FRST Lime Project Overview

Robert O. Miller

ALP Technical Director

Fort Collins, CO

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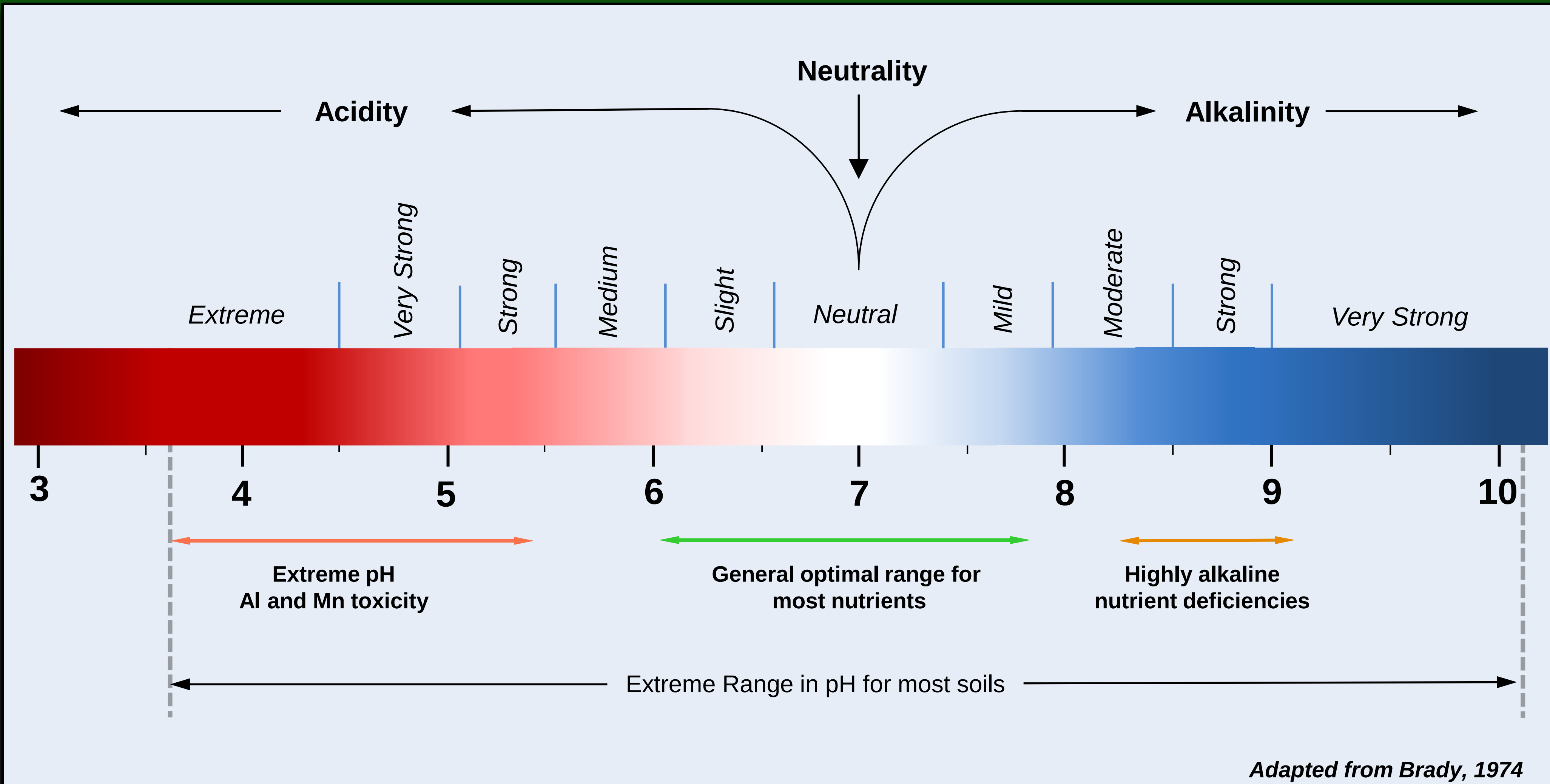
Background

Overview of pH, US distributions and impact of acid soils

Soil pH: Measure of acidity or alkalinity



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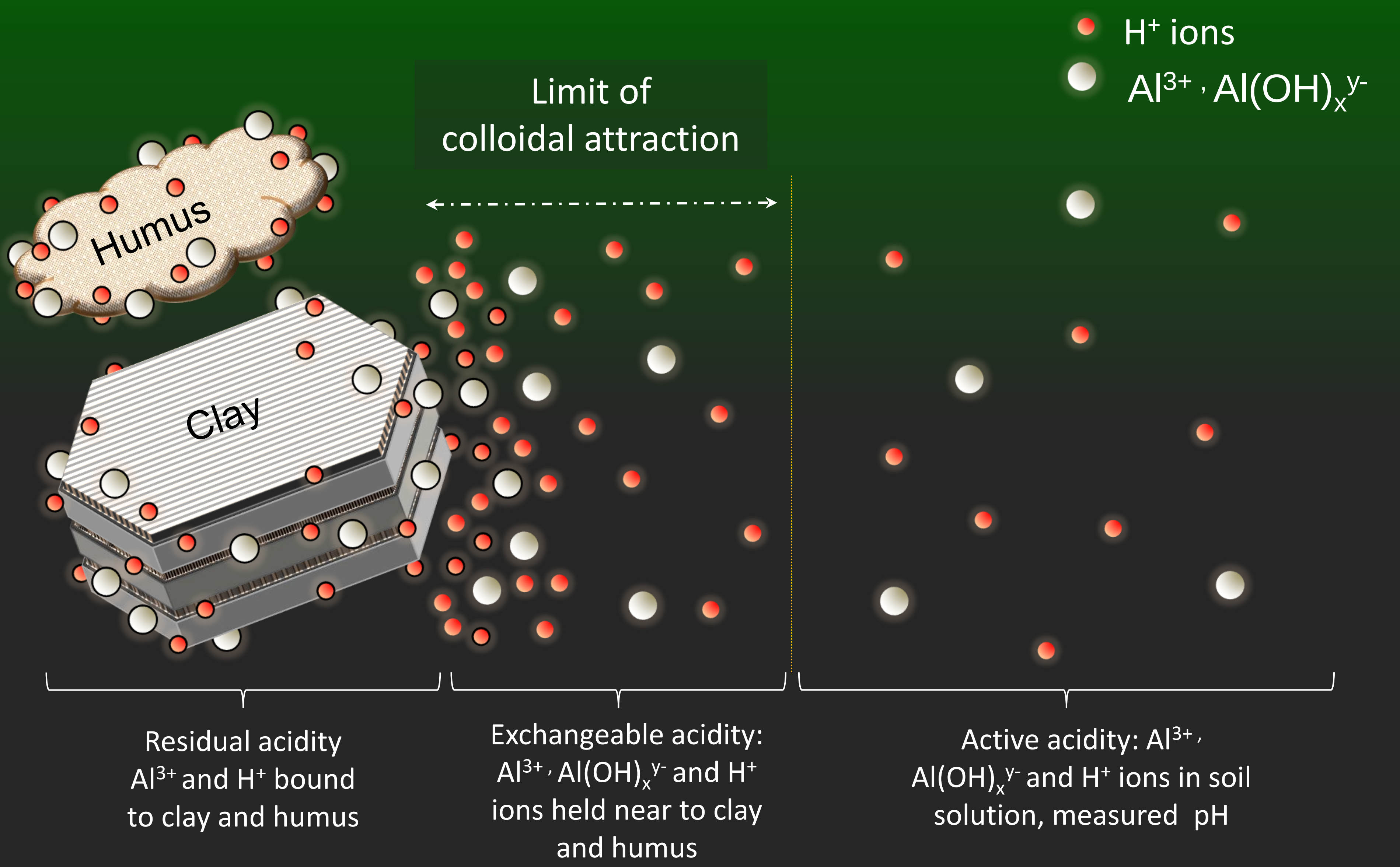
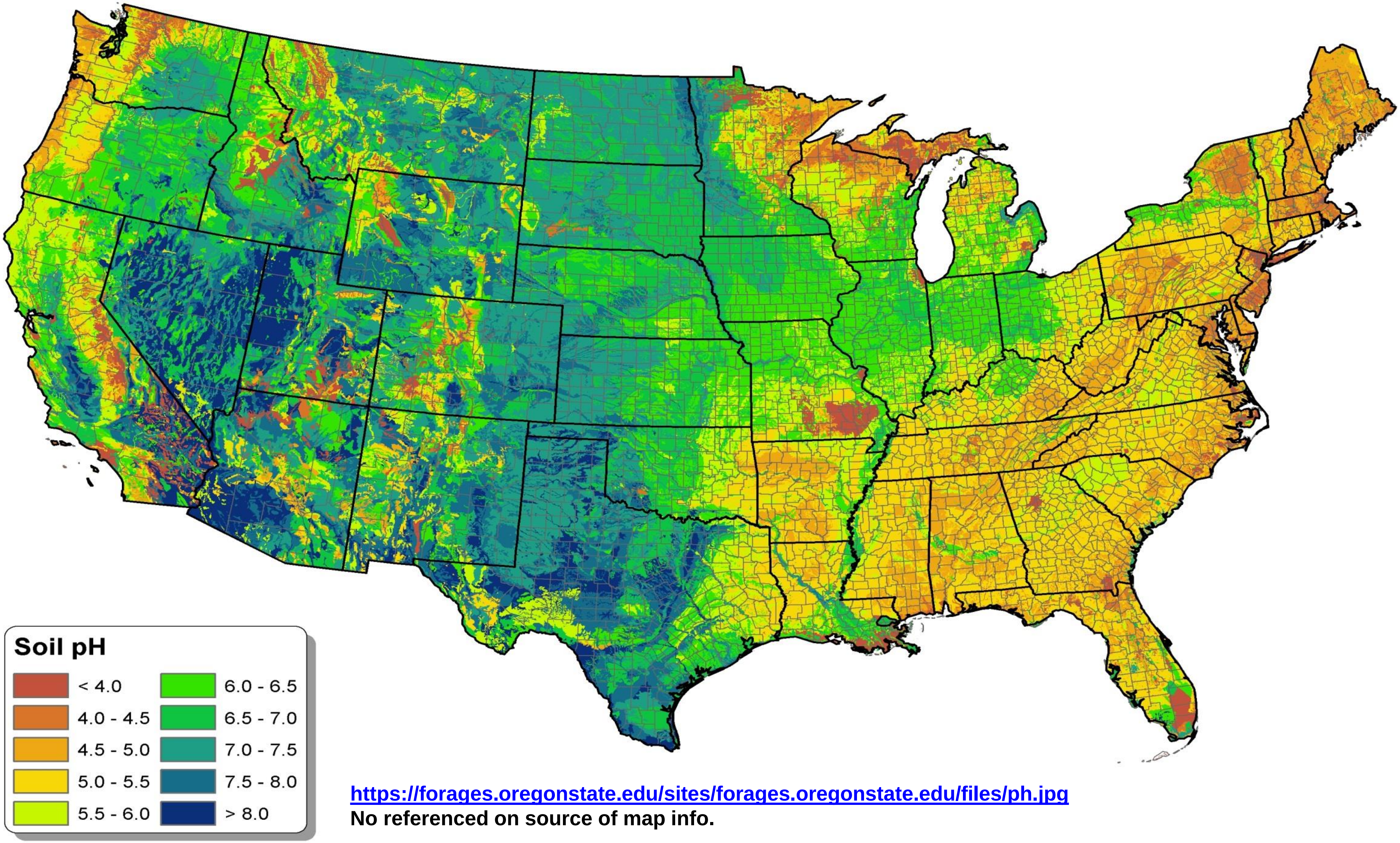
Soil Acidity: Active vs Reserve



Adapted from Brady and Weil , 2004

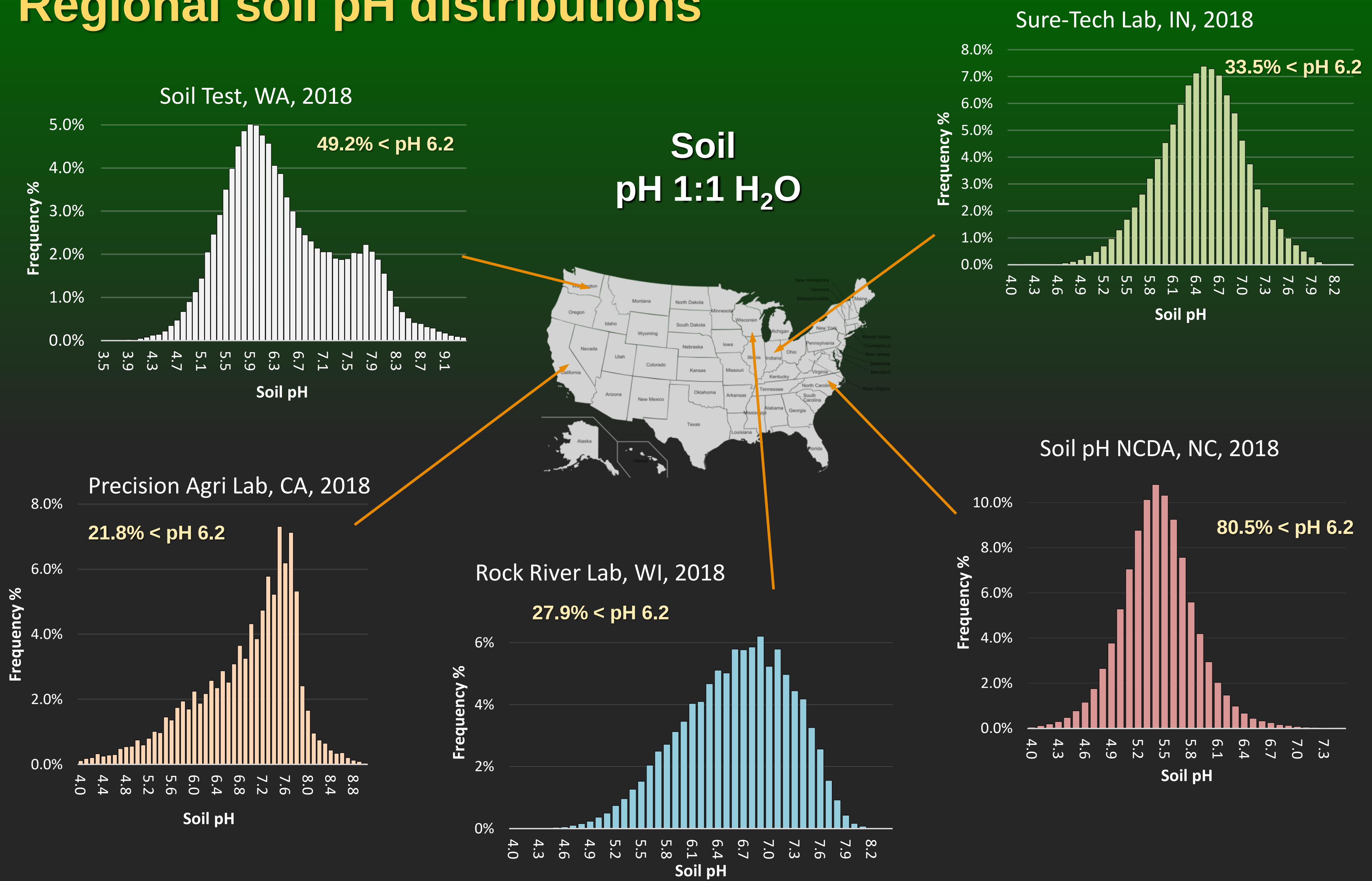
US Soil pH distribution



https://forages.oregonstate.edu/sites/forages.oregonstate.edu/files/ph.jpg

No referenced on source of map info.

