UCDAVIS
UNIVERSITY OF CALIFORNIA

Department of
LAND, AIR AND WATER RESOURCES
University of California, Davis
Climate Change • Sustainable Agriculture
Environmental Quality • Landscape Processes

Soil Properties and Soil Fertility

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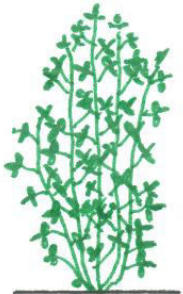
Alfalfa Symposium

November 27, 2018

Overview

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

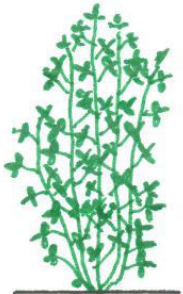


Soil fertility

What is soil fertility?

- The capacity of a soil to support plant growth

- Provide plants with
  - a space for roots to grow
  - mineral nutirents
  - water
  - air (O_2)



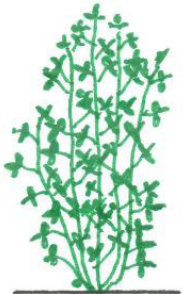
Input and output of plant available nutrients in soil

Input

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

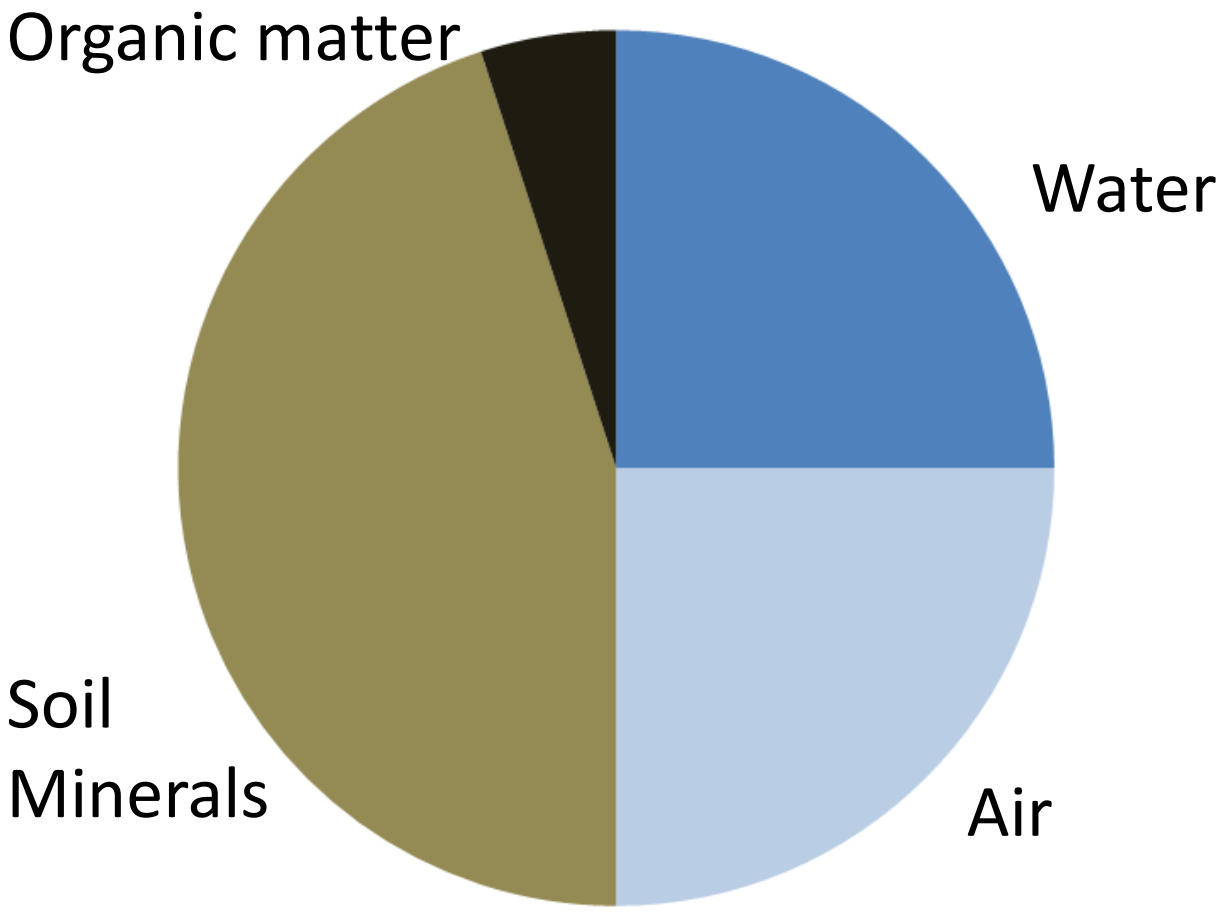
Output

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



Soil components

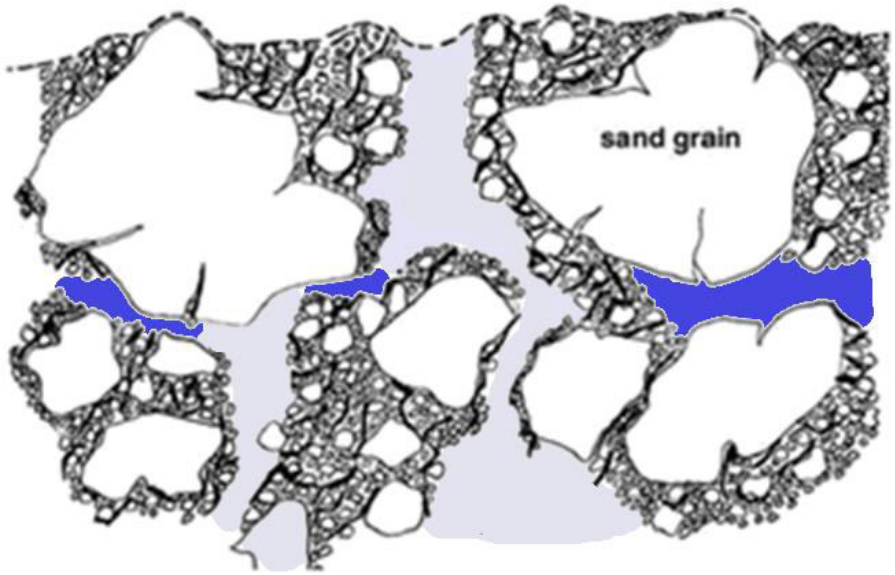
Solid material | **Pores**



Soil pores

Functions:

- Water infiltration
- Aeration
- Water retention

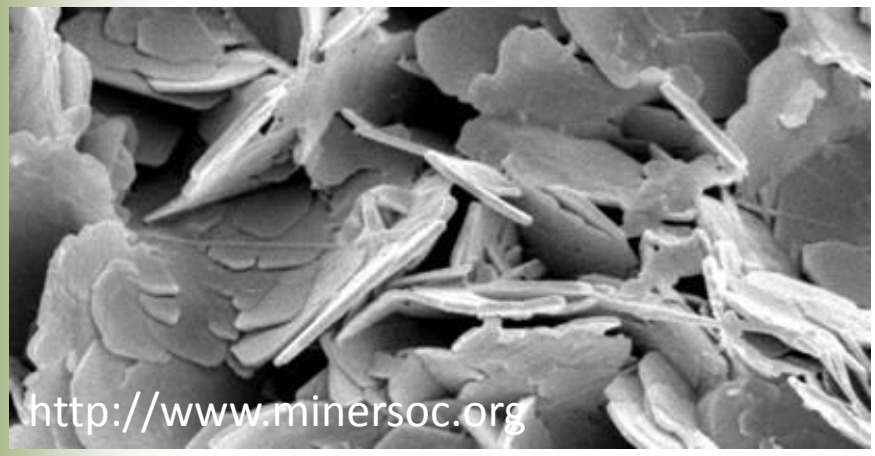


- Large pores are readily drained of water and filled by air after a heavy rain
- Small pores hold water against gravity and pull water up from a water table by capillary action.

