.0	6.6
2010	7.0	6.6	6.4	6.3	6.5	6.7	6.7	6.7	6.3	6.4	7.5	6.3	6.8	6.6
2015	7.0	6.6	6.3	6.3	6.4	6.4	6.7	6.7	6.4	6.4	7.5	6.4	6.8	6.7
2020	7.0	6.5	6.4	6.4	6.3	6.3	6.7	6.7	6.3	6.2	7.5	6.4	6.6	6.7
	Soil organic matter, %													
2020[b]	2.9	3.0	3.3	2.4	3.6	2.1	2.2	4.1	2.7	2.5	3.3	3.1	3.7	2.8

[a]Conterminous 48 U.S. states.
[b]Soil organic matter was first included in the 2020 summary.

Median state soil pH (surface depth) does not change drastically. Local issues will always need to be addressed

Jones et al., 2021

Illinois Liming Guideline Components

Illinois Agronomy Handbook (1997)

Table 8.3. Suggested limestone rates based on soil type, pH, cropping system, and 9-inch depth of tillage.

Soil type[a]	Soil pH value																				
	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	7.0
Tons of typical limestone[b] to apply to grain farming systems																					
A	8.0	8.0	8.0	8.0	8.0	8.0	7.8	7.0	6.3	5.5	4.8	4.0	3.3	2.5	1.8	1.0	Optional					
B	8.0	8.0	7.5	7.0	6.5	6.0	5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	Optional					
C	6.6	6.3	5.9	5.5	5.1	4.8	4.4	4.0	3.6	3.3	2.9	2.5	2.1	1.8	1.4	1.0	Optional					
D	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	Optional					
E	4.0	3.6	3.2	2.8	2.4	2.0																
Tons of typical limestone[b] to apply to forage farming systems (alfalfa, clover, lespedeza)																					
A	11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.3	9.6	8.9	8.1	7.4	6.7	6.0	5.3	4.6	3.9	3.1	2.4	1.7	1.0	Optional
B	11.0	11.0	11.0	10.4	9.9	9.3	8.8	8.2	7.7	7.1	6.6	6.0	5.4	4.9	4.3	3.8	3.2	2.7	2.1	1.6	1.0	Optional
C	10.0	9.6	9.1	8.7	8.2	7.8	7.3	6.9	6.4	6.0	5.5	5.1	4.6	4.2	3.7	3.3	2.8	2.4	1.9	1.5	1.0	Optional
D	6.0	5.8	5.5	5.3	5.0	4.8	4.5	4.3	4.0	3.8	3.5	3.3	3.0	2.8	2.5	2.3	2.0	1.8	1.5	1.3	1.0	Optional
E	6.0	5.4	4.9	4.3	3.8	3.2	2.7	2.1	1.6	1.0												

Illinois Agronomy Handbook (CH8, p. 7)

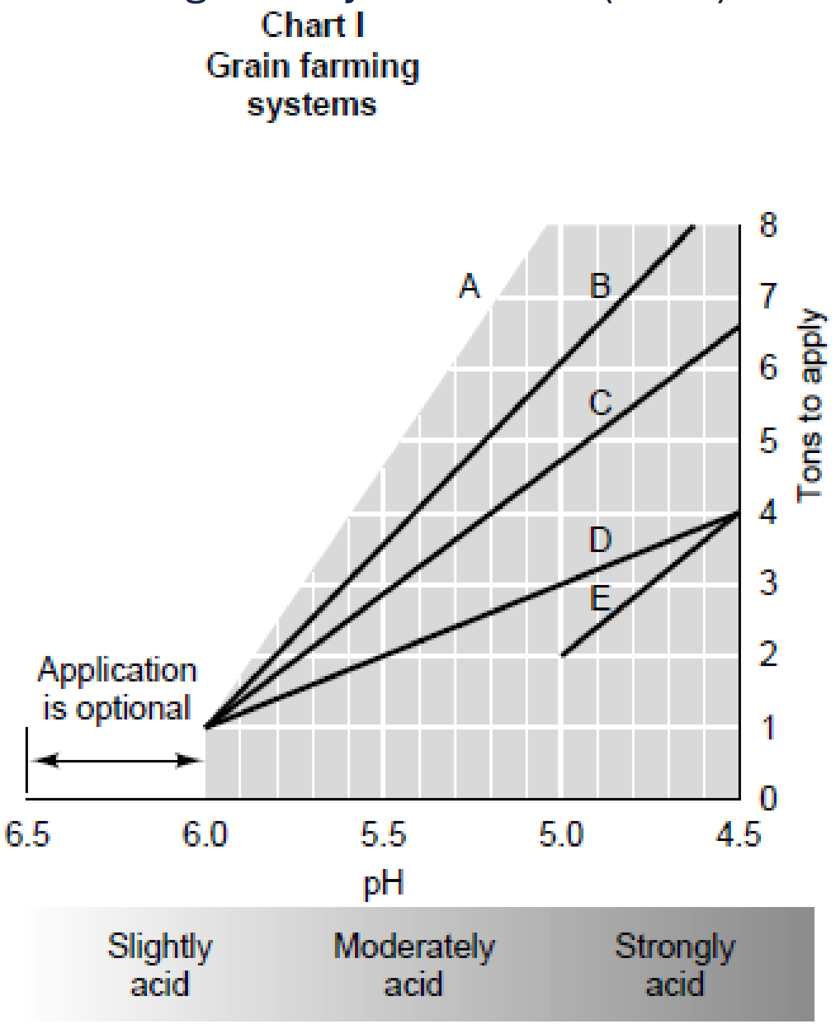
Illinois Liming Guideline Components

Table 8.3. Suggested limestone ... ...ch depth of tillage.

Soil type[a]	4.5	4.6	4.7	4.8	4.9
A	8.0	8.0	8.0	8.0	8.0
B	8.0	8.0	7.5	7.0	6.5
C	6.6	6.3	5.9	5.5	5.1
D	4.0	3.8	3.6	3.4	3.2
E	4.0	3.6	3.2	2.8	2.4
					Tons ...
A	11.0	11.0	11.0	11.0	11.0
B	11.0	11.0	11.0	10.4	9.9
C	10.0	9.6	9.1	8.7	8.2
D	6.0	5.8	5.5	5.3	5.0
E	6.0	5.4	4.9	4.3	3.8

6.1	6.2	6.3	6.4	6.5	7.0
...stems					
Optional					
Optional					
Optional					
Optional					
...a, clover, lespedeza)					
3.9	3.1	2.4	1.7	1.0	Optional
3.2	2.7	2.1	1.6	1.0	Optional
2.8	2.4	1.9	1.5	1.0	Optional
2.0	1.8	1.5	1.3	1.0	Optional

Illinois Agronomy Handbook (1997)



Illinois Agronomy Handbook (CH8, p. 7)

ISU PM1688 Approach seems to provide the most flexibility and logic when calculating lime rates

- Similar to P, K, and micronutrients, buffers need to be calibrated to the soils where the recommendations will be used.
- Likely will provide low, none, or legative values for low buffered soils with acidic pH values.

Table 16. Lime recommendations based on SMP or Sikora buffer pH methods, given in pounds per acre of Effective Calcium Carbonate Equivalent (ECCE) to increase soil pH from its present level to pH 6.0, 6.5, or 6.9 for the soil depth to be neutralized.†

	Depth of Soil to be Neutralized								
	2 inches			3 inches			6 inches		
	Target Soil pH								
Buffer pH	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9
	Amount of Effective Calcium Carbonate Equivalent to Apply (pounds/acre) ‡								
7.0	0	0	400	0	0	600	0	0	1,100
6.9	0	0	600	0	0	1,000	0	0	1,900
6.8	0	200	900	0	300	1,400	0	600	2,700
6.7	0	400	1,200	0	700	1,800	0	1,300	3,500
6.6	0	700	1,500	0	1,100	2,200	0	2,100	4,400
6.5	100	900	1,700	100	1,400	2,600	200	2,800	5,200
6.4	300	1,200	2,000	400	1,800	3,000	800	3,500	6,000
6.3	500	1,400	2,300	700	2,100	3,400	1,400	4,200	6,800
6.2	700	1,700	2,600	1,000	2,500	3,900	2,000	5,000	7,700
6.1	900	1,900	2,800	1,300	2,900	4,300	2,500	5,700	8,500
6.0	1,000	2,200	3,100	1,600	3,200	4,700	3,100	6,400	9,300
5.9	1,200	2,400	3,400	1,900	3,600	5,100	3,700	7,100	10,100
5.8	1,400	2,600	3,700	2,200	4,000	5,500	4,300	7,900	11,000
5.7	1,600	2,900	3,900	2,500	4,300	5,900	4,900	8,600	11,800

† For corn and soybean, soil pH 6.5 is recommended in soil association areas without calcareous subsoil and soil pH 6.0 is recommended in areas with calcareous subsoil (see text and Figure 1). Soil pH 6.9 is recommended for alfalfa and alfalfa-grass mixtures in all soil association areas. Soil pH 6.0 is recommended for other forage legumes or legume-grass mixtures and grasses in all association areas.