Regional soil pH distributions



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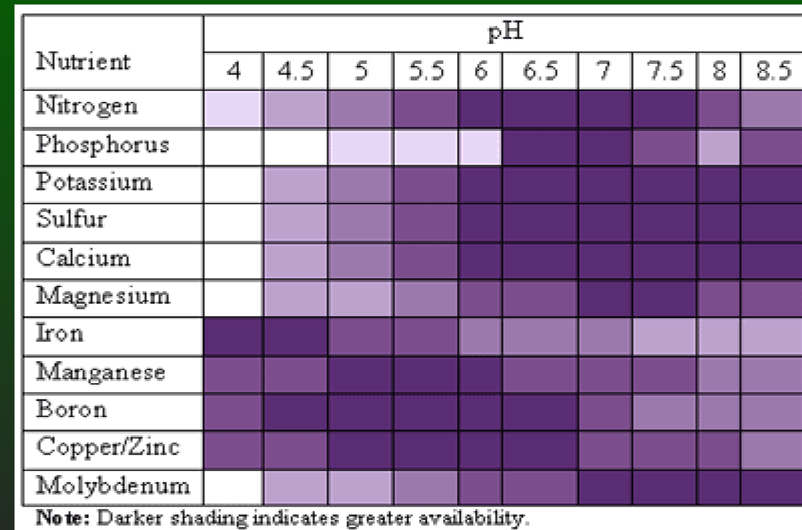
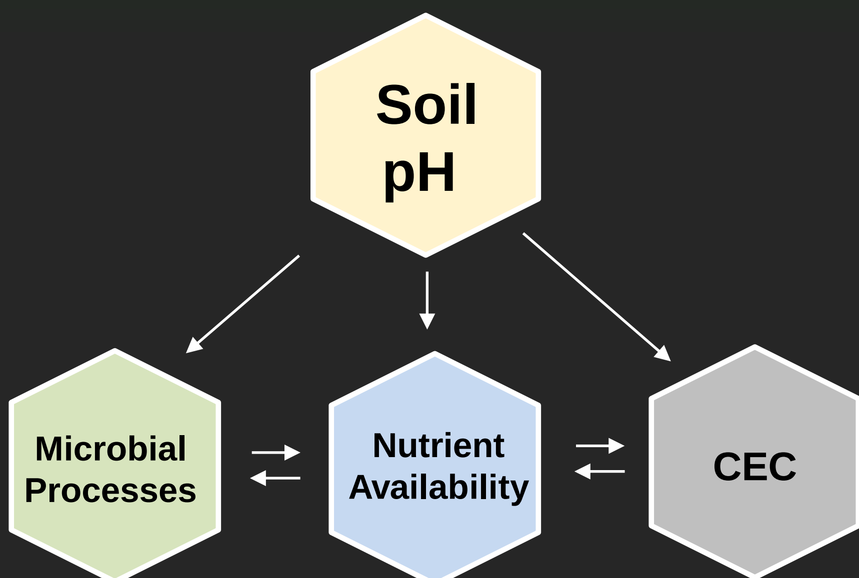
Impact of soil pH

- Nutrient availability / toxicity
- Cation Exchange Capacity (CEC)
- Base Saturation
- Nitrification
- Microbial processes





Low pH suppresses plant vigor and may result in Al and Mn toxicity for specific crops

Miller, 2020

Overview soil pH and liming

Acid soils are extensive with medium to strongly acid soils constituting 20 – 80% of soils tested in the US, all of which would result in a lime recommendation (pH< 6.2), estimate 3 million lab samples annually. Soil acidity impacts fertility, Al toxicity, CEC and crop productivity.

Agriculture used an estimated 11 M metric tons of ag lime in 2020, valued at $660 million. VRT lime application has become a standard of the industry, optimizing spatial placement and minimizing cost.

Lime recommendations are a state specific and often based on calibration research conducted more than 40 years ago using past cultural practices.

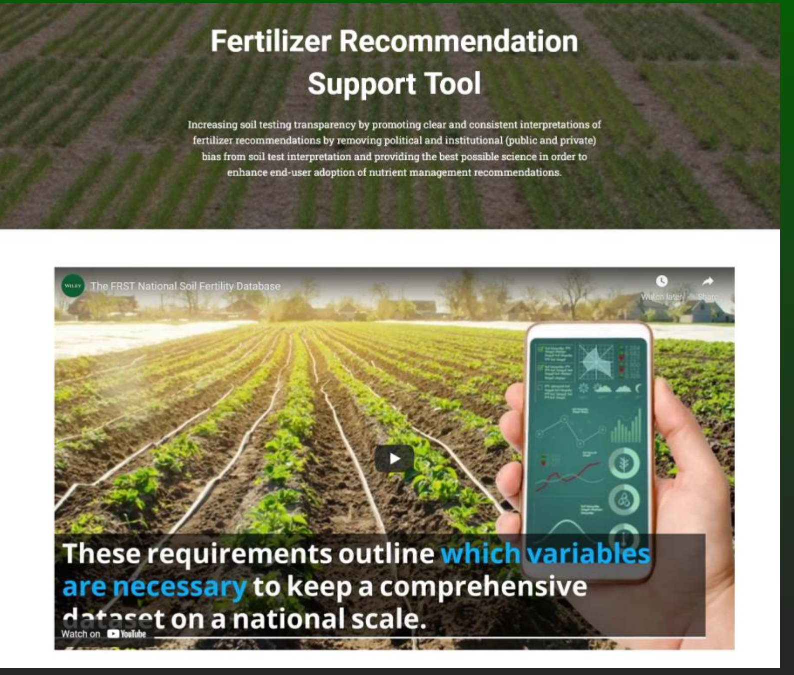
Miller, 2022

FRST Project

The FRST (Fertilizer Recommendation Tool) was initiated in 2016 to develop promote clear and consistent soil testing interpretations of fertilizer recommendations for nutrient management, and act as a catalyst for innovation.

The FRST project team is comprised of university and government researchers across the US. Initially FRST has focused on P and K soil test calibration and recommendations. Additional projects have focused on soil sampling and a SOP for conducting P and K calibration research.

In January 2022 established the FRST Lime Project.



soiltestfrst.org

Miller, 2022

FRST Lime Project Team

Brian Arnall	Oklahoma State University
Steve Culman	Ohio State University
Luke Gatiboni	North Carolina St University
David Hardy	NC Dept of Ag
Joseph Heckman	Rutgers University
Bryan Hopkins	Brigham Young University
Sindhu Jagadamma	University of TN
Clain Jones	Montana State University
John Jones	University of Wisconsin
Brian Kalmbach	University of Maryland
Quirine Ketterings	Cornell University
Jay Lessl	University of Georgia
Andrew Margenot	University of Illinois
Robert Miller	Colorado State University
Amber Moore	Oregon State University
Stephanie Murphy	Rutgers University
Rao Mylavarapu	University of Florida
Nathan Nelson	Kansas State University
Deanna Osmond	North Carolina St University
Rasel Parvej	Louisiana State University
Tim Pilkowski	USDA-NRCS
Manbir Rakkar	Montana State University
Ed Rayburn	West Virginia University
Dorivar Ruiz Diaz	Kansas State University
Kurt Schroeder	University of Idaho
Amy Shober	University of Delaware
Frank Sikora	University of Kentucky
Nathan Slaton	University of Arkansas
Jared Spackman	University of Idaho
Haiying Tao	University of Connecticut
Gurpal Toor	University of Maryland
Matt Yost	Utah State University
Hailin Zhang	Oklahoma State University

Miller, 2022

FRST Lime Project: objectives

Review the basis of: soil acidity, soil pH methods, BpH methods, lime rates and lime factors.

Lime recommendation survey, across the US.

Generate new lime calibration data and establish new regional or and/or national recommendations.

Develop a forecast model for predicting long term soil pH

Engage the laboratory industry and agronomist practioners in adopting and validating new lime recommendations.

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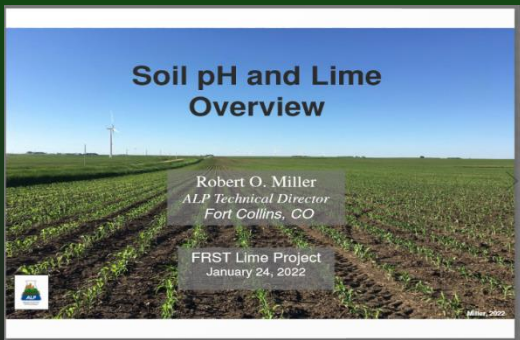
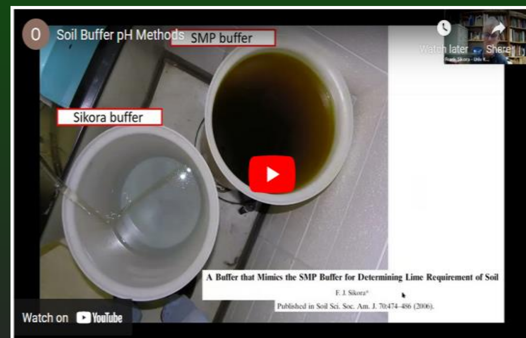
FRST Lime Project: presentations

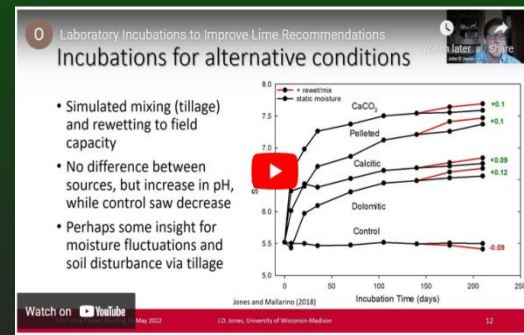
pH overview



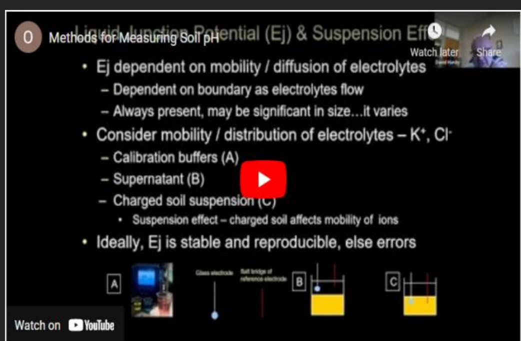
BpH method



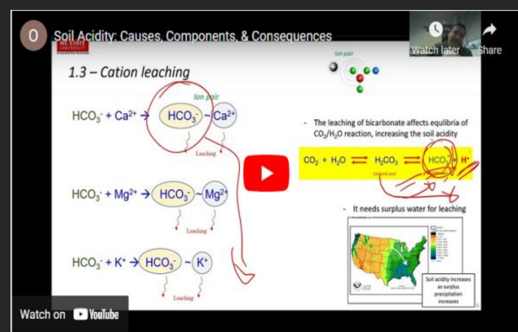
Lime incubation



pH method



Soil acidity



soiltestfrst.org/lime/

Miller, 2022

Current lime recommendations

- BpH lime recommendation table
- Algorithm base on pH_{H2O} and BpH
    - i. Soil depth adjustment
    - ii. Target final pH
    - iii. Adjustment for mineral vs organic soils
    - iv. Lime neutralizing value (NV) adjustment

University of Wisconsin

Target pH	Lime requirement formula[a] (tons/a 60–69 lime to apply[b])
5.2	36.1 – (3.29 x BpH) – (2.67 x WpH)
5.4	48.2 – (4.84 x BpH) – (3.03 x WpH)
5.6	51.0 – (5.40 x BpH) – (2.67 x WpH)
5.8	57.2 – (5.55 x BpH) – (3.50 x WpH)
6.0	72.7 – (7.59 x BpH) – (3.78 x WpH)
6.3	103 – (12.6 x BpH) – (3.18 x WpH)
6.5	134 – (17.2 x BpH) – (2.73 x WpH)
6.6	152 – (20.3 x BpH) – (2.17 x WpH)
6.8	195 – (28.4 x BpH) + (0.144 x WpH)

[a] Abbreviations: BpH = buffer pH, WpH = water pH.

Buffer Method – SMP/Sikora. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin (A2809).

Iowa State University

Buffer pH	Depth of Soil to be Neutralized: 2 inches, Target Soil pH 6.0	2 inches, pH 6.5	2 inches, pH 6.9	3 inches, pH 6.0	3 inches, pH 6.5	3 inches, pH 6.9	6 inches, pH 6.0	6 inches, pH 6.5	6 inches, pH 6.9
	Amount of Calcium Carbonate 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	1400	4,200	6,800

University of Delaware

Water pH	Adams-Evans Buffer pH 7.60	7.55	7.50	7.45	7.40	7.35	7.30
5.9	0.00	0.00	0.00	0.50	0.50	0.50	0.50
5.8	0.50	0.50	0.50	0.50	0.50	0.50	0.50
5.7	0.50	0.50	0.75	0.75	0.75	1.00	1.00
5.6	0.75	0.75	0.75	1.00	1.00	1.00	1.25
5.5	0.75	0.75	1.00	1.00	1.25	1.25	1.25
5.4	1.00	1.00	1.00	1.25	1.25	1.50	1.50
5.3	1.00	1.25	1.25	1.50	1.50	1.50	1.75
5.2	1.00	1.25	1.50	1.50	1.75	1.75	2.00
5.1	1.25	1.25	1.50	1.75	1.75	2.00	2.00
5.0	1.25	1.50	1.75	1.75	2.00	2.00	2.25

Target pH 6.5 (0-8”), Lime Rate tons per acre 67% ECCE.

