



# Soil Properties and Soil Fertility



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**Alfalfa Symposium**

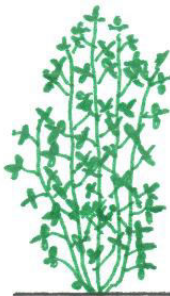
**November 27, 2018**



# Overview

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- Introduction
- Soil components
- Important soil physical and chemical properties



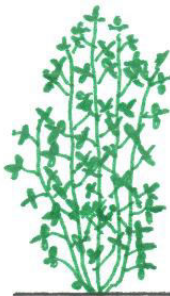


# Soil fertility

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What is soil fertility?

- The capacity of a soil to support plant growth
- Provide plants with
  - a space for roots to grow
  - mineral nutrients
  - water
  - air ( $O_2$ )





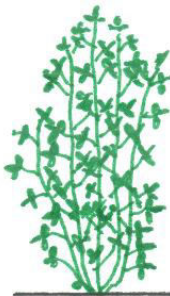
# Input and output of plant available nutrients in soil

## Input

- Weathering of soil minerals
- Biological N fixation
- Decomposition of plant litter
- Fertilizers, organic amendments

## Output

- Losses (leaching, runoff, gaseous losses)
- Removal with crops
- Chemical fixation in soil





# Soil components

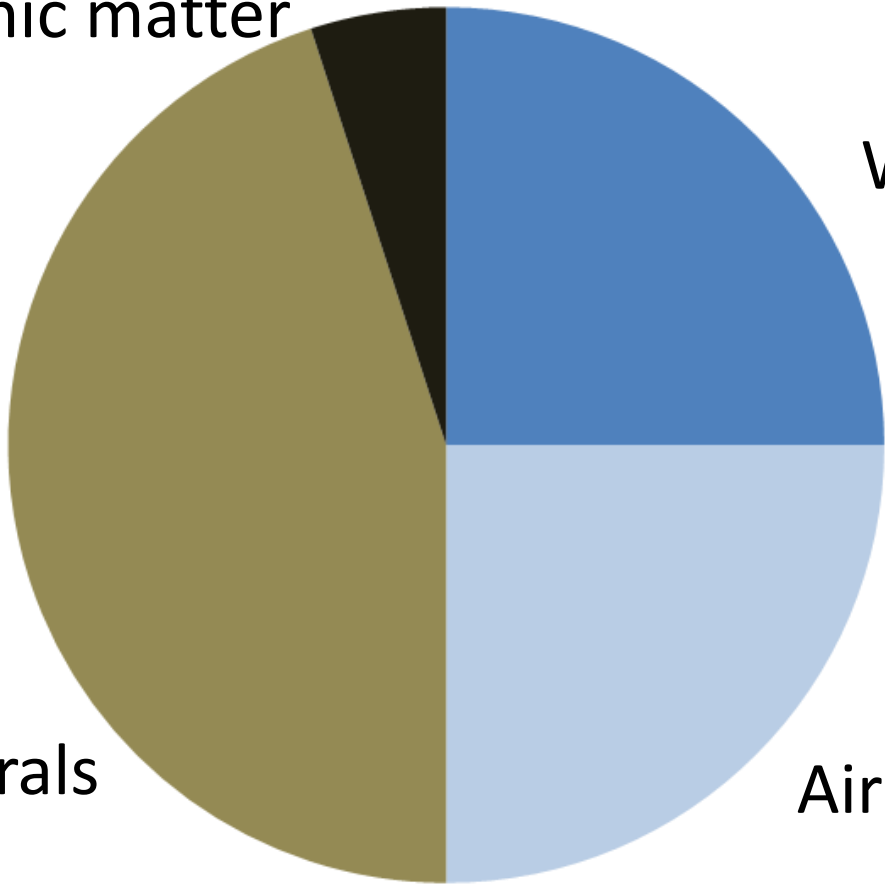


**Solid material**



**Pores**

Organic matter



Water

Soil  
Minerals

Air

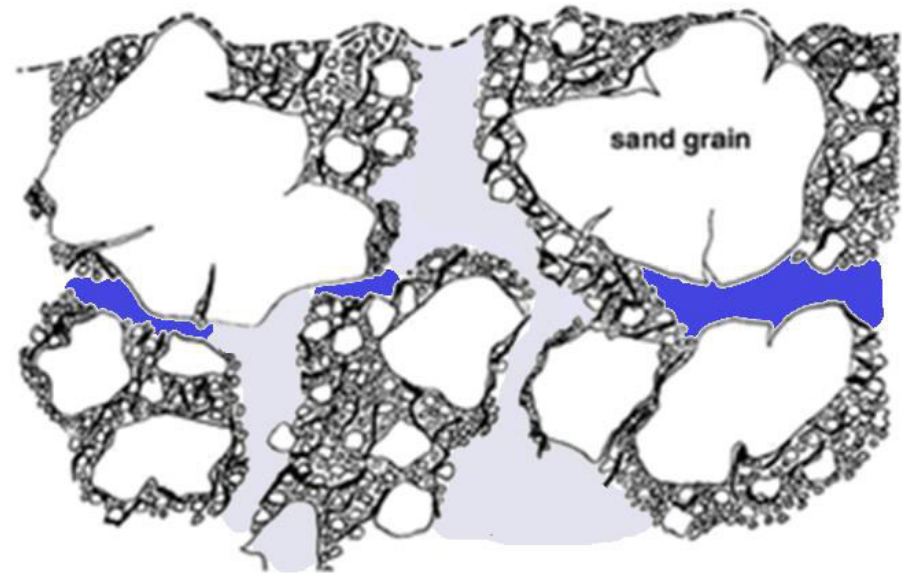




# Soil pores

## Functions:

- Water infiltration
- Aeration
- Water retention

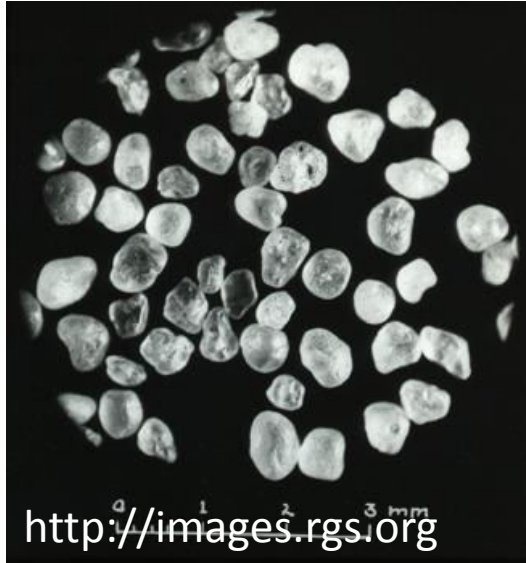


- Large pores are readily drained of water and filled by air after a heavy rain
- Small pores hold water against gravity and pull water up from a water table by capillary action.