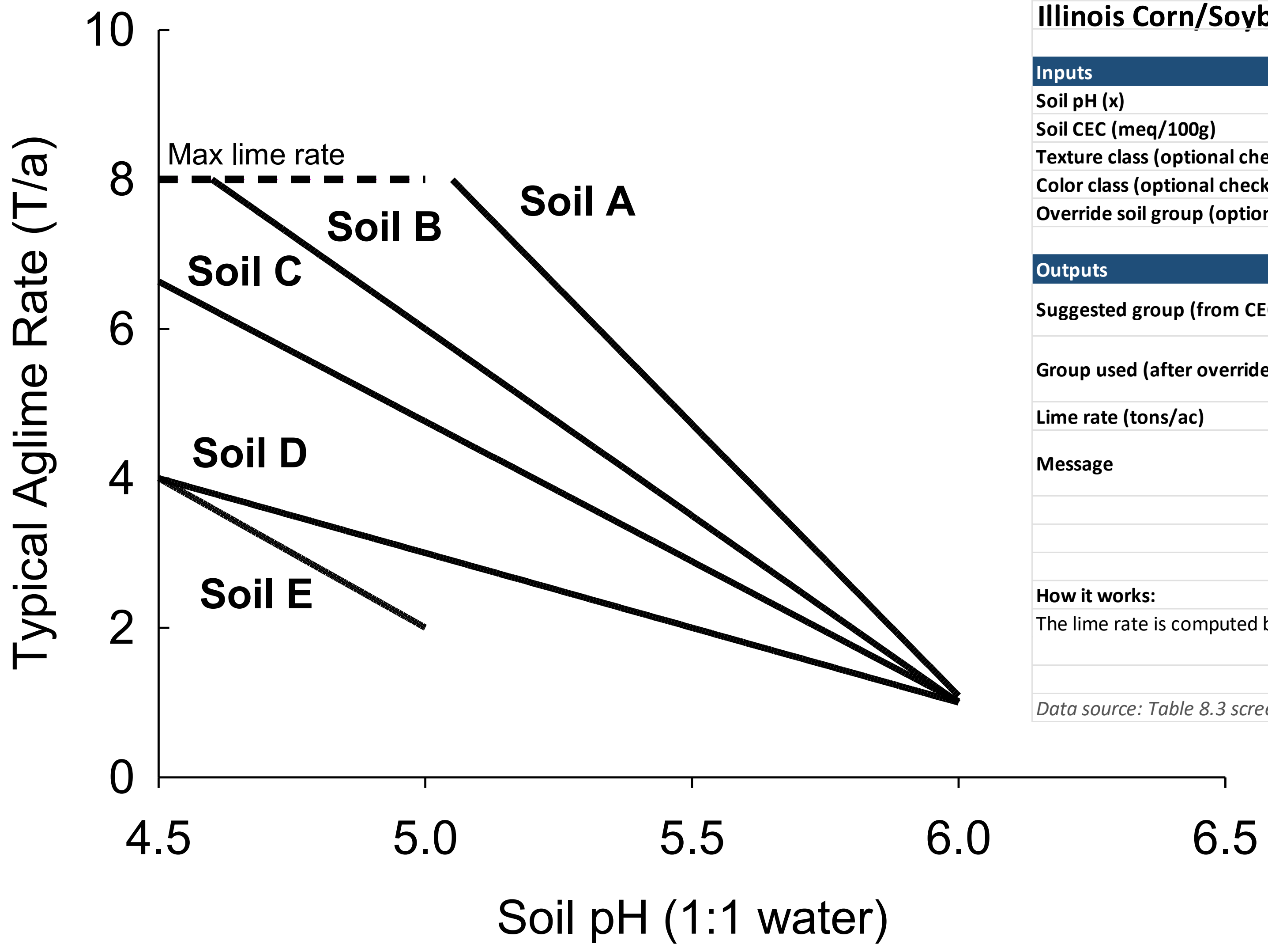
‡ Amounts were derived from the following calibration equations and rounded to 100 pounds:

Pounds of ECCE to raise pH to 6.0 = [38619 - (5915 x Buffer pH)] x [Depth x 0.167]

Pounds of ECCE to raise pH to 6.5 = [49886 - (7245 x Buffer pH)] x [Depth x 0.167]

Pounds of ECCE to raise pH to 6.9 = [58776 - (8244 x Buffer pH)] x [Depth x 0.167]

Maintaining Soil Groups?



Illinois Corn/Soybean Lime Rate Calculator (Piecewise Linear from Table 8.3)

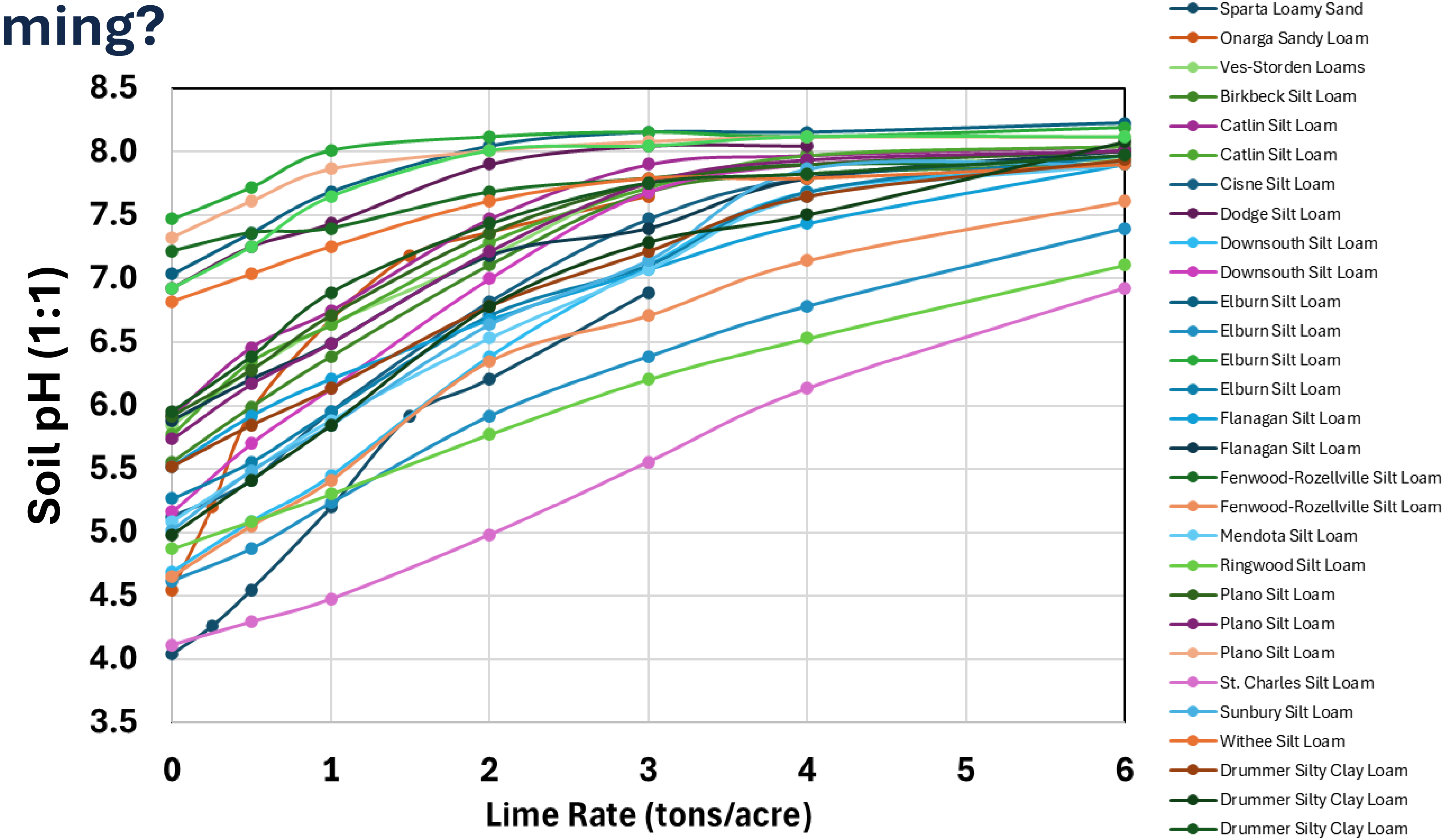
Inputs			
Soil pH (x)	4.7		
Soil CEC (meq/100g)	7.8		
Texture class (optional check)	Loam		
Color class (optional check)	Medium		
Override soil group (optional)			
Outputs			
Suggested group (from CEC)	D	**Texture/color check:**	Check D vs entered texture/color
Group used (after override)	D	**Reference description:**	< 8 | Loams; sandy loams; sands
Lime rate (tons/ac)	3.6		
Message			

How it works:

The lime rate is computed by piecewise linear interpolation between the 0.1 pH breakpoints in Table 8.3 (grain system).

Data source: Table 8.3 screenshot provided by user (9-inch tillage; grain farming systems).

How to categorize soils: soil properties or response to liming?



Goeken and Joern (2026)

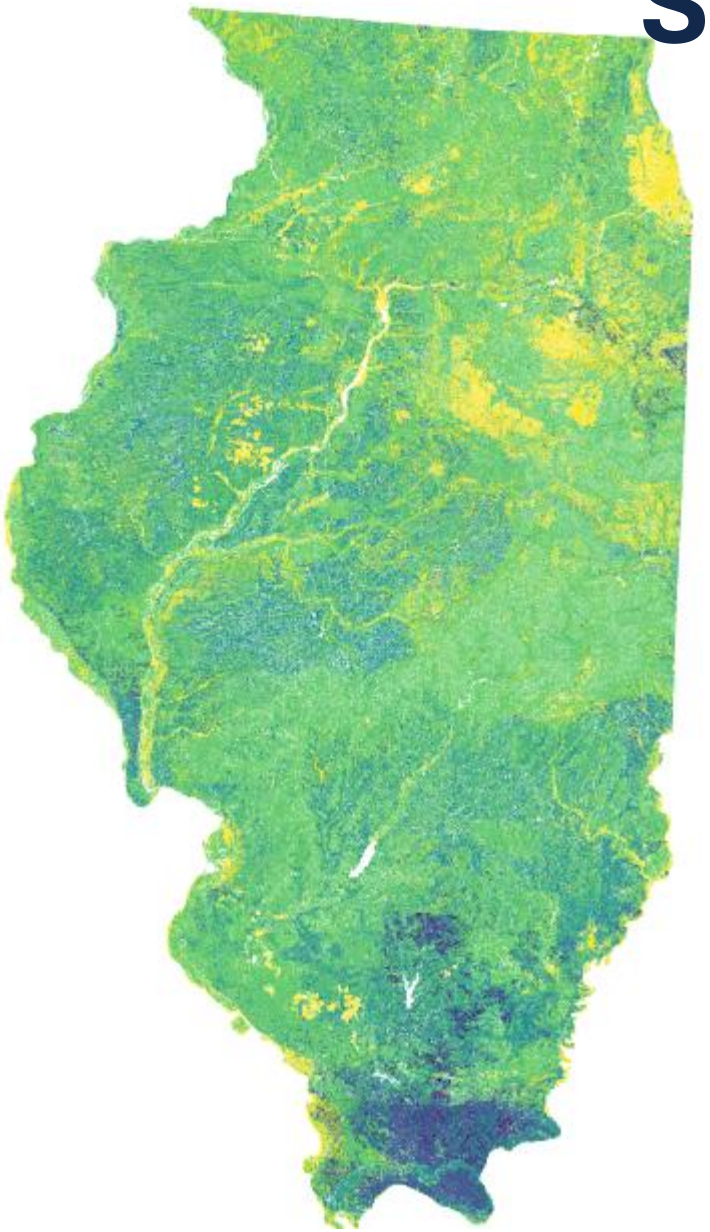
Interpretation Update Options for Illinois Lime Recommendations

- Provide recommended rates with the following assumptions
  - 100% effective neutralizing values (effective calcium carbonate equivalence)
  - Standard incorporation depth
- This would allow users to adjust the recommended rate for:
  - Lime quality (chemical & physical)
  - Incorporation depth
  - Tillage adjustments (above)
  - Multi-year efficacy? Is this substantiated?