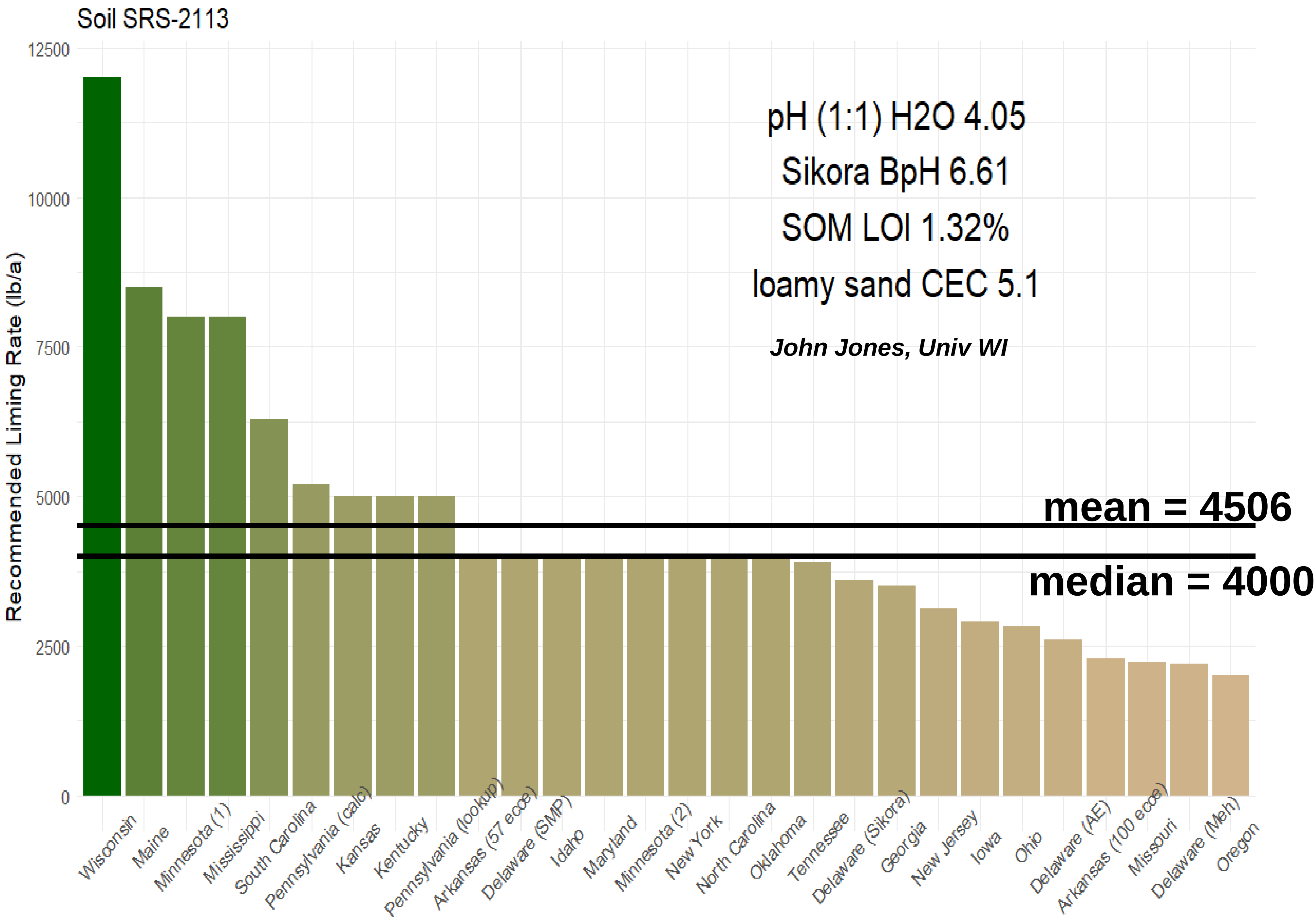
Miller, 2022

FRST Lime Project: recommendation survey

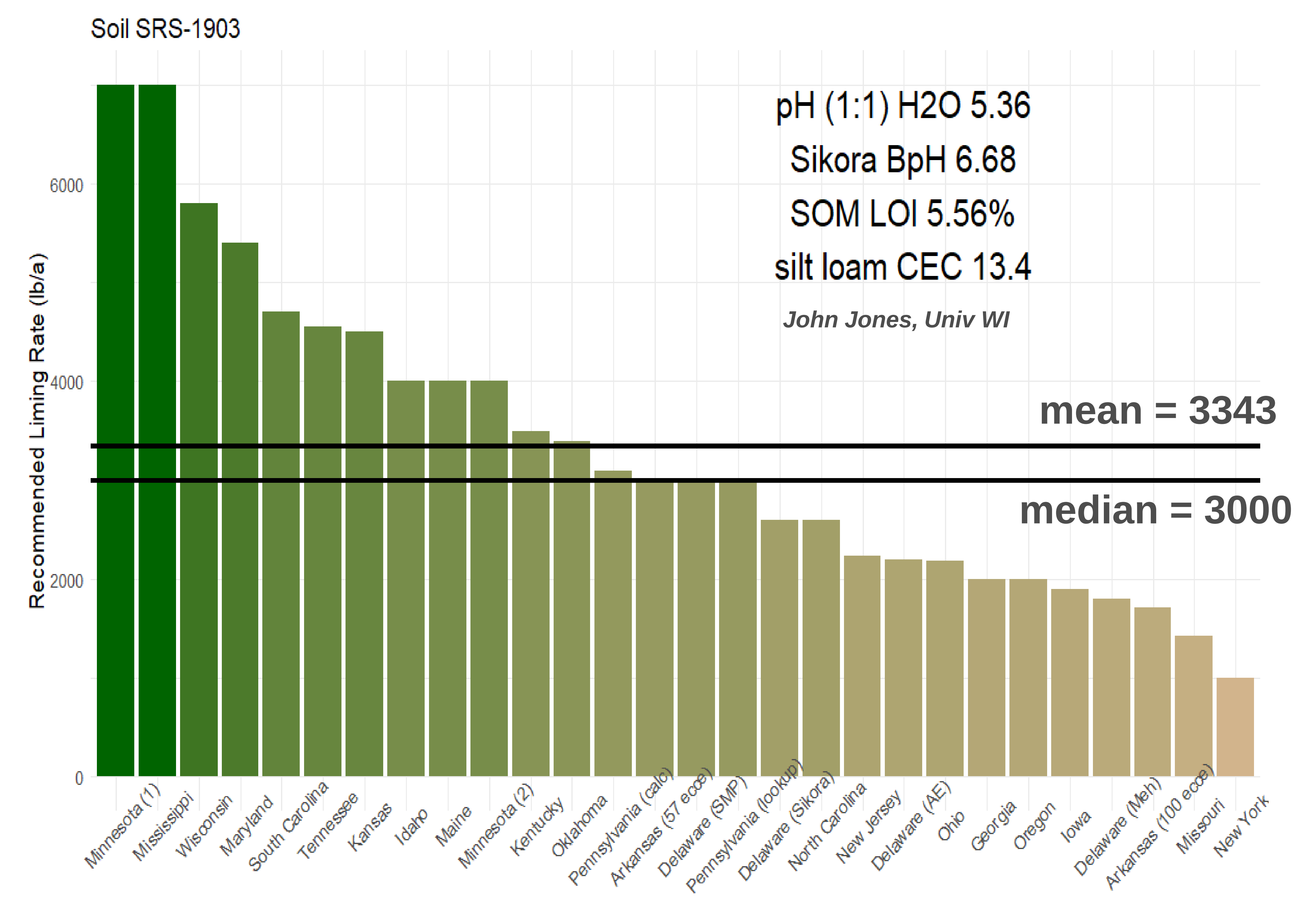
ALP pH and BpH data for six PT soils was submitted to 28 LGU labs for lime recommendations. Soils pH ranged in pH 4.05 – 5.89. Soil Properties:

ALP Soil ID	pH	BpH	CEC	SOM-LOI
			cmol kg^{-1}	%
SRS-2113	4.05	6.61	5.1	1.32
SRS-2102	4.23	6.36	6.6	1.19
SRS-1614	4.60	5.90	18.4	5.47
SRS-1903	5.36	6.68	13.4	5.56
SRS-1604	5.52	6.90	12.3	2.27
SRS-2115	5.84	6.81	12.7	1.94

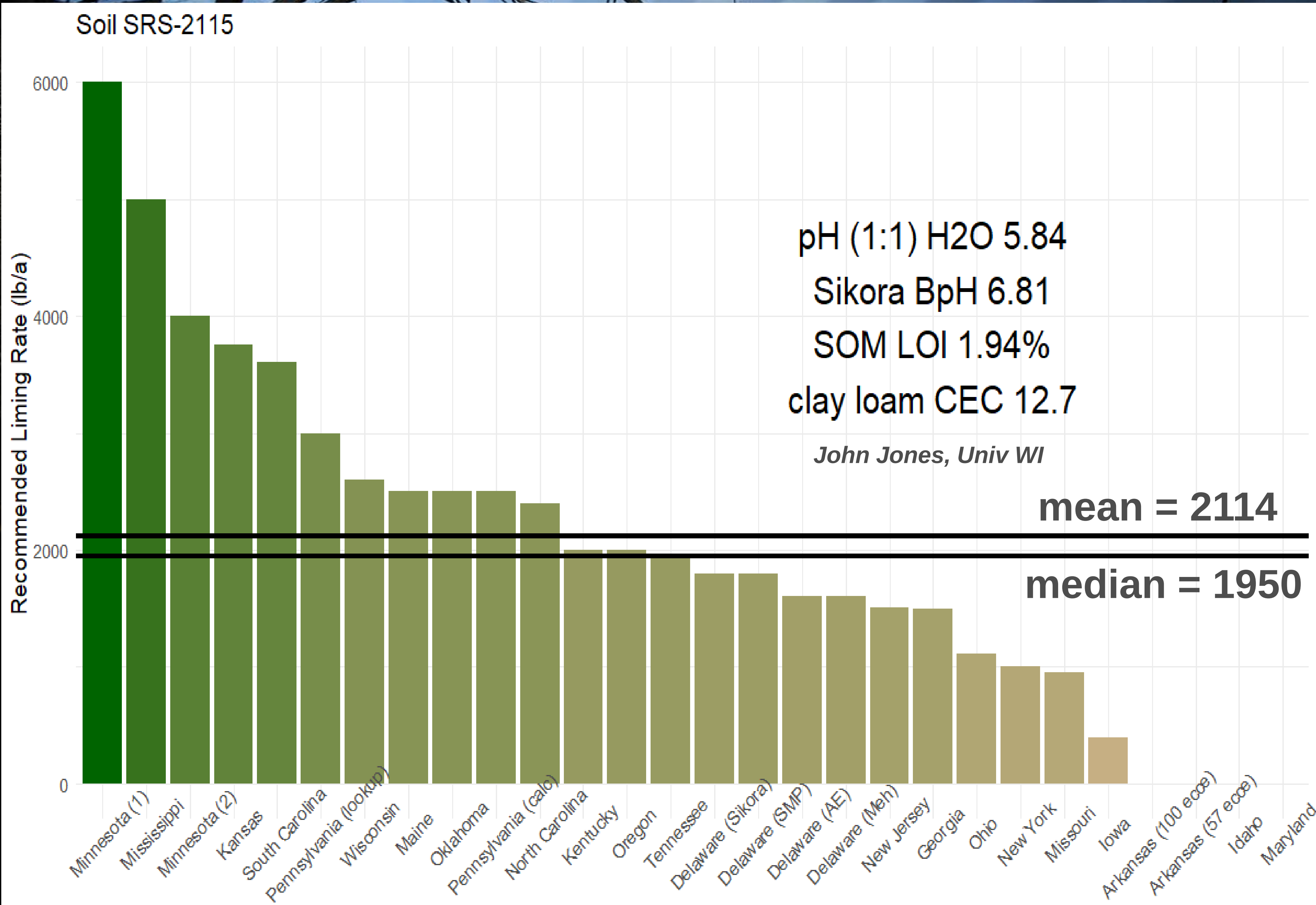
Miller, 2022



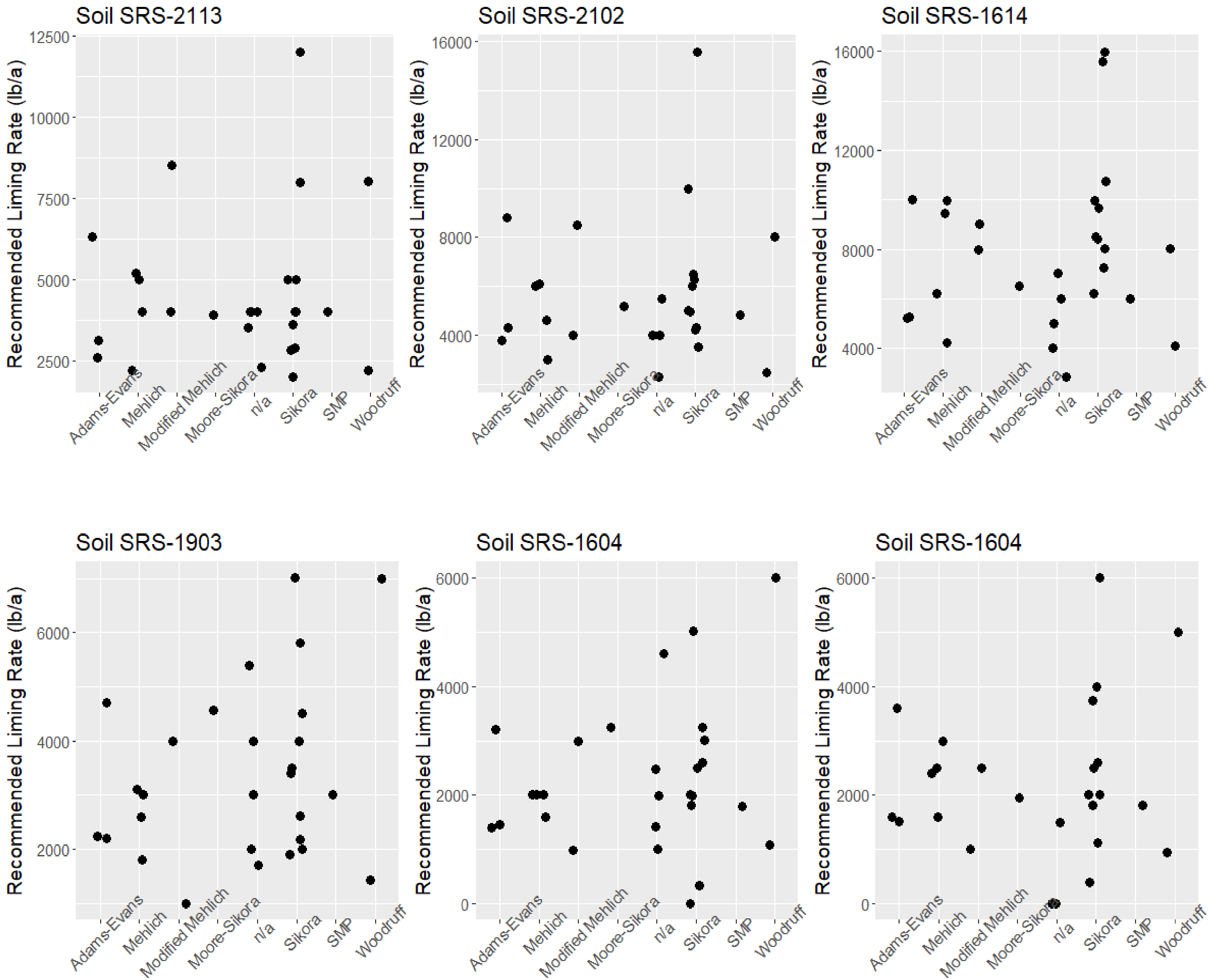
Soil SRS-2113
pH (1:1) H2O 4.05
Sikora BpH 6.61
SOM LOI 1.32%
loamy sand CEC 5.1
John Jones, Univ WI
mean = 4506
median = 4000
Recommended Liming Rate (lb/a)
12500
10000
7500
5000
2500
0
Wisconsin
Maine
Minnesota (1)
Mississippi
South Carolina
Pennsylvania (calc)
Kansas
Kentucky
Pennsylvania (lookup)
Arkansas (57 ecce)
Delaware (SMP)
Idaho
Maryland
Minnesota (2)
New York
North Carolina
Oklahoma
Tennessee
Delaware (Sikora)
Georgia
New Jersey
Iowa
Ohio
Delaware (AE)
Arkansas (100 ecce)
Missouri
Delaware (Meh)
Oregon



