Lime Requirement:
How Is It Determined?

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Lime Requirement (LR)

- the quantity of ag limestone needed to increase the pH of a soil to the optimal pH (target pH) for the crop or crop rotation

Calibrating LR Procedures or Processes

- field-based lime rate experiments on selected soils, representing the range of OM, clay content and clay types
- soil-lime incubations in controlled environment (*ex situ*)
  - less preferred but more practical

Lime Rate Field Experiment (MD)

- 3 lime materials
  - ag limestone, burnt lime and hydrated lime
- 2 lime rates
  - theoretical optimal and 2x
- 7 soils with range of properties
- monitored pH
  - 3 months, 1, 2 and 3 years

When was the experiment initiated?

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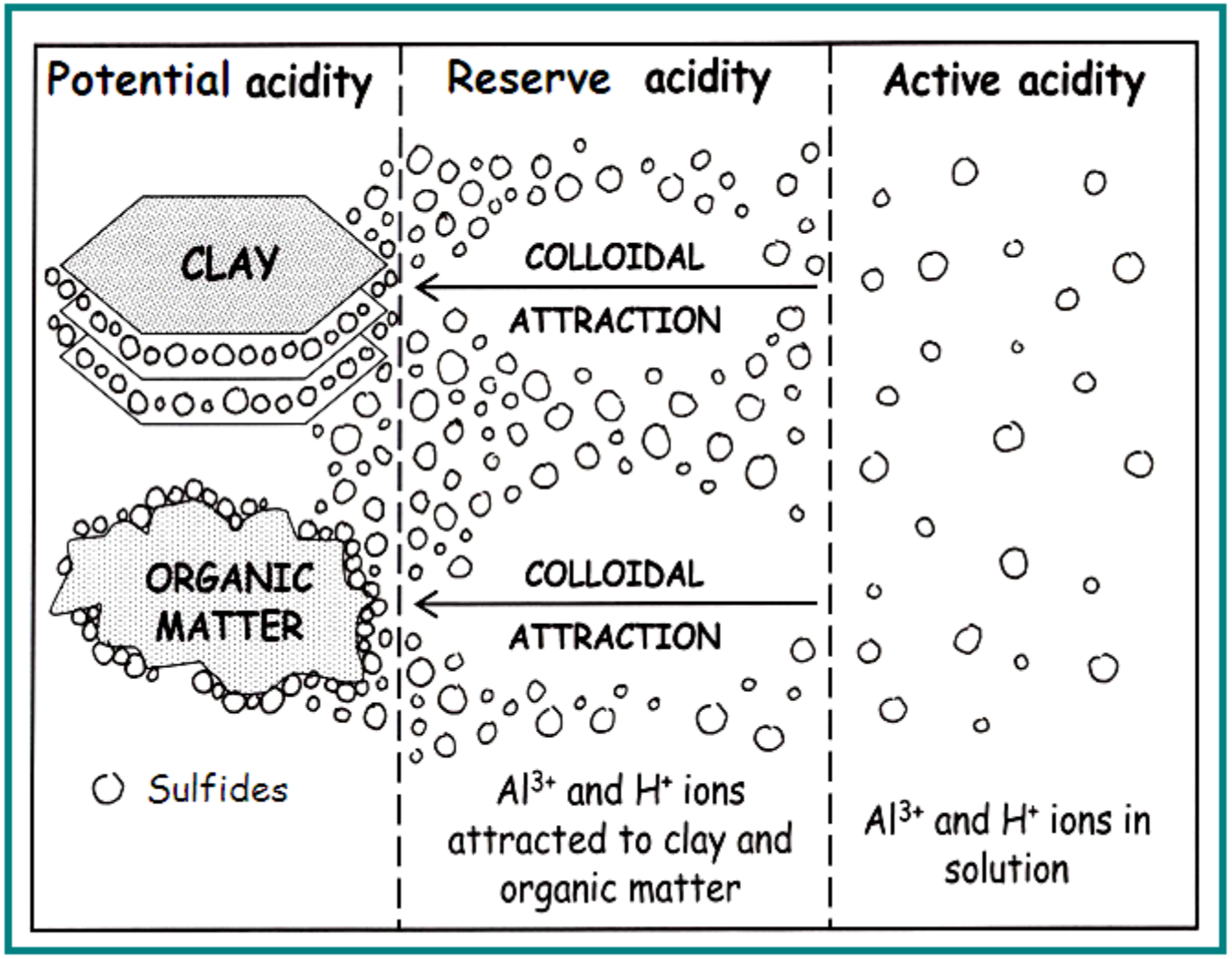
- Spring 1947