Surface & subsurface pH

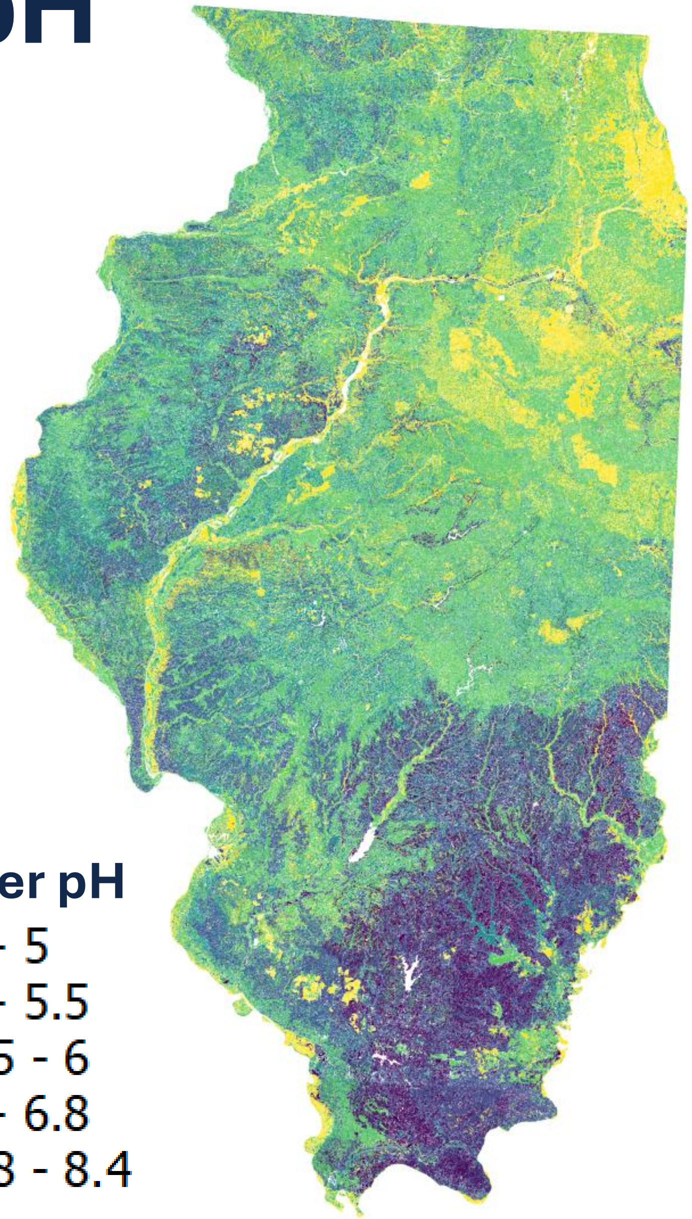
Soil survey SSURGO data (10m)

0 to 8-inch



- Field research supports lower optimum surface soil pH with high subsoil pH
- This characterization might be less important for Illinois than Minnesota and Iowa.

12 to 24-inch

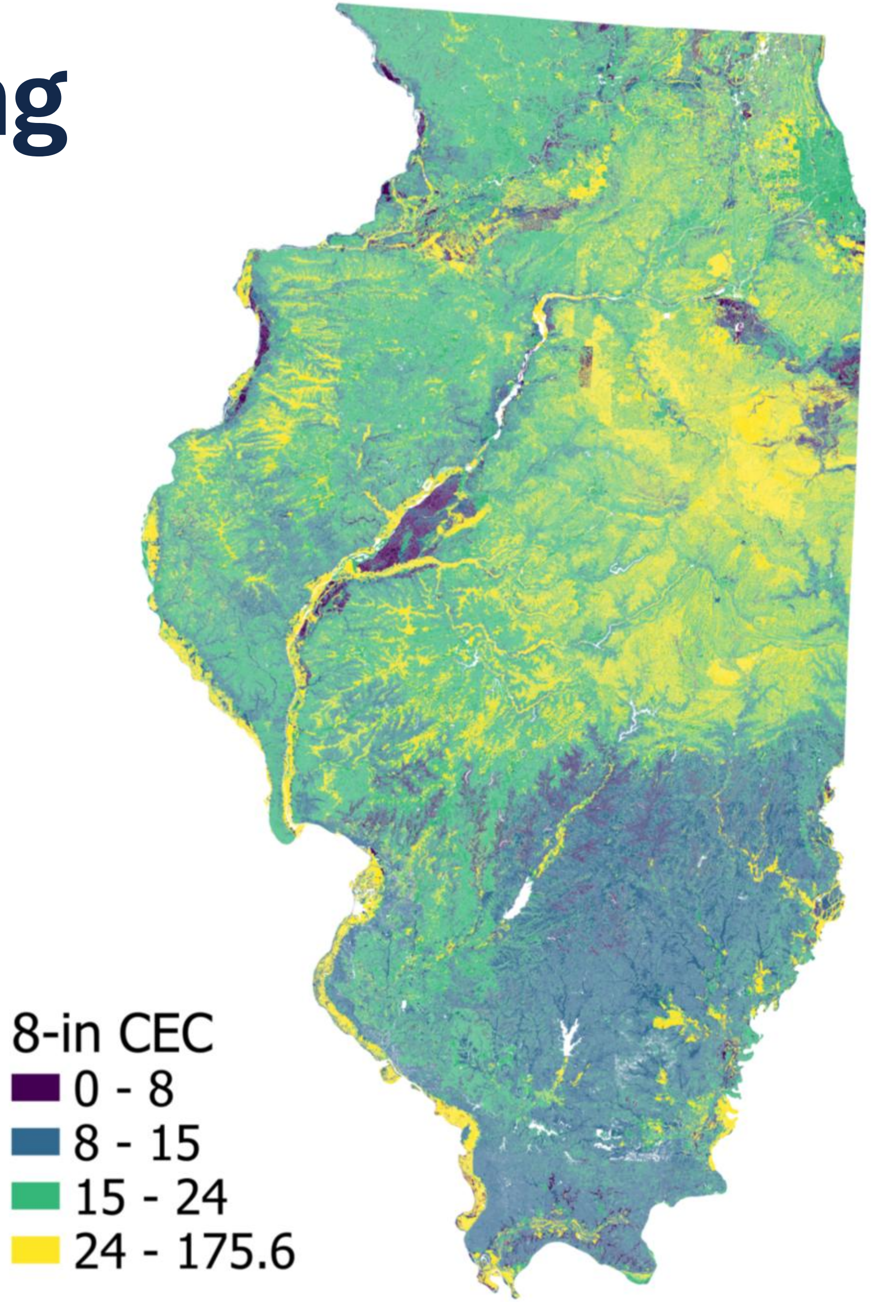


1:1 water pH

- 0 - 5
- 5 - 5.5
- 5.5 - 6
- 6 - 6.8
- 6.8 - 8.4

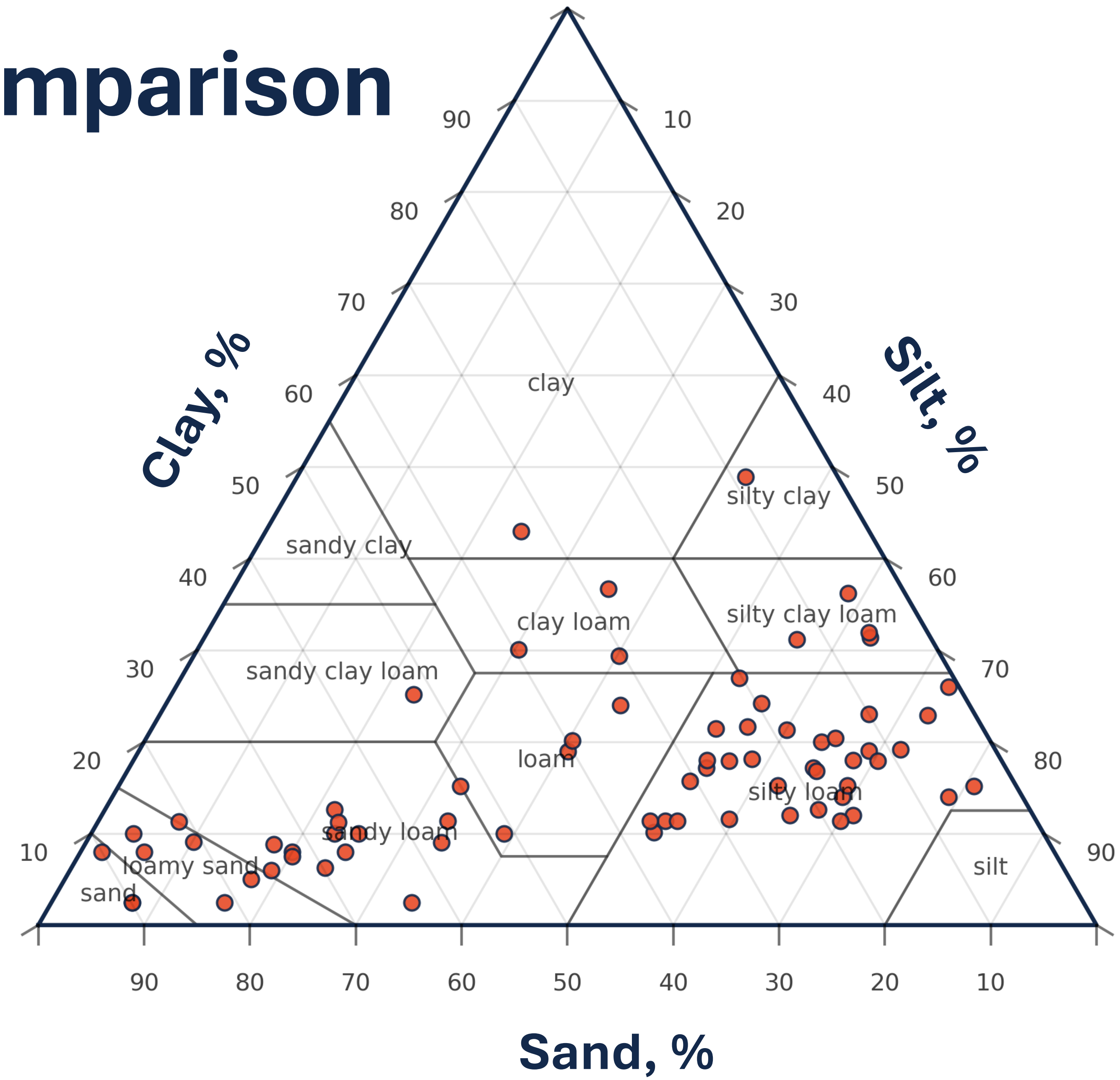
Buffer pH predictions of liming recommendation needed for each group