Soil SRS-1903
pH (1:1) H2O 5.36
Sikora BpH 6.68
SOM LOI 5.56%
silt loam CEC 13.4
John Jones, Univ WI
mean = 3343
median = 3000
Recommended Liming Rate (lb/a)
0
2000
4000
6000
Minnesota (1)
Mississippi
Wisconsin
Maryland
South Carolina
Tennessee
Kansas
Idaho
Maine
Minnesota (2)
Kentucky
Oklahoma
Pennsylvania (calc)
Arkansas (57 ecce)
Delaware (SMP)
Pennsylvania (lookup)
Delaware (Sikora)
North Carolina
New Jersey
Delaware (AE)
Ohio
Georgia
Oregon
Iowa
Delaware (Meh)
Arkansas (100 ecce)
Missouri
New York


Soil SRS-2115
Recommended Liming Rate (lb/a)
6000
4000
2000
0
pH (1:1) H2O 5.84
Sikora BpH 6.81
SOM LOI 1.94%
clay loam CEC 12.7
John Jones, Univ WI
mean = 2114
median = 1950
Minnesota (1)
Mississippi
Minnesota (2)
Kansas
South Carolina
Pennsylvania (lookup)
Wisconsin
Maine
Oklahoma
Pennsylvania (calc)
North Carolina
Kentucky
Oregon
Tennessee
Delaware (Sikora)
Delaware (SMP)
Delaware (AE)
Delaware (Meh)
New Jersey
Georgia
Ohio
New York
Missouri
Iowa
Arkansas (100 ecce)
Arkansas (57 ecce)
Idaho
Maryland

John Jones, Univ WI



Lime Survey Summary

- Liming recommendations represent considerable research effort and resources.
- As an agronomist advising farmers, how would you interpret 4.5, 5.0, 5.5 soil pH values?
- Variability by state and buffer solution type is great.
- Investigation methods focused on regional soils, but also biased towards state cropping systems? (e.g., WI considering alfalfa requirements and not simply lime to increase pH?)

Jones, 2022

FRST Lime Project: Incubation study

Collect 120 soils across the US representing major soil physiographic units across the four major soil regions (WERA-102, SERA-6, NEC-67 NECRA-13. Soils ranging in pH 4.0-6.4, loamy sand to clay loam, CEC, SOM and mineralology. In progress

Soil acidity is independent of soil type or location.

Miller, 2022

FRST Lime Project: Incubation study

Soil Analysis: pH (2 methods), BpH (4 methods), M3 analytes, SOM, SOC, CEC, titrateable acidity, and exch Al.

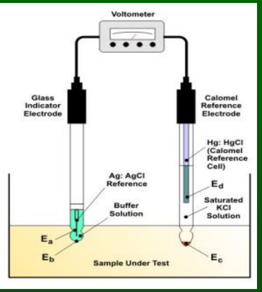
Lime incubation study: 7 rates of lime application, source $Ca(OH)_2$, 10 day equilibration, and assess pH and NO_3-N.

Develop lime recommendation algorithms based on the four 4 buffer pH methods (Sikora, Adams Evans, Mehlich Modified and Sikora-2) and multi- regression analysis.

Verify lime recommendation algorithms on 12 new soils.

Miller, 2022

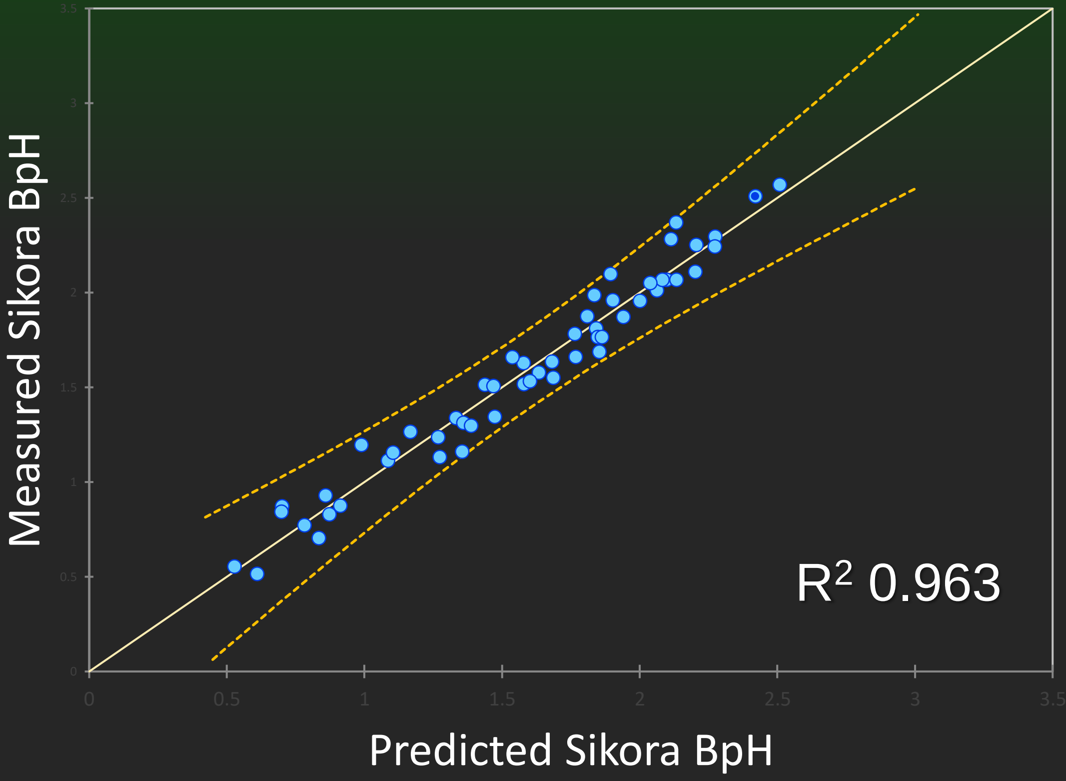
FRST Lime: BpH model



BpH model based on ALP data, multi linear regression utilizing soil pH_{salt}; CEC and M3-Ca, n=54 soils, pH < 6.3, BpH Sikora < 7.0.

Sikora BpH, as a measurement of reserve acidity, is highly related to pH, CEC and M3-Ca for ALP soils.

Results suggest a similar model relating lime neutralization of soil acidity could be developed using pH, M3 cations and CEC.



Miller, 2022

FRST Lime Project: support

The FRST project is supported through a USDA grant, and is funding for lime project soil collections for the initial incubation research.

Additional support will be need to complete soils analysis incubation research and data analysis.

Support will be sought from the fertilizer industry, lime manufacturers and commodity workgroups.

Summary

Acid soils are extensive in the US, with agriculture utilizing 79 M metric tons of aglime in 2018, valued at $3.3 billion. Across the US soil s with pH < 6.2 constitute 20-80% of soils tested.

FRST lime project survey of lime recommendations used in the US show high variability in recommendations.

Given pH and BpH, LGU lime Recs are highly variable across the US ranging from 1000 – 6000 lbs/ac on an acid soil. Even labs using the same BpH mehtod had highly variable lime recs.

The goal of the FRST Lime project is to develop new lime recommendations based on current BpH methods, basd on a national US database.

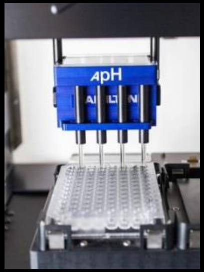
Miller, 2020

Thank you for your time and attention

E-mail:
Robert.Miller@cts-interlab.com
Txt: 970-217-2572

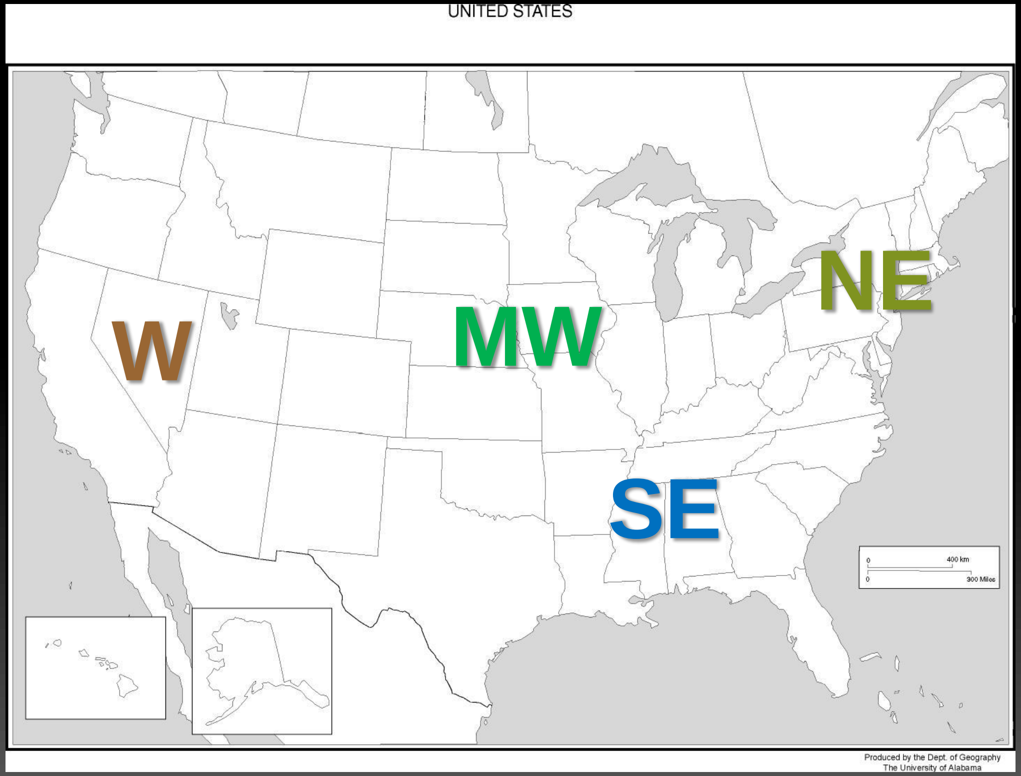
http://upload.evocdn.co.uk/fruitnet/uploads/asset_image/2_1208010_e.jpg

Soil buffer pH methods, North America



Measurement of reserve acidity

1) SMP BpH (MW, W)
2) Sikora BpH (SE, MW)
3) Adams Evans BpH (SE, MW, W)
4) Moore-Sikora BpH (SE)
5) Mehlich BpH_{orig} (SE)
6) Mehlich BpH_{mod} (NE, SE)
7) Sikora 2 BpH (SE, MW)
8) Woodruff BpH (MW)
9) $CaOH_2$ Titration (SE)



A Sikora BpH method was developed on 2002 to replace hazardous reagents components of the SMP BpH method, and has been widely adopted. Moore-Sikora represents a modification of the Adams Evans BpH implemented at Clemson University, 2012. Modified Mehlich BpH introduced in 2002, substituting Ca for Ba in the BpH reagent.

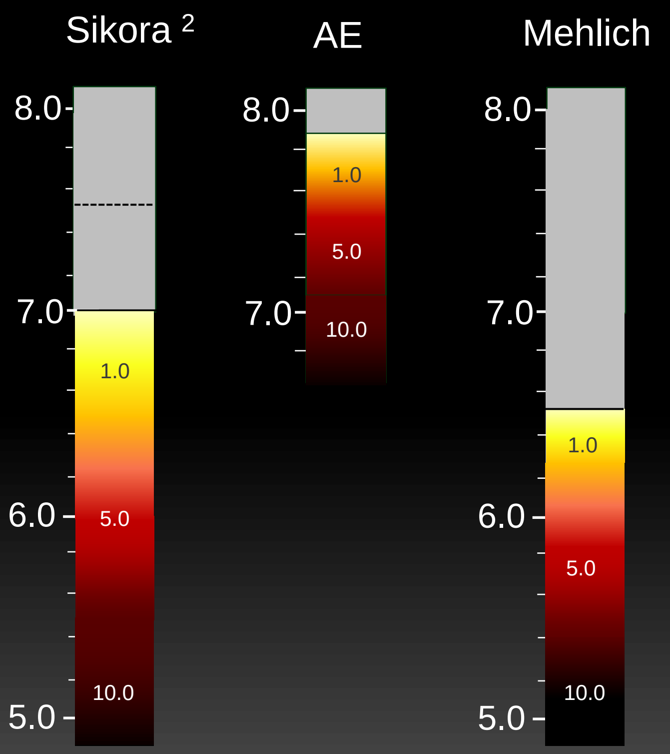
Miller, 2020

Soil BpH methods

Lab BpH methods[1] are based on soil/buffer equilibration: SMP, 10 minutes stirring and 30 minutes settle time;, Mehlich BpH is 5 seconds stir and 30 min settle.

The Adam Evans (AE) BpH was developed for soils with low CEC, low in 2:1 clay minerals. Whereas, SMP was developed for soils CEC 10 -25 cmol/kg dominant in 2:1 soil clay minerals.

Response range for AE BpH is narrower 7.90 – 7.20 than SMP or Sikora BpH. Mehlich BpH range 6.6 – 5.1.



[2] Max range of lime rates 0-10 ton/ac

Measurement uncertainty
Sikora BpH: ± 0.05 pH
AE BpH: ± 0.03

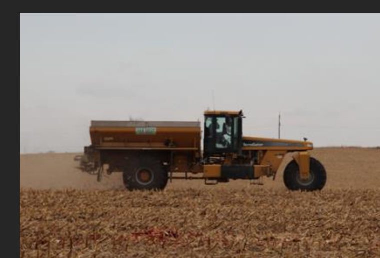
[1] Sikora, F. 2014. Soil test Methods for the Southeastern United States. Southern Cooperative Series Bulletin No. 419ISBN# 1581614195

Miller, 2022

FRST Lime Project: Identify need

Need of updating Recs. Lime rate recommendations, with few exceptions, are more than three decades old. Over this period tillage systems have shifted and both nutrient applications rates and yields increased. Need to update lime recommendations.

Lime-Rec inconsistencies. Recommendations are mostly state specific, based on researcher/grad student studies, and as a result rates are variable.



Lab pH and BpH quality. Today more than 80% of soil testing today is done by commercial labs. Method issues of both inter and intra lab consistency.