Soil-Lime Incubation Study (VA)

- 17 ag soils from across the state
- lime material
  - calcium carbonate
- 3 months duration
- moistened soils to field capacity initially and again at 30 and 60 days
- monitored pH
  - at 3 months


Potential acidity
Reserve acidity
Active acidity
CLAY
COLLOIDAL
ATTRACTION
ORGANIC MATTER
COLLOIDAL
ATTRACTION
Sulfides
Al3+ and H+ ions attracted to clay and organic matter
Al3+ and H+ ions in solution

Why Aluminum is “Acid”

- undergoes hydrolysis
  - reaction of a material with water
- $Al^{+3} + H_2O = Al(OH)^{+2} + H^+$ (1)
- $Al(OH)^{+2} + H_2O = Al(OH)_2^{+1} + H^+$ (2)
- $Al(OH)_2^{+1} + H_2O = Al(OH)_3 + H^+$ (3)

Factors Affecting Reserve Acidity

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- amount of clay-sized particles
- type of clay
- amount of organic matter

What soil property provides information about the amount of clay-sized particles?

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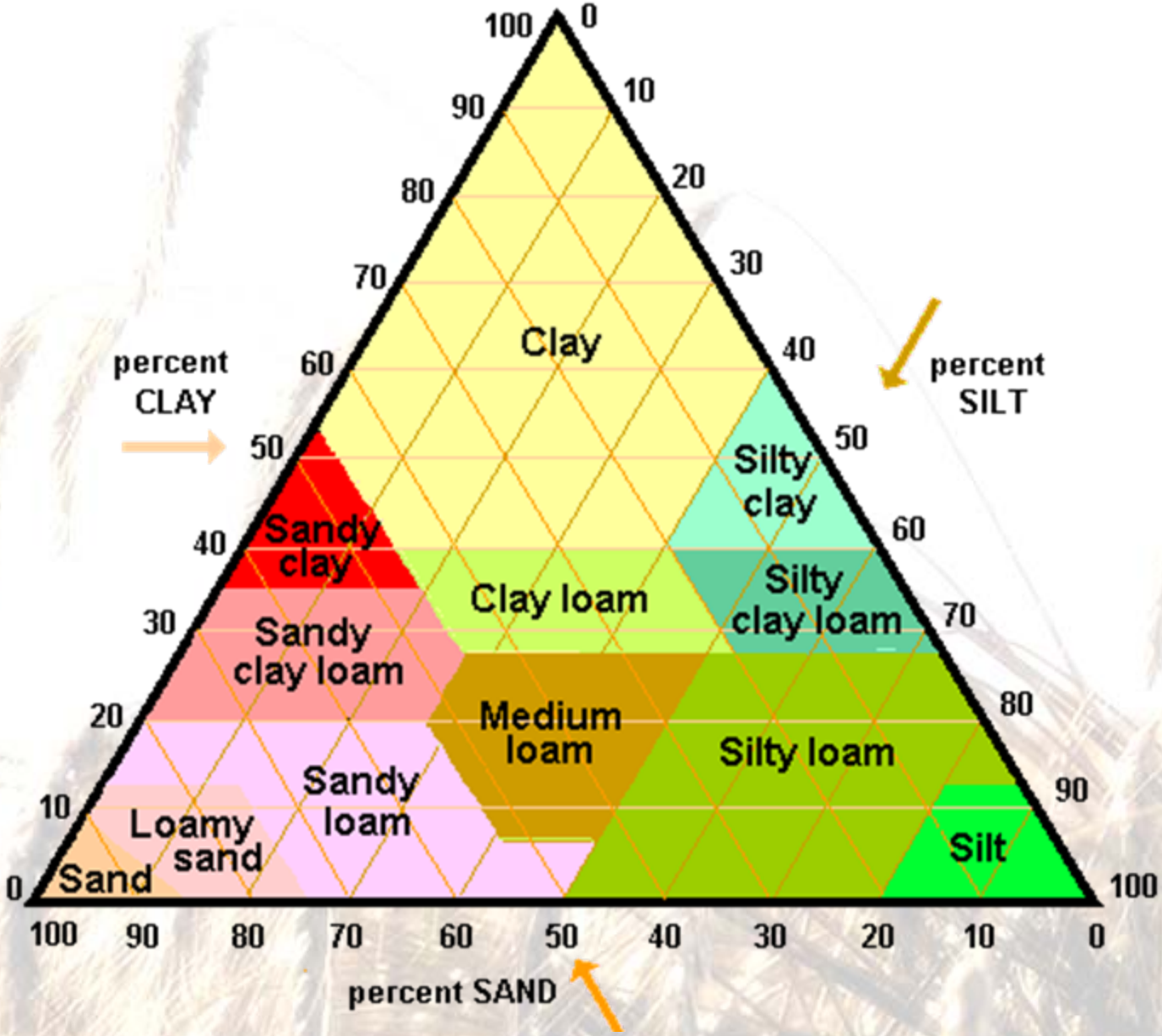
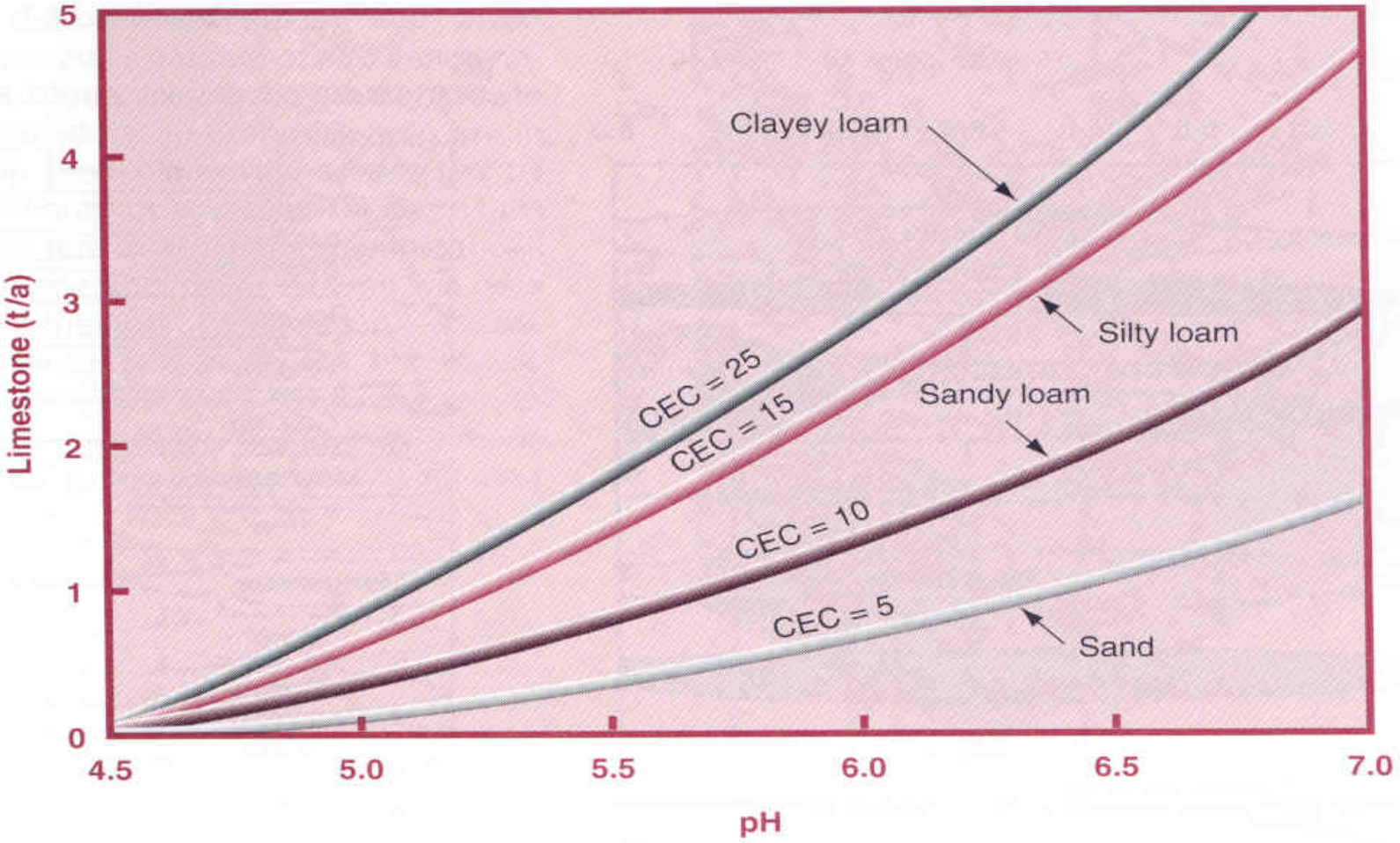
- textural class
  - communicates a range of clay-sized particles