1. Lab incubations (pH response to liming vs. buffer pH)
2. Field pH change ratio with buffer pH change (validation)

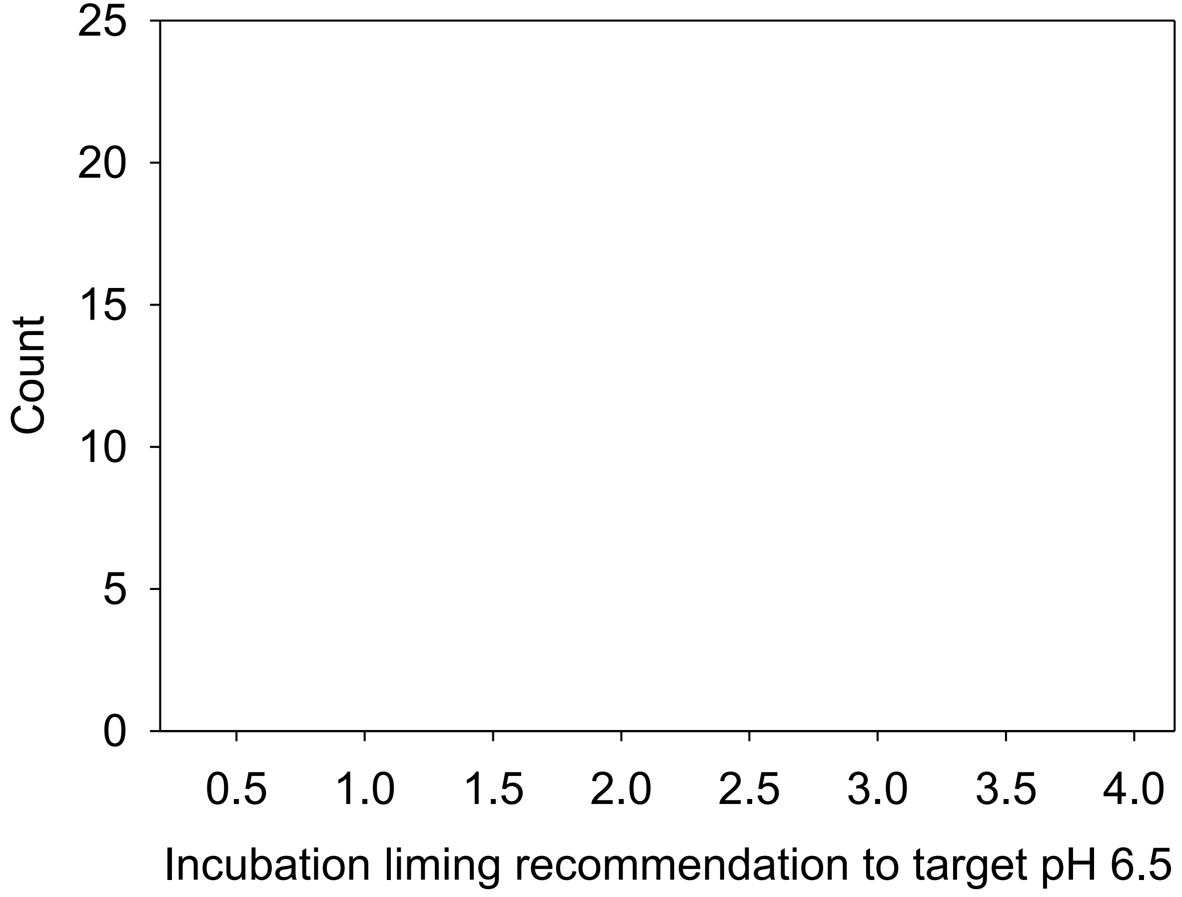


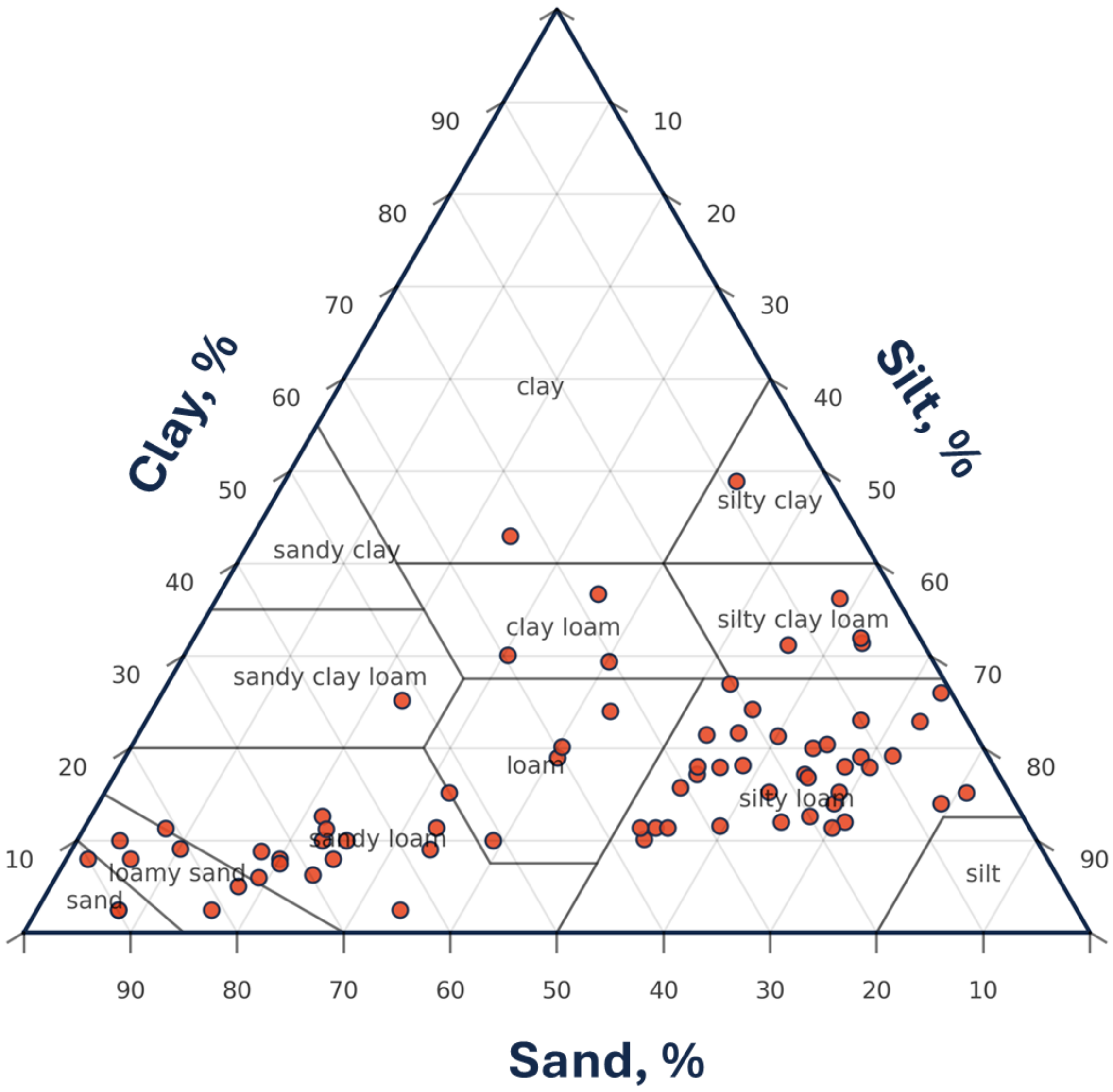
Example Soils for Comparison

- Represent Illinois, Indiana, Iowa, and Wisconsin
- Pooled incubation data from our group in IA, WI, and IL; and the FRST dataset.
- Soil pH (1:1 H_2O): 4.04 to 6.17
- Soil pH (1:1 salt):3.62 to5.91
- Sikora BpH: 5.79 to 6.96
- Sand to Clay texture (right)