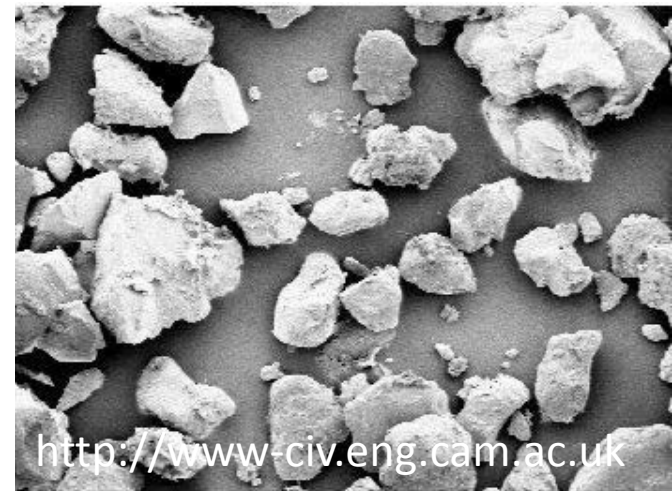




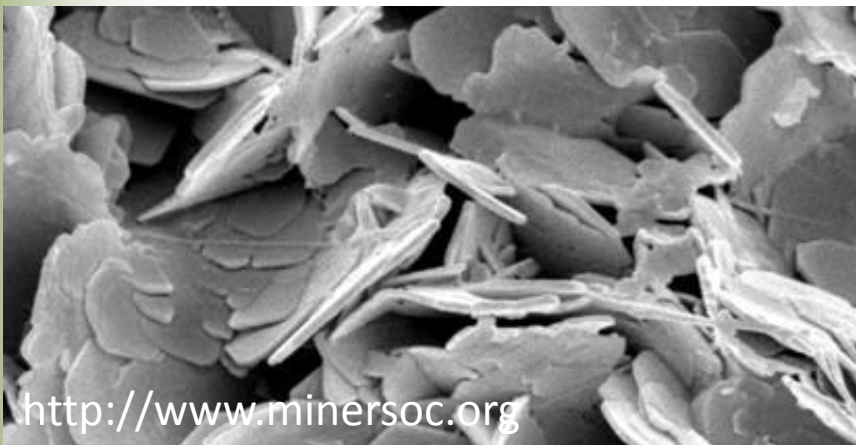
# Soil mineral particles



Sand: feels gritty



Silt: feels smooth



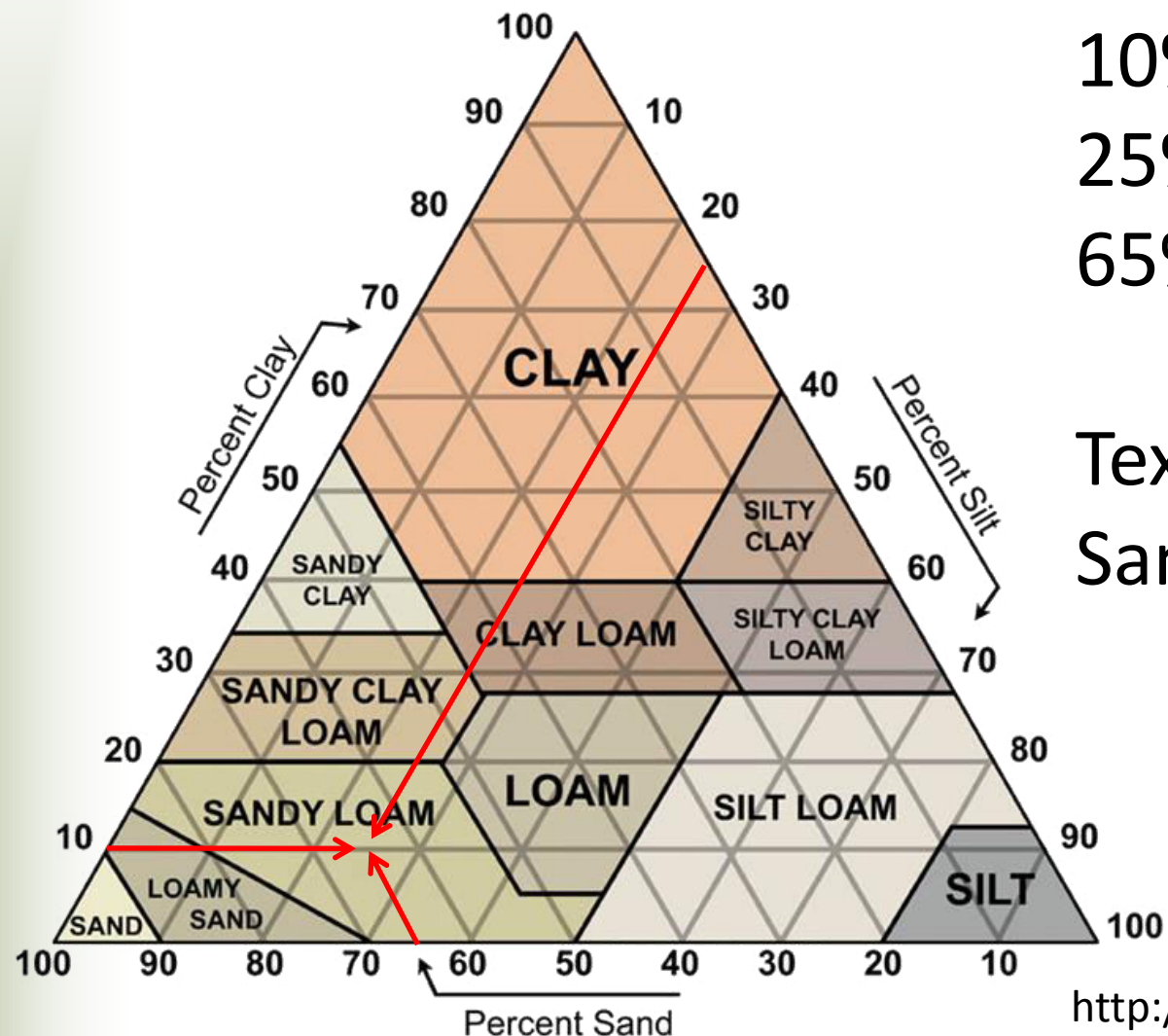
Clay: feels sticky







# Particle size distribution: Texture



10% clay  
25% silt  
65% sand

Texture class:  
Sandy loam







# Effect of soil mineral particles on soil properties

Property/Behavior	Sand	Silt	Clay
Water holding capacity	Low	Med-high	high
Aeration	Good	Med	Poor
Leaching potential	High	Med	Low
OM decomposition	Fast	Med	Slow
Water erosion susceptibility	Med	High	Low
Wind erosion susceptibility	Med	High	Low
Susceptibility to compaction	Low	Med	High
Nutrient supply	Poor	Med-high	High





# Functions of organic matter

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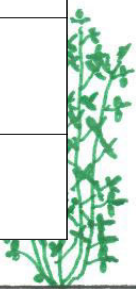
- Supplies nutrients to soil organisms and plants
- Prevents cations from leaching (CEC)
- Energy and carbon source for soil organisms
- pH buffer
- Improves soil structure and aggregate formation
- Increases pore volume, water holding capacity and infiltration
- Binds toxic compounds



# Effect of soil organic matter on soil properties

## Effect of soil organic matter

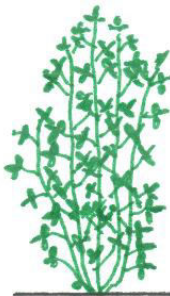
Property/Behavior		Sand	Silt	Clay
Water holding capacity	↗	Low	Med-high	high
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Susceptibility to compaction	↘	Low	Med	High
Nutrient supply	↗	Poor	Med-high	High





# Sources of organic material

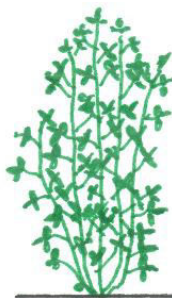
- Plants
  - Shoots (if not harvested)
  - Roots
  - Root exudates
- Microbial residues
- Soil animals
- Organic amendments (e.g. manure, compost)





# Managing soil organic matter

- Apply manure or compost
  - Reduce tillage intensity
  - Grow cover crops
  - Increase crop residue input
- 
- ⇒ Provide plant available nutrients
  - ⇒ Improve soil health