Clay
Silty clay
Sandy clay
Clay loam
Silty clay loam
Sandy clay loam
Medium loam
Silty loam
Sandy loam
Loamy sand
Sand
Silt
percent CLAY
percent SILT
percent SAND
100
90
80
70
60
50
40
30
20
10
0

Texture and Lime Requirement



The Initial and (Perhaps Current) Methods)

- indirect methods
- LR estimated based on

  1) pH

  2) properties associated with reserve acidity (OM, CEC, texture, clay content, soil series, and/or soil region)

Lime Requirement Methods

- indirect methods
- direct methods
  - soil-lime titrations

Titration with $Ca(OH_2)$

- direct method, applicable to any soil
- slow and laborious
- add incremental amounts of lime to a soil, allow to equilibrate and construct response curve

Lime Requirement Methods

- indirect methods
- direct methods
  - soil-lime titrations
  - soil buffer equilibrations
    - rapid

Soil-Buffer Equilibrations

- mix soil and a carefully-designed buffer solution
  - buffer solution strongly resist a change in pH
- equilibrate (15 – 30 min.)
- measure pH of soil-buffer mixture
- the more the soil lowers the pH of the buffer-soil mixture, the greater the lime requirement

Popular Buffers

- SMP buffer (pH 7.0)
  - named for Shoemaker, McLean and Pratt
  - developed in mid-West for soils with high LR
    - high organic matter content and medium to fine textures, 2:1 clays
- Adams-Evans buffer (pH 8.0)
  - developed in southern U.S. for soils with low CEC and small amounts of 2:1 clays and OM
- Mehlich buffer (pH 6.6)
  - developed in North Carolina

Let's Look More Closely at the SMP Buffer…

- mixture of chemical compounds
- strong salts to replace H^+ and Al^{+3} on exchange sites
  - calcium chloride
- various compounds to react across a wide range of pHs
  - potassium chromate, *p*-nitrophenol, calcium acetate, triethanolamine

LR as a function of buffer pH and target pH (SMP buffer)

	LR (tons/acre)			
	Target pH			
	Mineral Soils			Organic Soils
pH Buffer	7.0	6.5	6.0	5.2
6.8	1.4	1.2	1.0	0.7
6.7	2.4	2.1	1.7	1.3
6.6	3.4	2.9	2.4	1.8
6.5	4.5	3.8	3.1	2.4
6.4	5.5	4.7	3.8	2.9
.....				

