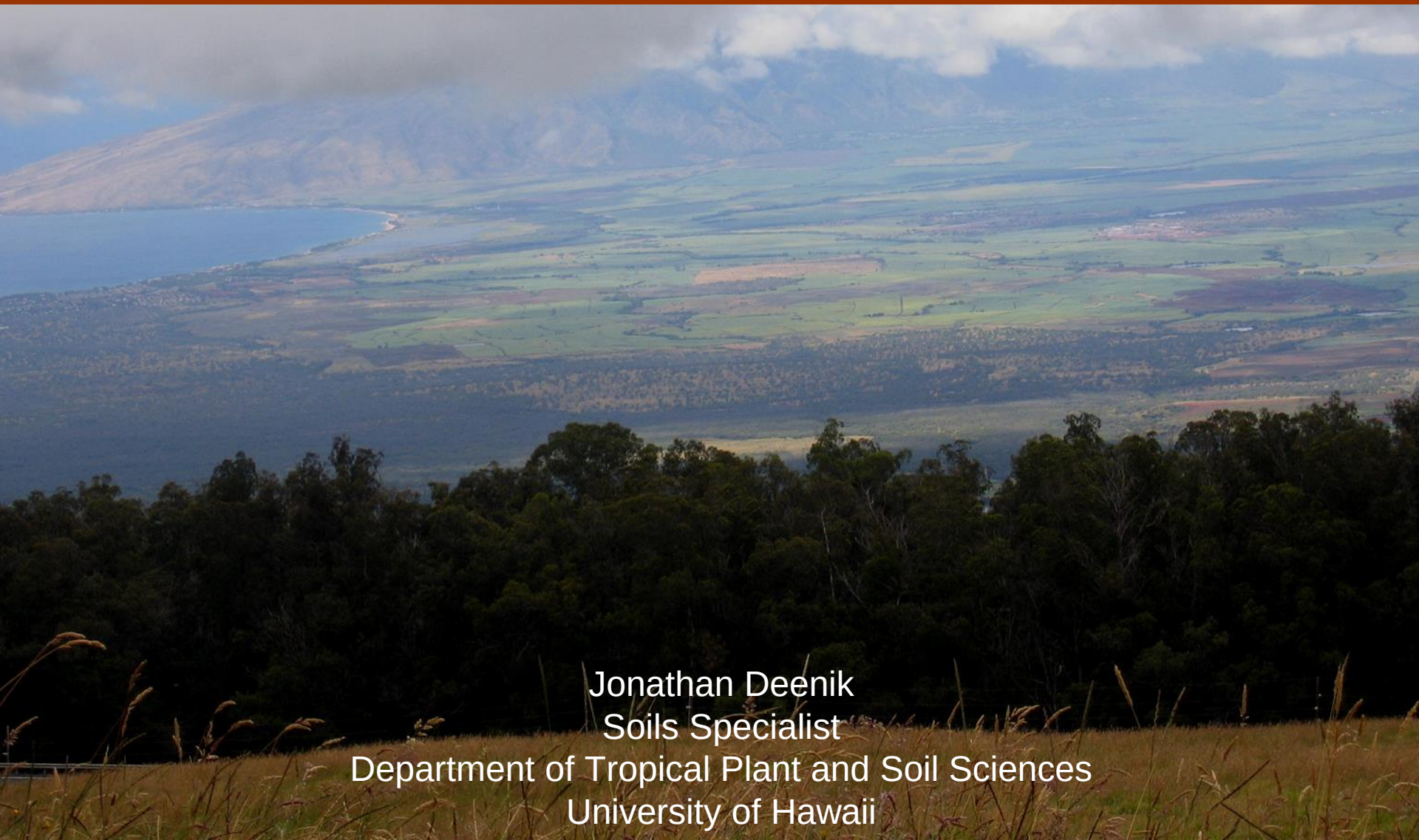
Understanding and Managing Soils for a Healthy Landscape



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Soil Nutrient Management for Maui County

College of Tropical Agriculture and Human Resources (CTAHR)

Introduction

The purpose of this web resource is to provide fundamental concepts for managing nutrients in tropical soils and container crop production. Though basic in principle, the importance of nutrient management cannot be underestimated. If growers are to maximize crop productivity, it is imperative they supply plants with the proper nutrition in both field and greenhouse environments.

The organization of this website consists of four sections:

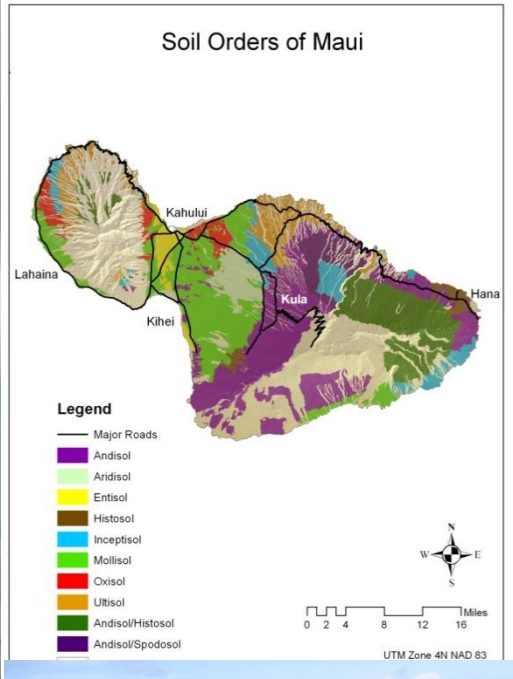
- Section 1 explores the basic principles that govern crop performance in tropical soils.
- Section 2 discusses the diversity of soils which make up the island of Maui.
- Section 3 focuses on the proper management techniques for maintaining or enhancing the nutrition of tropical soils.
- Section 4 introduces nutrient management strategies for container crop production in soil less media.

Much of the information provided in this website is unique to Maui. We aim to provide the College of Tropical Agriculture and Human Resources' (CTAHR) clients with resources, knowledge and tools that are easily accessible, comprehensible and useful for properly managing their crops. Despite the localized nature of some information supplied here, much of it can be applied elsewhere in the tropics particularly throughout the Pacific.

http://www.ctahr.hawaii.edu/mauisoil/

Outline

- Importance of Soils
- Soil Diversity on Maui
- Soil Properties
- Diagnosis and soil testing
- Management for Health