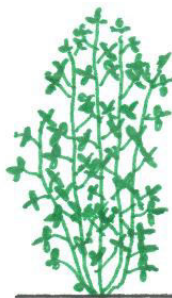




# Soil structure

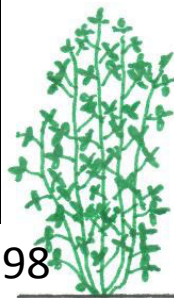
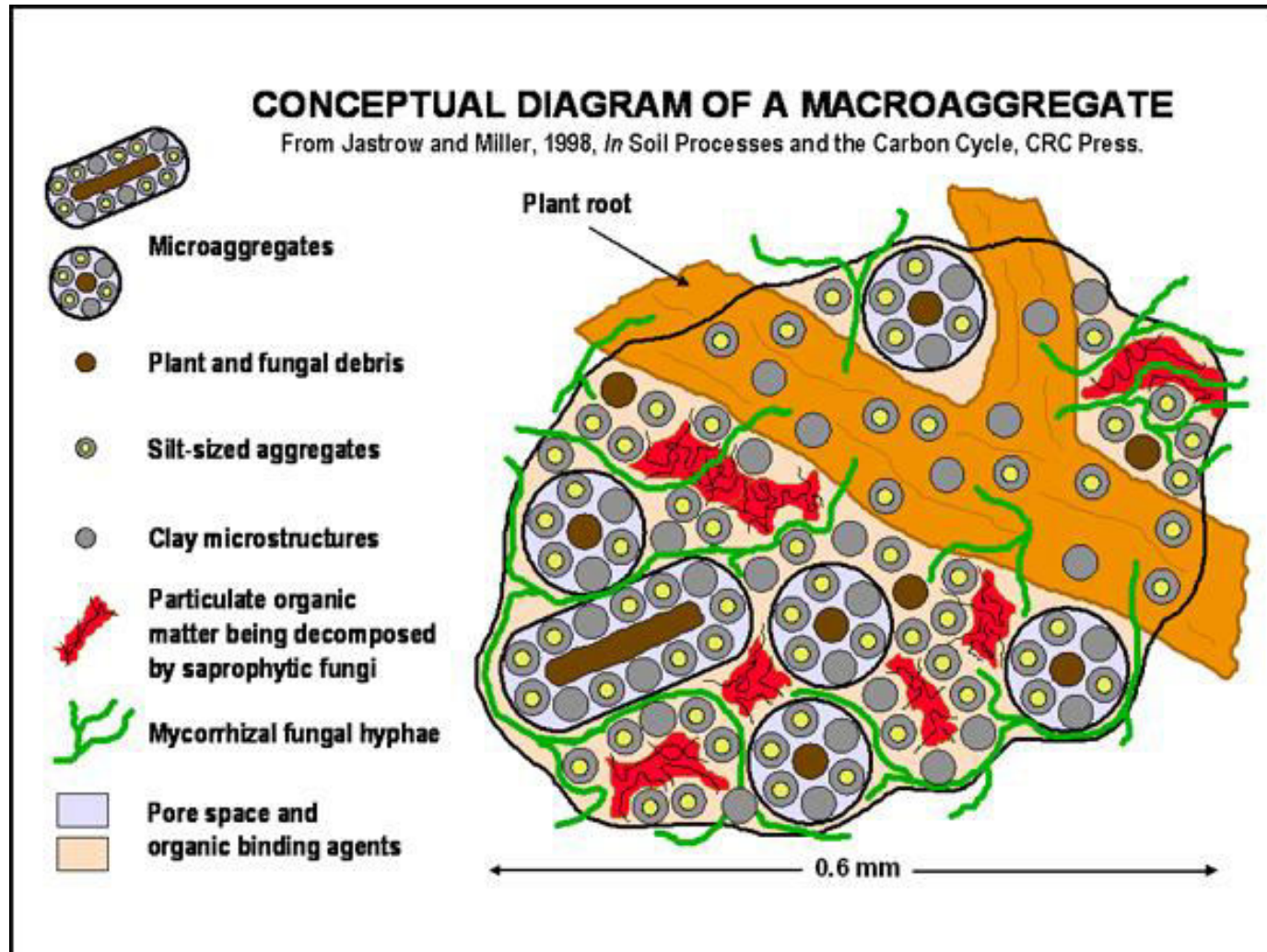
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- Three-dimensional arrangement of particles
- Strong effect on
  - Water infiltration
  - Aeration
  - Pore volume





# Soil structure: Aggregates

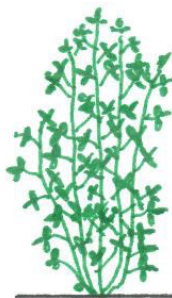






# Managing soil structure

- No tillage when soil is too wet
- Reduced tillage
- Addition of organic material
  - Cover crop
  - Compost
  - Manure