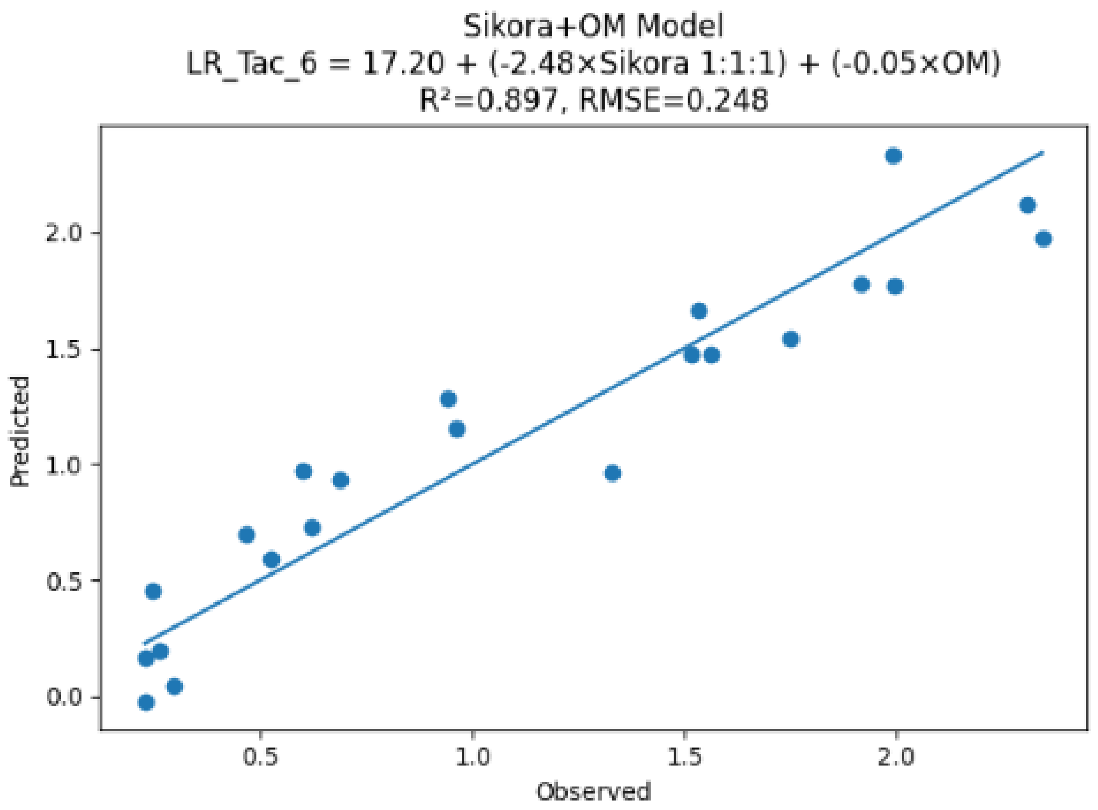
Example Soils for Comparison

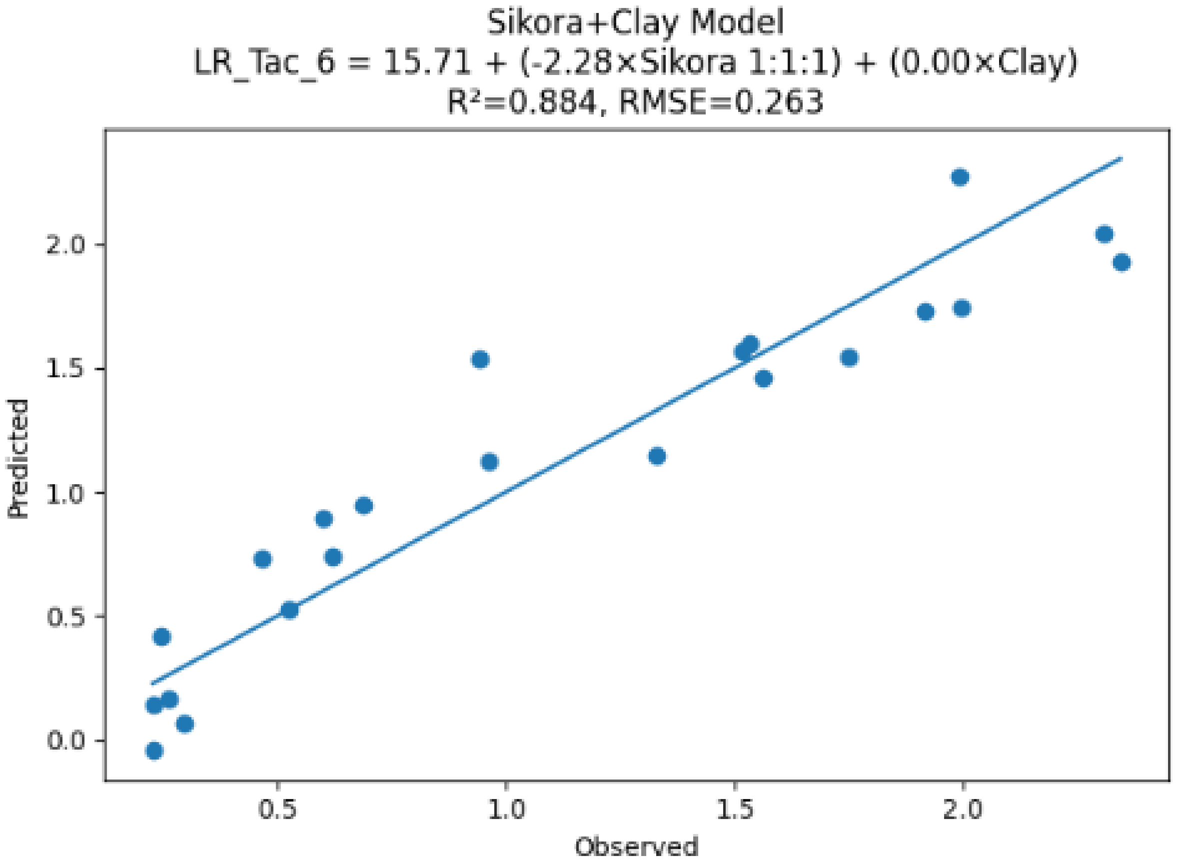




Examples of Regressions by Soil Group

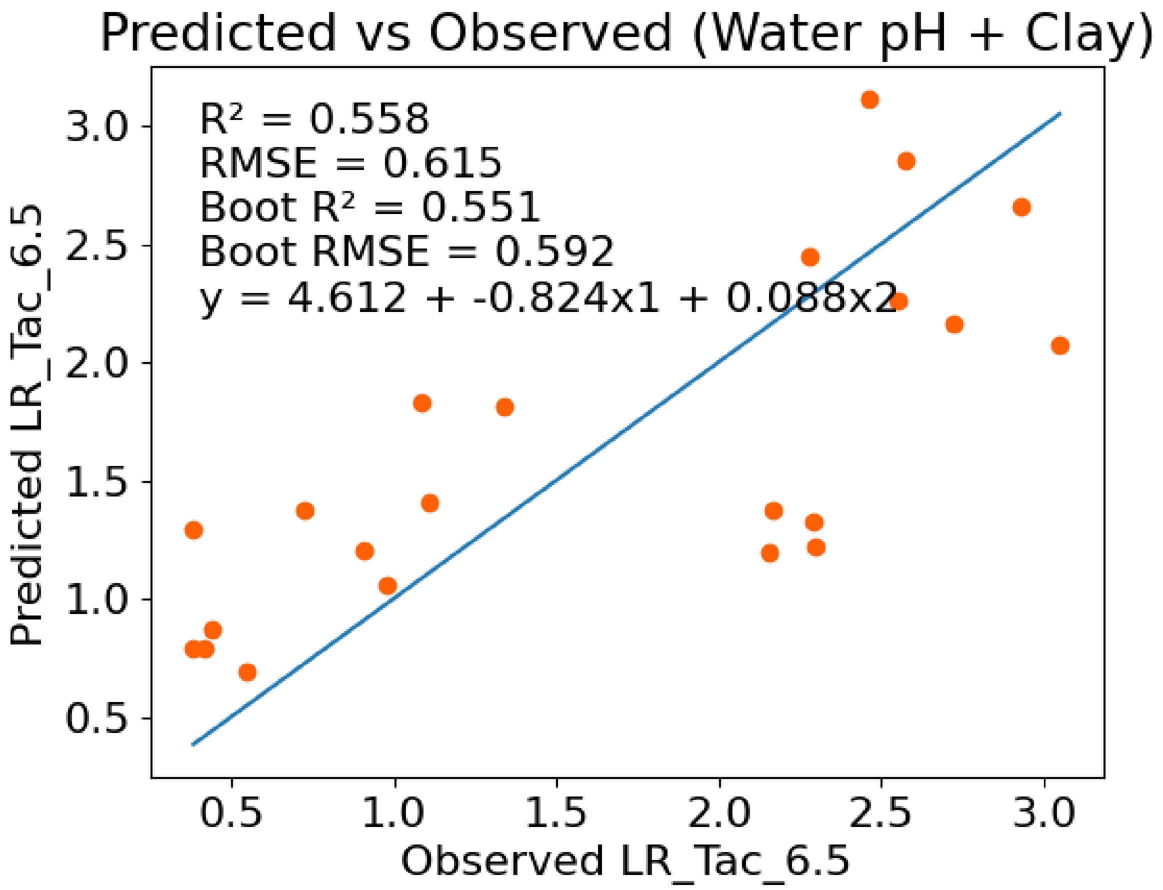
Illinois Groups C&D

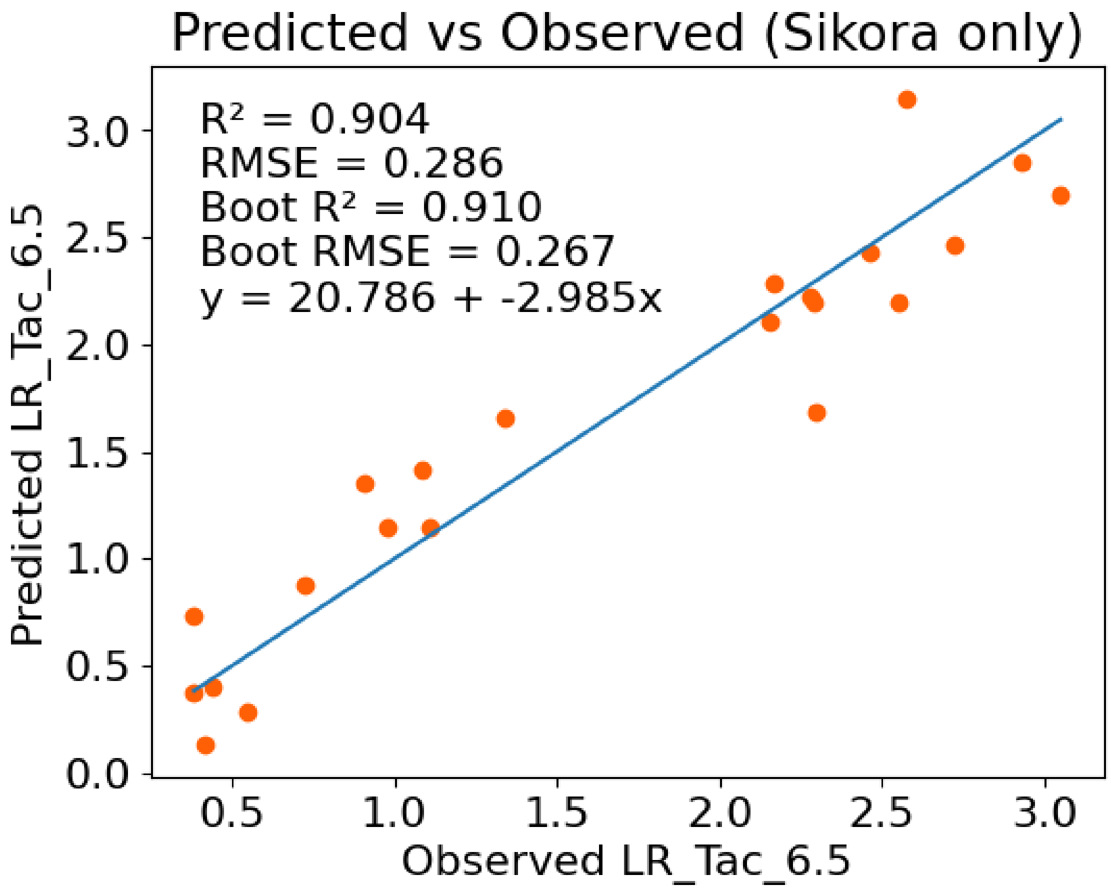




Best predictors of incubation lime rate to target pH 6.5

Examples of lower CEC soils below