From Adams-Evans Buffer to LR

target pH = 6.5, pounds of limestone

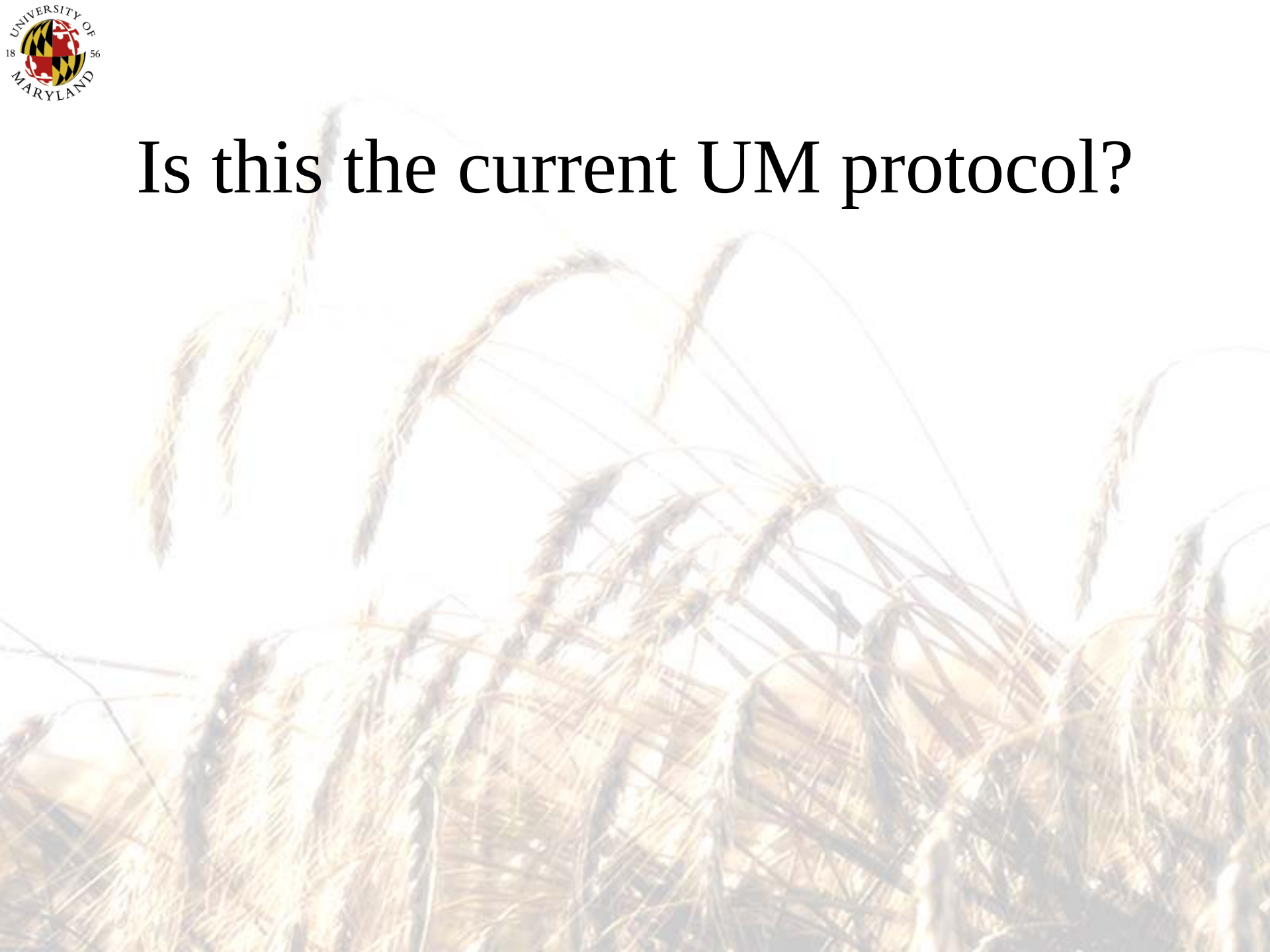
pH buffer				
pH_{water}	**7.8**	**7.6**	**7.4**	**7.3**
6.3	366	732	1098	1281
6.1	648	1295	1943	2267
5.9	872	1744	2616	3052
5.7	1056	2112	3169	3697
4.7	1672	3343	5015	5850