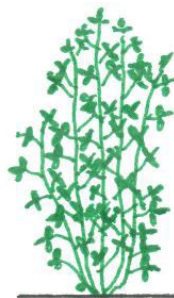
# Soil pH

## What is pH?

- Concentration of  $H^+$  ions in solution
  - Scale 1-14.
  - Low pH (acidic): High  $H^+$  ion concentration
  - High pH (alkaline): Low  $H^+$  ion concentration

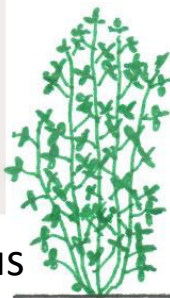
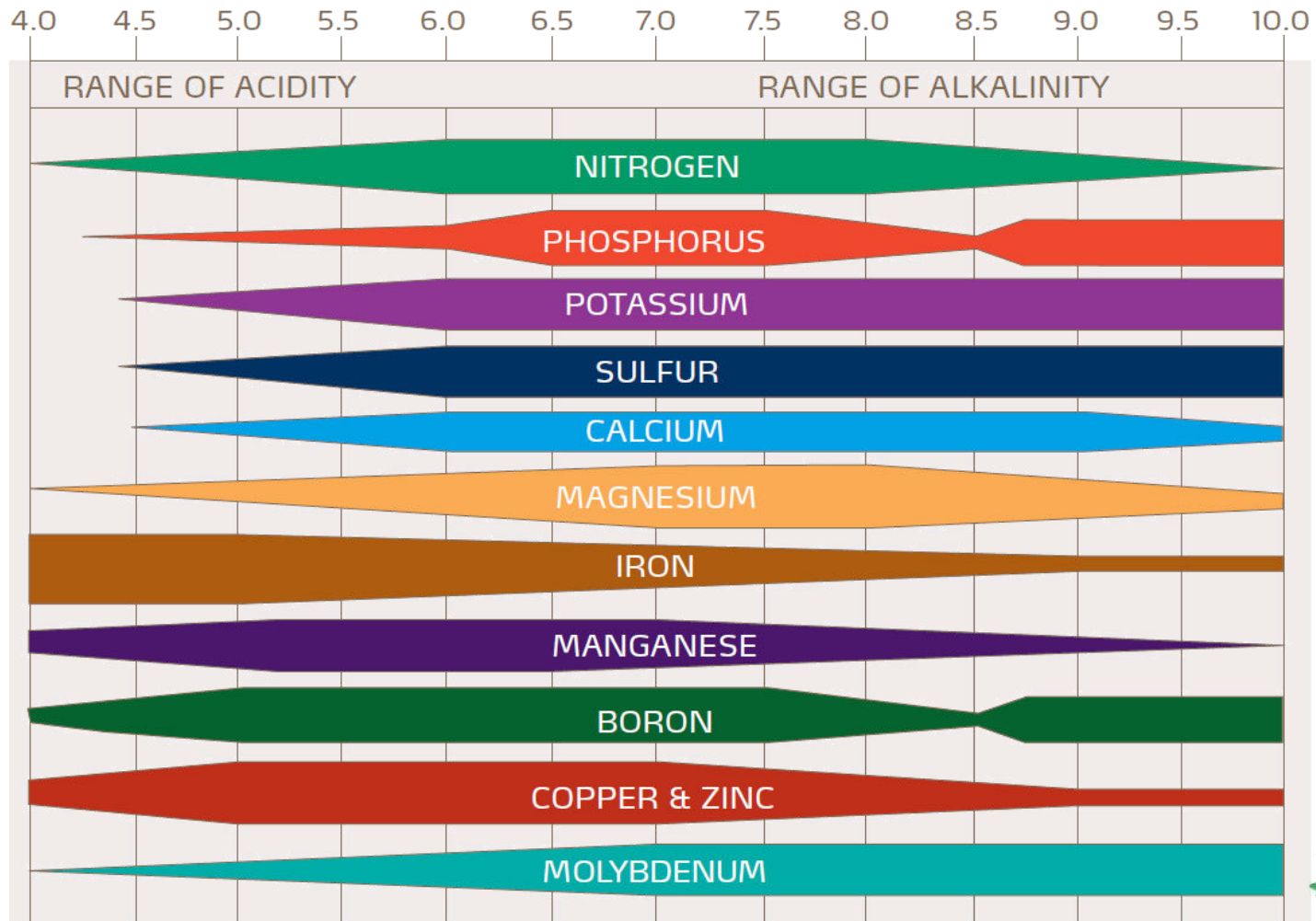
## Why is pH important?