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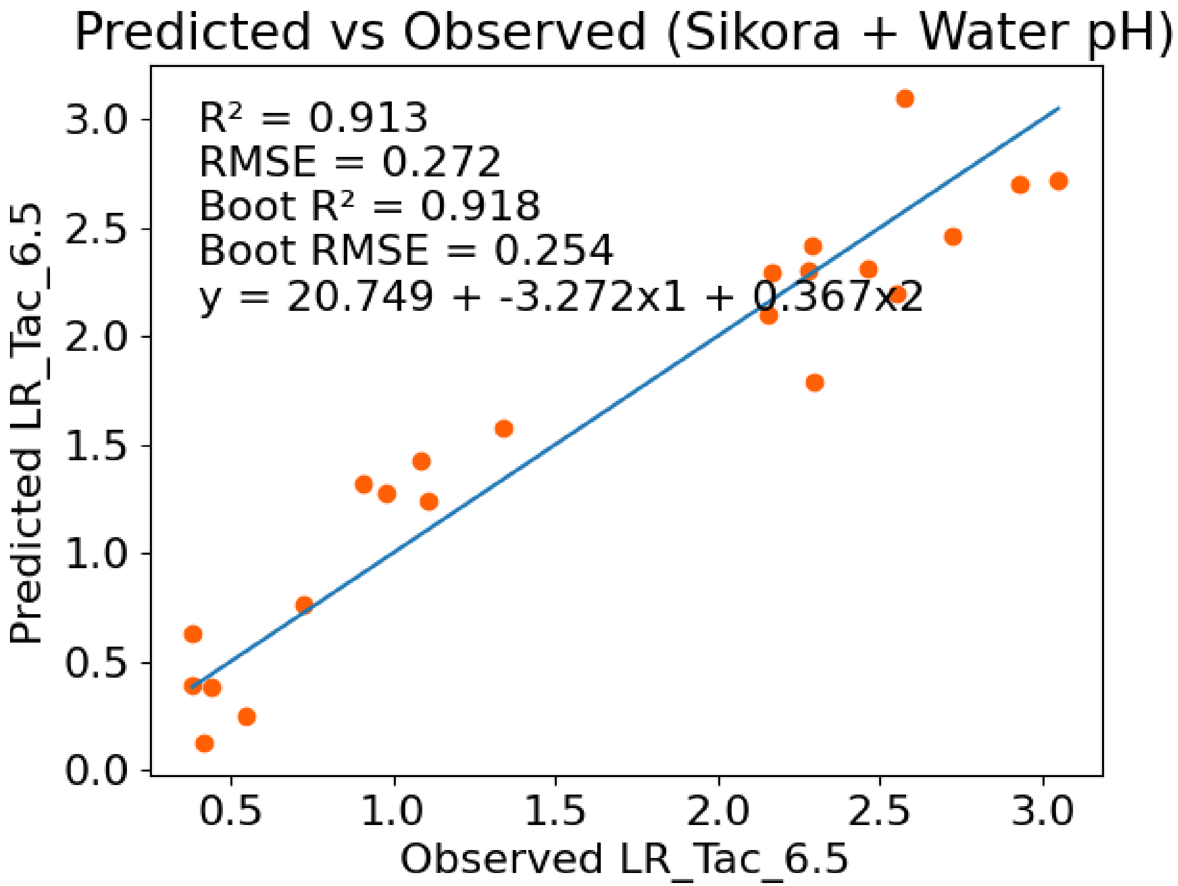
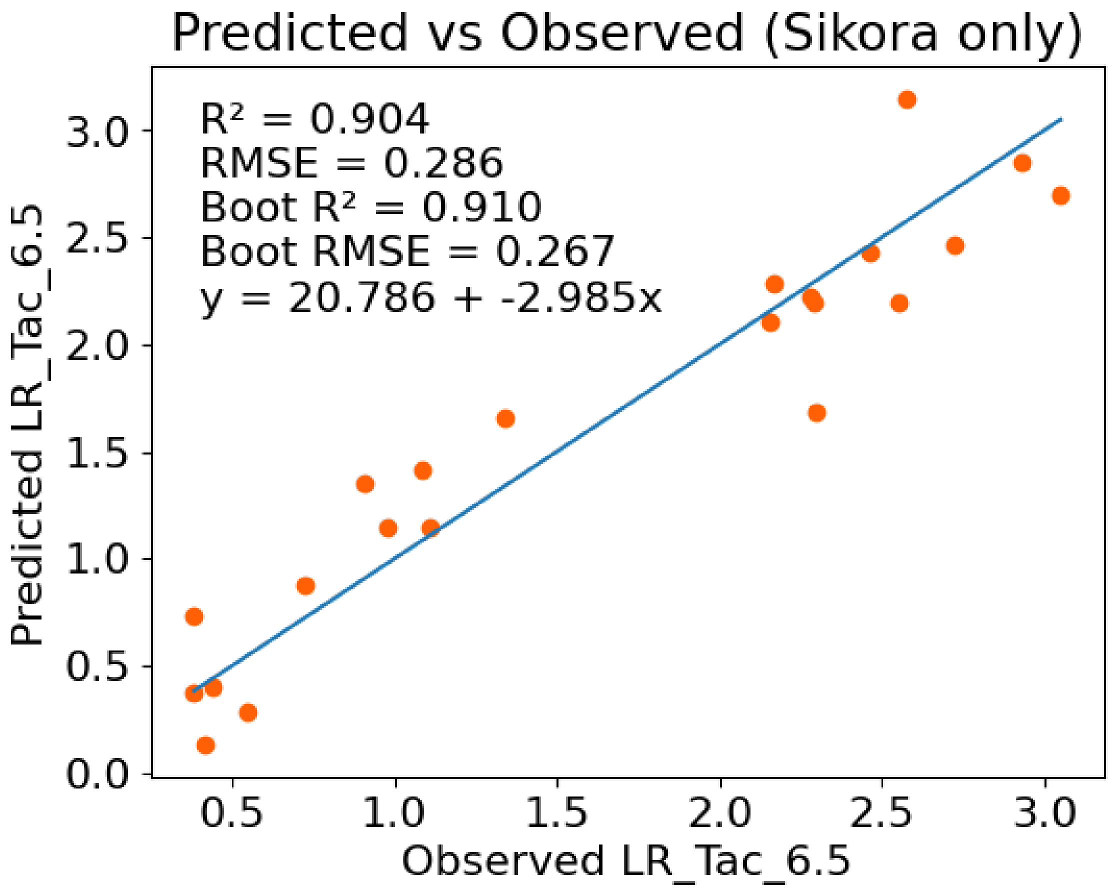




Liming Rate Prediction Comparisons

Target pH 6.5 for all soils

Model	R^2	Adj R^2	RMSE
Sikora+OM	0.921	0.910	0.279
Sikora+pH	0.913	0.901	0.293
Sikora+Clay	0.905	0.892	0.307
Sikora	0.904	0.900	0.300
pH+OM+Clay	0.848	0.829	0.399
pH+OM	0.846	0.828	0.391
pH+Clay	0.558	0.520	0.661