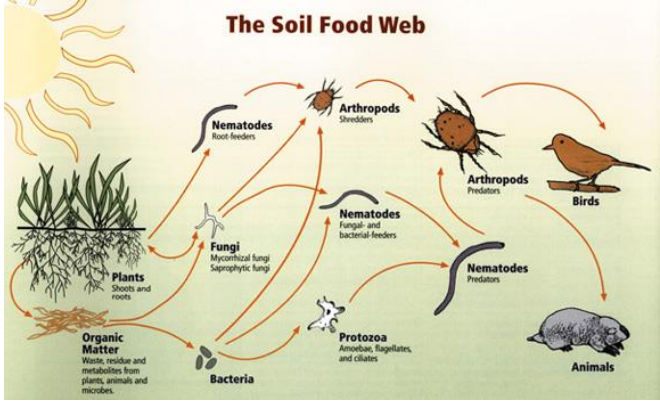


Importance of Soil

6 Functions of Soil

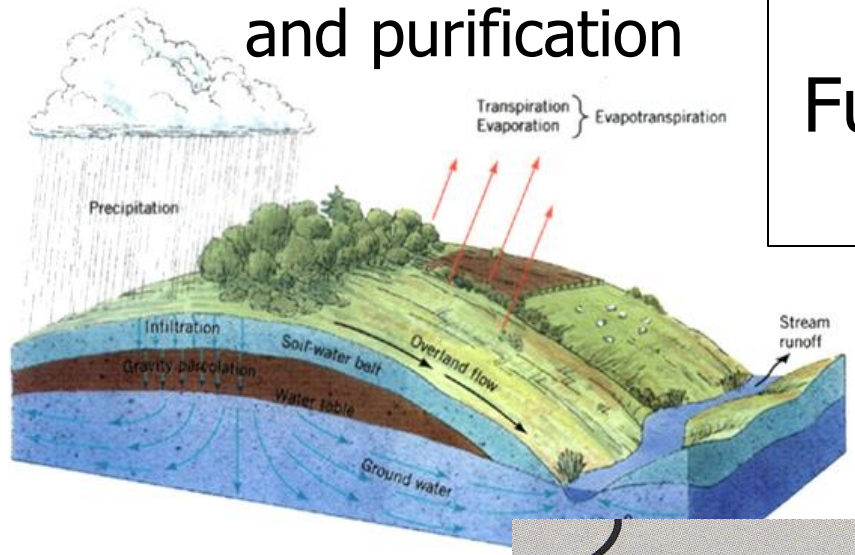
Medium for Plant growth

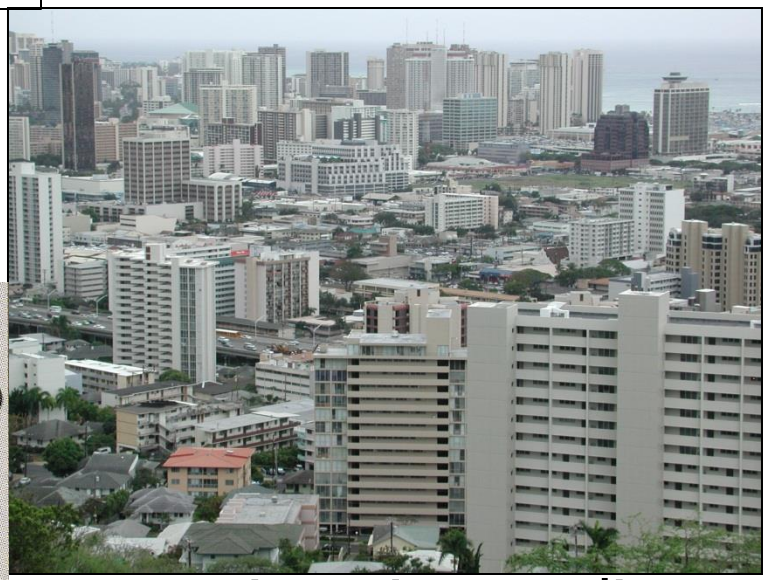
Habitat for Soil organisms



Recycling system

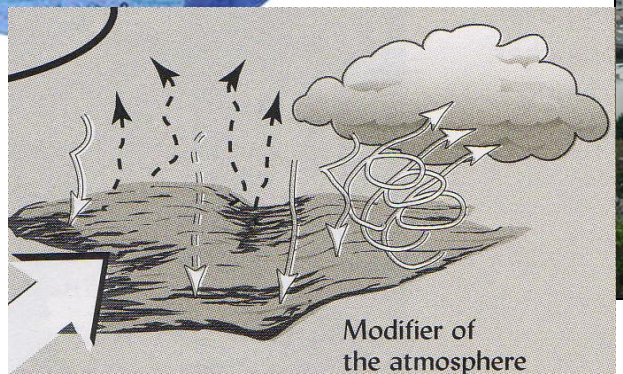
Water supply and purification



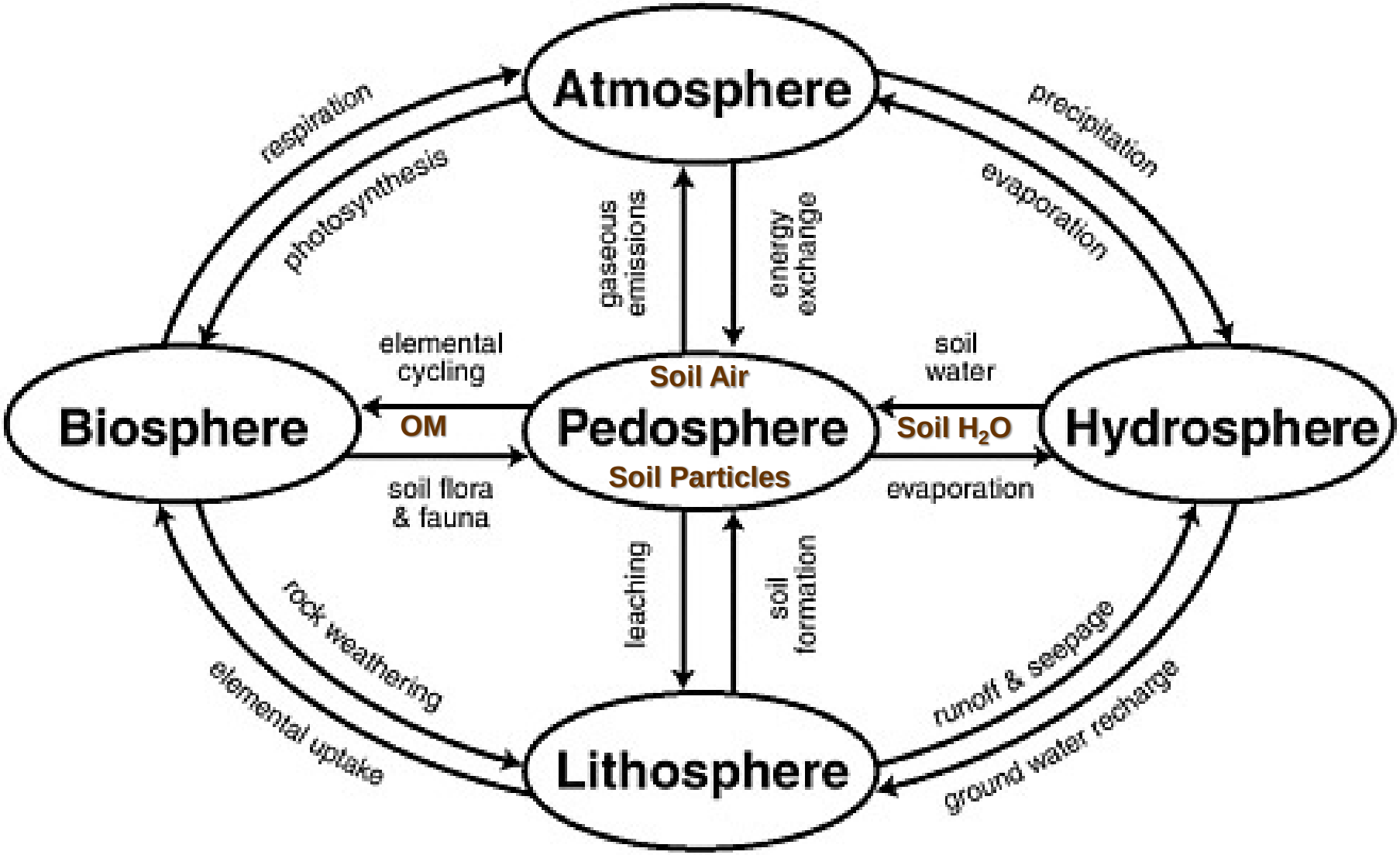


Engineering Medium

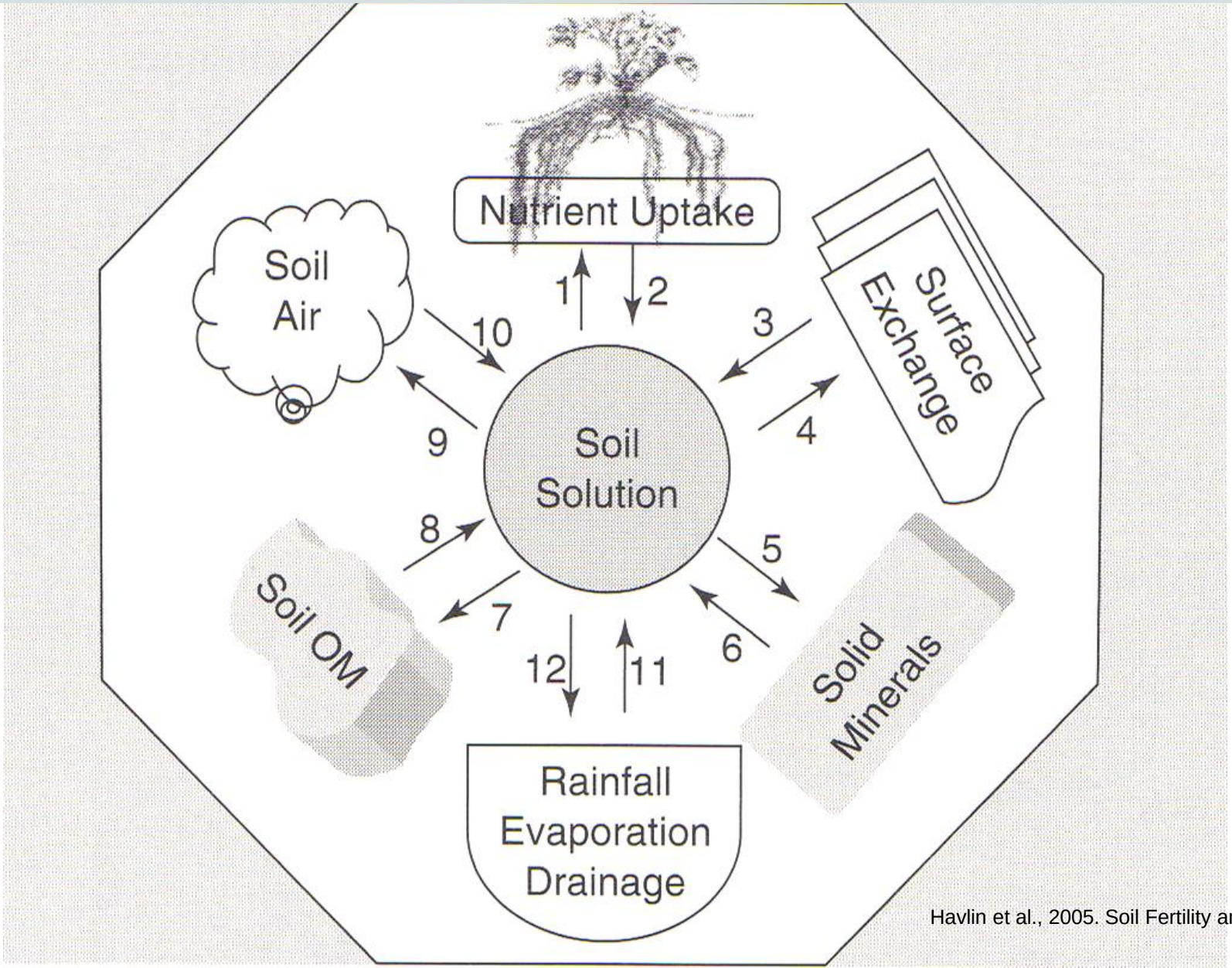
Modifier of the atmosphere



Soil: The Central Resource

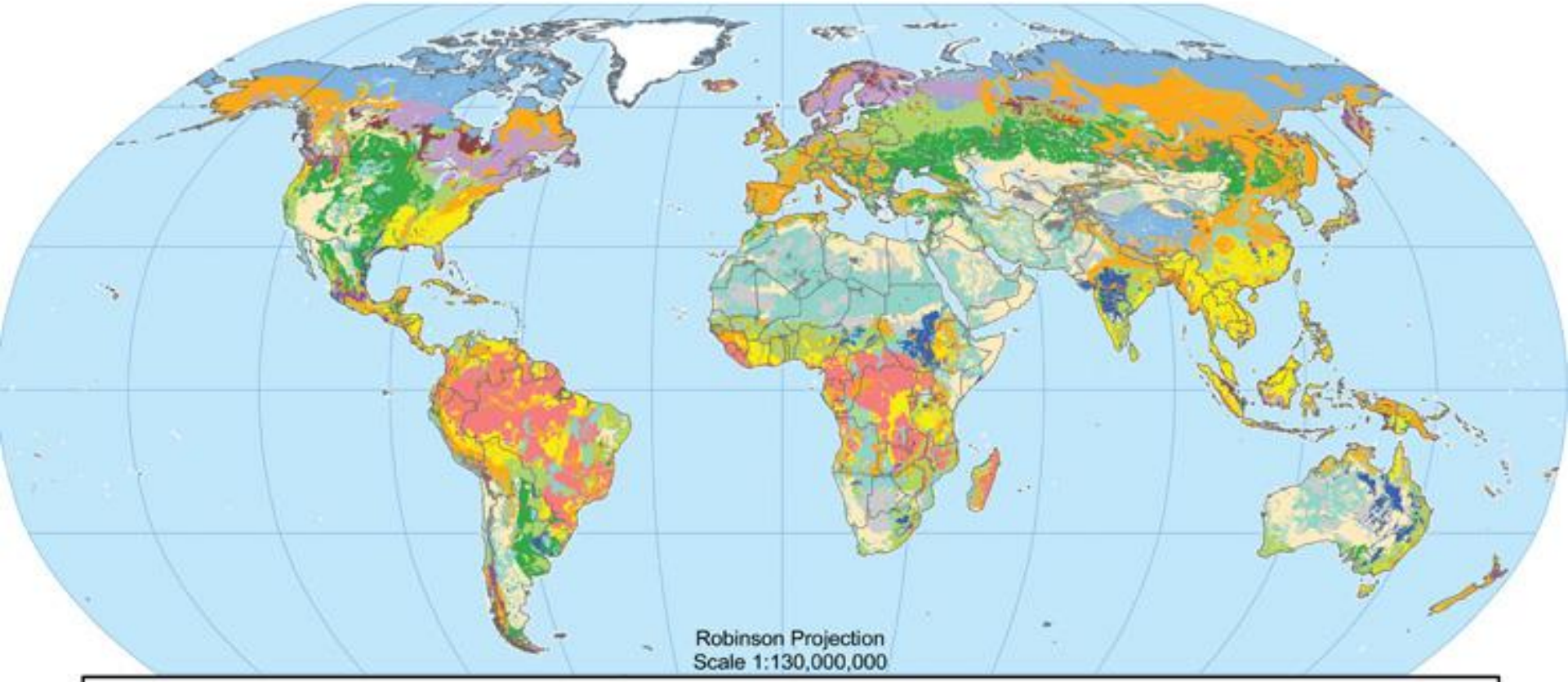


Soil Plant Relationships



Havlin et al., 2005. Soil Fertility and Fertilizers

Global Soil Regions



Soil Orders

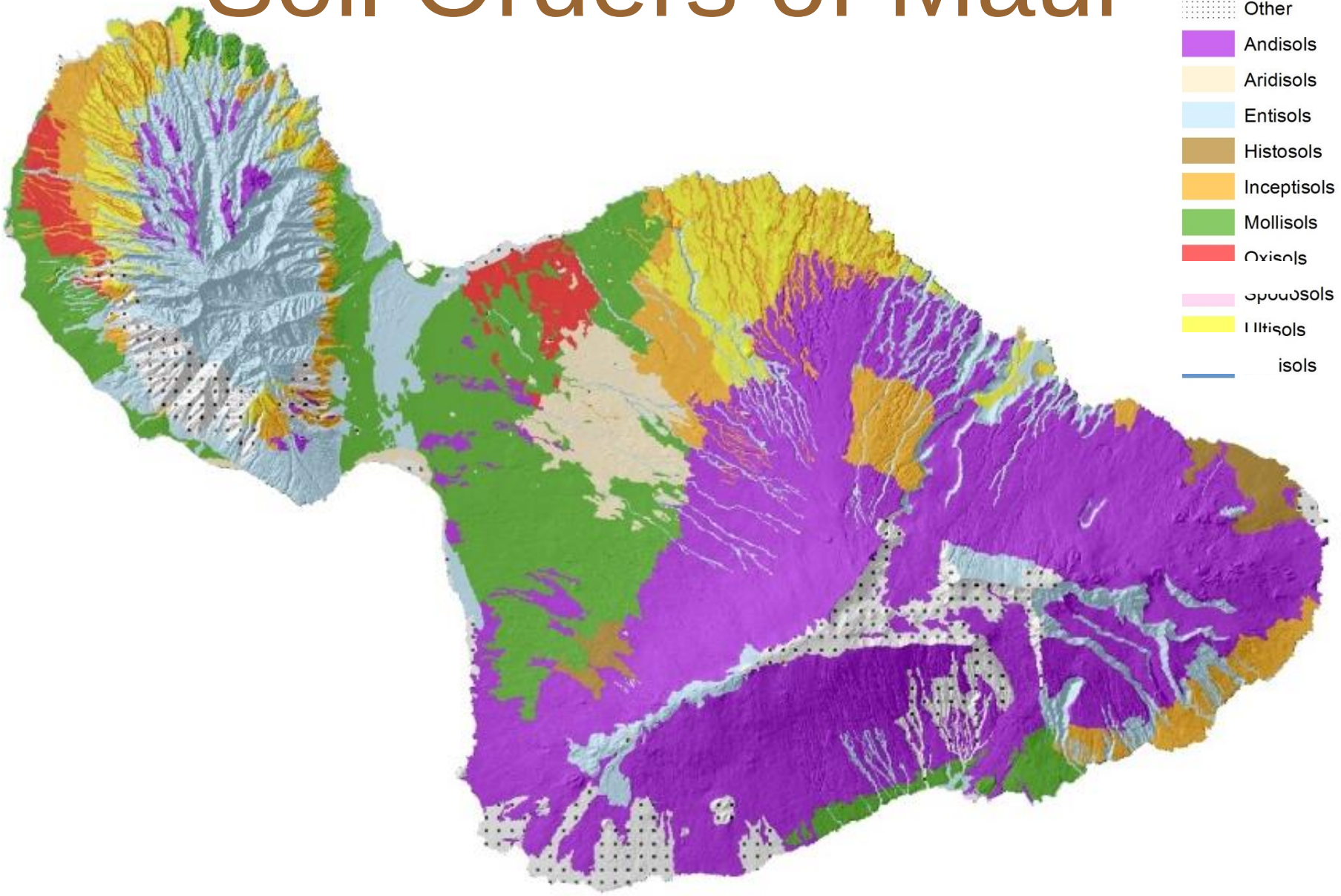
Alfisols	Entisols	Inceptisols	Spodosols	Rocky Land
Andisols	Gelisols	Mollisols	Ultisols	Shifting Sand
Aridisols	Histosols	Oxisols	Vertisols	Ice/Glacier

USDA NRCS US Department of Agriculture
Natural Resources
Conservation Service

Soil Survey Division
World Soil Resources
soils.usda.gov/use/worldsoils

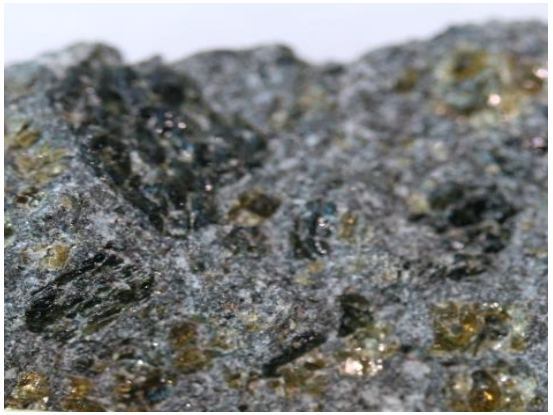
November 2005

Soil Orders of Maui



Soil Diversity

Soil Formation

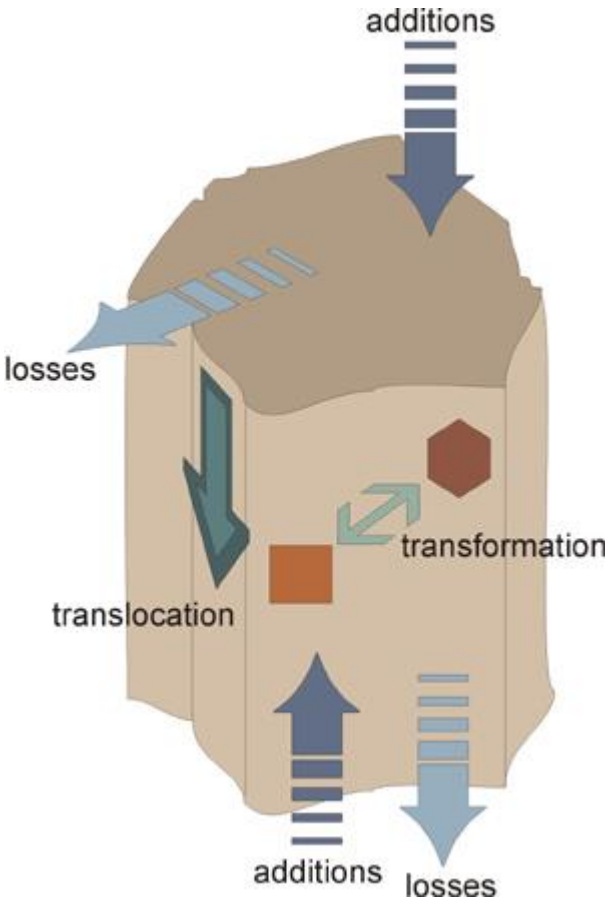


Factors

- Parent material
- Age
- Climate
- Biota
- Topography

Processes

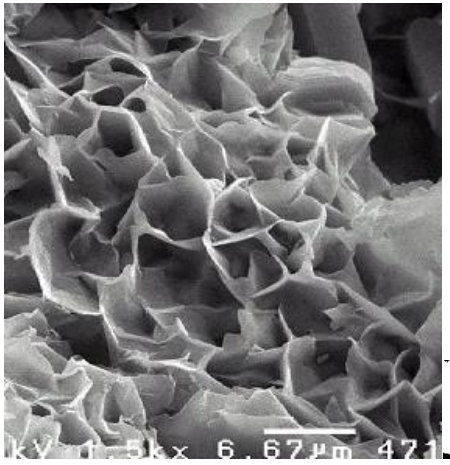
- Additions
- Transformations
- Translocations
- Losses



Weathering of Parent Rock

Augite $Ca(Mg,Fe)Si_2O_6 \cdot (Al,Fe)_2O_3$

Olivine $(Mg,Fe)_2SiO_4$



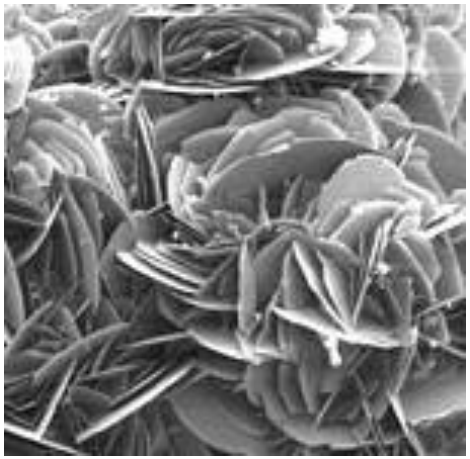
Chemical Weathering

Montmorillonite

$(Al,Mg)_8(Si_4O_{10})_3(OH)_{10} \cdot 12H_2O$

Hematite

Fe_2O_3



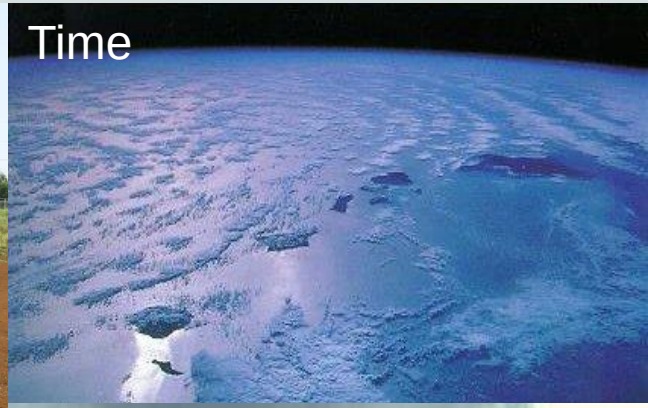
Origin of Soil Diversity

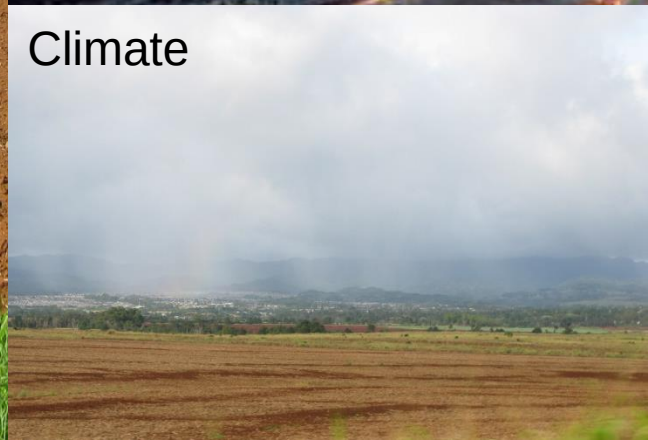
Factors

- Time
- Parent Material
- Climate
- Biota
- Topography

Processes

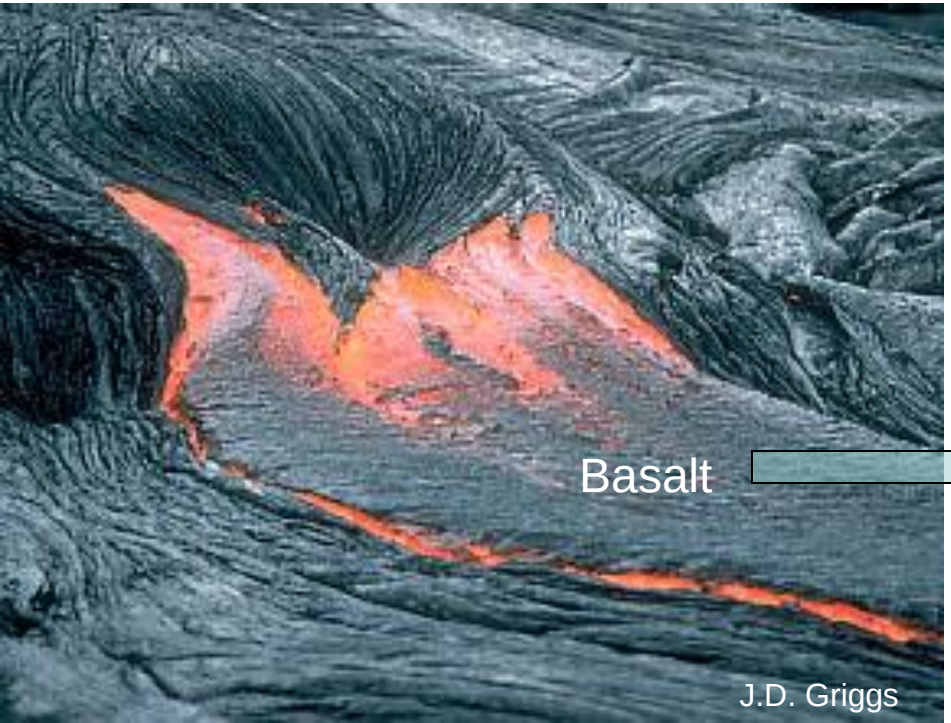
- Physical weathering
- Chemical weathering