- Nutrient availability
- Nutrient toxicity (i.e. aluminum at low pH)
- Extreme pH can physically injure plants
- Affects microbial activity



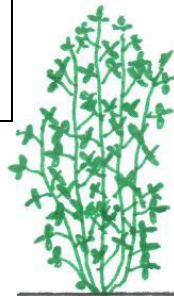
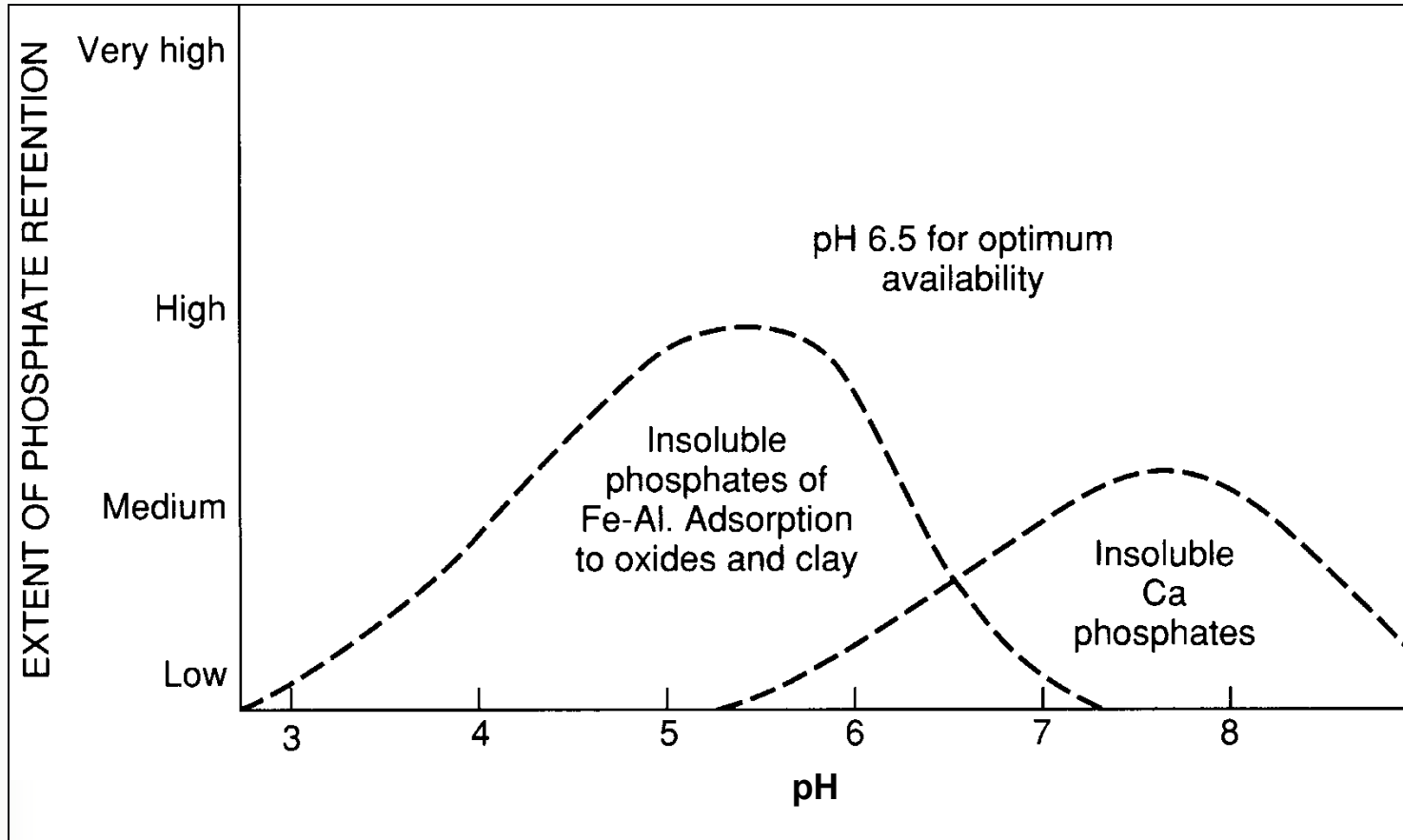