Soil mineral particles

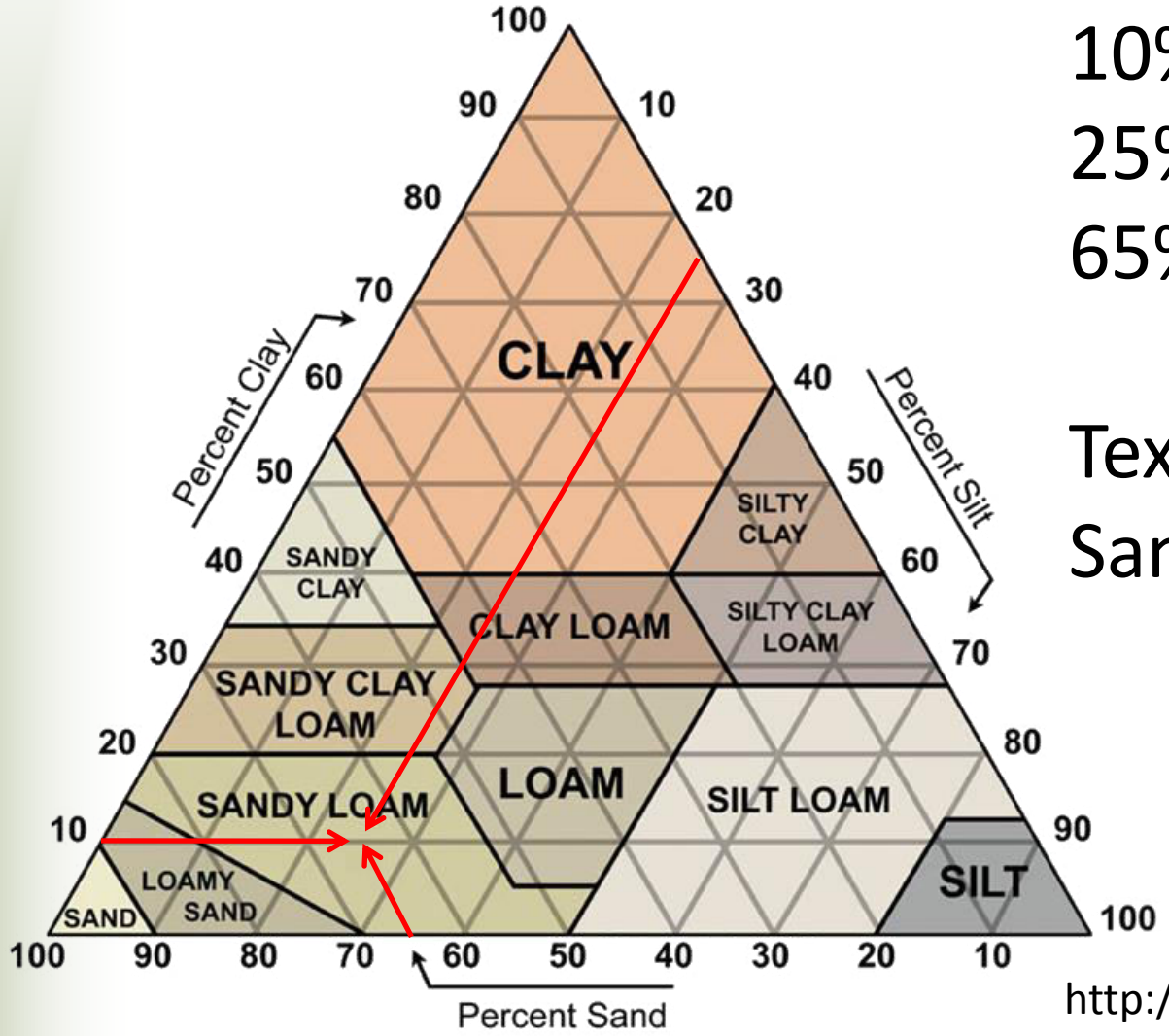
Sand: feels gritty

Silt: feels smooth



Clay: feels sticky

Particle size distribution: Texture



10% clay
25% silt
65% sand

Texture class:
Sandy loam

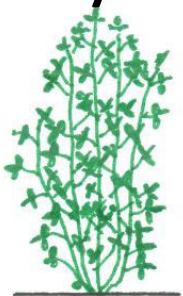
http://www.soilsensor.com

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

- 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



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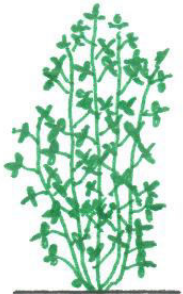
Sources of organic material

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

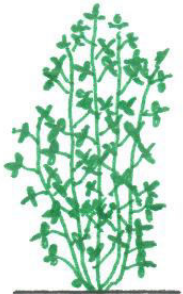


Managing soil organic matter

- Apply manure or compost
- Reduce tillage intensity
- Grow cover crops
- Increase crop residue input