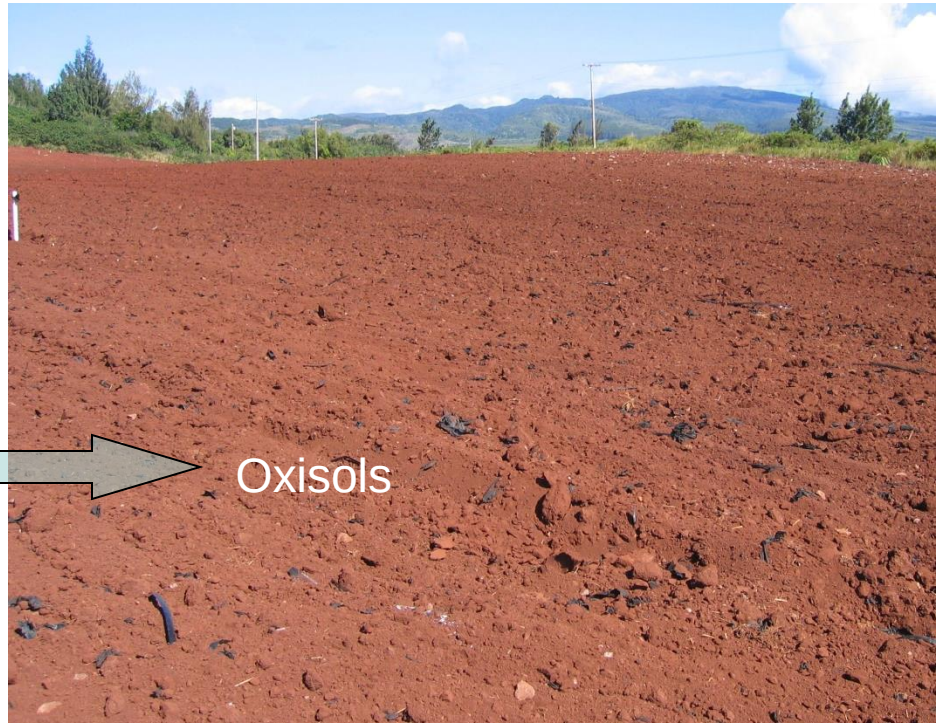





Volcanic Ash


Andisols


Basalt
J.D. Griggs


Oxisols

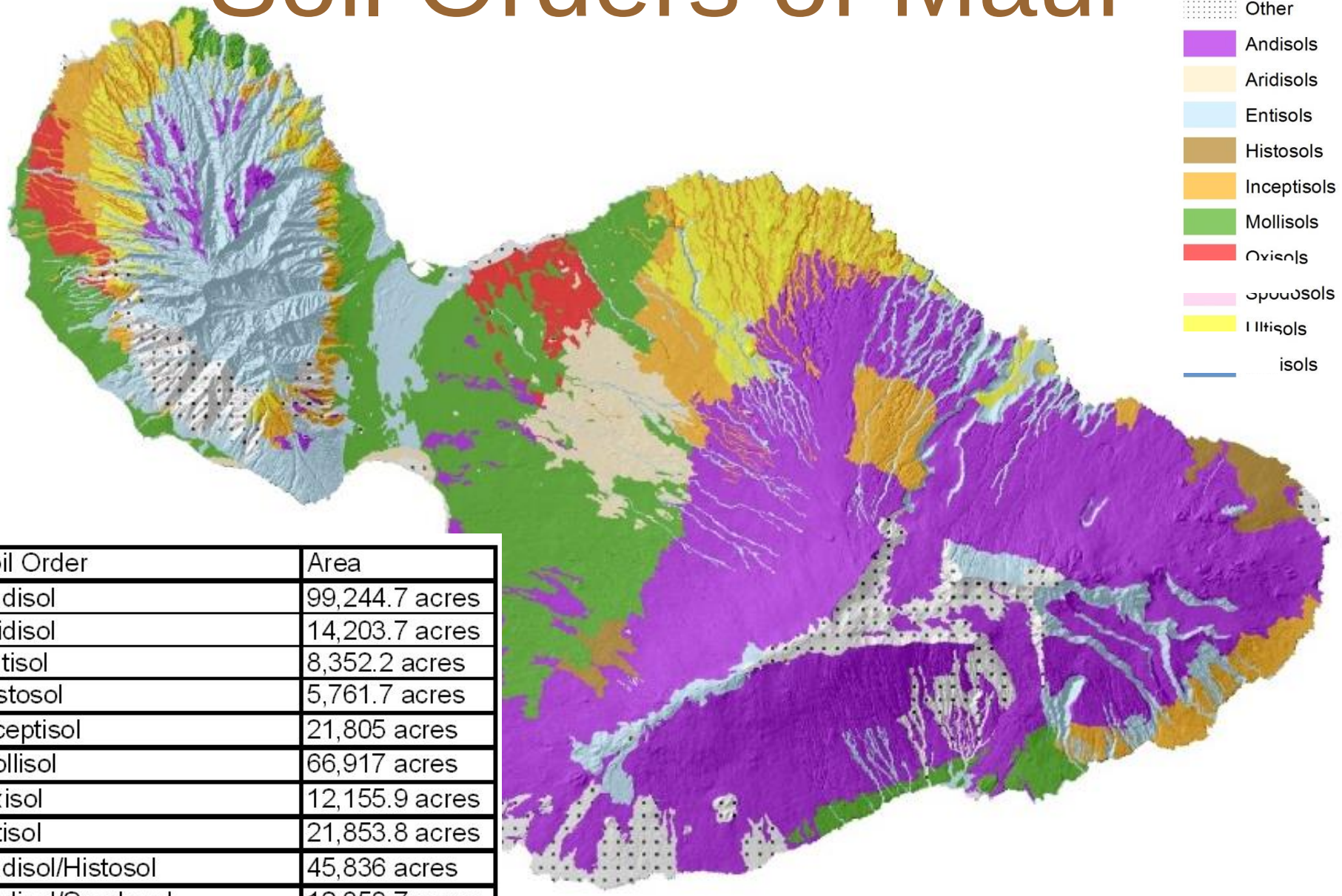
Origin of Soil Diversity

Climate - Precipitation

Wet = high weathering, acid & infertile
Haiku series

Dry = less weathering, fertile
Keahua series

Soil Orders of Maui



Soil Order	Area
Andisol	99,244.7 acres
Aridisol	14,203.7 acres
Entisol	8,352.2 acres
Histosol	5,761.7 acres
Inceptisol	21,805 acres
Mollisol	66,917 acres
Oxisol	12,155.9 acres
Ultisol	21,853.8 acres
Andisol/Histosol	45,836 acres
Andisol/Spodosol	12,350.7 acres

Andisols of Maui

<u>General Characteristics</u>

- light and fluffy (low bulk density
- high in organic matter
- tendency to “fix” P

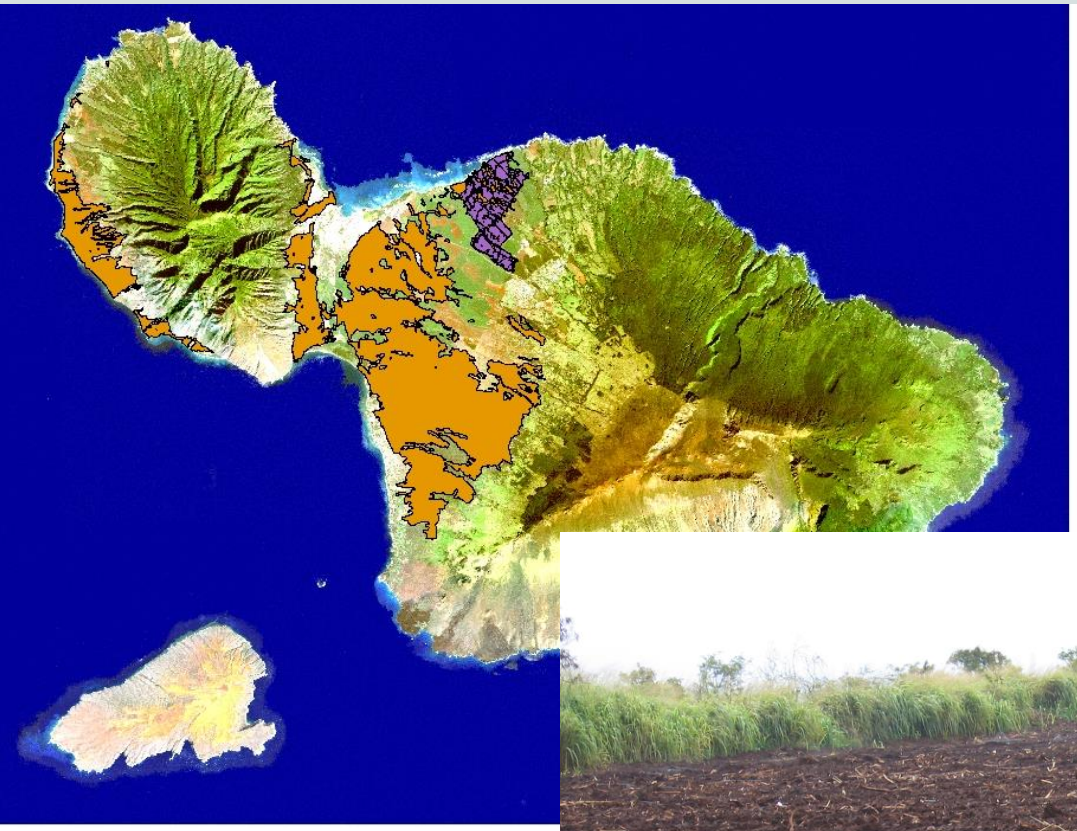
<u>*Kula* Series (dry areas)</u>

- Very fertile
- well-suited to vegetable, fruit, flower production

<u>*Hana* Series (wet areas)</u>

- Infertile (low in Ca & K)
- P deficient

Mollisols of Maui



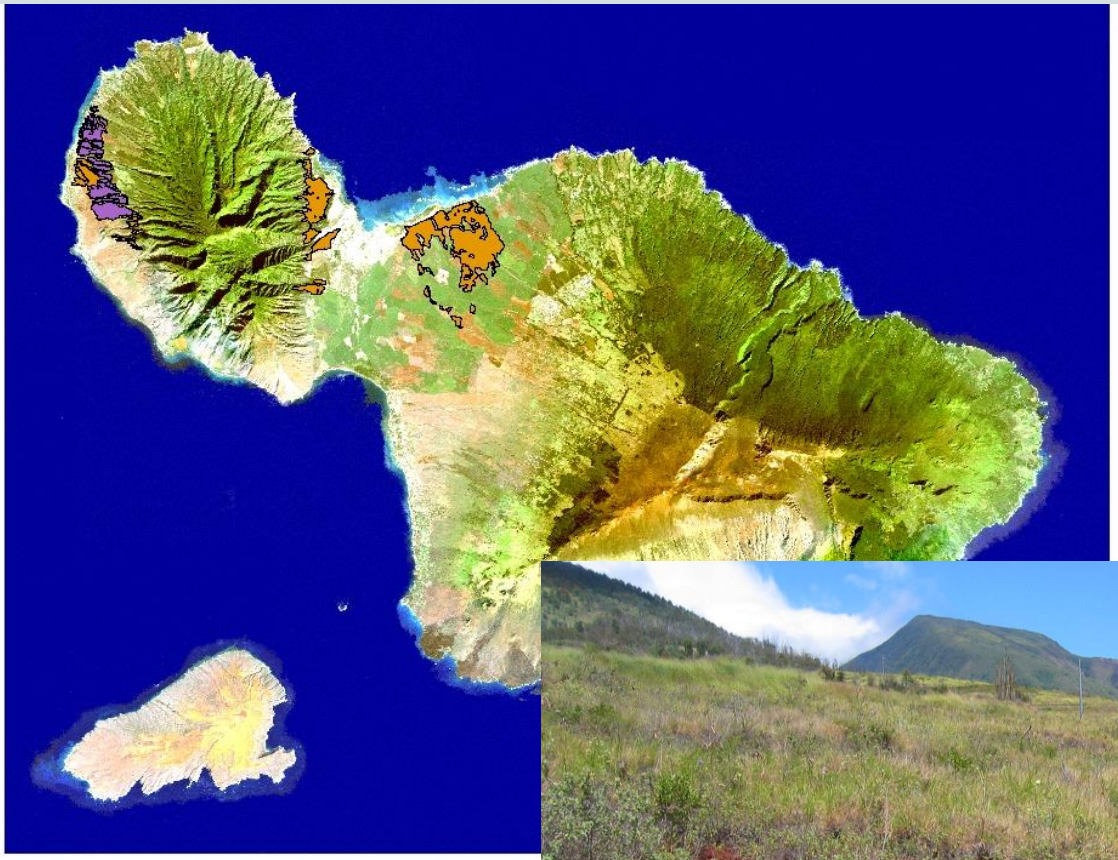
<u>General Characteristics</u>

- fertile, productive soils
- rich in Ca, K, Mg
- shrink/swell clay

<u>Common Examples:</u>

Ewa
Iao
Kaupo
Paia
Pulehu,
Wailuku

Oxisols of Maui



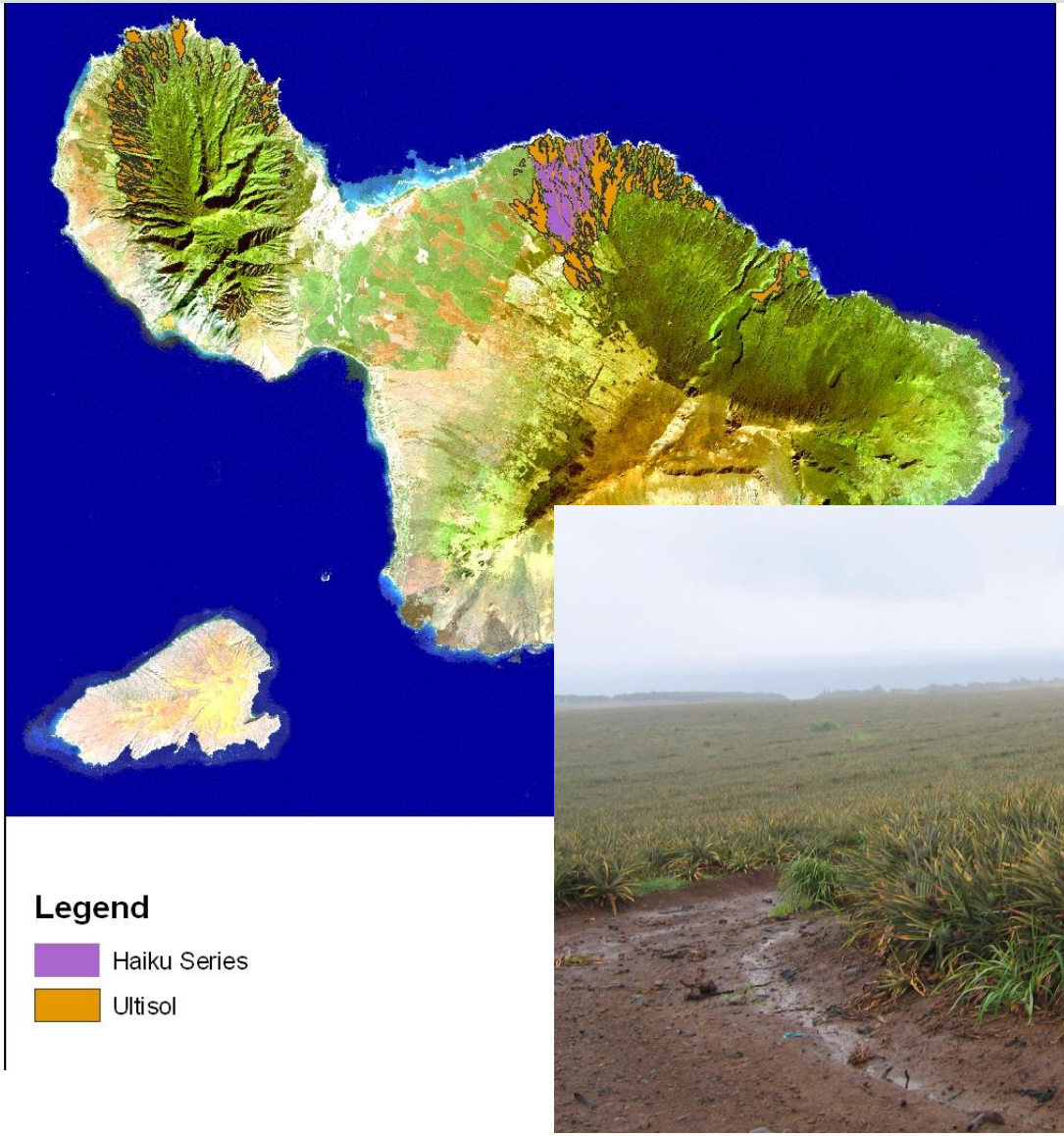
General Characteristics

- moderately fertile soils
- can be low in Ca, K, Mg
- good physical properties

Common Examples:

Lahaina
Molokai

Ultisols of Maui



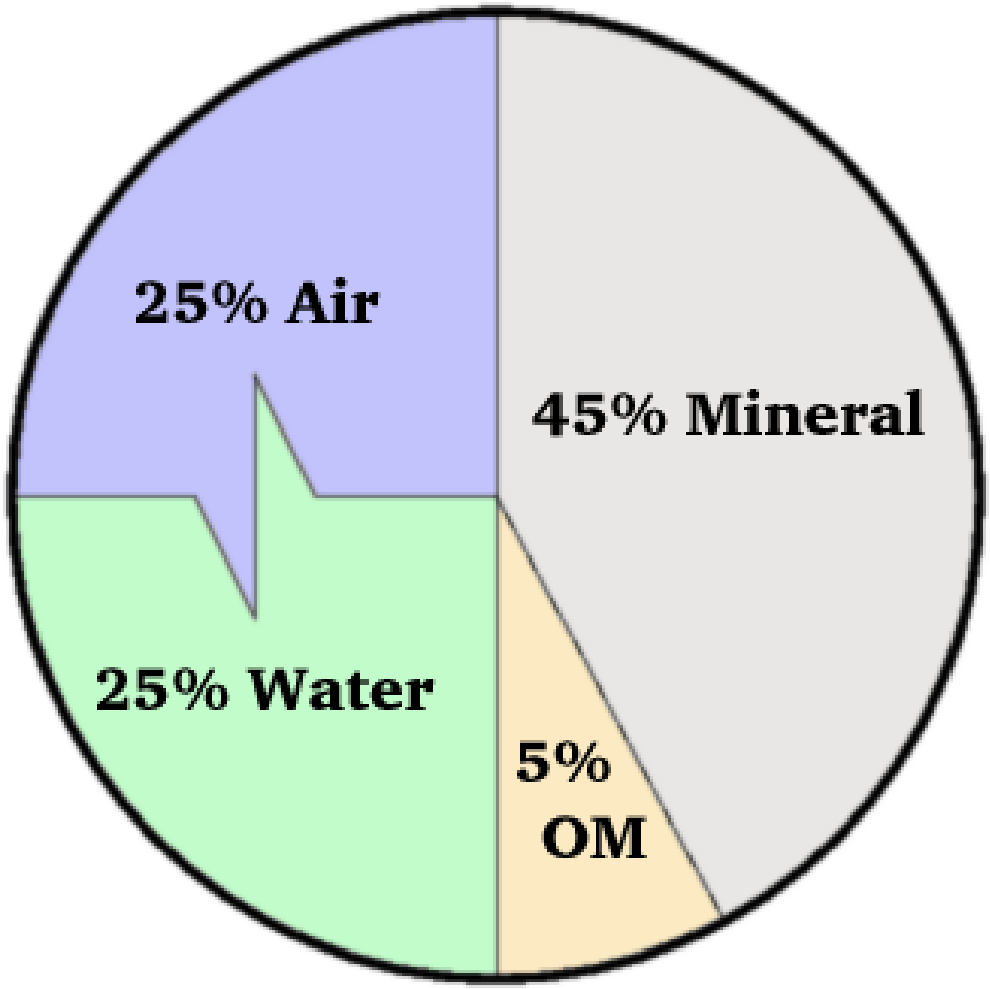
General Characteristics

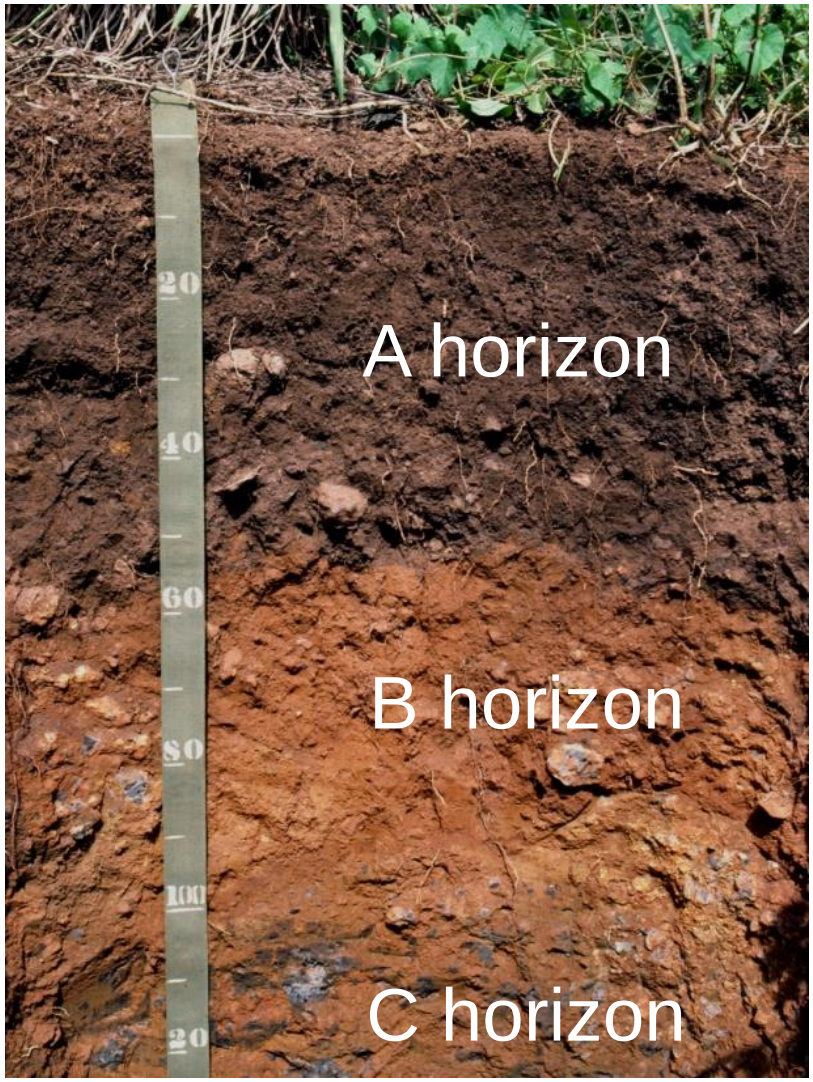
- strongly acidic soils
- depleted in Ca, K, Mg
- good physical properties

Common Examples:

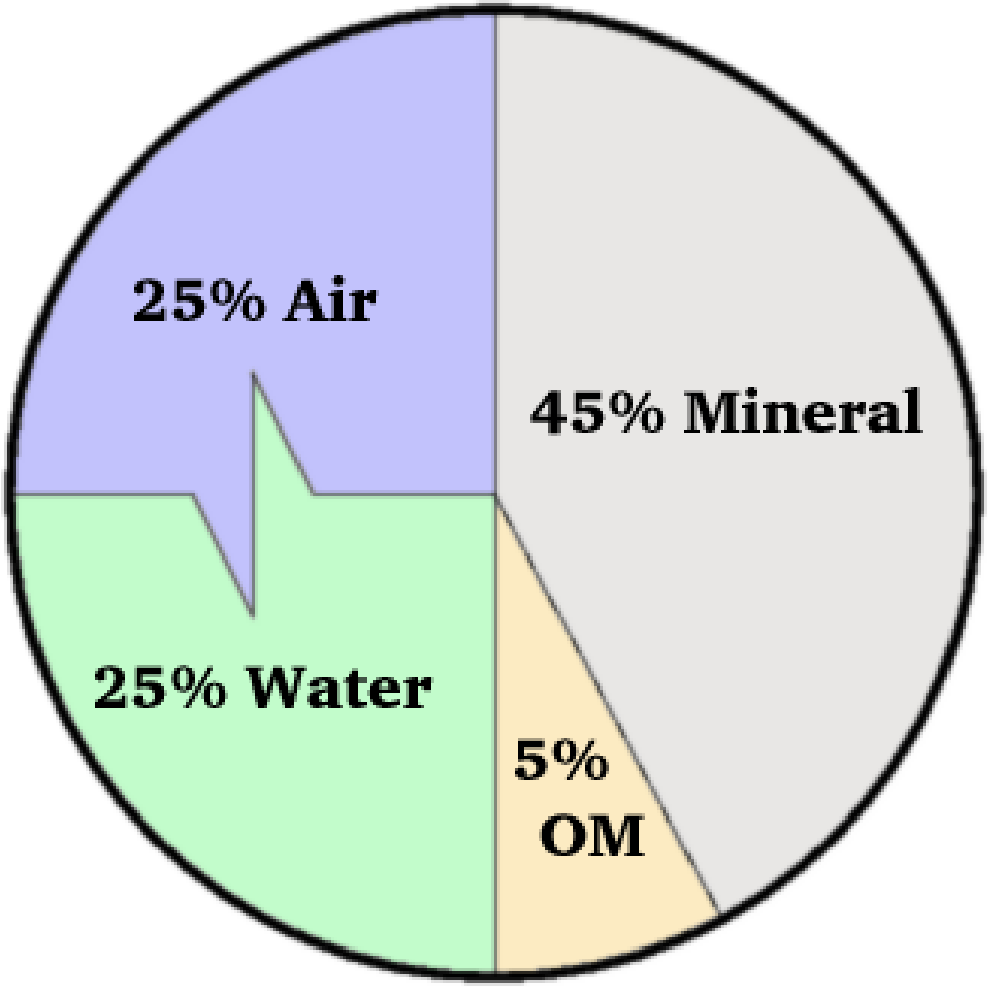
Alaeloa
Haiku
Honolua
Makawao
Olelo

What is Soil?



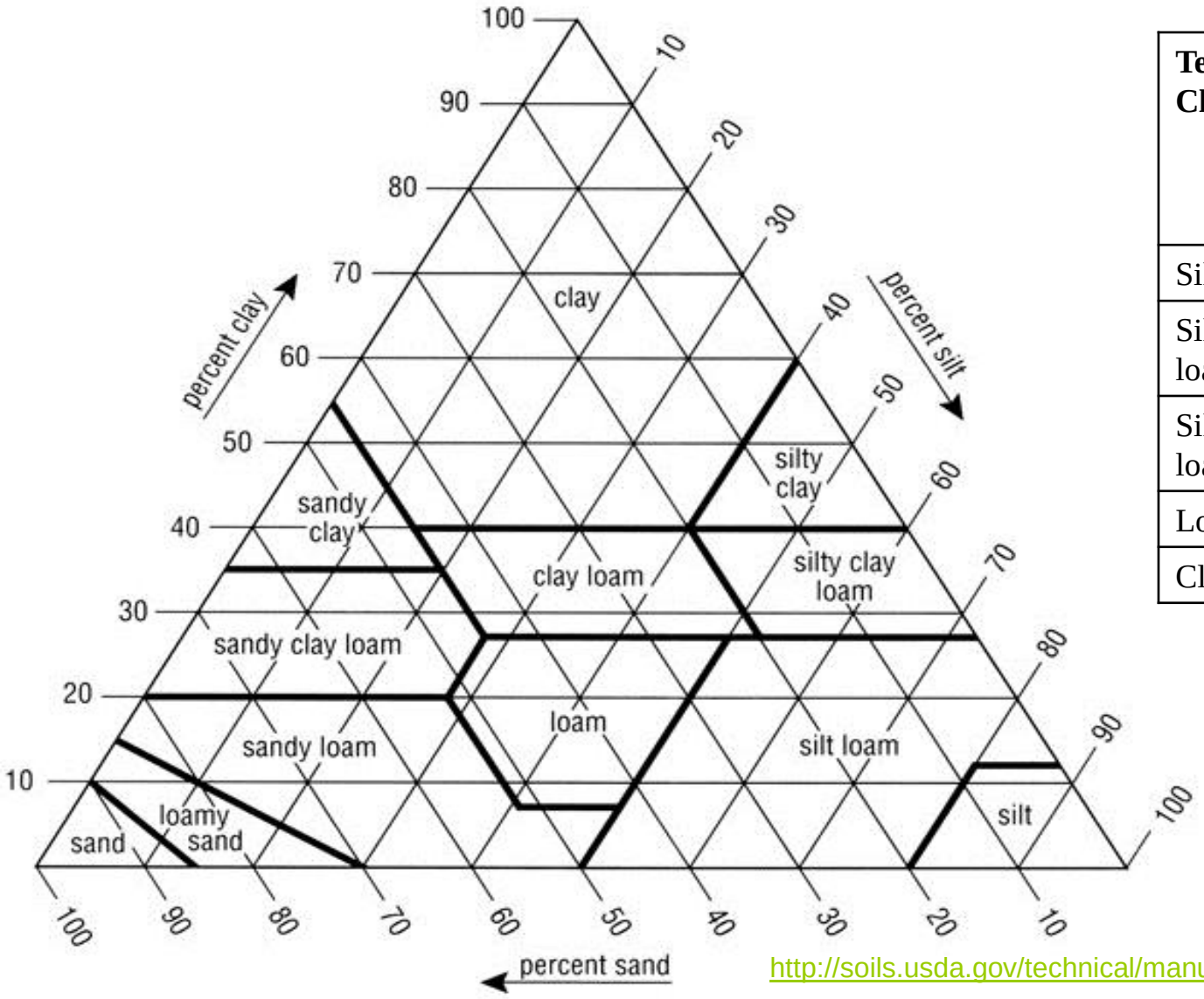


Soil Physical Properties



1. Soil texture/structure
2. Soil Water
3. Soil Organic Matter

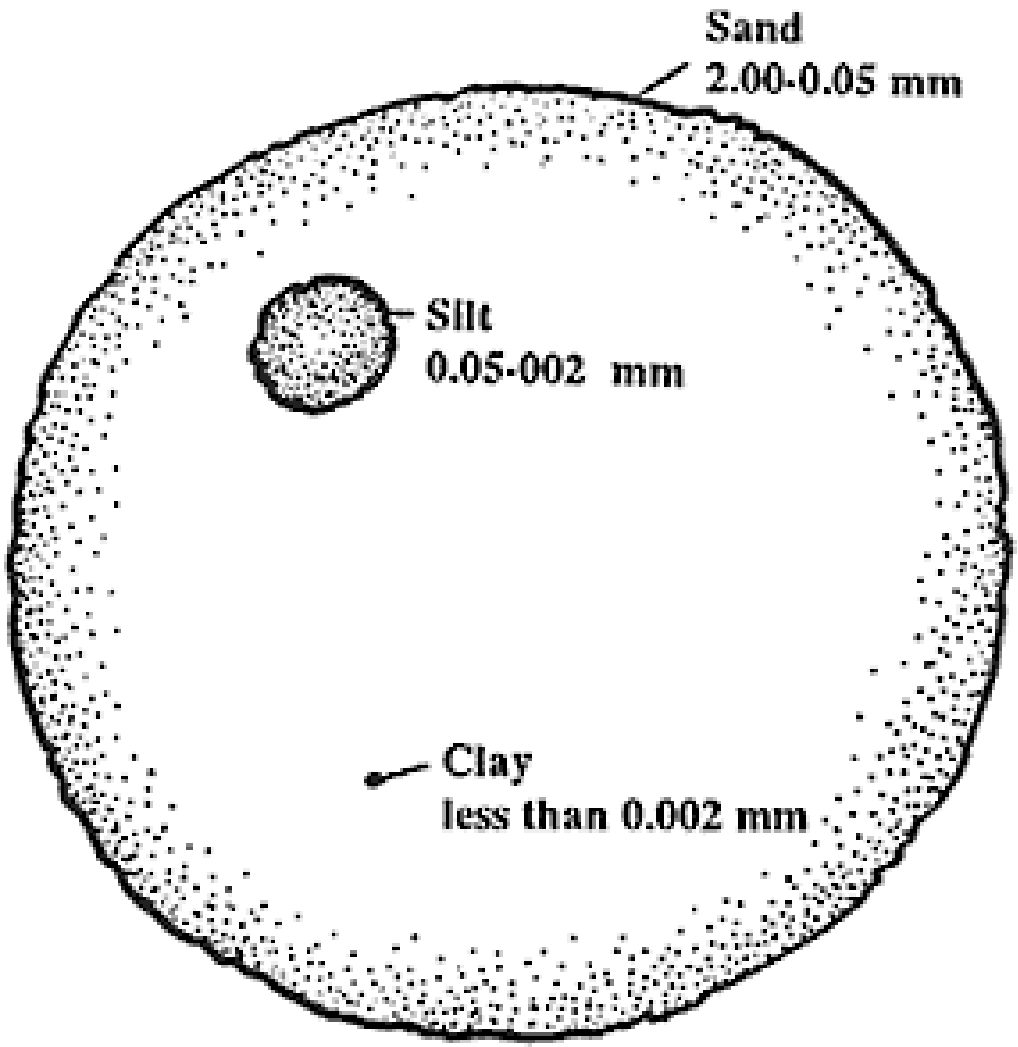
Soil Texture



Textural Class	Percentage of Maui soils that fall within the major textural classes
Silty clay	44%
Silty clay loam	23%
Silty loam	11%
Loam	10%
Clay	5%

http://soils.usda.gov/technical/manual/print_version/complete.html

Soil Texture

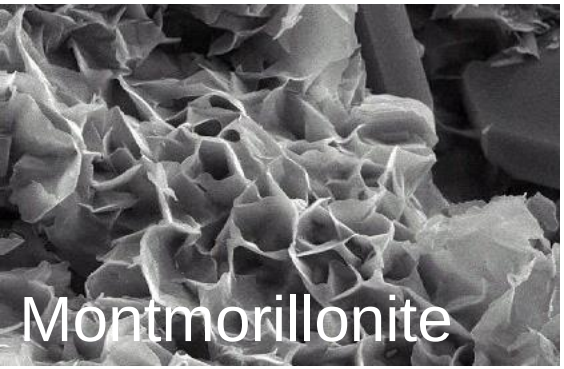


http://www.cst.cmich.edu/users/Franc1M/esc334/lectures/physical.htm

Important Clay Minerals

1. Kaolinite
   - non-expanding
   - Low CEC
2. Al/Fe oxides
   - non-expanding
   - no CEC
3. Smectite
   - expanding
   - high CEC
4. Allophane
   - high surface area