# Soil pH and nutrient availability



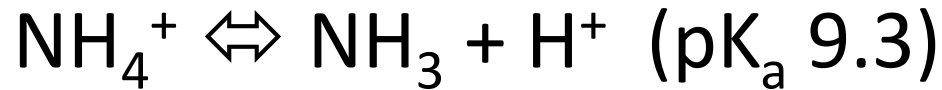


# Effect of pH on forms and availability of soil phosphorus

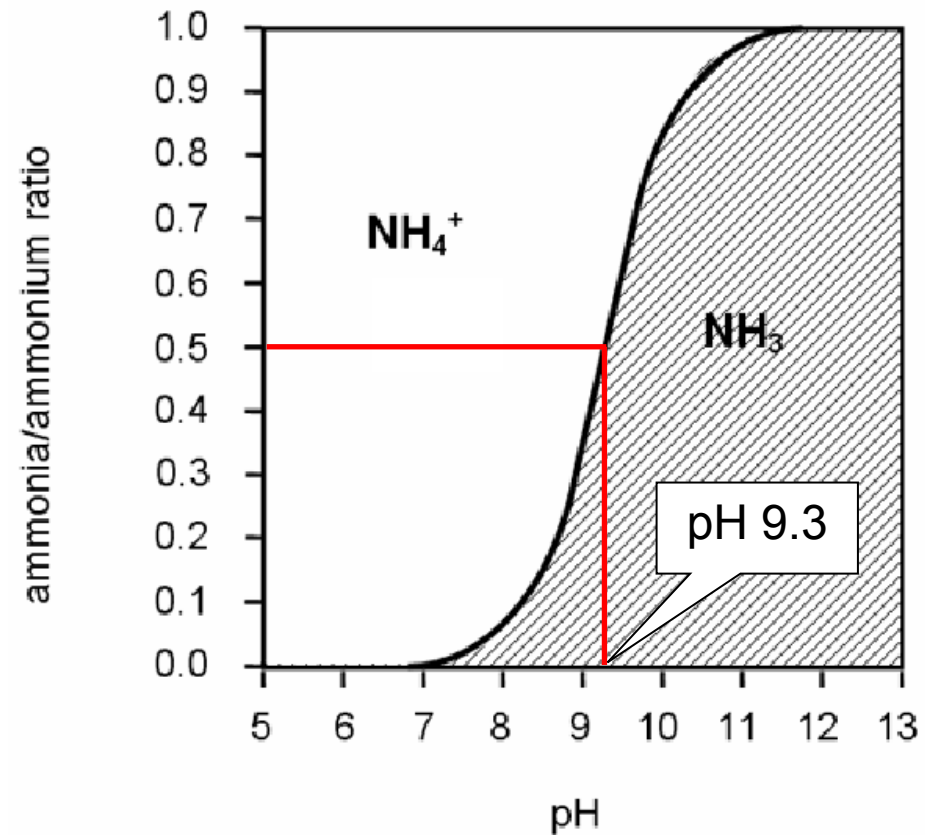




# pH and ammonia volatilization



Chemical  
equilibrium  
reaction





# Managing soil pH

- Correct pH
  - Acidic soils: Apply lime
  - Alkaline soils: Apply elemental sulfur, sulfuric acid, phosphoric acid
- Nutrient management
  - Increase application rate  $\Rightarrow$  expensive
  - Band application of P instead of broadcasting
    - $\Rightarrow$  may damage roots in established alfalfa stands
  - Foliar application of micronutrients





# Cation exchange capacity (CEC)

Capacity of a soil to adsorb positively charged ions (e.g. ammonium, magnesium, calcium, potassium, ....)

## Sources:

- Clay minerals
- Soil organic matter
- Iron and aluminum oxides

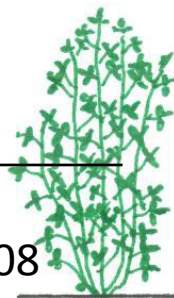






# CEC and soil type

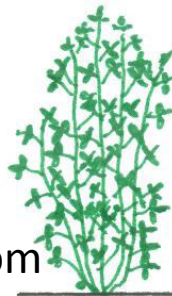
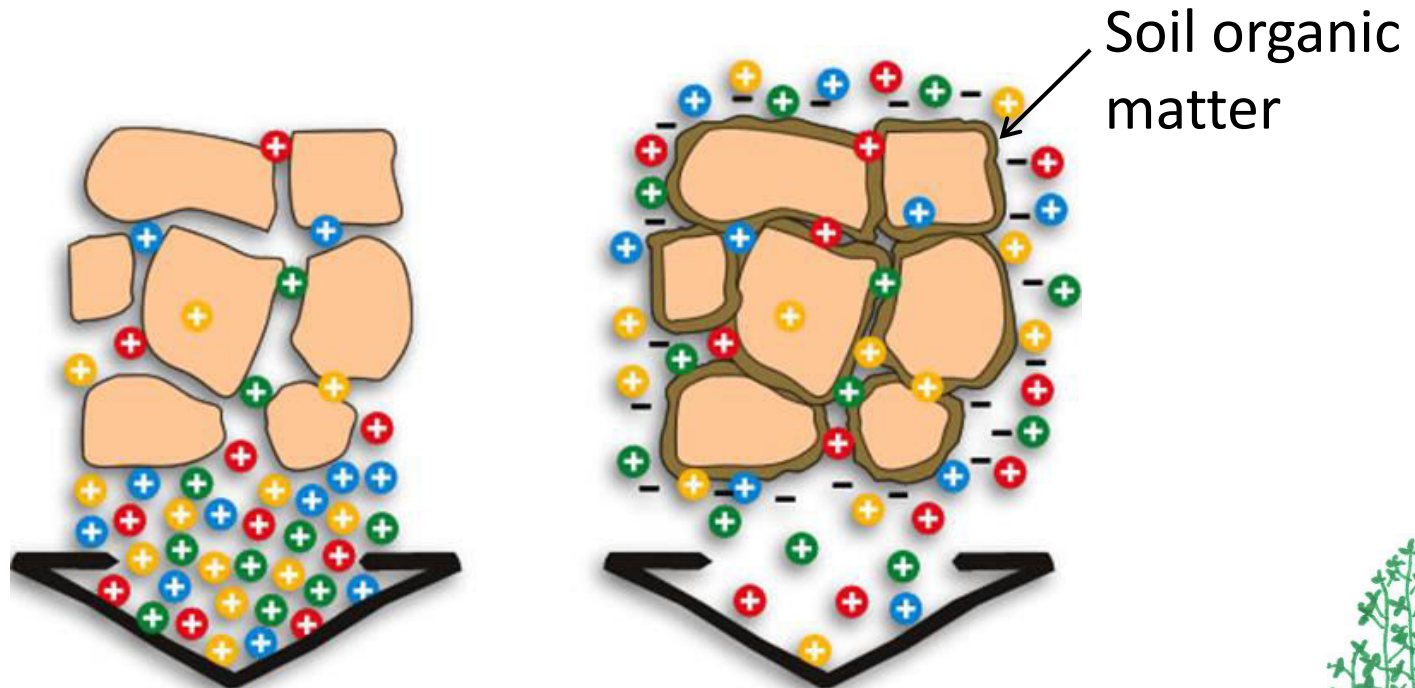
<b>Soil type</b>	<b>Classification</b>	<b>CEC</b> (mmol <sub>c</sub> kg <sup>-1</sup> )
Strongly weathered, often acidic soil	Ultisol	35
Intermediately weathered soil	Alfisol	90
Soil with organic top soil	Mollisol	187
Clay soil	Vertisol	356
Organic soil	Histosol	1280