⇨ Provide plant available nutrients

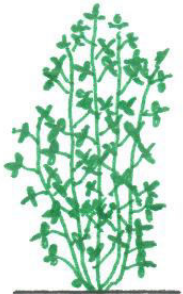
⇨ Improve soil health



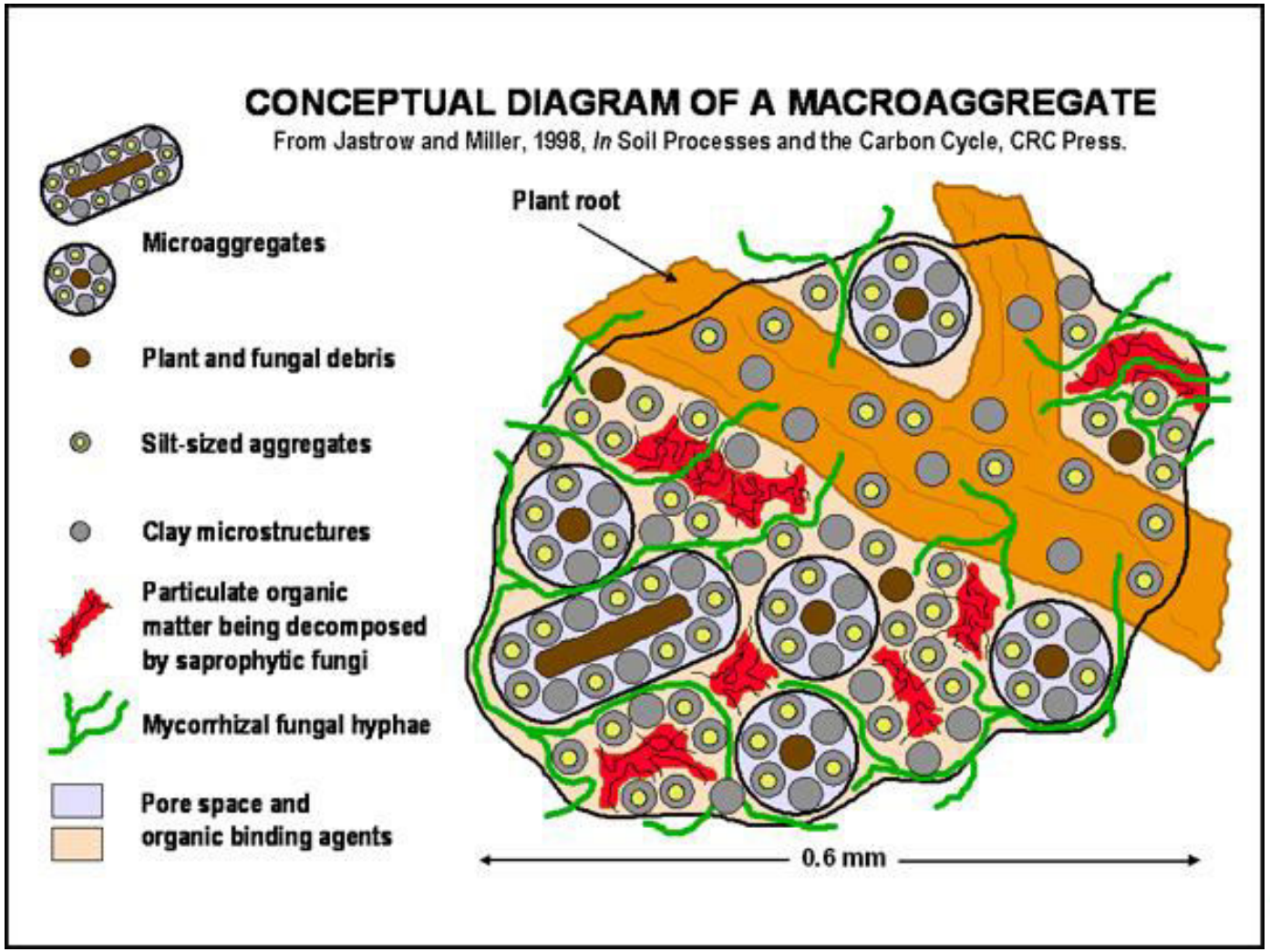
Soil structure

- Three-dimensional arrangement of particles

- Strong effect on
  - Water infiltration
  - Aeration
  - Pore volume



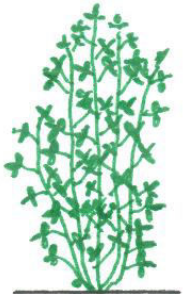
Soil structure: Aggregates