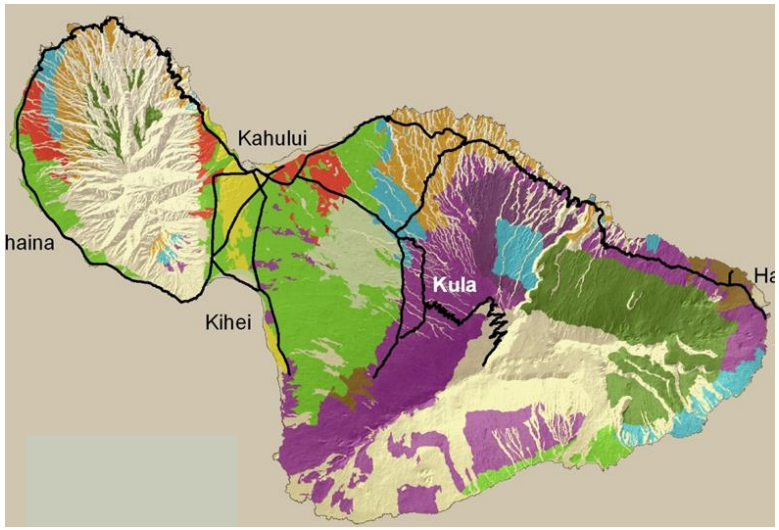
Some Important Clay Minerals

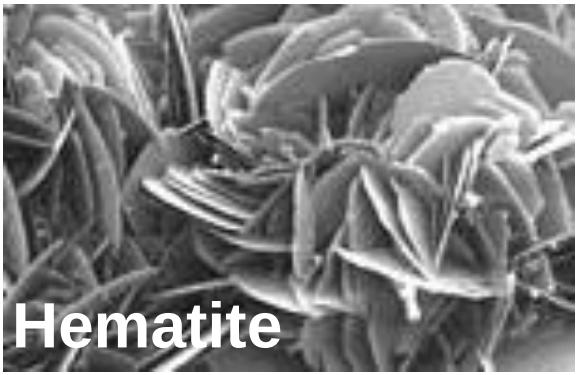


Properties:

- Shrink/swell
- High surface area
- High nutrient retention (cation exchange capacity, CEC)
- Sticky

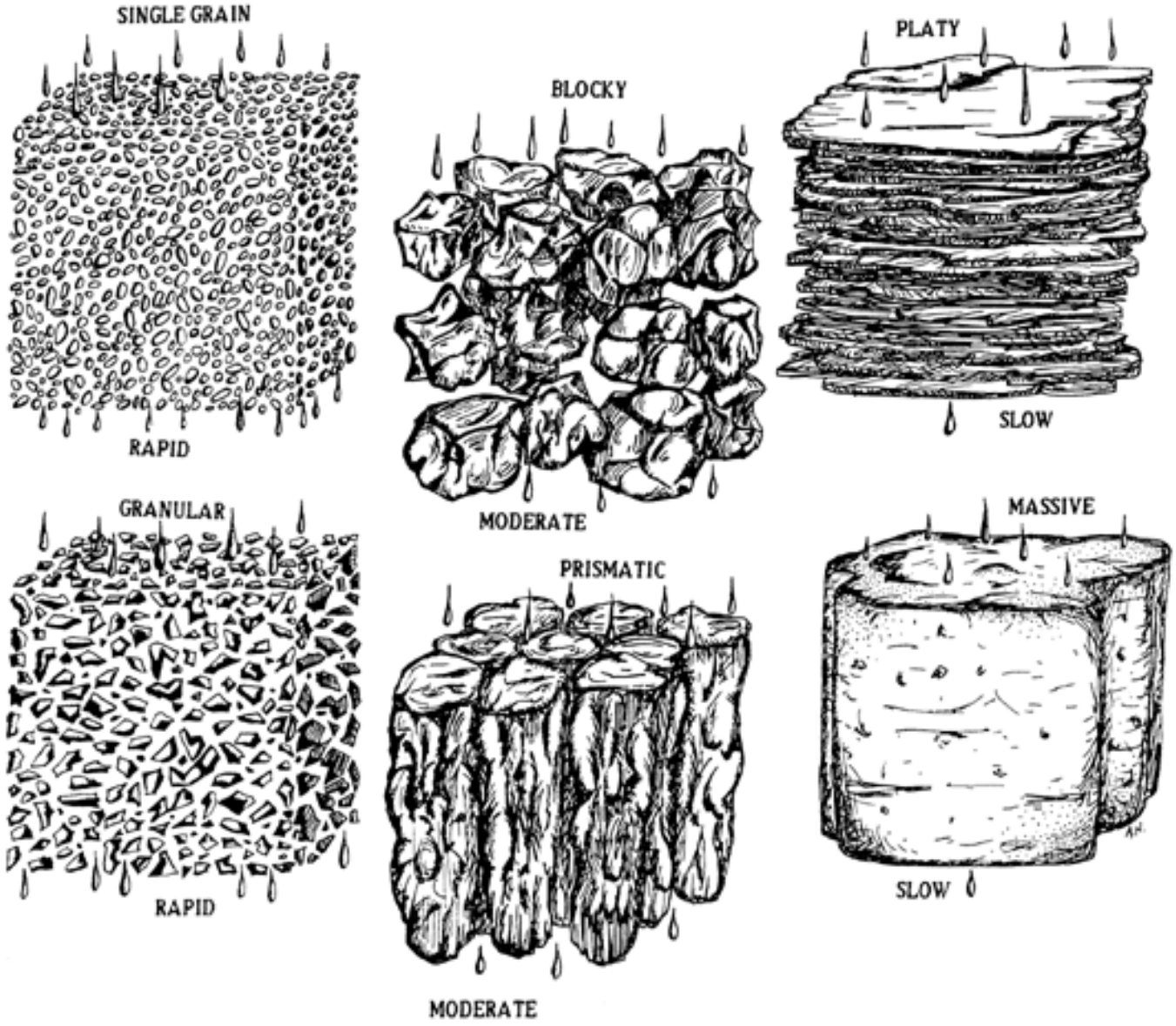
- Non-expanding
- Variable charge
- Low surface area
- Low CEC
- Non-sticky