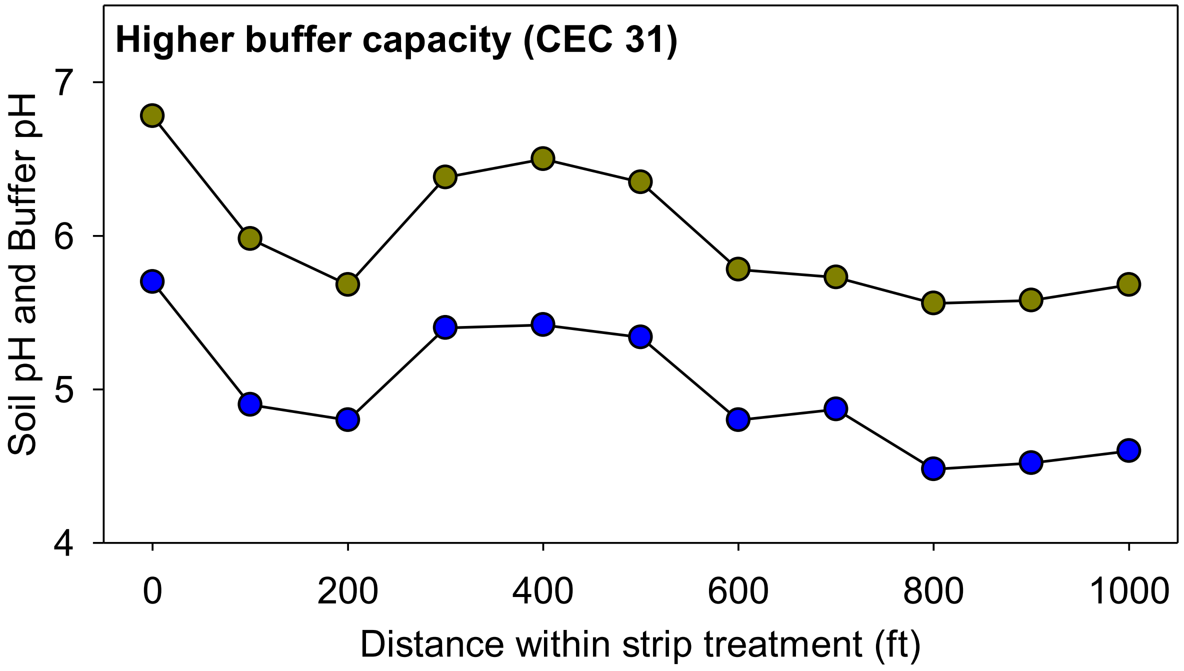
Liming Rate Prediction Comparisons

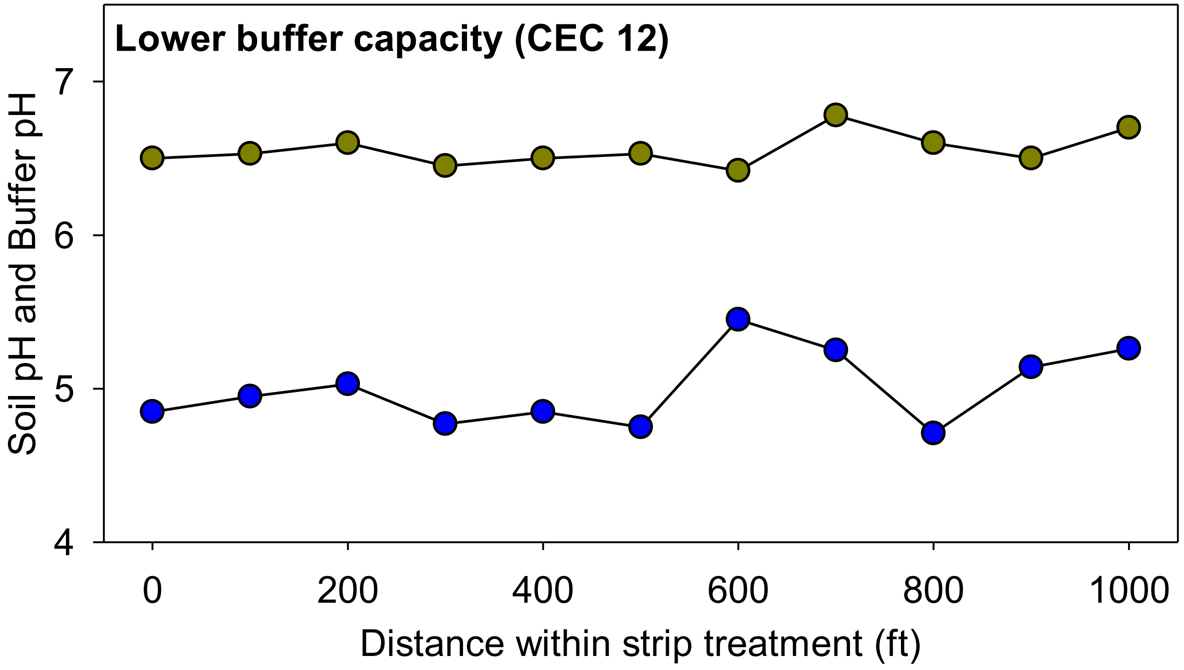
Target pH 6.8 for all soils

Model	R^2	Adj R^2	RMSE
Sikora+OM	0.928	0.918	0.305
Sikora+wpH	0.912	0.900	0.338
Sikora	0.882	0.875	0.381
Sikora+Clay	0.883	0.871	0.390
wpH+OM+Clay	0.859	0.840	0.441
wpH+OM	0.857	0.839	0.431
wpH+Clay	0.511	0.471	0.798

Variable Rate Liming: pH_w & CEC vs. Buffer pH

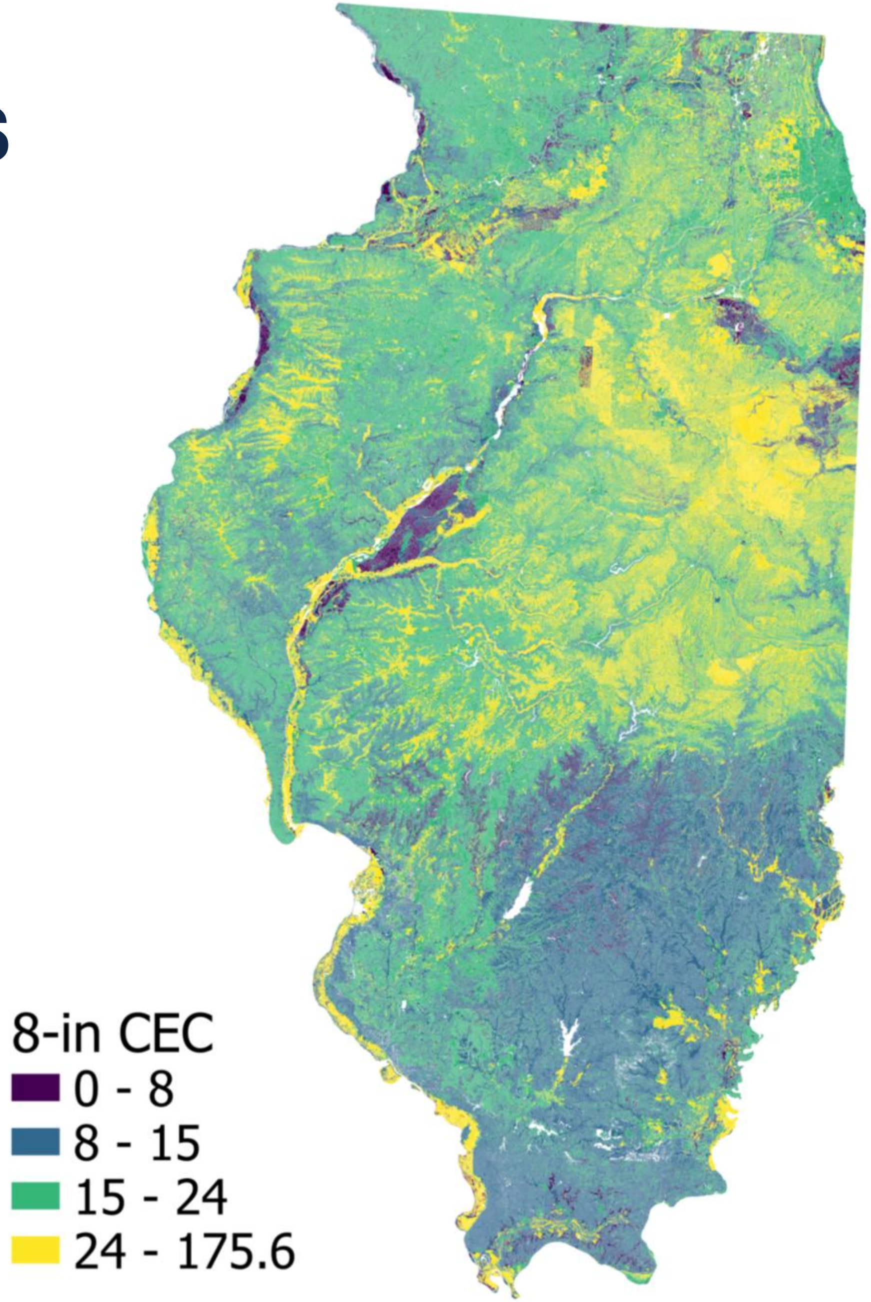
- Higher soil buffer pH values (Sikora below) = lower buffering capacity
- Extreme cases below, but if CEC will change within a field, using buffer pH can simplify that process (as opposed to water pH and CEC).





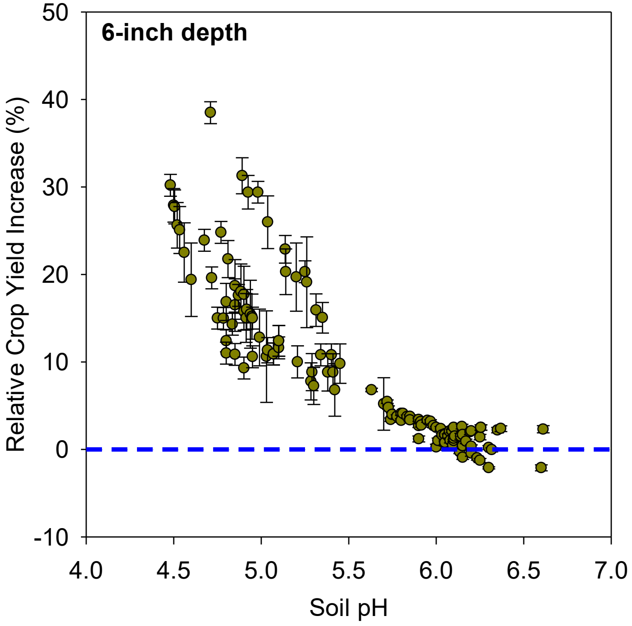
Potential Illinois LR Additions

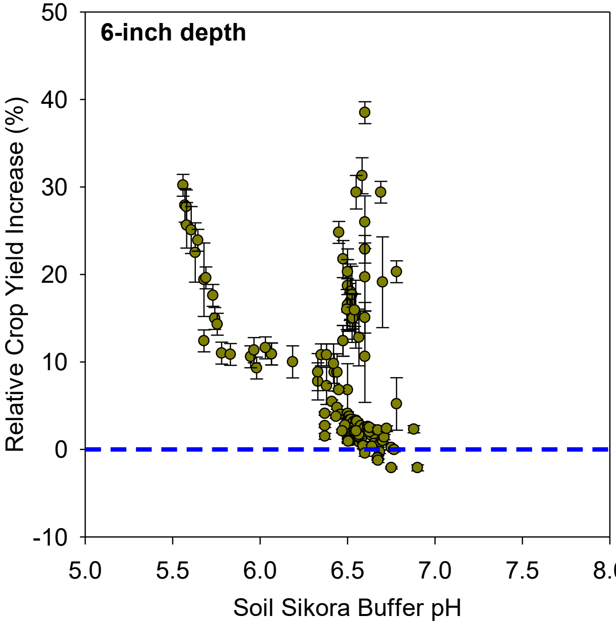
- For low CEC soils that are acidic, minimum and maximum lime rate rules (e.g., 1T/a minimum on soils 0.2 units below target, but no more than 2T/a)
- Align liming recommendation CEC breaks with potassium recommendation breaks (12 meq/100 g soil)?

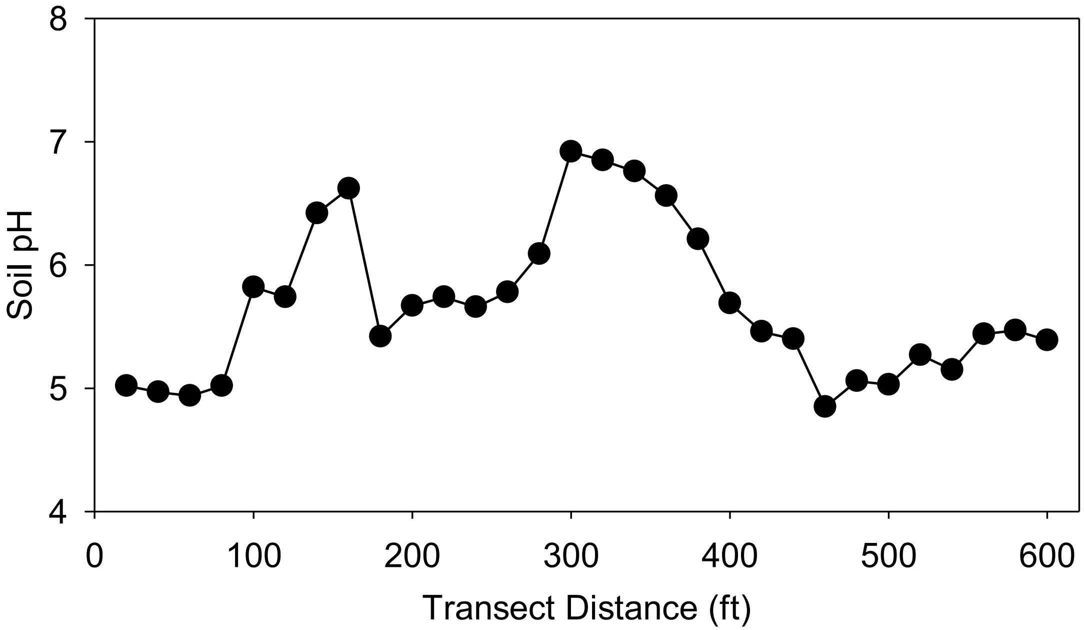


Steps to calibrate the Sikora Buffer in Illinois?