Jastrow and Miller, 1998

Managing soil structure

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



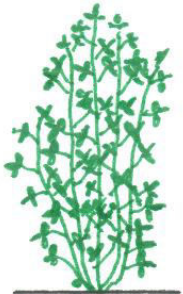
Soil pH

What is pH?

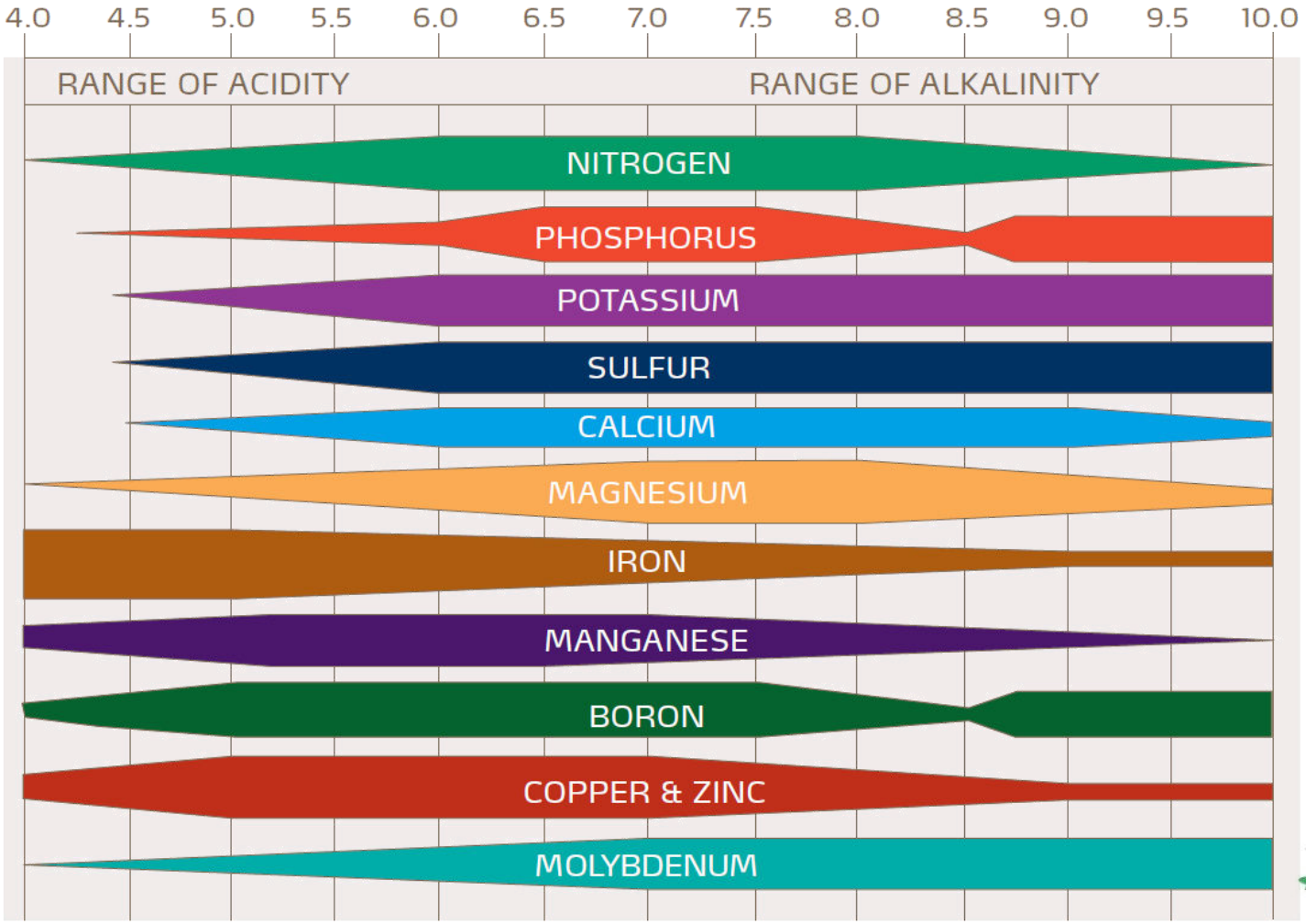
- Concentration of H^+ ions in solution
  - Scale 1-14.
  - Low pH (acidic): High H^+ ion concentration
  - High pH (alkaline): Low H^+ ion concentration