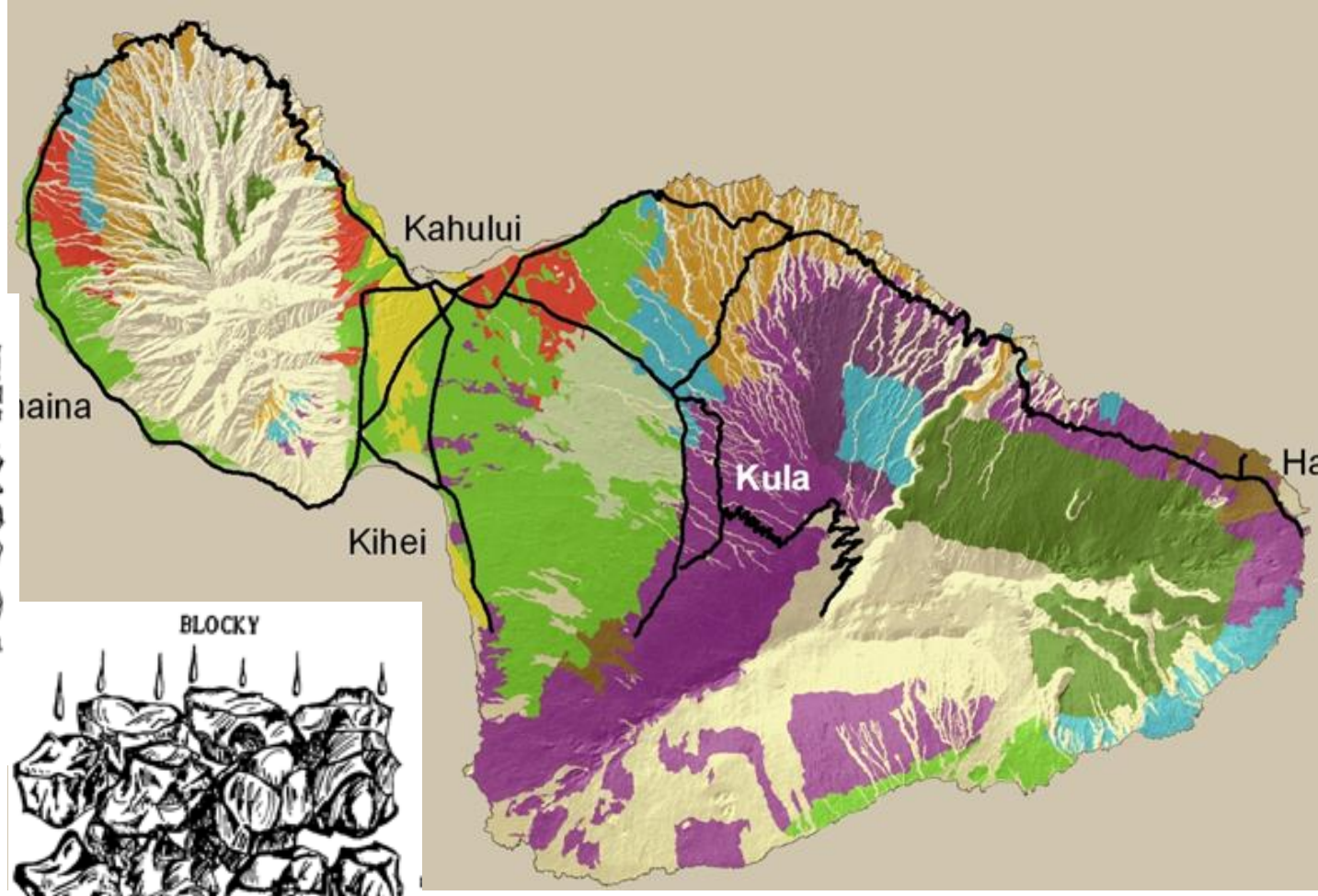




- Non-expanding
- Variable charge
- Low surface area
- Very low CEC
- Non-sticky

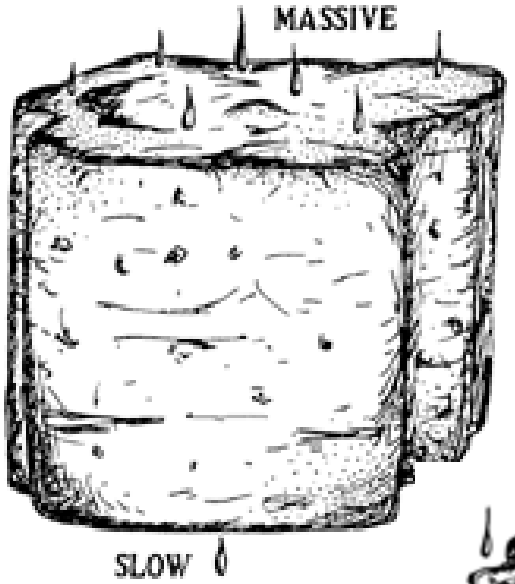
Soil Structure

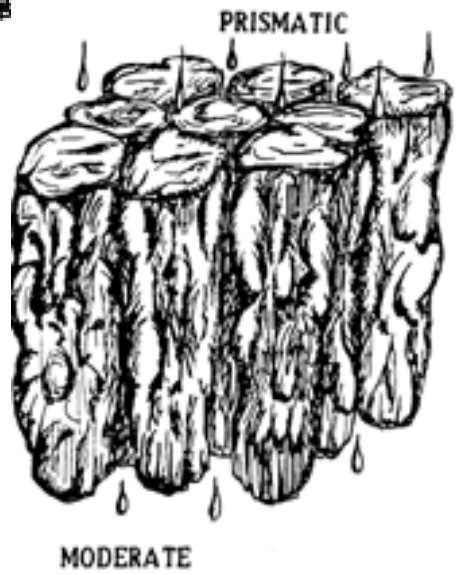


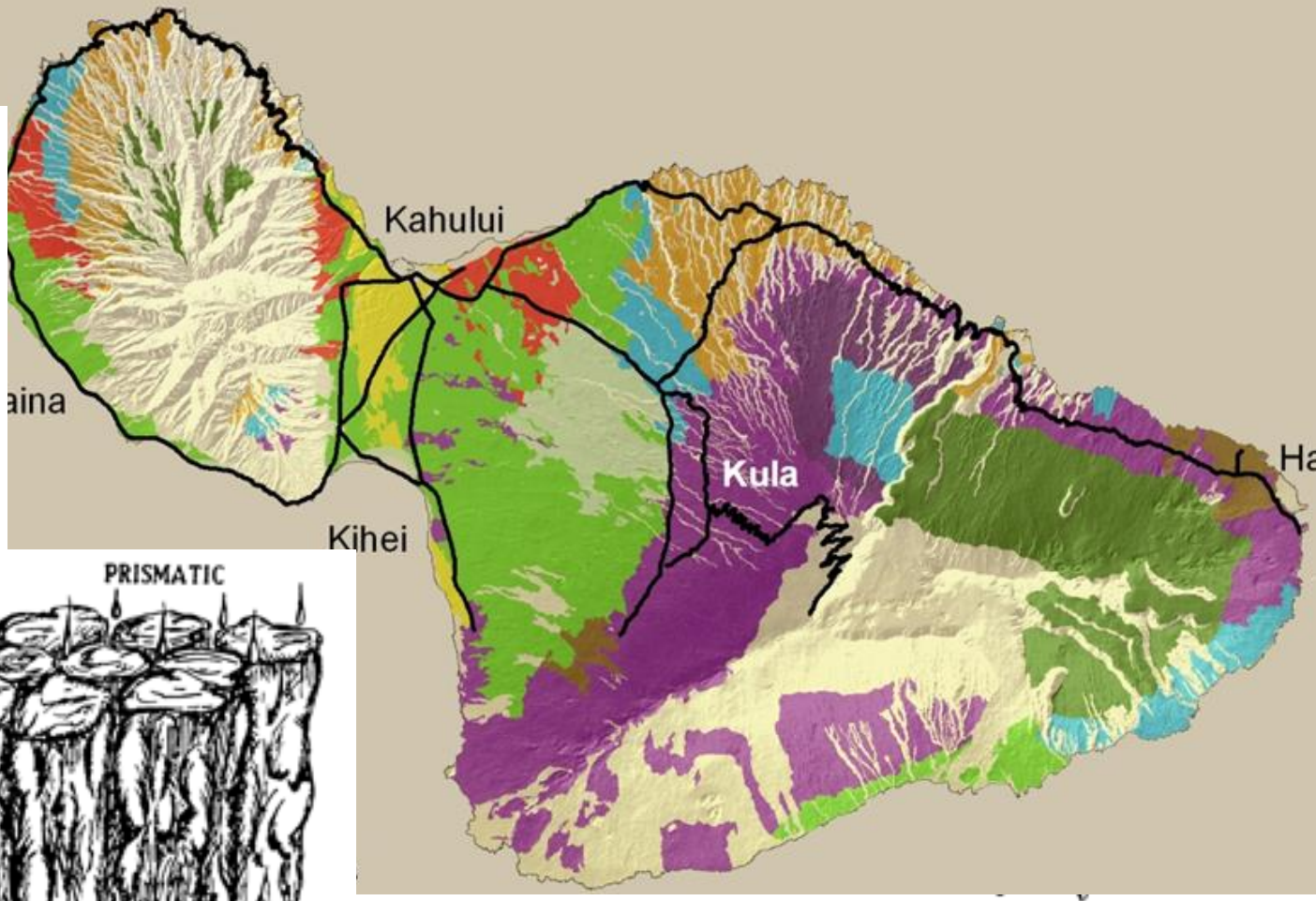


Well-drained soils that resist compaction

- Andisols
- Ultisols
- Oxisols
- Entisols





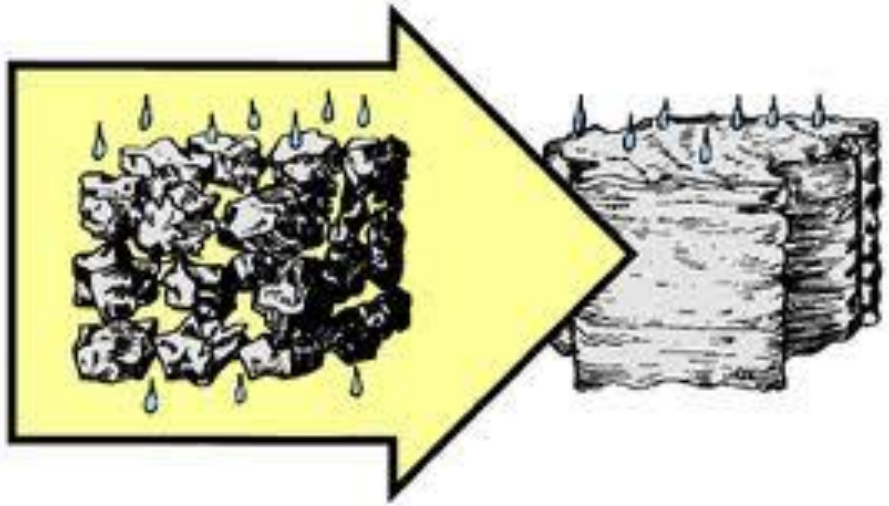


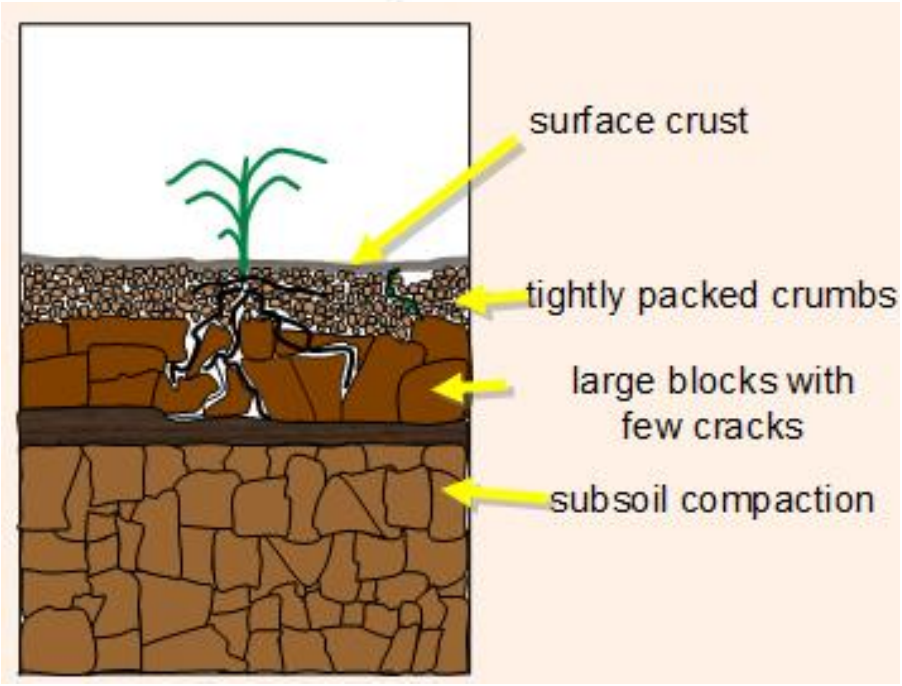
Poorly-drained soils that compact easily

Mollisols

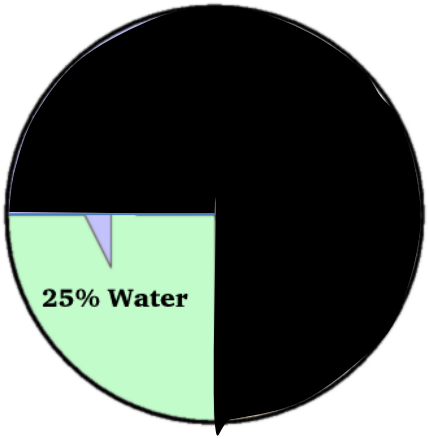
Adverse Effects of Soil Compaction

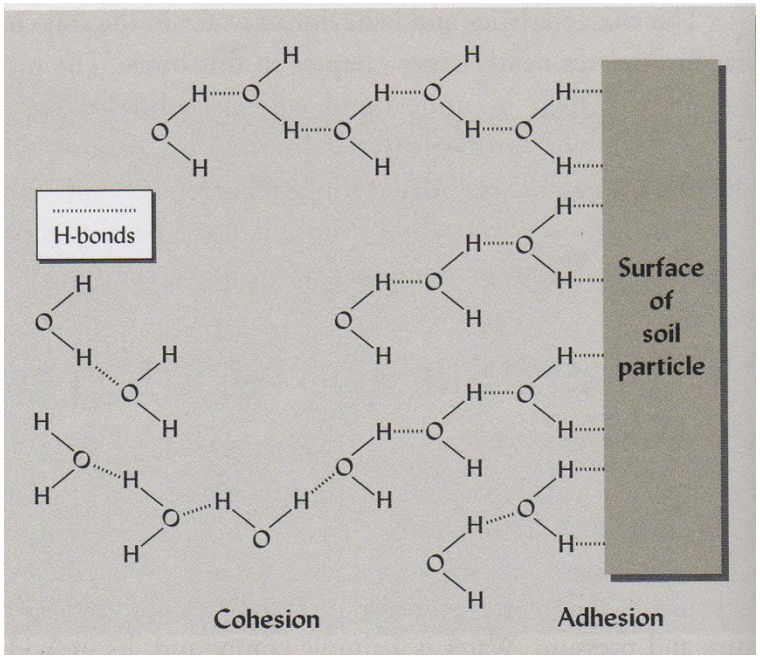
- Reduced pore sapce
- Increased bulk density
- Root growth inhibition
- Lower water holding capacity
- Reduced water infiltration and percolation
- Reduced aeration and anaerobic conditions
- Increased erosion

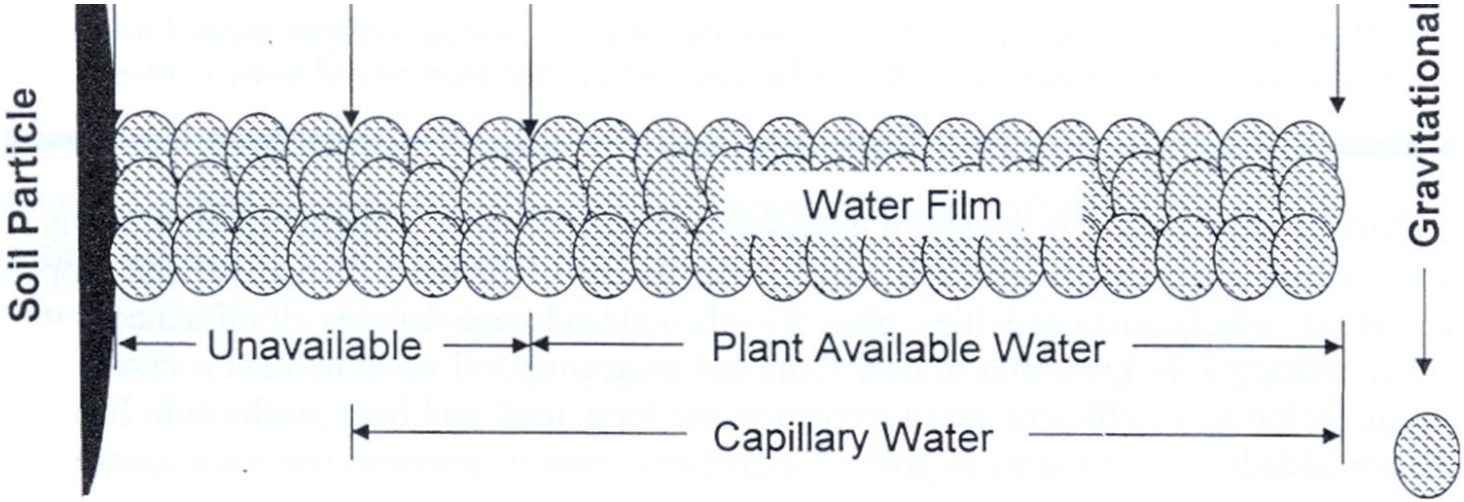




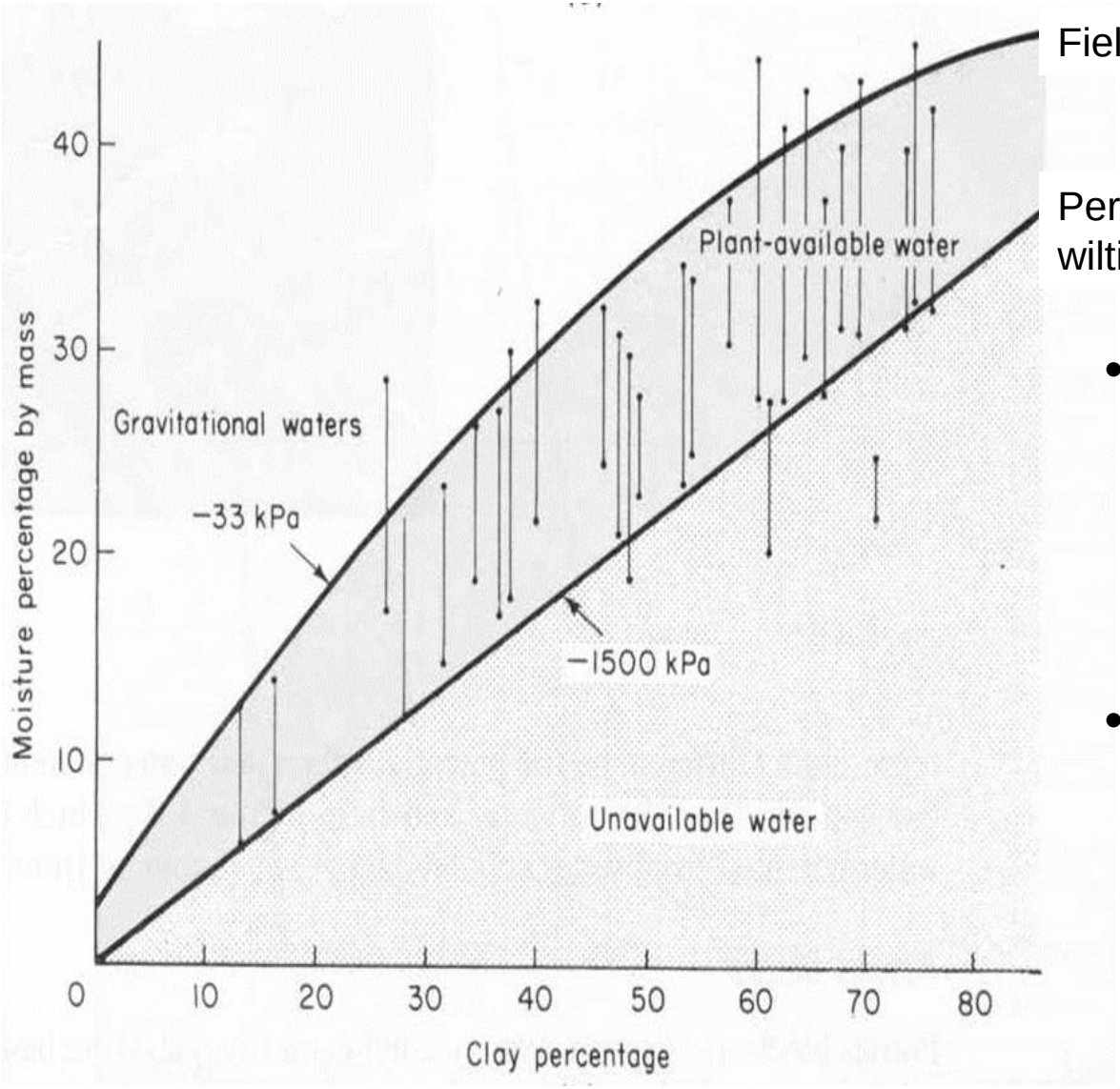
Soil Water


25% Water


H-bonds
Surface of soil particle
Cohesion
Adhesion


Soil Particle
Water Film
Gravitational
Unavailable
Plant Available Water
Capillary Water

Soil Texture and Water Retention



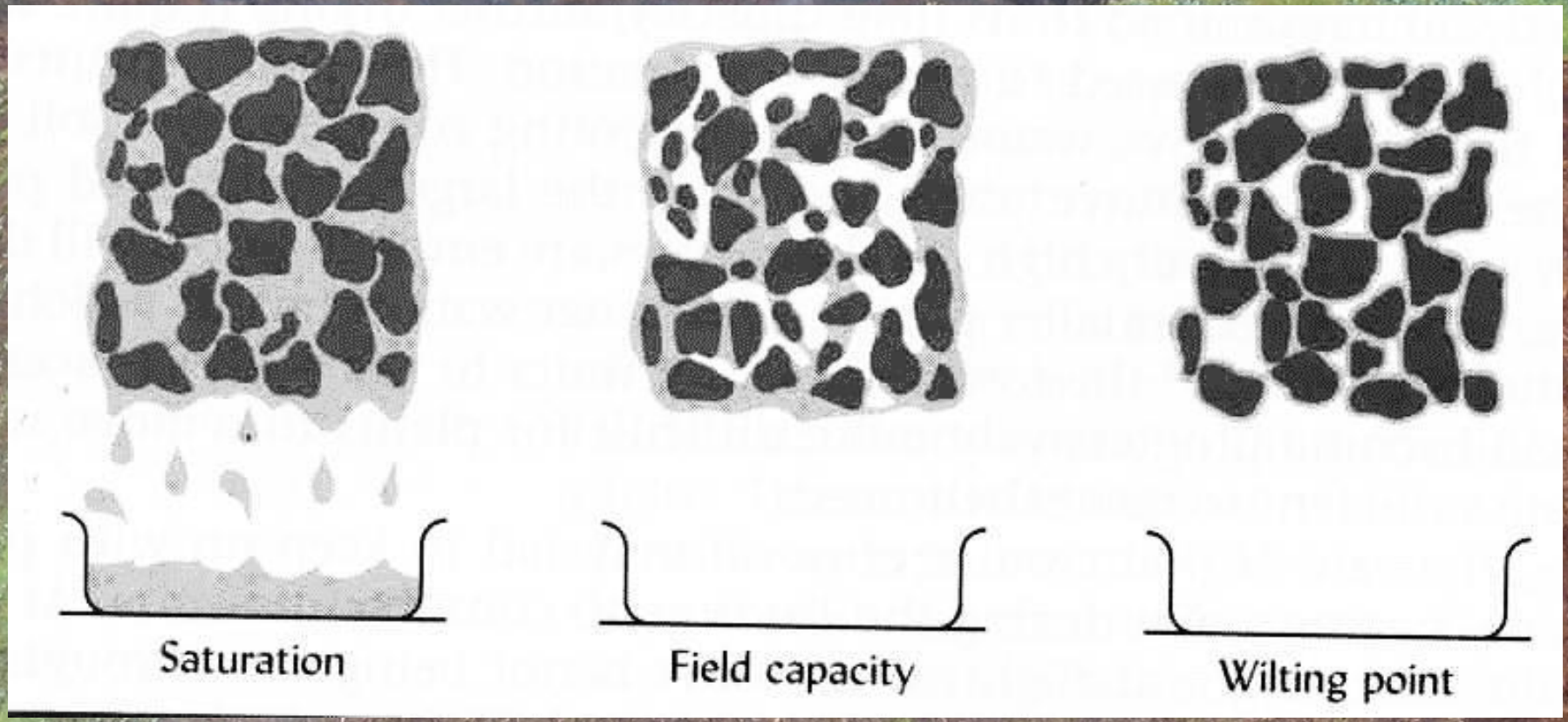
Field capacity

Permanent wilting point

- Plant available water is water loosely held on particles surfaces accessible to plants
- Unavailable water is water held close to particle surfaces or in micropores