1. Laboratory incubations to understand basic soil pH response to liming for most soil associations in IL.
2. Coordinated field trials to determine pH and crop yield responses.
3. Transect strip trials to identify variable rate equations considering subsoil pH and field characteristics.







Thank you!

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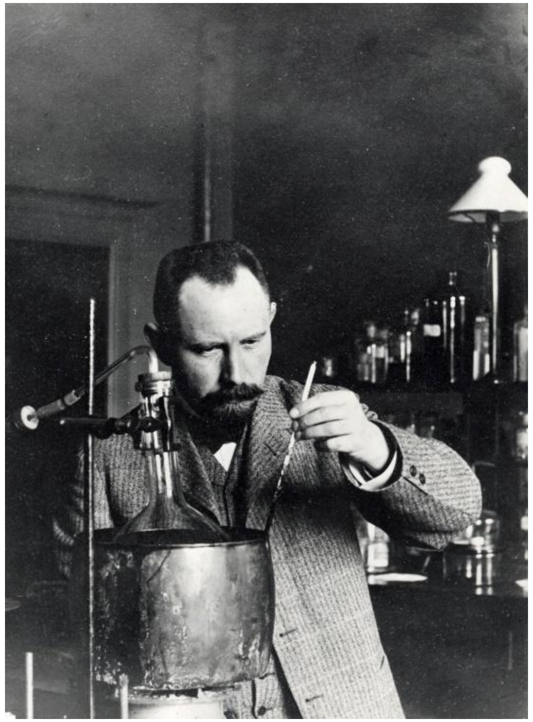
https://soilfertility.cropsci.illinois.edu/

ILLINOIS
Crop Sciences
COLLEGE OF AGRICULTURAL, CONSUMER & ENVIRONMENTAL SCIENCES

Use pH values? Thank the beer industry!

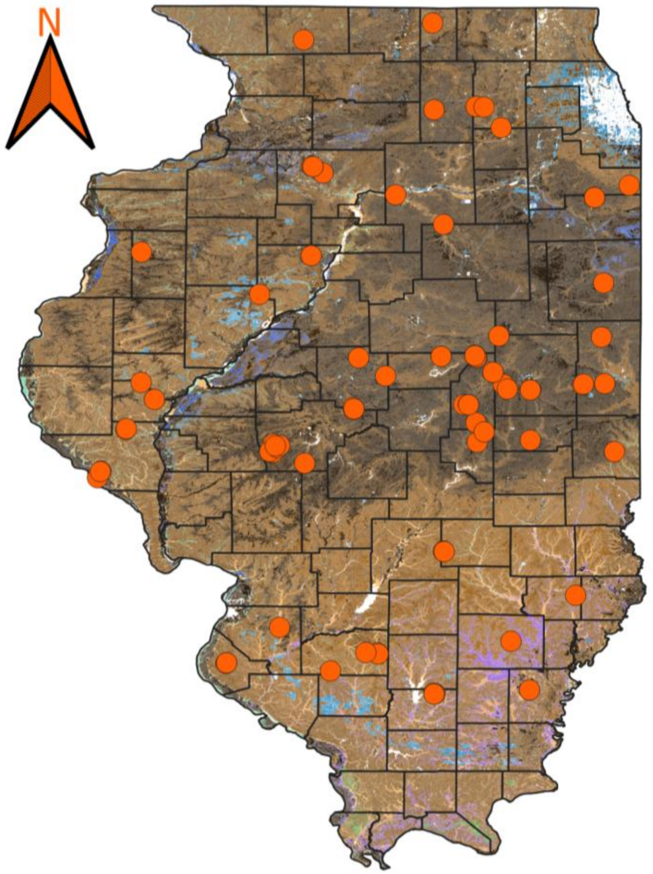
- Carlsberg brewery and beers (popular in Europe still)
- Soren Sorensen (Carlsberg Lab Department of Chemistry 1901-1938)
- Developed the pH scale to inform ion concentrations in proteins
- Also monitored fermentation status using pH
- Instead of "acidic tasting" new brews could be given a pH value
- Also see history of "Student's t-test to separate treatment means (developed by Gosset, a Guiness brewer)



https://www.carlsberggroup.com/pursuit-of-better/scientific-discoveries/ph-scale/

Yield and Economic Return Analyses

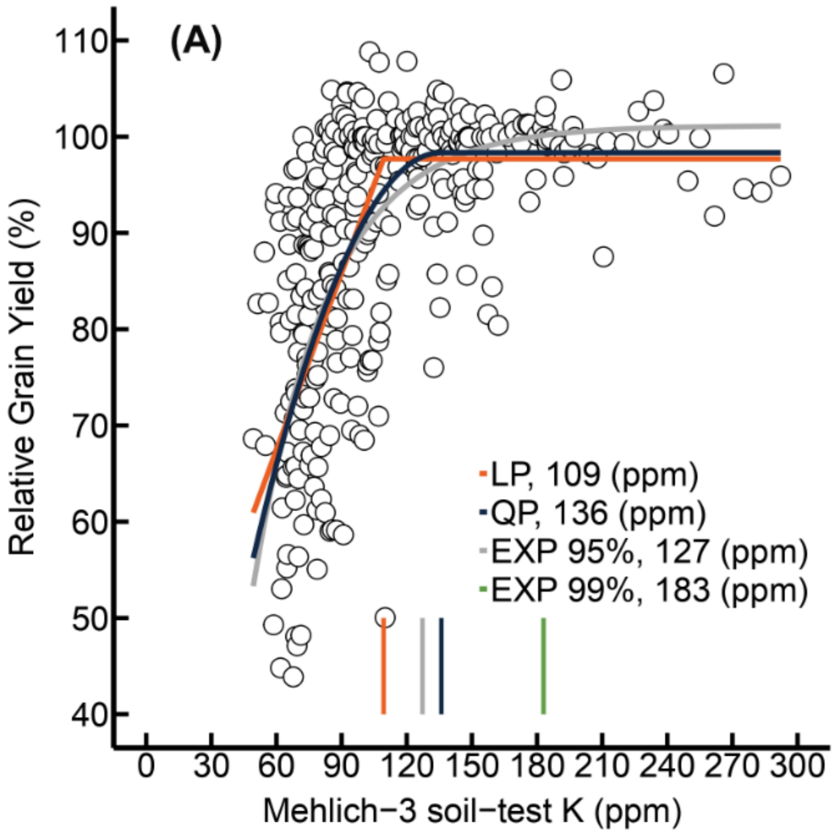
- Hundreds of field trials to identify maximum yield and associated N rate across cropping systems, hybrids, soils, and weather.
- Longer-term approach to aggregate data
  - Illinois uses a 10-year dataset updated annually and old data dropped
  - **73 N response curves in 2025, most with true controls and six N rates; all replicated 3-4 times.**
- The N rate to produce a maximum yield is adjusted down for price conditions (**commonly 10-18 lb N/a and average of 1.34 bushel/a in 2025**)
- An Economic Optimum N Rate (EONR) is identified and profitable ranges are provided.

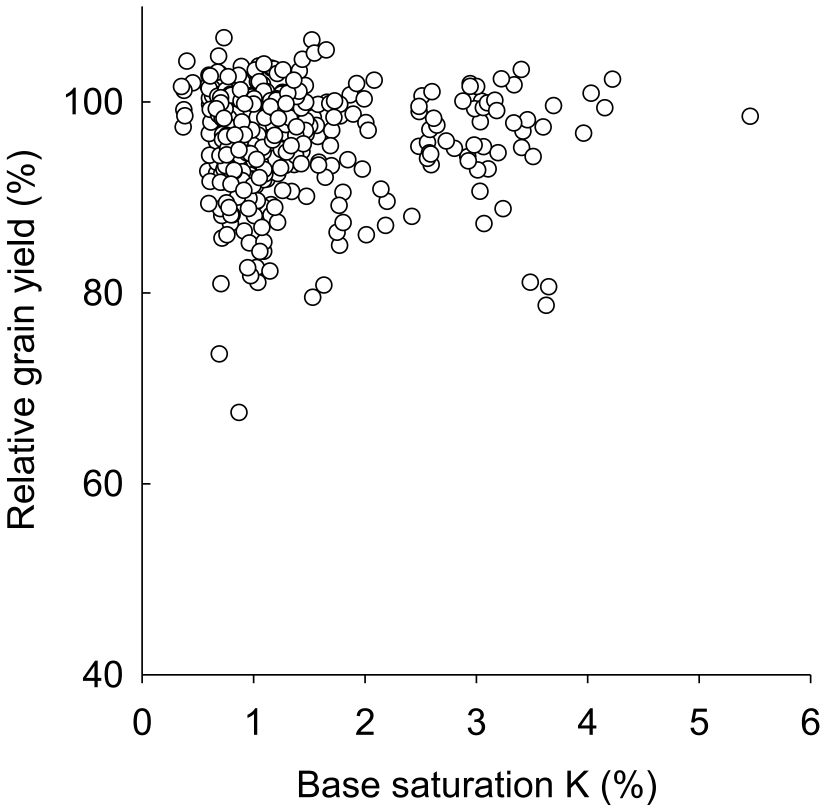


Base Saturation Evaluation for Potassium

included in new long-term, multi-site research

BS% K: poor relationship with relative yield (no response model fit). No indication you should chase 3, 4, or 8 percent K base saturation!





Bardeggia, Joern, Smith & Jones (2025)