Why is pH important?

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

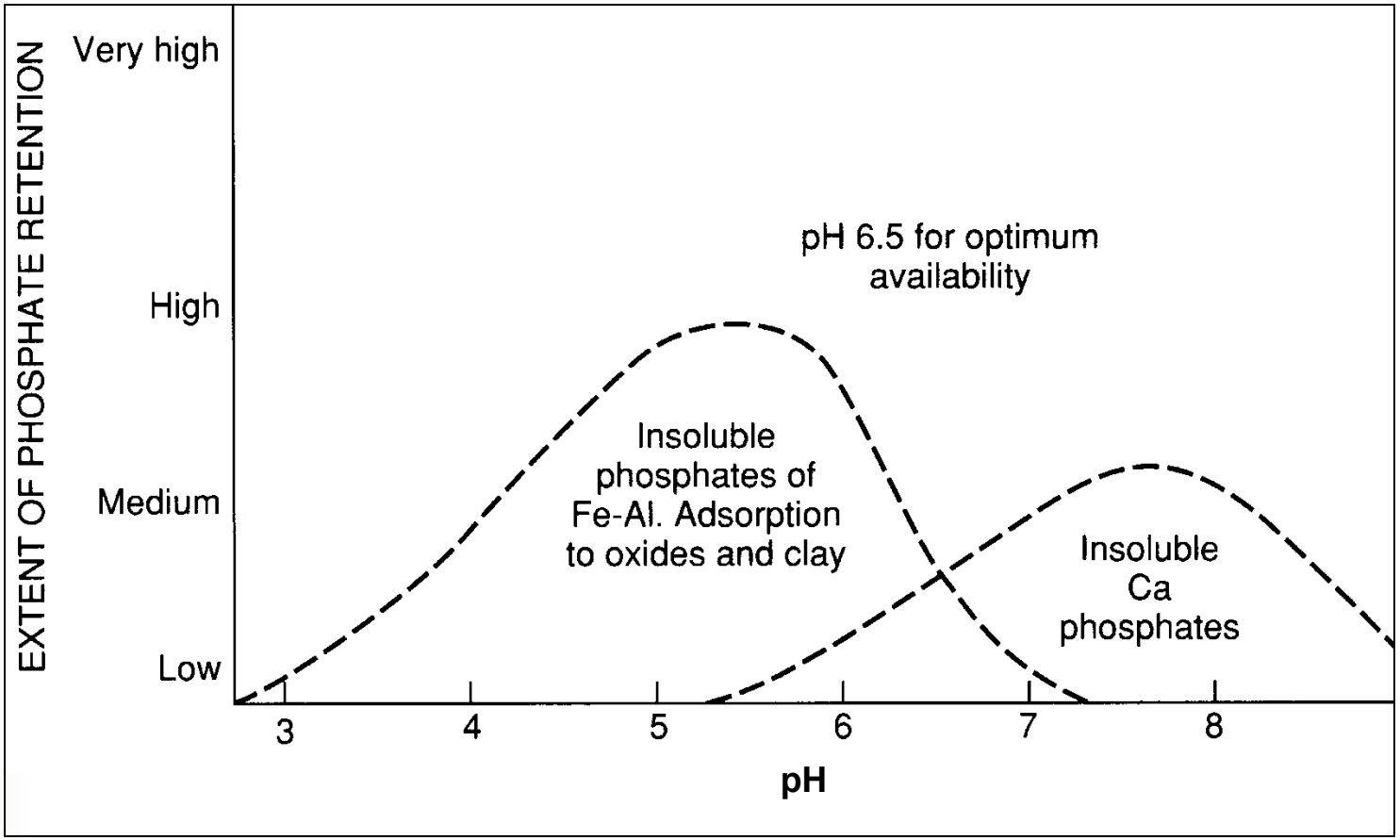


Soil pH and nutrient availability



http://www.yara.us

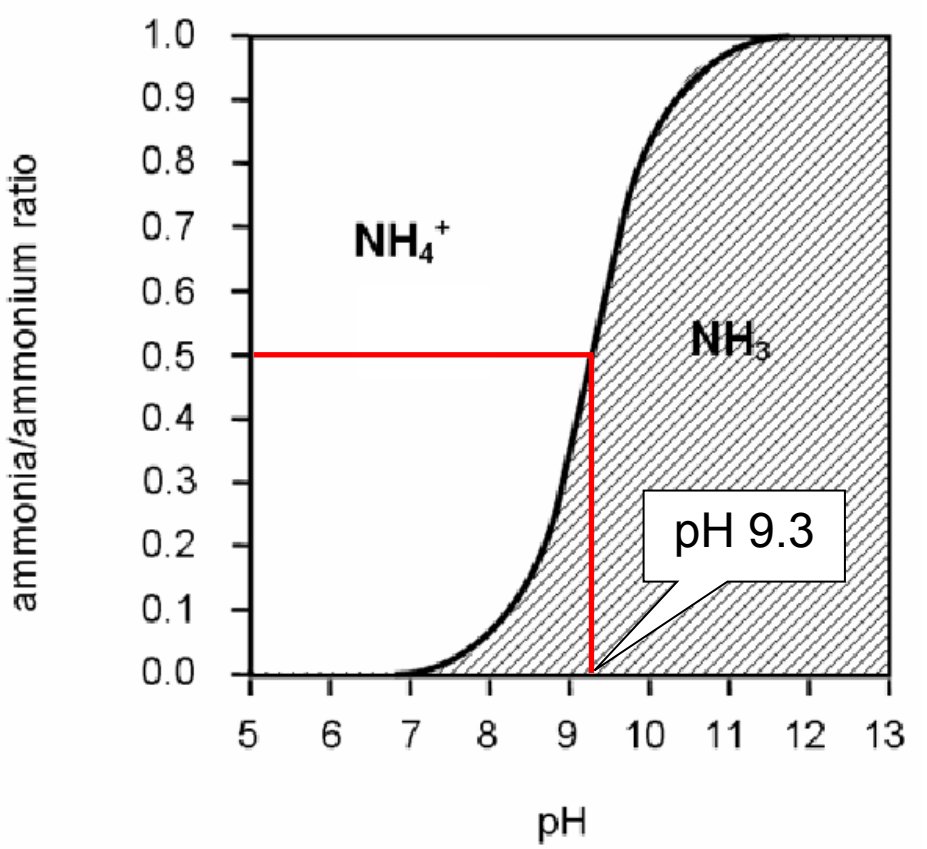
Effect of pH on forms and availability of soil phosphorus



pH and ammonia volatilization

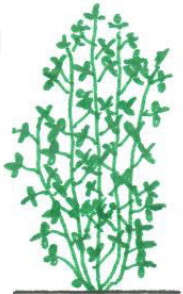
$NH_4^+ \Leftrightarrow NH_3 + H^+$ (pK_a 9.3)

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 ⇨ expensive
  - Band application of P instead of broadcasting ⇨ may damage roots in established alfalfa stands
  - Foliar application of micronutrients

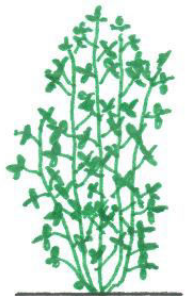


Cation exchange capacity (CEC)