Soil Water Availability

Soil water holding capacity depends on texture



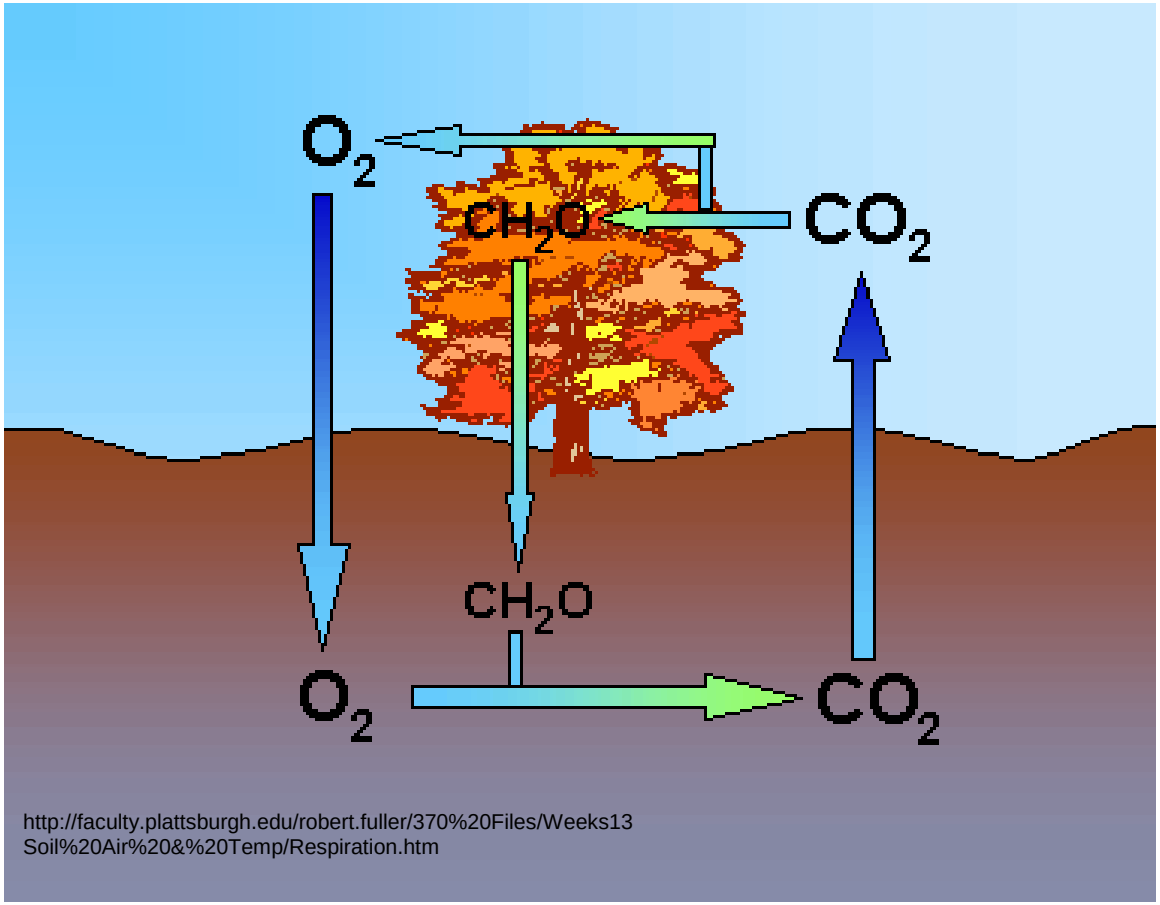
Soil Air

Soil Air

$$CH_2O + O_2 = CO_2 + H_2O$$

Respiration

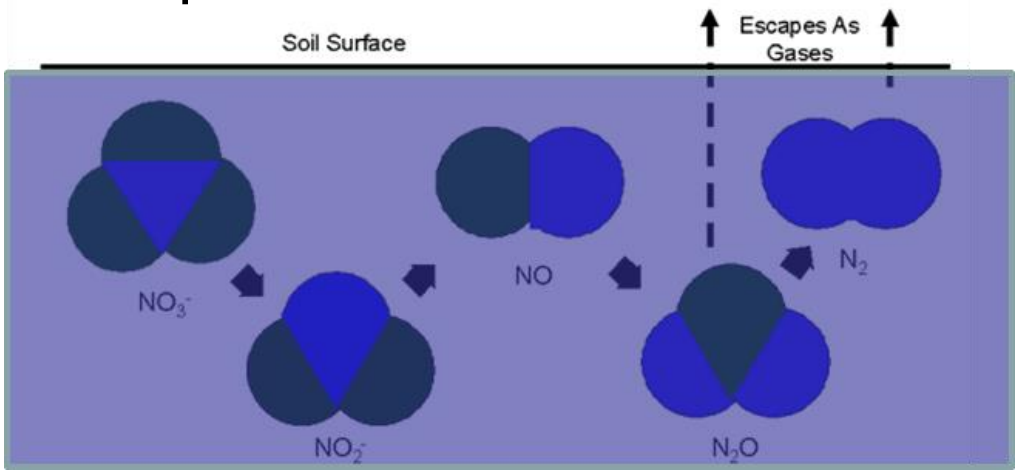
soil microorganisms > plant roots > soil animals



http://faculty.plattsburgh.edu/robert.fuller/370%20Files/Weeks13 Soil%20Air%20&%20Temp/Respiration.htm

Importance of Soil Air

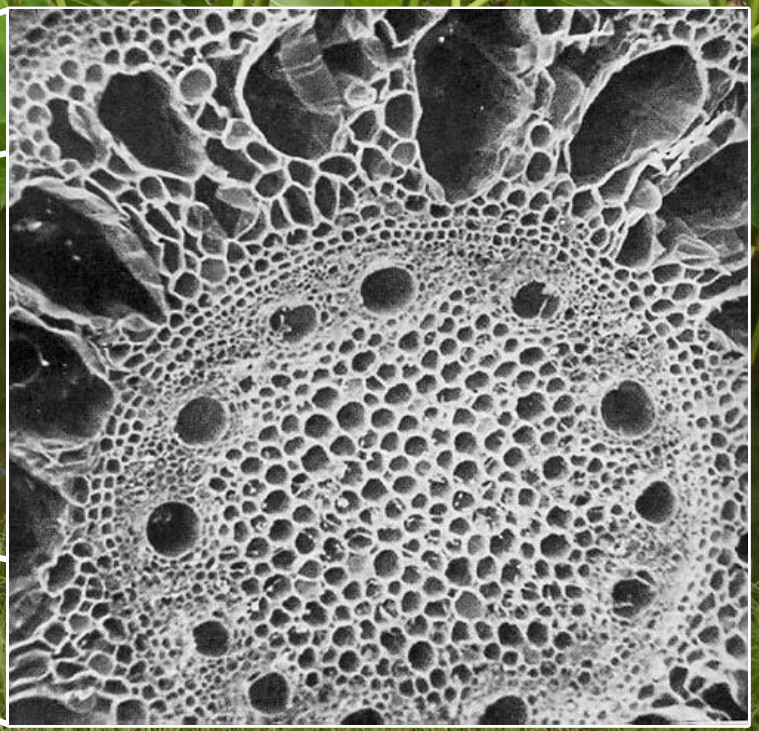
- In compacted and/or waterlogged soil, O_2 is present in very low concentrations creating reducing conditions
  - Gaseous loss of plant available N
  - Increase in toxic levels of Manganese in some soils
  - Fermentation and production of toxic by-products of anaerobic respiration



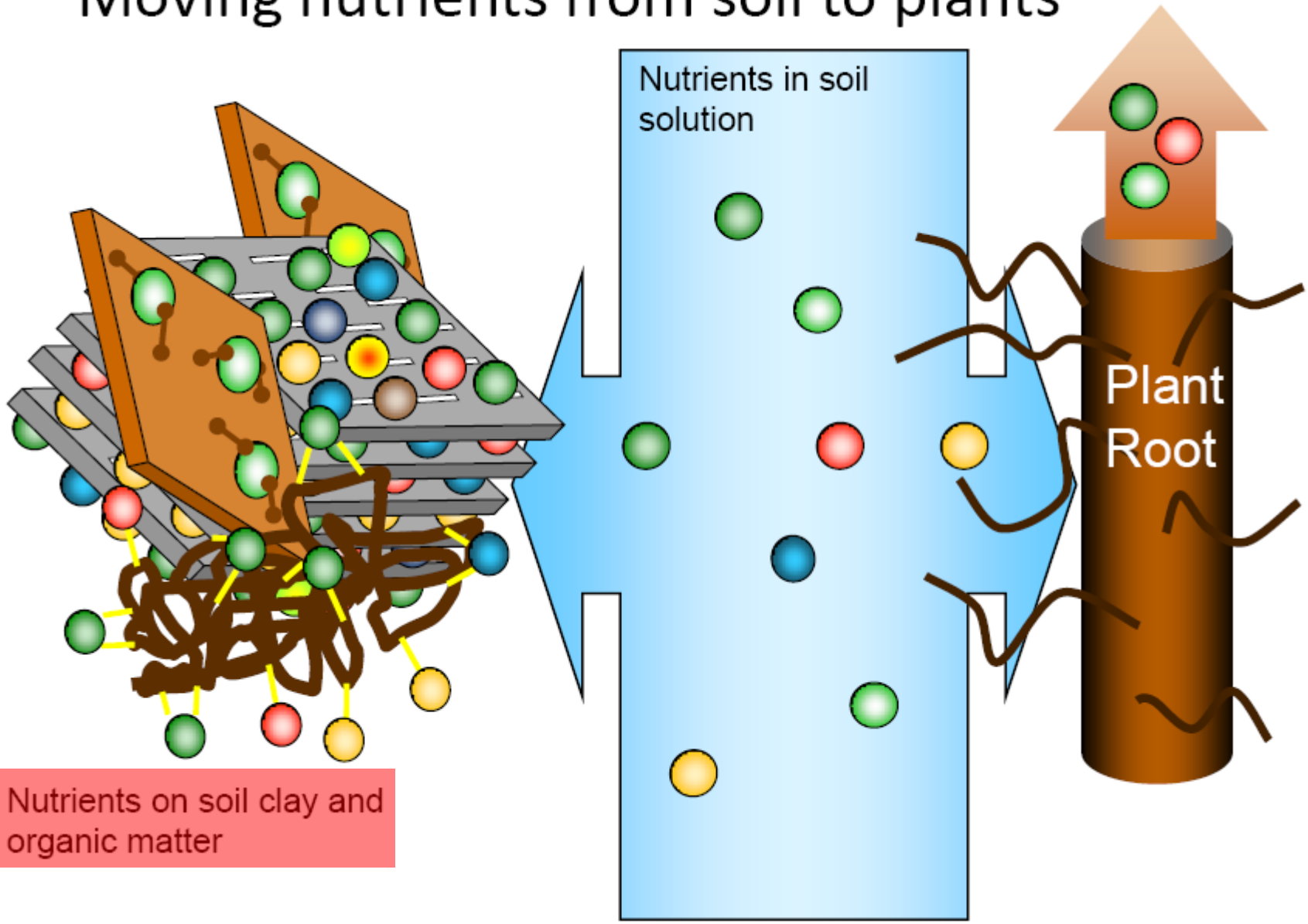
Loss of plant available N in saturated soils

Soil Air

Arenchyma transport O_2 from atmosphere down to root zone



Moving nutrients from soil to plants

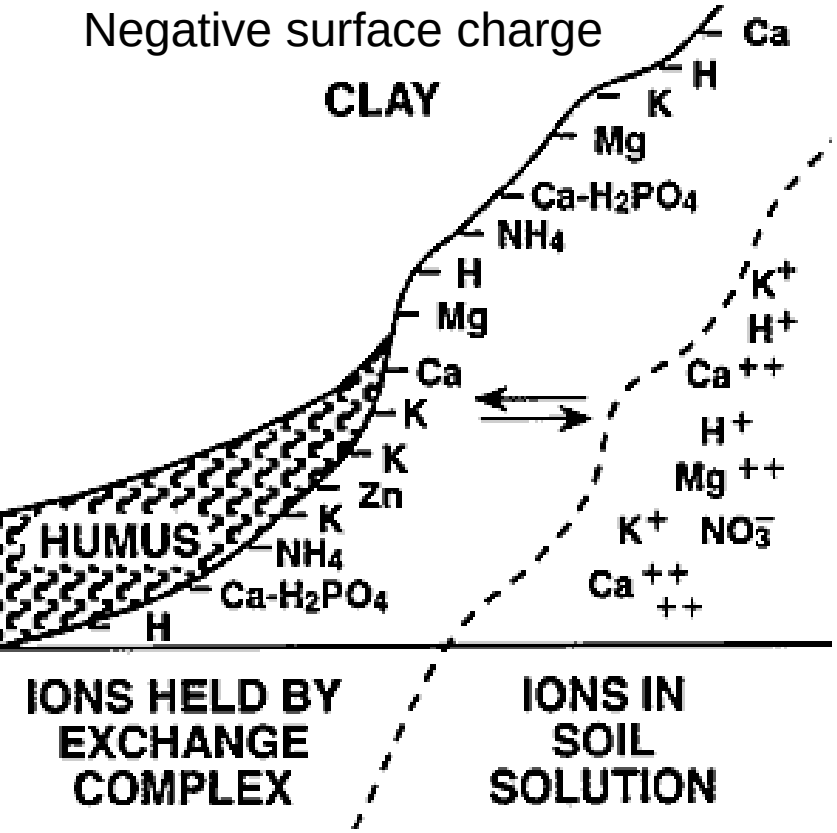


Soil Chemical Properties

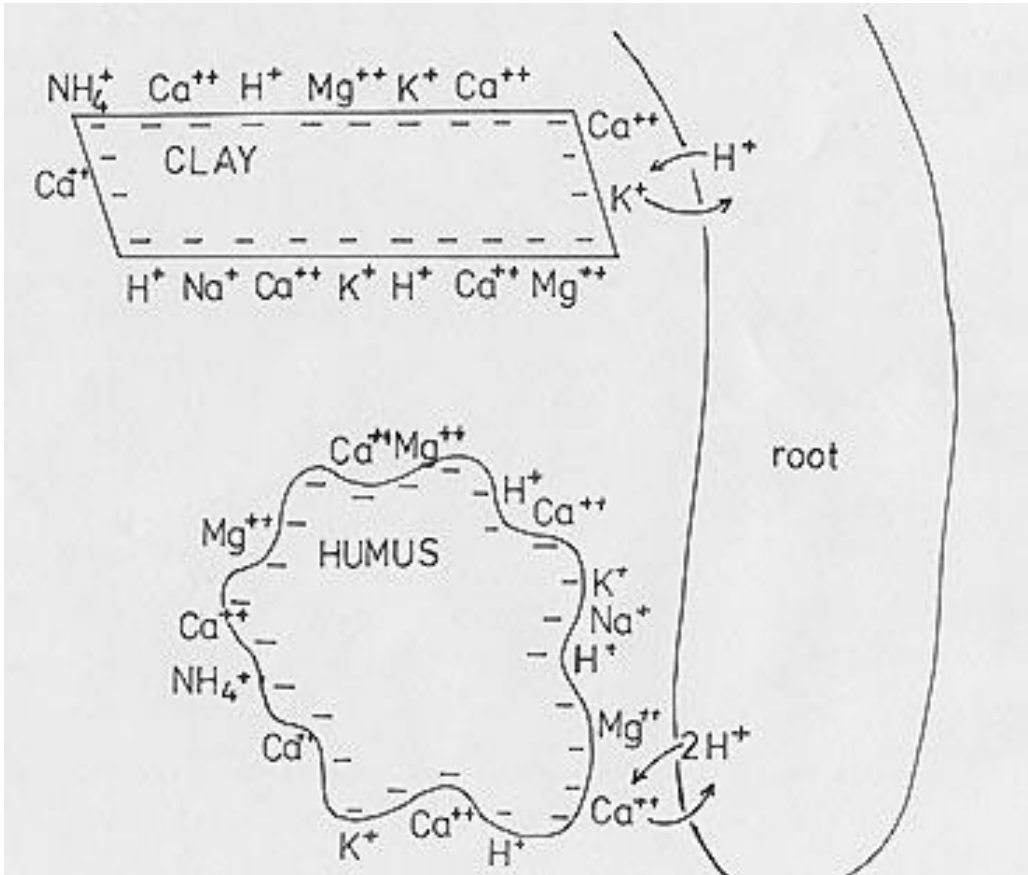
Cation Exchange Capacity

CEC is defined as the degree to which a soil can adsorb and exchange cations

(NH_4^+, K^+, Ca^{++}, Mg^{++}, Fe^{++}….)