UM Lime Requirement Evolution

- Hoyert and Axley, field work 1947-1949
- in 1949 ag stats indicated 220,000 tons of lime used in MD
- wanted to convince farmers of the value of lime
- lime rate experiments at 7 locations
- monitored pH for 3 years

Lime Recommendations (tons/acre) for Various Soil Textural Classes in Maryland to Attain pH 6.5 (1952, *Soil Science*, Hoyert and Axley)

initial pH	sandy loam	silt loam	silty clay loam
4.8	2.5	4.0	6.0
5.0	2.25	3.6	5.40
5.5	1.5	2.4	3.6
6.0	0.75	1.2	1.8



Is this the current UM protocol?

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- No, refinements have occurred
- added soil region (physiographic province)
  - better estimation of reserve acidity
  - includes knowledge of dominant clay mineral in various regions
- look at LR for target pH of 6.5 (pounds oxides per acre, excerpted from SFM-5)

	loamy sand	**sandy loam**	**loam**	**loam**	**silt loam & clay loam**	**silt loam & clay loam**
pH_{H2O}	all regions	all regions	CP	Pdmnt & Mtn	CP	Pdmnt & Mtn)
6.0	500	1,000	1,000	1,000	1,000	2,000
5.5	1,000	1,500	2,000	2,500	2,000	3,500
5.0	1,500	2,500	2,500	3,500	3,000	4,500
4.5	2,000	3,000	3,500	4,000	3,500	4,500

target pH is 6.5; recommendation is pounds oxides

UM Extension Soil Testing Lab

- Estimated LR by a combination of
  - pH, target pH, soil texture and physiographic province
- Method programmed into *NuManPro*
- Published in SFM-5
  - target pHs of 6.5, 7.0, 5.6 & 5.4

Why do some states have no lime requirement procedure?

Why do some states have no lime requirement procedure?

- Some states do not have acid soils
  - AZ, NM, ND, SD, NV, WY, UT, MT

Soil Testing Collides with RCRA*

- SMP buffer
  - – *p*-nitrophenol
  - – potassium chromate (carcinogen)
- Mehlich buffer
  - – barium chloride
- Adams-Evans buffer
  - – *p*-nitrophenol

* Resource Conservation and Recovery Act; governs use, production, transportation and disposal of hazardous materials

Soil Testing Collides with RCRA

- cost of disposal of soil suspensions used for LR is very expensive

- RCRA permit required (hazardous waste generator)
  - permit, recordkeeping requirements, inspection of storage facility, records of utilization and disposal manifests

New Interest in Lime Requirement Procedures

- reliable & comparable LR with no "hazardous" components in the buffer
- new round of soil-lime incubations studies
- comparison of LR via different methods
- development of new or modified LR buffers
- many states have changed to a different LR buffer in last 10 years

Some of the changes …

- Georgia changed from Adams-Evans to 2-point titration
- Moore-Sikora buffer developed to replace Adams-Evans
- Mehlich modified to remove the hazardous component
  - calcium chloride substituted for barium chloride
- modified Mehlich buffer replaced SMP in many states

Things to Remember When Selecting or Interpreting a Buffer pH

- old methods should be avoided if hazardous waste disposal cost are to be avoided
  - why use SMP when Mehlich provides comparable LR?
- buffer should be appropriate for the soil properties of clients served
  - don't use SMP for clients in Coastal Plain
  - don't use Adams-Evans in soils with moderate and high 2:1 clay content


Any Questions?