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



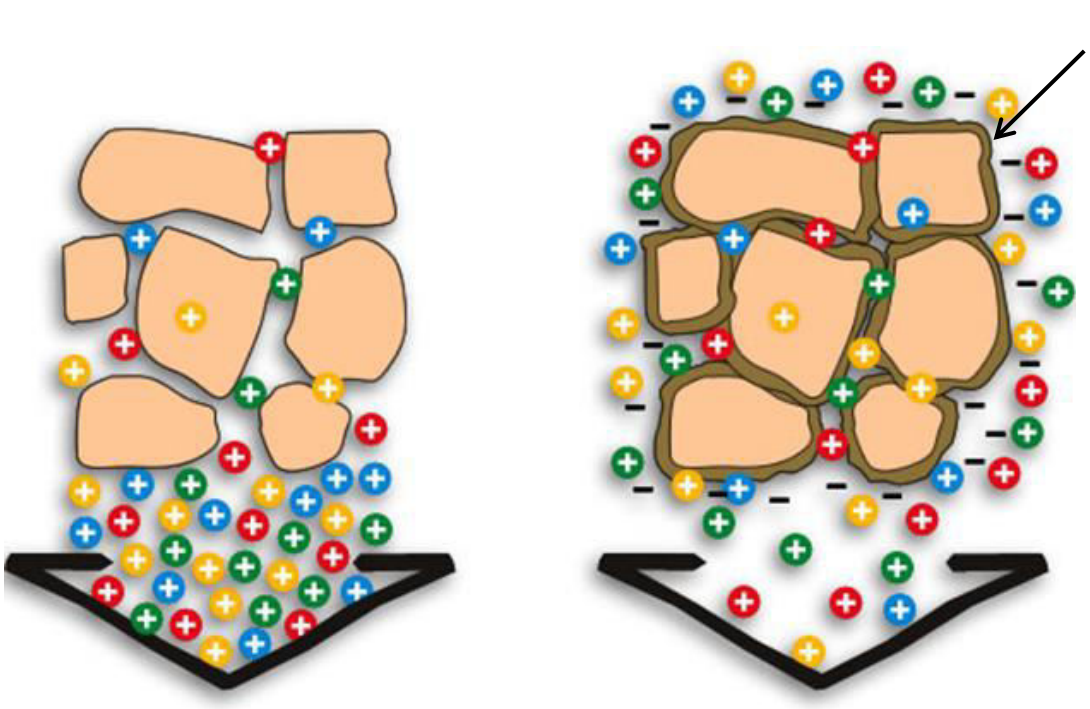
CEC and soil type

Soil type	Classification	CEC ($mmol_c\ kg^{-1}$)
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

Brady and Weil, 2008

Significance of CEC

- Pool of readily available nutirents
- Reduces leaching of cations



Essential nutrients - cations

Structural elements:

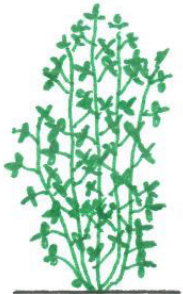
- Carbon (CO_2)
- Oxygen (CO_2, H_2O)
- Hydrogen (H_2O)

Macronutrients:

- Nitrogen (NH_4^+, NO_3^-)
- Phosphorus (HPO_4^{2-}; $H_2PO_4^-$)
- Potassium (K^+)
- Calcium (Ca^{2+})
- Magnesium (Mg^{2+})
- Sulfur (SO_4^{2-})

Micronutrients:

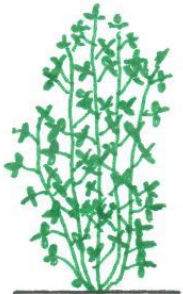
- Boron (H_3BO_3)
- Chlorine (Cl^-)
- Copper (Cu^{2+})
- Iron (Fe^{2+}; Fe^{3+})
- Manganese (Mn^{2+})
- Molybdenum (MoO_4^{2-})
- Nickel (Ni^{2+})
- Silicon (H_4SiO_4)
- Sodium (Na^+)
- Zinc (Zn^{2+})