Miller, 2022

Comparison of lime recommendations

Soil ID [1]	SRS-1910	SRS-2001	SRS-2006	SRS-2003
pH_{H2O}	5.78	5.19	5.48	6.01
Sikora BpH	6.87	6.65	6.50	6.85
AE BpH	7.54	7.44	7.30	7.45

	Calculated lime rate lbs/ac [2]			
Kansas St Univ	1000	1600	2100	200
Tri-State (OH-MI-IN)	500	2100	3200	700
Mid West LGU	200	16700	22300	0
Clemson Univ	1100	1900	2100	1100
Univ Delaware	1400	2500	2800	1400

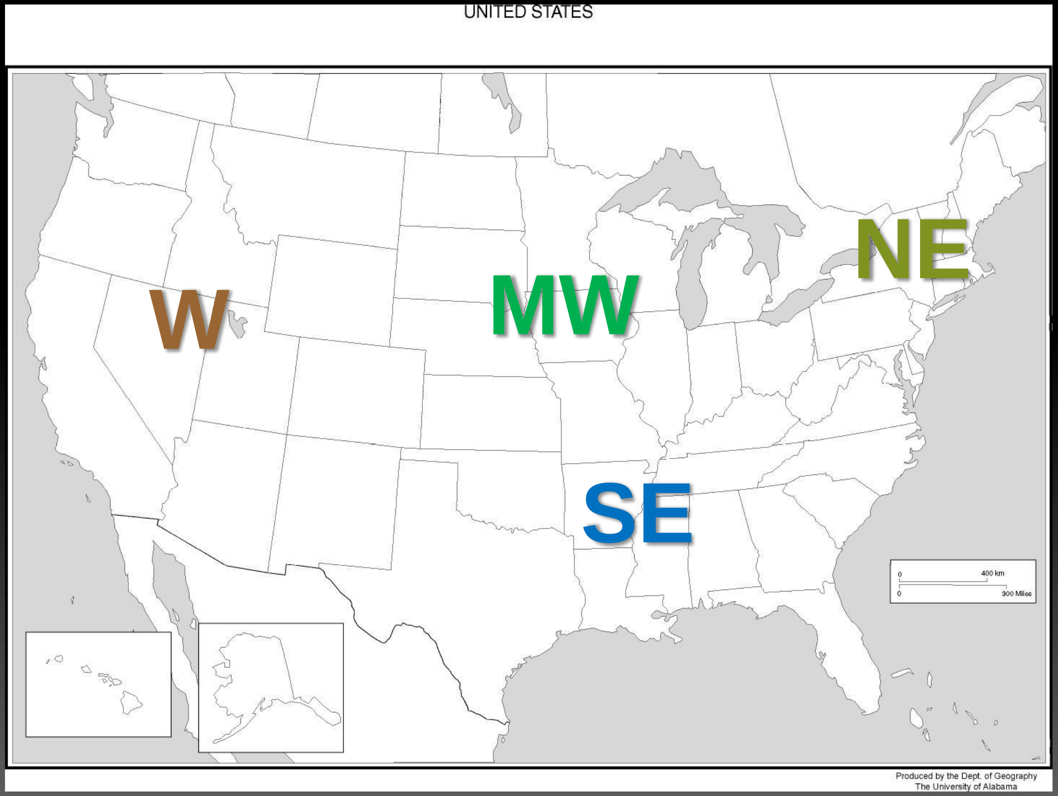
[1] Soil data source ALP program 2019-2020, population median values.
[2] Recommendations based on a 3” depth, target pH of 6.5, and 100% ECCE.

Miller, 2022

Soil pH methods, North America

Measurement of active acidity

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

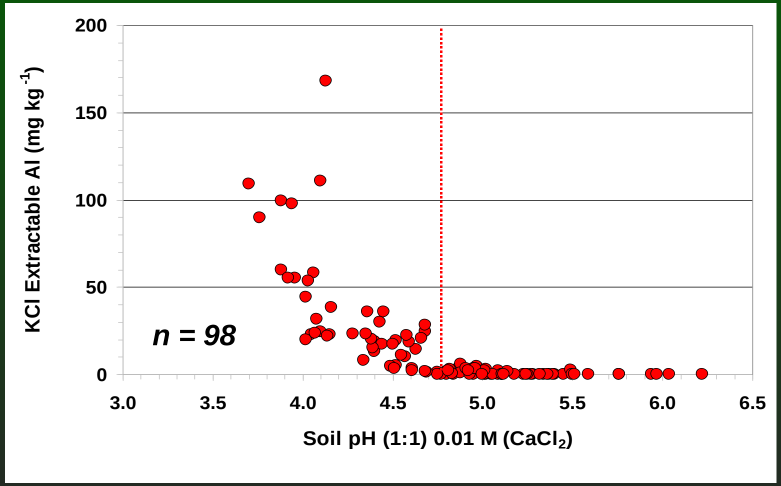


[1] Usage of the pH salt method has increased in the last decade to address low ionic strength soil slurry solutions and improve accuracy.

Miller, 2022

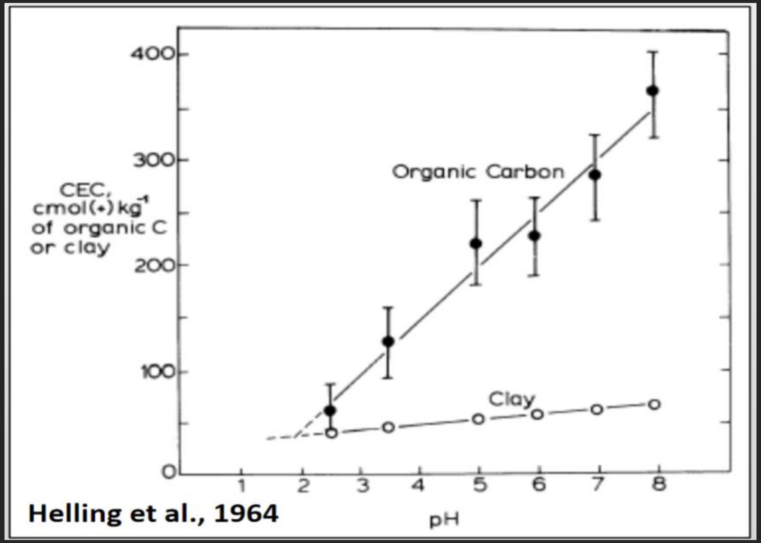
Soil pH: Al^{3+} and CEC

Extractable Al^{3+} increases as pH (salt) declines below 5.0. Low pH suppresses plant vigor and may results in Al^{3+} toxicity for specific crops.



Miller R.O. 2005. California Department of food and Agriculture, Project Report.

Soil CEC is pH dependent. Soil minerals show a slight increase in CEC transitioning from pH 5.0-7.0, whereas organic carbon, shows a dramatic change, increasing 32%.



Miller, 2020

Lab quality of BpH analysis

Upper Midwest Region

Double-blind ALP reference soils were submitted to 7 labs and replicated 3 times, 2019. Lime rates calculated based on ISU recommendations. Lab ID CIA BpH resulted in lime rates range 3800 lbs/ac, $114/ac.

Soil ID ALP SRS-1814		Lab ID CIA	
Date of Analysis	pH_{H2O}	Sikora BpH	Lime rate (lbs/ac) [1]
10 / 2019	6.10	6.48	2,900
11 / 2019	5.60	6.10	5,700
12 / 2019	6.20	6.63	1,900
Ref Value	6.08	6.67	1,600

[1] Lime recs bases on ISU lime recommendations, based on 1550 ECCE.

Southeast Region

Double-blind reference soils submitted to 5 labs, and replicated 3 times, 2000. Lime rates calculated based on SERA-6 recommendations. Lab ID AYT BpH values range in lime rate 5,700 lbs/ac, $171/ac.

Soil ID ALP SRS-1913		Lab ID AYT	
Date of Analysis	pH_{H2O}	BpH	Lime rate (lbs/ac) [2]
5 / 2020	4.5	6.1	11,500
6 / 2020	4.5	6.2	10,000
7 / 2020	4.8	6.5	5,800
Ref Value	4.6	6.5	5,800

[2] Lime recs based on SERA-6, SMP method (KY) lime recommendations, based on 1550 ECCE.

* Lime cost estimate $60/ton

Miller, 2022

pH, liming and VRT

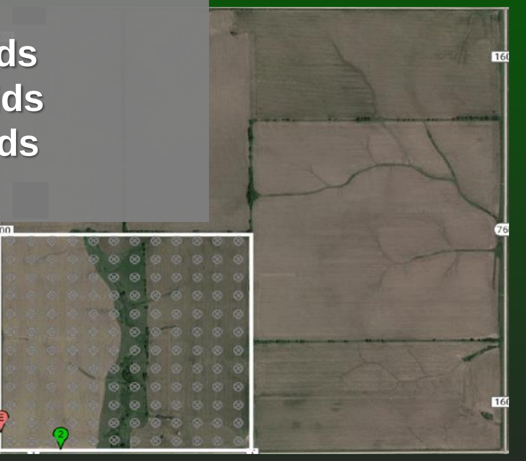
Liming has increased with the advent of precision Ag and VRT specific placement across the field.

Lime evaluation on a 155 acre field shows a 40% reduction in cost, for 2.5 ac grid relative to composite. Lime cost savings pays for sampling.

Nebraska Field
Sampled April 2017
155 acres

Field sampling split into:
One composite sample
Grid sampling
- **1.1 Acre grids**
- **2.5 Acre Grids**
- **4.4 acre Grids**

Zones: 6



Soil Density Sampling	Ag Lime Tons	Field Lime Cost
Grid - 1.1 ac	280	$11,780
Grid - 2.5 ac	240	$10,008
Grid - 4.4 ac	272	$11,424
Field composite	399	$16,721
Zone : n=6	401	$16,842

Ag Lime: Rec based on SMP BpH and LGU Rec, lime used in formulas is 1,500 ECCE, $42.00/ton

Cost of Lime $10 - $20/tn - OH
Trucking delivery: $10/tn
VRT application cost: $8 - $12/tn
VRT cost $40 - $50/tn – NE, IA, NC

Lime application frequency:
Midwest: 3 yrs new ground;
7 yrs when BpH reaches 6.9/7.0;
High rainfall regions, annually

Miller, 2020

Quality of BpH analysis

Southern Region

Six double-blind reference soils were submitted to five labs, and replicate 3 times in the spring of 2020. Lime rates were calculated based on SERA-6 lime recommendations.

Lab ID AYT (at right) showed a wide range in SMP BpH values resulting in a range in lime rate of 5,700 lbs/ac. BpH repeatability was an issue on 2 of 6 soils evaluated.

Soil ID ALP SRS-1913			
Date of Analysis	Soil pH_{H2O}	BpH	Lime rate (lbs/ac) [1]
5 / 2020	4.5	6.10	11,500
6 / 2020	4.5	6.21	10,000
7 / 2020	4.8	6.52	5,800
Ref Value	4.6	6.54	5,500

[1] Lime recs based on SERA-6, SMP method (KY) lime recommendations, based on 1550 ECCE.

5,700 lbs/ac results in a difference in $128/ac, @ a lime cost: $45/ton

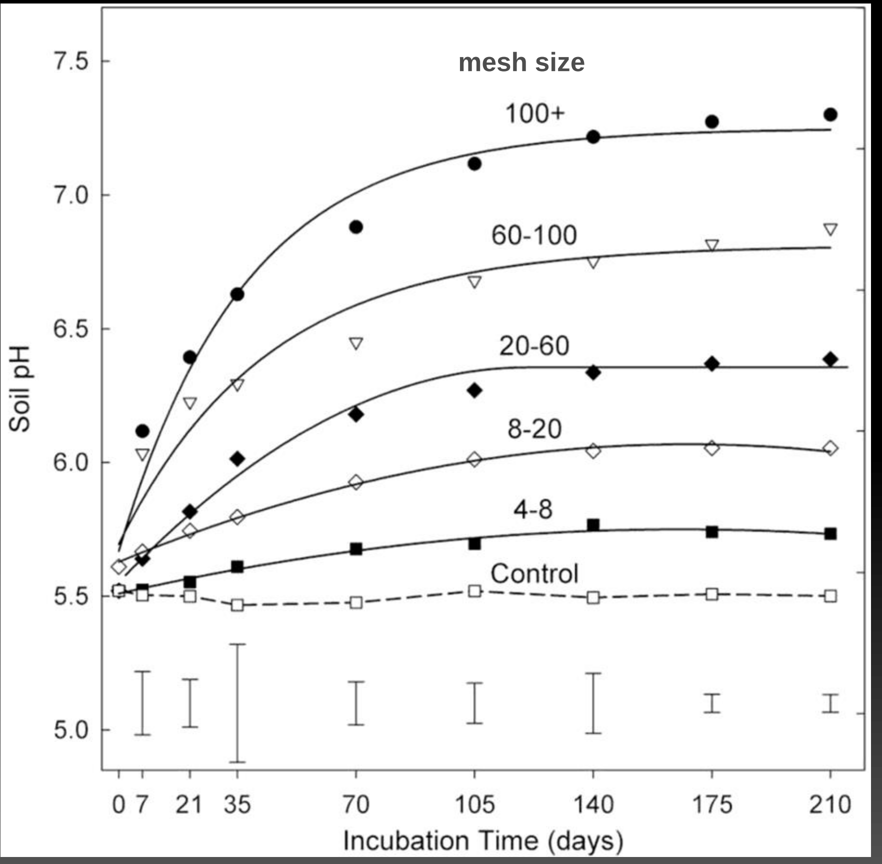
Miller, 2020

Lime quality - finess

Lime finess impact the reaction time. Efficiency of lime at raising pH relative to $CaCO_3$ increases with incubation time and particle fineness.

Finer particle sizes reduce incubation time for neutralizing soil acidity.

Pelleted lime, calcitic aglime, and dolomitic aglime efficiencies across all incubation periods were 60 to 90, 47 to 65, and 12 to 47% respectively (Jones and Mallarino, 2018).



https://www.google.com/url?sa=i&url=https%3A%2F%2Facsess.onlinelibrary.wiley.com%2Fdoi%2Ffull%2F10.2136%2Fsssaj2017.06.0207&psig=AOvVaw1O8dGcxBqJhvvme0rEs2uL&ust=1601230474287000&source=images&cd=vfe&ved=0CAMQjB1qFwoTCND6yYW3h-wCFQAAAAAdAAAAABAT

Jones and Mallarino. 2018. Influence of Source and Particle Size on Agricultural Limestone Efficiency at Increasing Soil pH. SSSAJ 82: 271-282.

Miller, 2020

Soil depth and liming

Stratification of pH and BpH provide challenges for making lime recommendations.

N-8 field on the left has low lime rate on surface but higher rec in sub soil. Challenge in no-Till field.

K-9 is more typical with acid soil at surface and trend upward with depth.

Nitz 80 - 2017

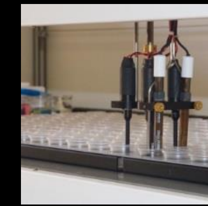
Depth [1]	pH	BpH
0 – 2”	6.3	6.7
2 – 4”	5.9	6.5
4 – 6”	5.3	6.1
6 – 8”	5.4	6.3

K9 - 2017

Depth [1]	pH	BpH
0 – 2”	5.0	6.3
2 – 4”	5.1	6.4
4 – 6”	5.5	6.6
6 – 8”	6.0	6.8

Ag Lime: Application based on 100% ECCE, lime used in formulas is 1,500 ECCE corrected to 100%, $42.00/ton

Soil BpH methods



BpH methods based on soil + buffer reagent, stirring, equilibration time with subsequent measurement of pH with ISE. Equilibration times: 10 – 15 minutes.