# Significance of CEC

- Pool of readily available nutrients
- Reduces leaching of cations





# Essential nutrients - cations

## Structural elements:

- Carbon ( $\text{CO}_2$ )
- Oxygen ( $\text{CO}_2$ ,  $\text{H}_2\text{O}$ )
- Hydrogen ( $\text{H}_2\text{O}$ )

## Macronutrients:

- Nitrogen ( $\text{NH}_4^+$ ,  $\text{NO}_3^-$ )
- Phosphorus ( $\text{HPO}_4^{2-}$ ;  $\text{H}_2\text{PO}_4^-$ )
- Potassium ( $\text{K}^+$ )
- Calcium ( $\text{Ca}^{2+}$ )
- Magnesium ( $\text{Mg}^{2+}$ )
- Sulfur ( $\text{SO}_4^{2-}$ )

## Micronutrients:

- Boron ( $\text{H}_3\text{BO}_3$ )
- Chlorine ( $\text{Cl}^-$ )
- Copper ( $\text{Cu}^{2+}$ )
- Iron ( $\text{Fe}^{2+}$ ;  $\text{Fe}^{3+}$ )
- Manganese ( $\text{Mn}^{2+}$ )
- Molybdenum ( $\text{MoO}_4^{2-}$ )
- Nickel ( $\text{Ni}^{2+}$ )
- Silicon ( $\text{H}_4\text{SiO}_4$ )
- Sodium ( $\text{Na}^+$ )
- Zinc ( $\text{Zn}^{2+}$ )





# Managing CEC

- Increase CEC
  - Change texture  $\Rightarrow$  Not realistic in a field
  - Increase pH  $\Rightarrow$  Only in acidic soils
  - Increase soil organic matter  $\Rightarrow$  May be slow, especially in sandy soils
- Adjust management; especially K
  - No applications that supply enough nutrients for several years
  - Split applications (similar to N)





# Soil survey data: <http://ucanr.edu/soilweb>

The screenshot shows the UC Davis California Soil Resource Lab website. The navigation bar includes links for HOME, SOILWEB APPS, PEOPLE, PROJECTS, SOFTWARE, LINKS, and BLOG. The main content area is titled "SoilWeb Apps" and provides an overview of the available tools. Below the overview, there are four distinct sections, each featuring a thumbnail image of the respective application interface:

- SoiWeb:** Described as an interactive Google map for exploring soil survey areas, providing detailed information on map units and their components. It is compatible with desktop computers, tablets, and smartphones.
- SoilWeb Earth:** Explains that soil survey data is delivered dynamically in a KML file, which can be viewed in a 3-D display using Google Earth or other KML viewing software.
- SEE: Soil Series Extent Explorer:** A tool for exploring the spatial extent of soil types nationwide, showing a map of California with various soil series highlighted.
- Soil Properties App:** A tool for exploring a variety of soil properties in map form, displaying a map with a color-coded legend for different soil characteristics.







# Soil survey data:

## <http://ucanr.edu/soilweb>

**SoilWeb** UCDAVIS NRCS University of California Agriculture and Natural Resources

Map Unit Name: **TOCALOMA-MCMULLIN-URBAN LAND COMPLEX, 30 TO 50 PERCENT SLOPES** Symbol: **182**  
 Component Name: **Tocaloma**  
[Official Series Description](#)

**Soil Profiles**

Typical Profile >

Org. Matter Clay

Sand Ksat

pH Kf Factor

EC SAR

CaCO<sub>3</sub> Gypsum

CEC @ pH7

Linear Ext.

A11	0cm
A12	10cm
A13	23cm
A14	38cm
B2	48cm
	99cm
Cr	114cm

**Soil Taxonomy**

Order: Mollisols

Suborder: Xerolls [Map of Suborders](#)

Greatgroup: Haploxerolls

Subgroup: Typic Haploxerolls

Family: Fine-loamy, mixed, mesic Typic Haploxerolls

Soil Series: Tocaloma [Link to SM Tool](#)

Data: [Lab Data](#)

Raw Data: [Component](#) [All Horizons](#)

**Land Classification**

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Lon: -122.6295



P  
N  
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# Thank you!