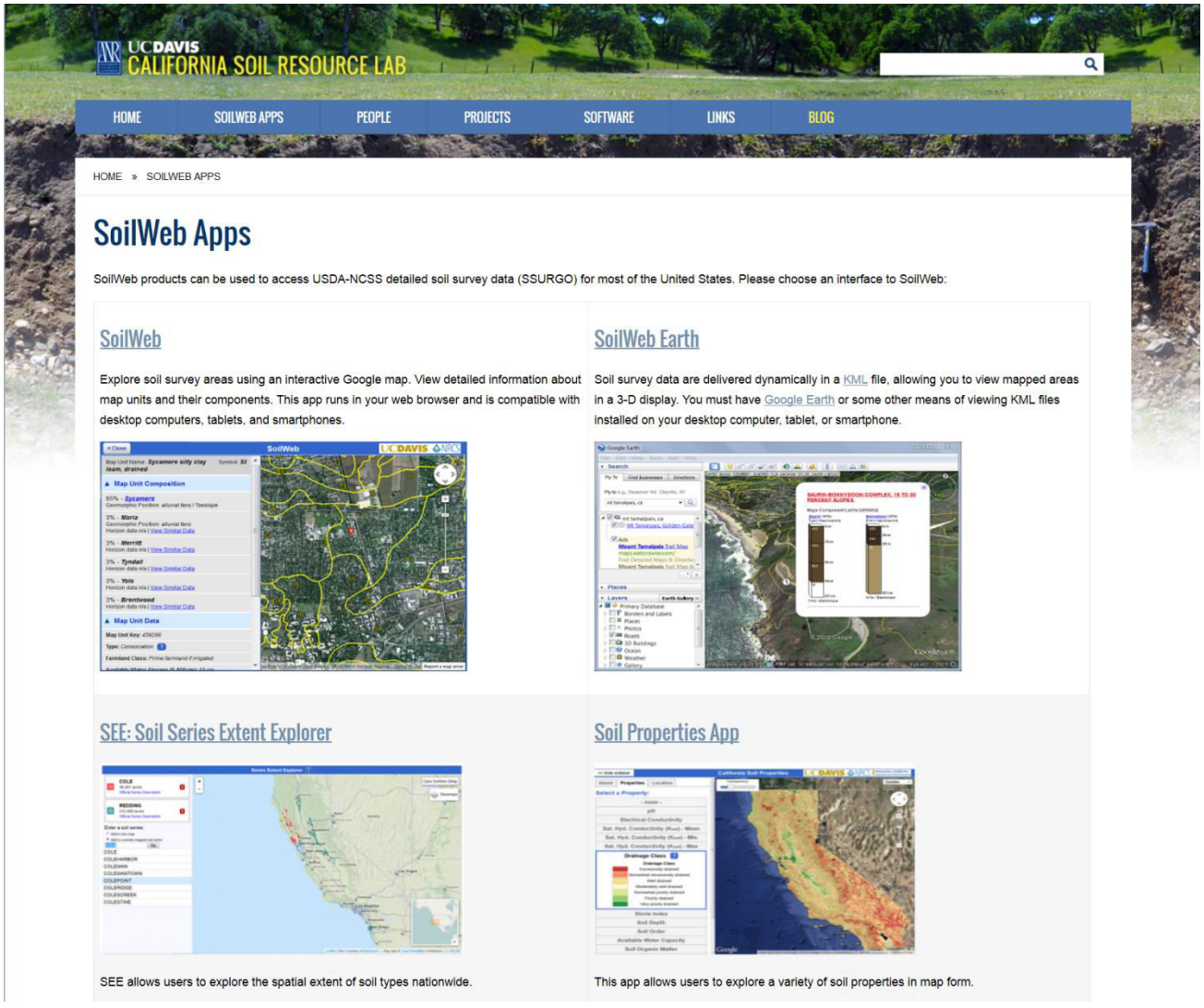
Managing CEC

- Increase CEC
  - Change texture ⇨ Not realistic in a field
  - Increase pH ⇨ Only in acidic soils
  - Increase soil organic matter ⇨ 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



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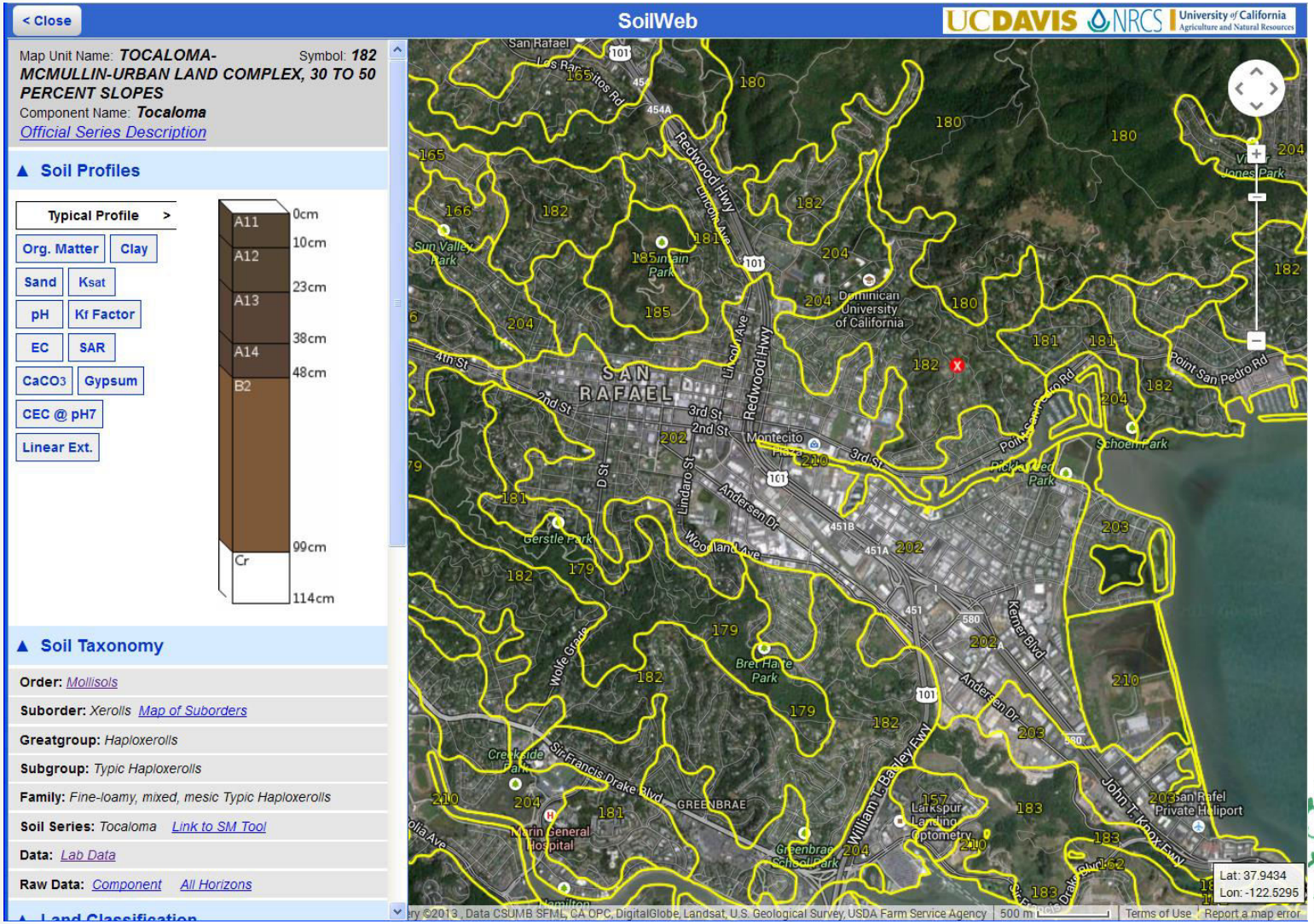

Thank you!