Response range for Adams Evans (AE) BpH is narrower 7.20 – 7.90 than other BpH methods.

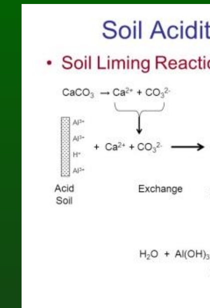
Across methods BpH lab std errors ($\sigma\bar{x}$) range from 0.01 – 0.03 BpH units across the working range 5.0 - 7.5 .

Method [1]	Mean	Std error
pH 1:1 $_{H_2O}$	5.91	0.05
pH 1:1 $_{0.01\ M\ CaCL2}$	7.70	0.01
SMP BpH	6.73	0.02
Sikora BpH	6.72	0.01
Adam Evans BpH	7.44	0.02
Mehlich BpH	6.13	0.02

[1] Data Source: ALP program, soil ID SRS-1814.

Sikora, F. 2014. Soil test Methods for the Southeastern United States. Southern Cooperative Series Bulletin No. 419ISBN# 1581614195

Amelioration of Acidity - Liming



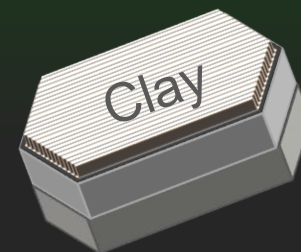
$CaCO_3$

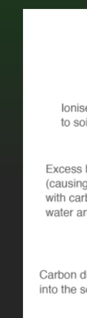
In moist soil calcium carbonate dissolves into calcium and carbonate ions

Ca^{2+}

Calcium replaces hydrogen on soil constituents

CO_3^{2-}





$2H^+$

Excess hydrogen ions react with carbonate to form water and carbon dioxide

H_2O

Carbon dioxide is Released to the air

CO_2

Hydrogen chemically bound to soil water

Miller, 2020

Soil BpH methods

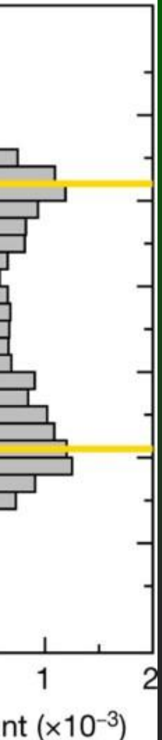
BpH methods based on soil + buffer reagent, stirring, equilibration time with subsequent measurement of pH with ISE. Equilibration times: 10 – 15 minutes.

Response range for Adams Evans (AE) BpH is narrower 7.20 – 7.90 than other BpH methods.

Across methods BpH lab std errors ($\sigma_{\bar{x}}$) range from 0.01 – 0.03 BpH units across the working range 5.0 - 7.5 .

Method [1]	Mean	Std error
pH 1:1 $_{H_2O}$	5.91	0.05
pH 1:1 $_{0.01\ M\ CaCL2}$	7.70	0.01
SMP BpH	6.73	0.02
Sikora BpH	6.72	0.01
Adam Evans BpH	7.44	0.02
Mehlich BpH	6.13	0.02

[1] Data Source: ALP program, soil ID SRS-1814.



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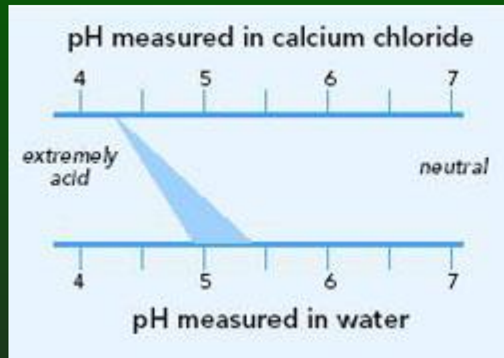


https://agriculture.vic.gov.au/__data/assets/image/0008/560834/figure-1_ph-measured-calcium-water.jpg

The pHW may be higher by 0.6 to 1.2 in low salinity soils and higher by 0.1 to 0.5 in high salinity soils. Research has shown a difference of 0.7 for a wide range of soils.
Higher pHW values to around 10 may be associated with alkali mineral soils containing sodium carbonates and bicarbonates.
Research has shown that seasonal variation of pHW can vary up to 0.6 of a pH unit in any one year. In comparison, soil pHCa measurements are less affected by seasons.

Soil BpH methods

BpH methods based on soil + buffer reagent, stirring, equilibration time with subsequent measurement of pH with ISE.

Across methods BpH uncertainty averages ± 0.06 BpH units across the working range 5.0 -7.5 .

The difference between BpH - pH reflects the amount of reserve acidity neutralized, and is proportional to CEC.

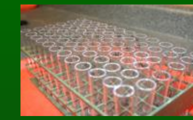
Lime recommendations, based on buffer pH, are calibrated based on soil $CaCO_3$ equilibration research and assessment of neutralization of acidity.

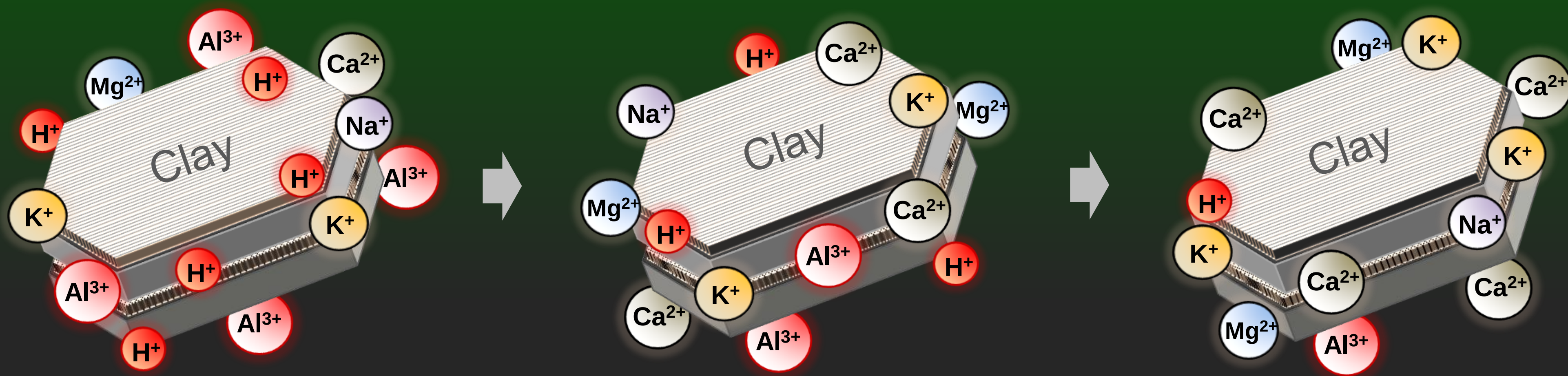
Soil ID [1]	CEC Cmol/kg	pH (1:1) H2O	BpH Sikora
SRS-1706	2.7	5.34	7.07
SRS-1511	6.7	5.60	6.82
SRS-1705	11.5	5.50	6.60
SRS-2006	20.2	5.48	6.48

[1] Data Source: ALP program, 2015-2020, median values.

Miller, 2020

Soil pH and Base Saturation (BS)





pH 4.0

Base Saturation 30%

pH 5.0

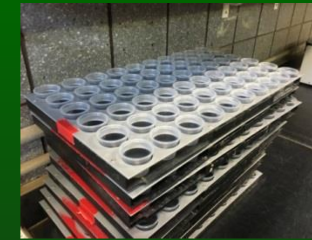
Base Saturation 50%

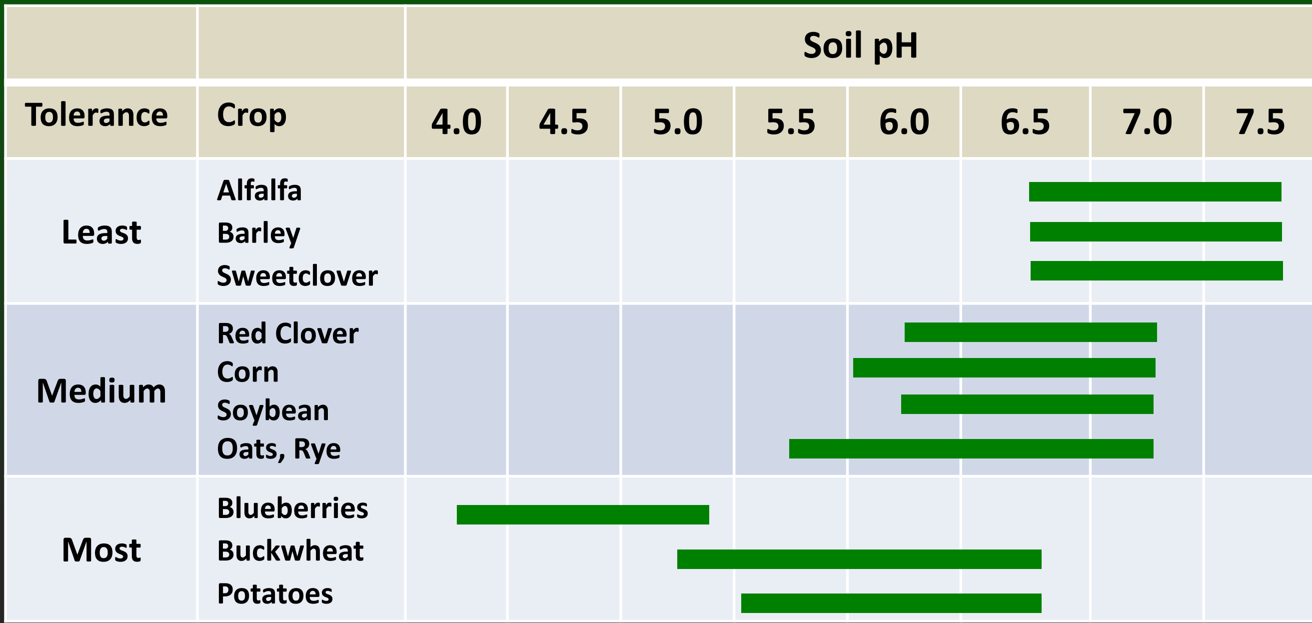
pH 6.0

Base Saturation 80%

Adapted from www.agric.wa.gov.au/soil-acidity

Impact of soil pH on crop tolerance





https://www.agry.purdue.edu/ext/forages/publications/AY-267_fig2.jpg

Table 1. Crop yields relative to pH.

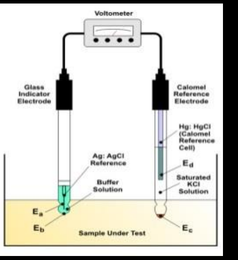
Crop	Soil pH				
	4.7	5	5.7	6.8	7.5
	Relative Yield (100 is the best, 0 is the worst)				
Corn	34	73	83	100	85
Wheat	68	78	89	100	99
Soybeans	65	79	80	100	93
Oats	77	93	99	98	100
Barley	0	23	80	95	100
Alfalfa	2	9	42	100	100
Timothy (grass)	31	47	[illegible]	[illegible]	95

Methods for Assessing Soil Quality, page 173 (SSSA, 1996)

https://www.fssystem.com/Port
resize566x333.jpg

Miller, 2019

Soil pH (1:1) method performance

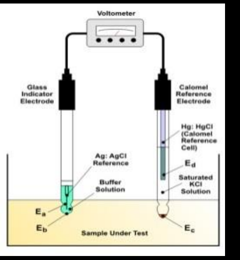


Soil ID [1]	pH (1:1) H_2O		pH (1:1) 0.01 M $CaCl_2$	
	Mean	Stdev	Mean	Stdev
SRS-1911	5.46	0.06	5.05	0.03
SRS-1912	8.13	0.05	8.10	0.06
SRS-1913	4.60	0.06	4.30	0.03
SRS-1914	5.43	0.08	5.10	0.03
SRS-1915	7.46	0.05	7.30	0.04

[1] Source Agricultural Laboratory Proficiency program cycle 41 data base, 2019. Data intra-lab method performance, three replications.

Miller, 2020

Soil buffer pH method comparison



Soil ID [1]	pH (1:1) H_2O	SMP Buffer		Sikora Buffer		Adams Evans Buffer	
	Mean	Mean	Stdev	Mean	Stdev	Mean	Stdev
SRS-1911	5.36	6.62	0.04	6.68	0.05	7.43	0.03
SRS-1912	6.16	6.90	0.04	6.92	0.06	7.53	0.03
SRS-1913	6.88	6.88	0.06	7.01	0.05	7.67	0.03
SRS-1914	4.60	6.54	0.03	6.61	0.09	7.46	0.03
SRS-1915	5.43	6.56	0.04	6.64	0.04	7.39	0.04

[1] Source Agricultural Laboratory Proficiency program cycle 39-41 data base, 2019. Data intra-lab method performance, three replications.

Miller, 2020

Nitrogen fertilizer and equivalent acidity

Material	% Nitrogen	kg of Lime per kg of N
Ammonium Sulfate	20.5	5.35
Calcium Nitrate	16.0	0.0
Urea	46.6	1.8
UAN 32	45.5	1.8
Organic Biomass	2.2	0.9

[1] Source: Andrews, 1954. The Response of Crops and Soils to Fertilizer and Manures.

Miller, 2019

BpH lab data quality

Reference soils (double –blind) were submitted to 7 Midwest labs fall 2019, and replicate three times over 3 months.

Lab ID CIA (at right) showed a wide range in Sikora BpH values resulting in variance in lime rate of 2200 lbs/ac for soil ID SRS-1612 and 3848 lbs/ac for SRS-1814, BpH repeatability was an issue on 5 of 6 soils evaluated.

Buffer pH repeatability was an issue for 2 of 7 labs tested in 2019.

Soil ID ALP SRS-1612

Date of Analysis	Soil pH_{H2O}	Sikora BpH	Lime Rate (lbs/ac) [1]
10 / 2019	5.40	6.67	1565
11 / 2019	5.10	6.53	2581
12 / 2019	5.80	6.79	694
Ref Value	5.11	6.62	1780

[1] Lime recs bases on ISU lime recommendations, based on 1550 ECCE.

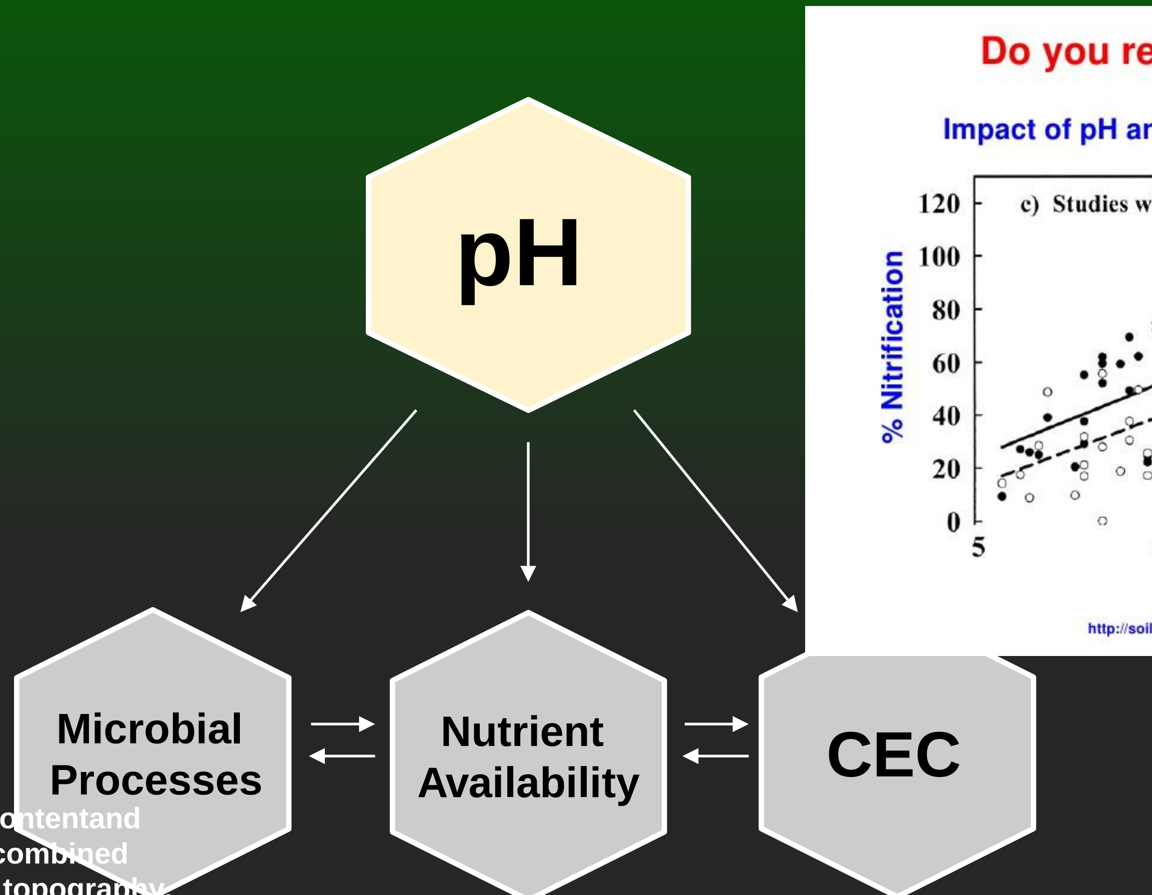
Soil ID ALP SRS-1814

Date of Analysis	Soil pH_{H2O}	Sikora BpH	Lime Rate (lbs/ac) [1]
10 / 2019	6.10	6.48	2944
11 / 2019	5.60	6.10	5703
12 / 2019	6.20	6.63	1855
Ref Value	6.08	6.67	1565

Miller, 2020

Impact of Soil pH

pH impacts multiple soil properties ed by all three soil components. It is associated with clay and SOM and modified by pH.



Inherent factors affecting soil pH such as climate, mineral contentand soil texturecannot be changed. Natural soil pH reflects the combined effects ofsoil-forming factors (parent material, time, reliefor topography, climate,and organisms). The pH of newly formed soilsis determined bymineralsin the soil'sparent material. Temperature and rainfall control leachingintensity and soil mineral weathering. In warm, humid environments,soil pH decreases over time in a process called soil acidification, due to leaching from high amounts of rainfall. In dry climates, however, soil weathering and leaching are less intense and pHcanbe neutral or alkaline. Soils with high clay and organic matter content are more able to resist a drop or rise in pH (have a greater buffering capacity)than sandy soils. Although clay content cannot be modified, organic matter content can be changed by management

Miller, 2020

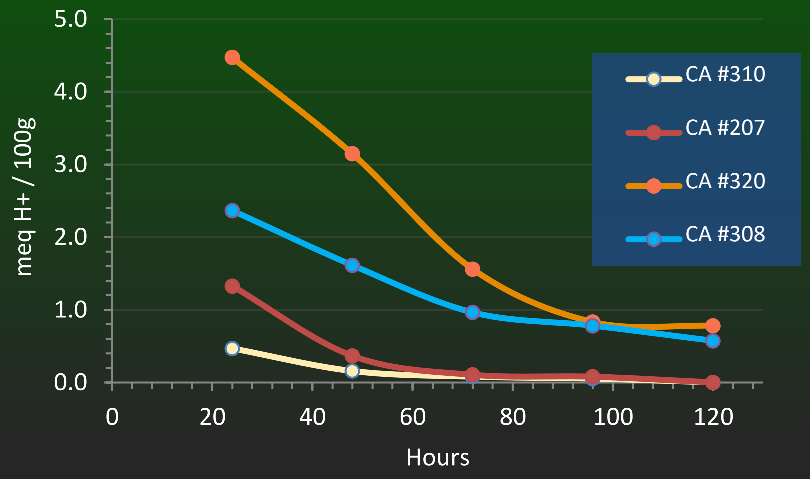
Soil BpH methods

Lab BpH methods[1] are based on soil/buffer equilibration: 10 minutes stirring and 30 minutes settle time, (note Mehlich BpH is 5 seconds stir and 30 min settle).

BpH is an approximate measure of soil reserve acidity (H^+), and the value represents a short term equilibrium.

Response range for Adams Evans (AE) BpH is narrower 7.20 – 7.90 than SMP and Sikora BpH methods.

Intra-lab BpH method std errors ($\sigma\bar{x}$) range from 0.02 – 0.03 BpH units.



Method [1]	Mean	Std error
SMP BpH	6.73	0.03
Sikora BpH	6.72	0.02
Adam Evans BpH	7.44	0.03
Mehlich BpH	6.13	0.03

[1] Data Source: ALP program, soil ID SRS-1814.

[1] Sikora, F. 2014. Soil test Methods for the Southeastern United States. Southern Cooperative Series Bulletin No. 419ISBN# 1581614195

Miller, 2020

Impact of Soil pH

pH

Soil pH reflects the combined effects of soil-forming factors (parent material, time, relief or topography, climate, and biology).

pH of newly formed soils is determined by soil parent material. Temperature and precipitation impact leaching intensity and soil mineral weathering.

In warm, humid environments, soil pH decreases over time due to leaching and mineral weathering. Dry climates, however, soil weathering and leaching are less and pH may be neutral or alkaline.

Soils high in clay and SOM content have greater buffering capacity and resist pH changes. Sandy soils commonly have low SOM content, resulting in a low buffering capacity, and have high rates of H_2O infiltration making them more vulnerable to acidification.

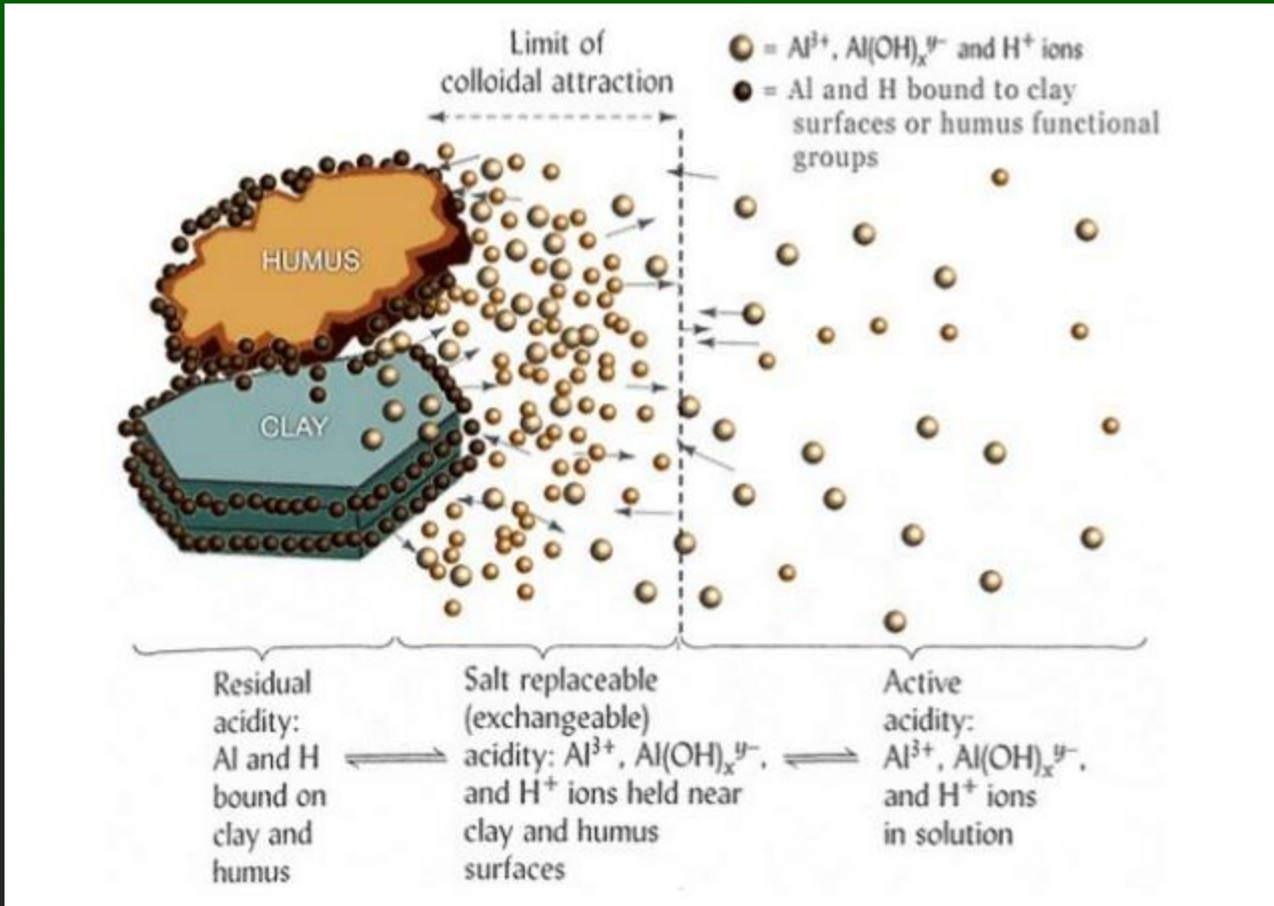
Miller, 2020

Impact of EC on soil pH method differences

ALP ID	EC (1:1) dS/m	pH $(1:1)_{H2O}$	pH $(1:1)_{0.01\ M\ CaCl2}$	Δ pH
SRS-1204	0.07	5.23	4.46	0.77
SRS-0907	0.15	5.52	4.93	0.59
SRS-1414	0.31	5.40	4.95	0.45
SRS-1702	0.45	5.25	4.90	0.35
SRS-1803	0.61	5.13	4.87	0.26
SRS-1814	1.07	5.91	5.70	0.21

[1] Source Agricultural Laboratory Proficiency program data base 2009 and 2018, median pH $(1:1)_{H2O}$ results based on 62 laboratories reporting.

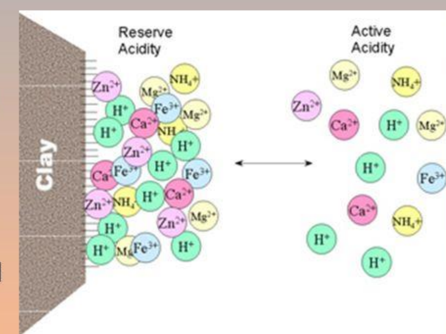
Miller, 2019



http://www.landfood.ubc.ca/soil200/images/15_3acidity.jpg

Active vs. Reserve Acidity

- active acidity
  - H^+ ions in soil solution
  - what is actually measured by a pH test
- reserve acidity
  - H^+ and Al^{+++} ions adsorbed to soil colloids



PAC Program

In February 2019 The Illinois Soil Testing Association (ISTA) and the Soil and Plant Analysis Council (SPAC), agreed to develop a memorandum of understanding (MOU) to develop a plant analysis certification (PAC) program for labs providing plant/botanical analyses in North America.

In July 2019 the MOU approved by both organizations and a PAC sub-committee was formed from members of the organizations. A draft of PAC protocols was developed in the fall of 2019 and a program logo was approved in February 2020.

PAC Committee: Vernon Pabst, Dustin Sawyer, Bryan Thayer, John Spargo

Lab plant performance, 2018

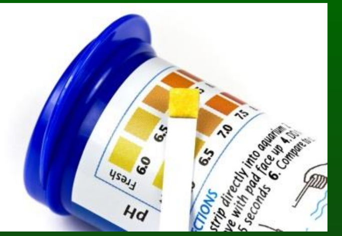
Analysis [1]	Confidence Limits as percent of the median	Total number of results [2]	Percent of labs with > 2 failures
N Comb	6	300	36.0 %
P	13	408	23.5 %
K	16	420	17.1 %
S	15	420	27.3 %
Zn	19	396	21.2%
B	21	408	26.5 %
Cu	18	348	17.2 %

[1] Plant analysis method failures based on 95% CL of median, all reporting labs, 12 samples, 2018.

[2] Total based on number of labs x number of plant samples evaluated.

Miller, 2020

Dissociation of H_2O



- $H_2O \rightarrow H^+ + OH^-$
- $K_{eq} = [H^+]\,[OH^-]$
- $\log K_{eq} = -14 = \log K_w$

$$K_{eq} = \frac{[H^+]\,[OH^-]}{[H_2O]}$$

- $pH = -\log\,[H^+]$
- $pOH = -\log\,[OH^-]$
- $pK = pOH + [H^+] = 14$

$pH = 2$

$[H^+] = 10^{-2}$

Soil vs plant method performance

ISTA Results	Method	Total number of results [1]	Lab method failures [2]	Percent of labs with > 2 failures
	pH (1:1) $_{H2O}$	330	30	9.5 %
	M3-P ICP	255	45	17.6 %
	M3-K	300	44	15.0 %

ALP Results	N-Comb	300	108	36.0 %
	P	408	96	23.4 %
	K	420	72	17.6 %
	S	420	115	27.3 %

[1] Total based on number of labs x number of results reported.

[2] Number of PT sample results exceeding 95% confidence limits of the median.

Miller, 2020

PAC Program Outline

PAC assessment of lab performance

- Laboratory ALP plant analysis data assessed annually across three cycles, total twelve (12) plant materials.

- Certification requirements. A lab must successfully pass on ten of twelve analyte results. Lab performance failure will require automatic retest. Re-test failure, removal from PAC web site.

- PAC nutrient classes:

  Macro: N, P, K, Ca, Mg, S

  Micro: B, Cu, Fe, Mn, Zn

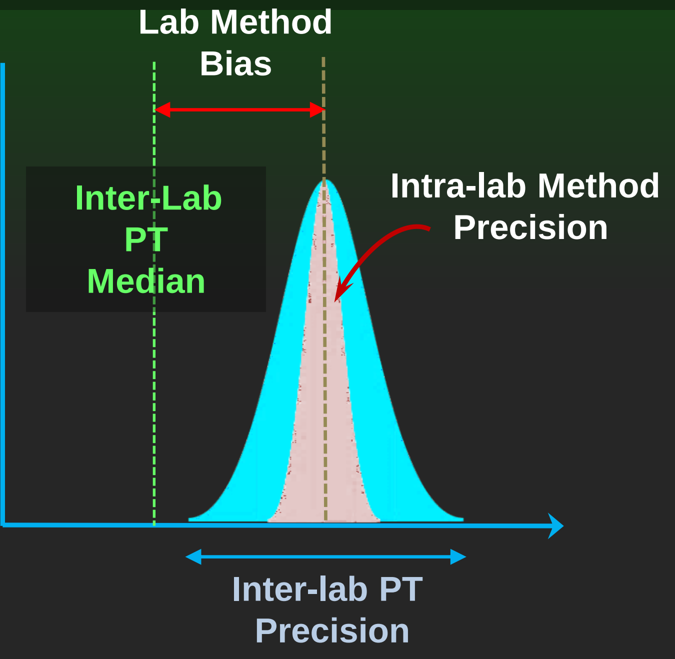
  Anion option: NO_3-N, PO_4-P, Cl

PAC Program

Assessment of lab results will be based on PAC lab participant data.

Outliers deleted based on IQR statistical analysis, and lab performance evaluated based on mean and 95% confidence range limits for each analyte.

Laboratory precision will be documented, but will not be utilized to evaluate performance.

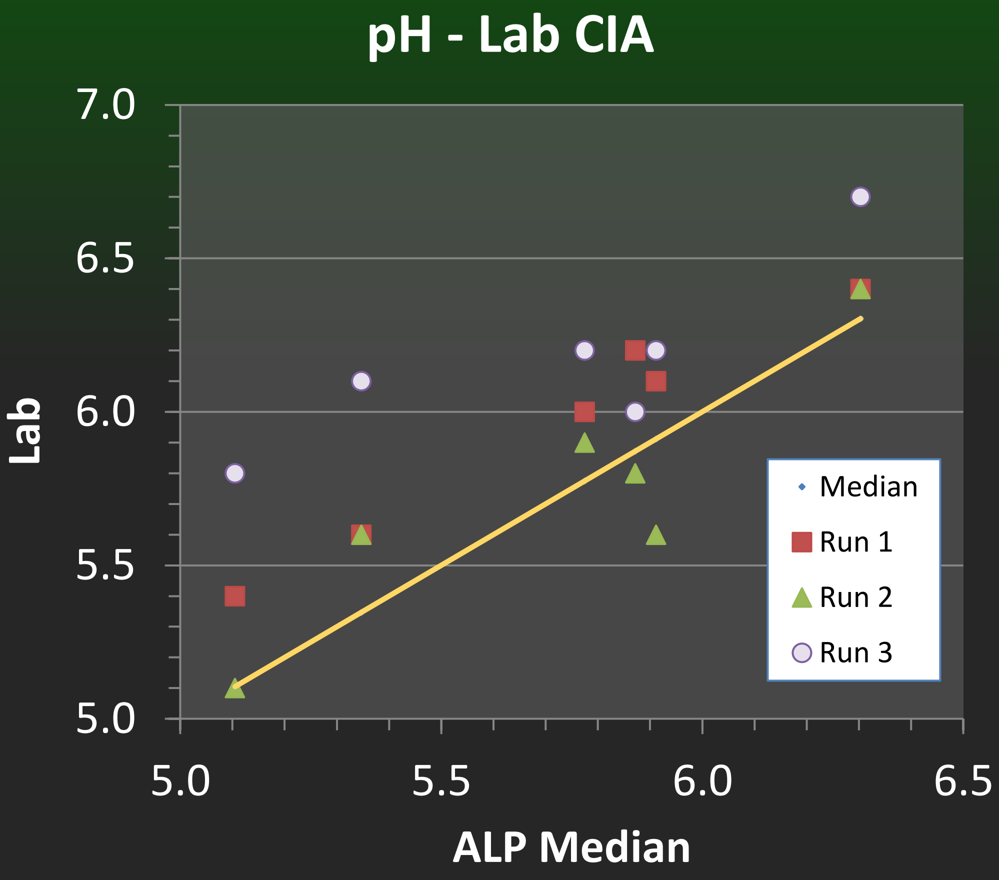


Miller, 2020

DB - Summary

Soil pH for the six soils is at left for lab CIA. Yellow line designates the median pH.

The lab has consistent high bias on strongly acid soils, and inconsistent in reported values across the three submissions.



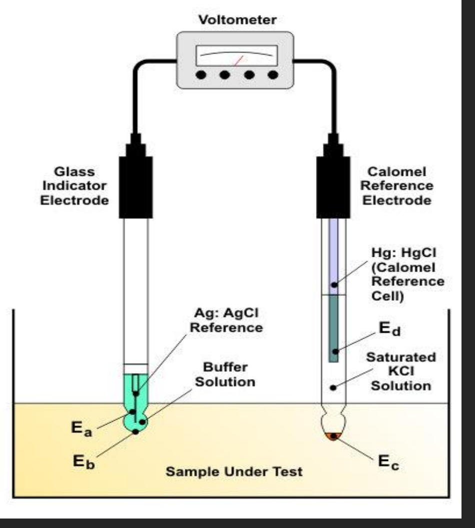
Measurement of pH

The hydrogen ion activity of a soil solution slurry can be measured visual using indicators photometric dyes, and potentiometric methods.

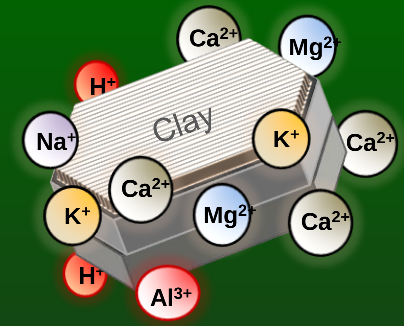
Potentiometric methods determine pH by using the electrical voltage potential of a pH-sensitive electrode (ISE) as a measurement signal in millivolts.

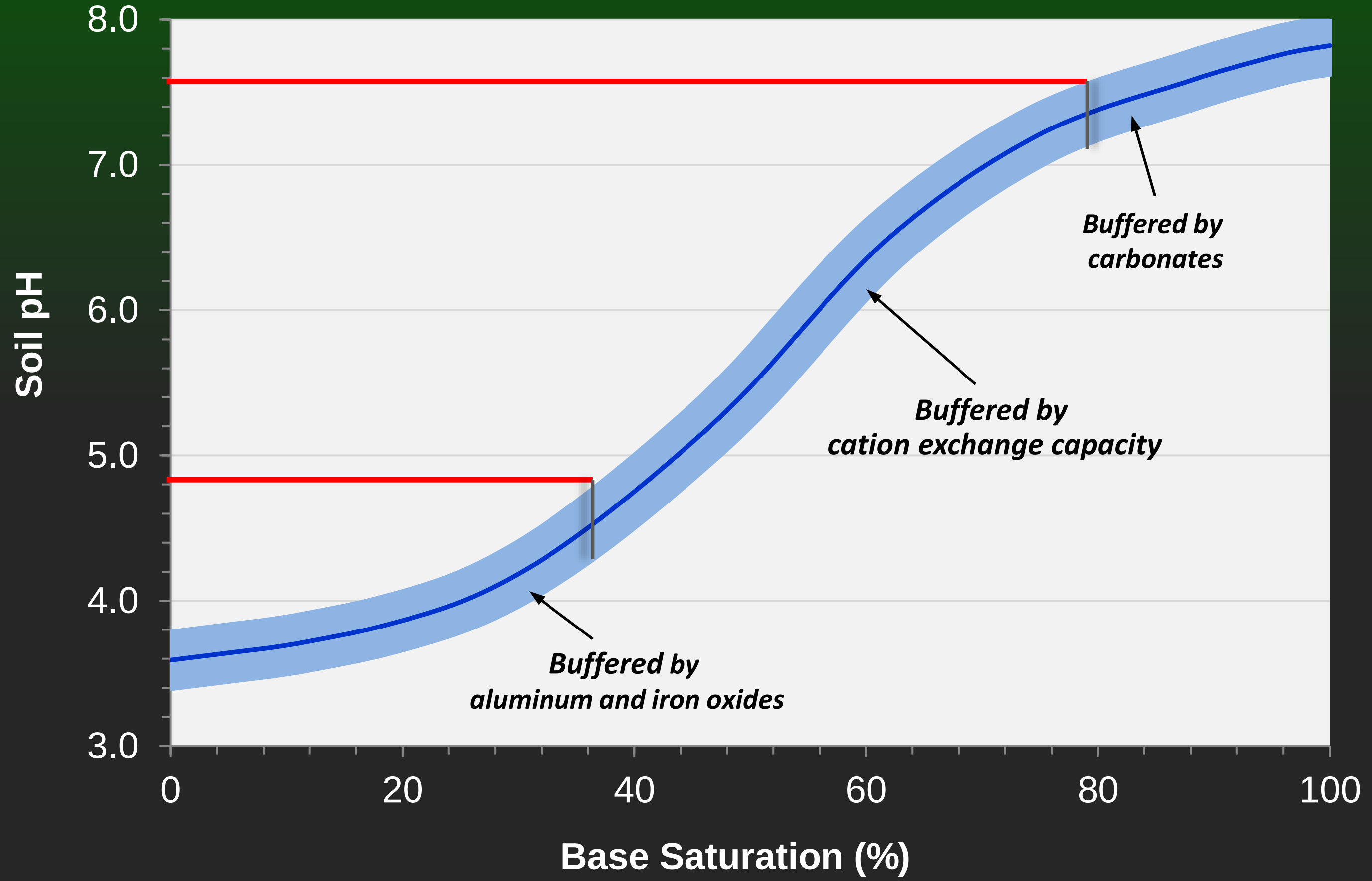
Soil pH is commonly measured by ISE, but extractants and ratios vary by region.

https://images.ctfassets.net/zma7thmmcinb/4psmPQMa6koaKK4aik04uE/75778999614becd99346caab5b8aa3e2/ht-do-a-soil-3.jpg



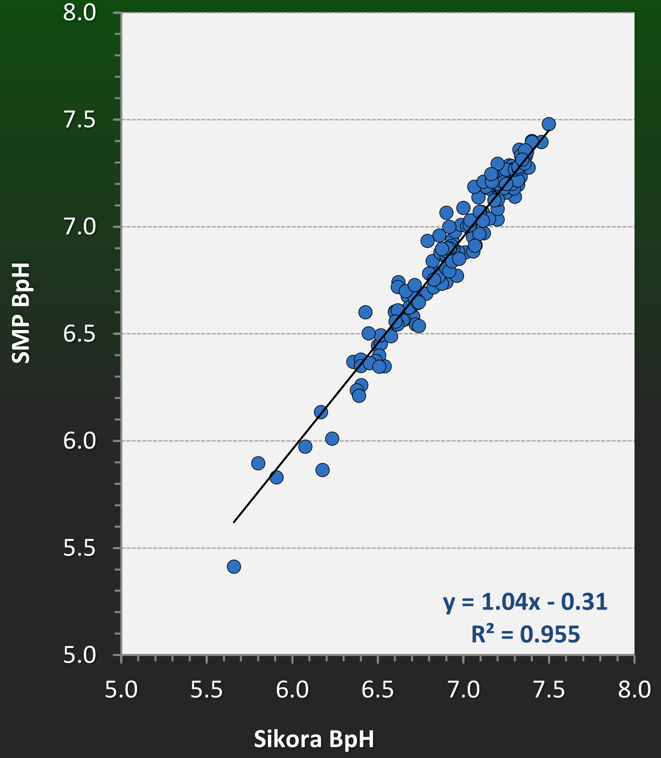
Soil Acidity and Base Saturation

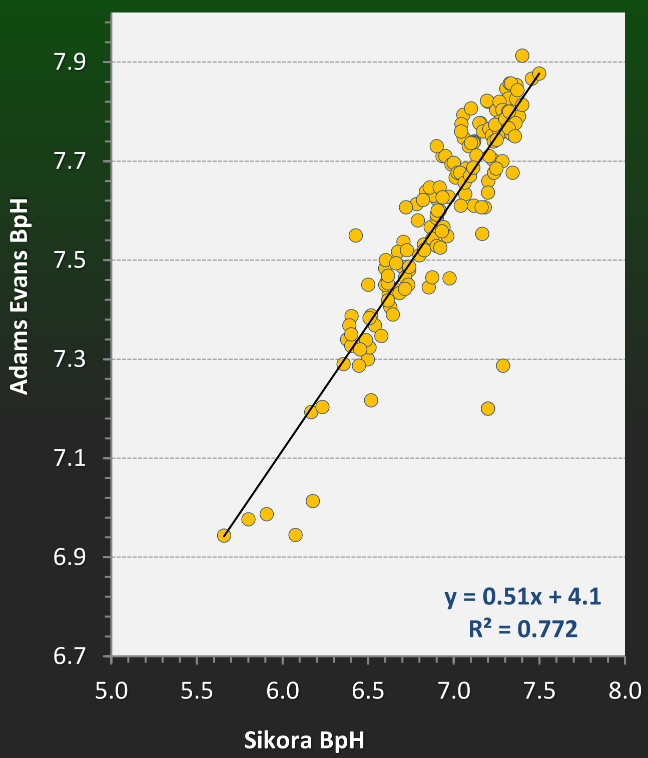


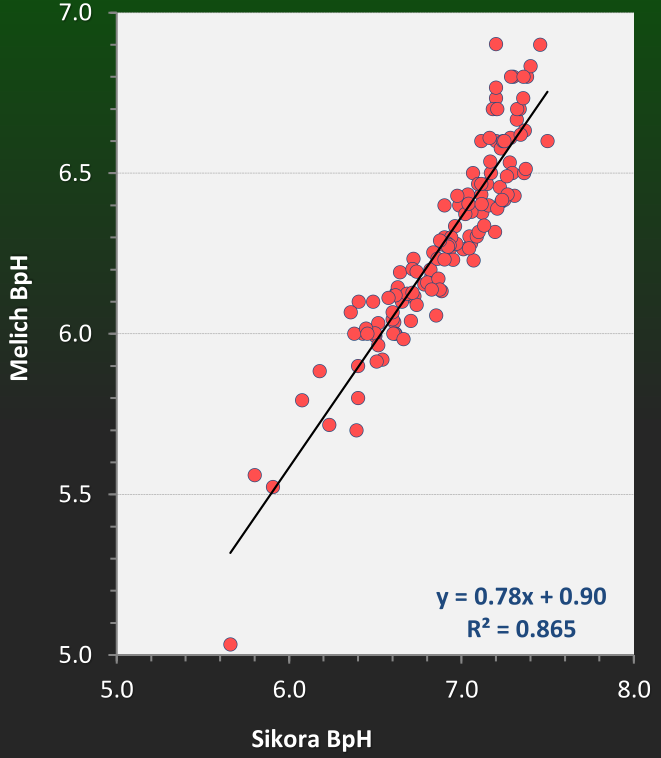


Adapted from Brady and Weil , 2001

BpH method comparison







Data Source: Agricultural Laboratory Proficiency program cycle data base, 2006-2020, 157 soils pH 1:1 0.01M $CaCl_2$ < 7.2 collected across North America.

Miller, 2020