http://www.extension.umn.edu/distribution/cropsystems/images/6437f01.gif

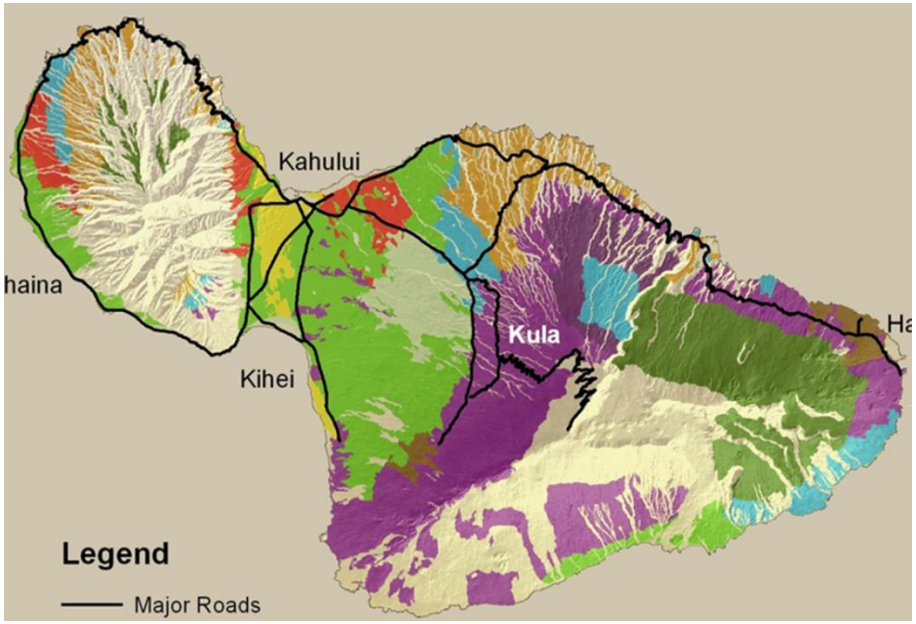


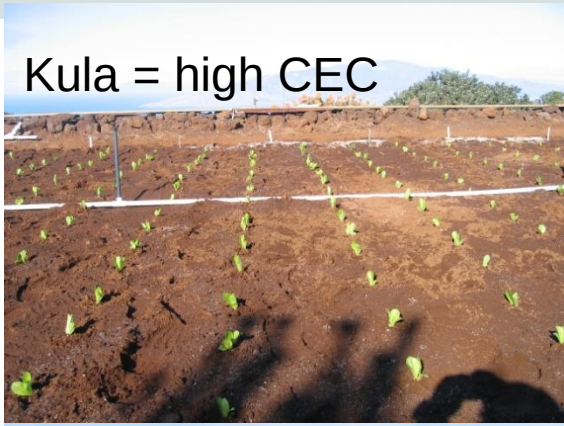
http://www.vabf.org/InfoImages/soil1.jpg

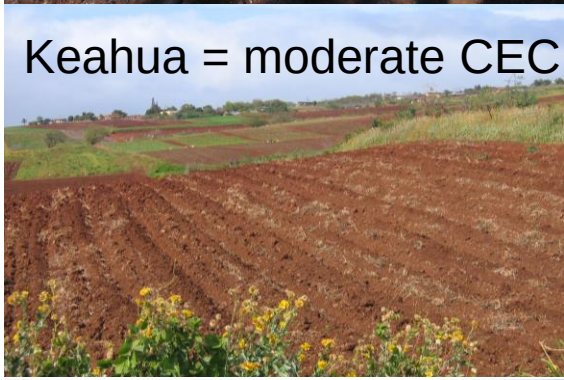
Cation Exchange Capacity

Cation Exchange Capacity

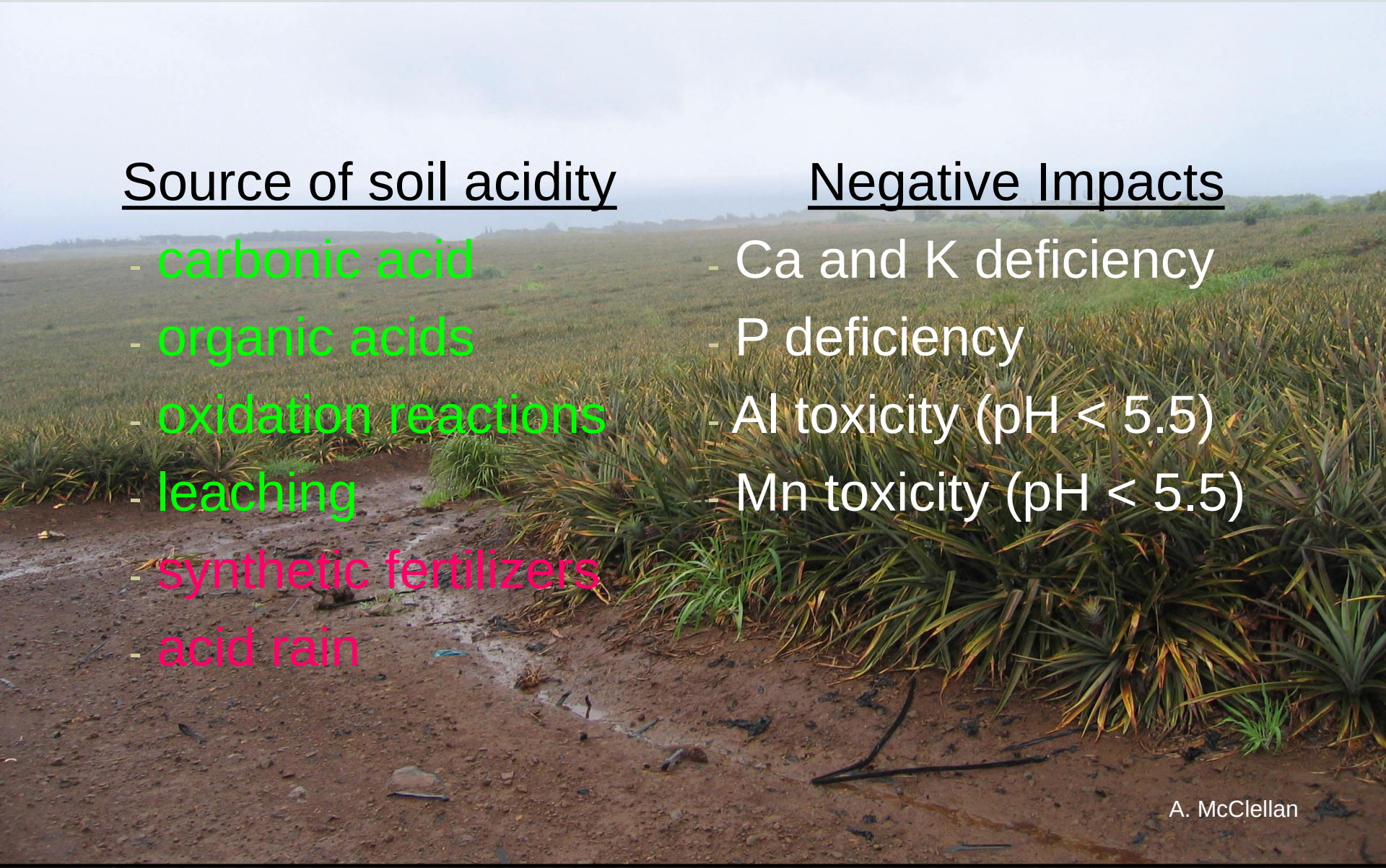
1. Clay surfaces
   - Smectite: 80 – 100 $cmol_c kg^{-1}$
   - Kaolinite: 3 – 15 $cmol_c kg^{-1}$
   - Al/Fe oxides: 0 $cmol_c kg^{-1}$
2. Organic matter
   - Humus: 200 $cmol_c kg^{-1}$







Soil Acidity



Source of soil acidity

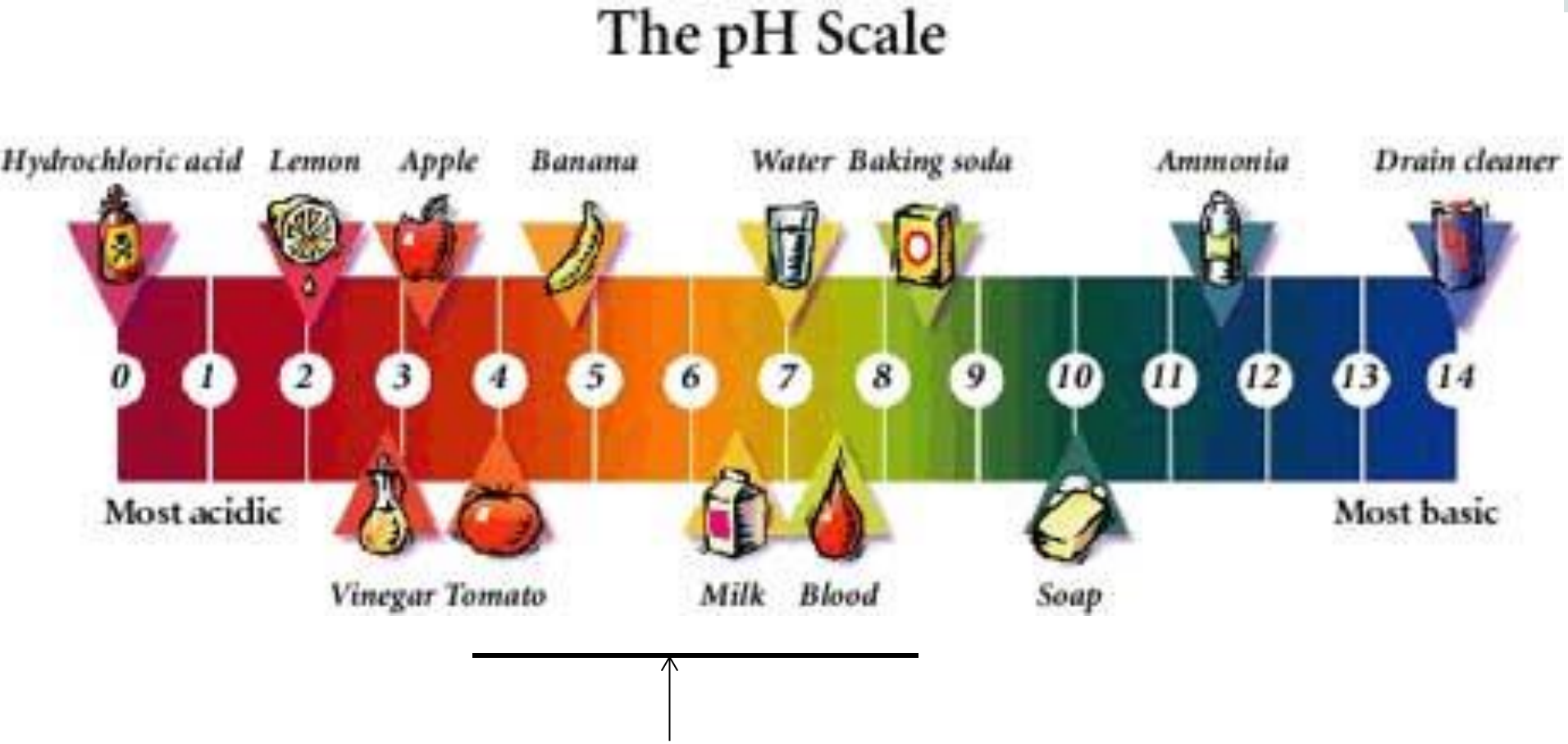
- carbonic acid
- organic acids
- oxidation reactions
- leaching
- synthetic fertilizers
- acid rain

Negative Impacts

- Ca and K deficiency
- P deficiency
- Al toxicity (pH < 5.5)
- Mn toxicity (pH < 5.5)

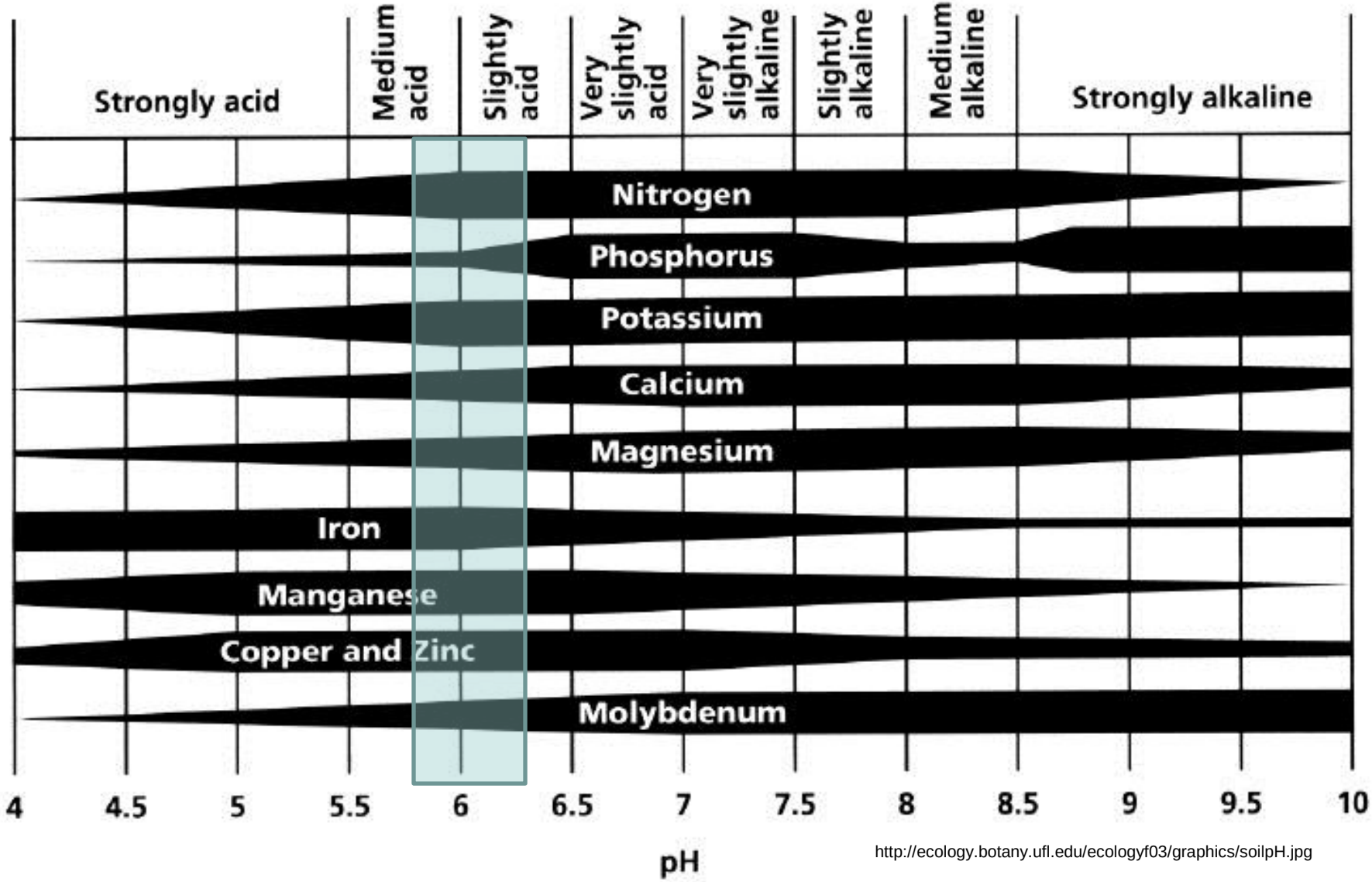
A. McClellan

Soil pH is an Expression of Acidity/Alkalinity



Typical pH range in soils

Soil Acidity

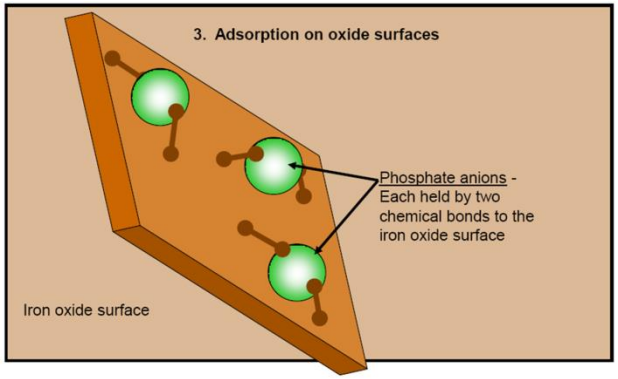


http://ecology.botany.ufl.edu/ecologyf03/graphics/soilpH.jpg

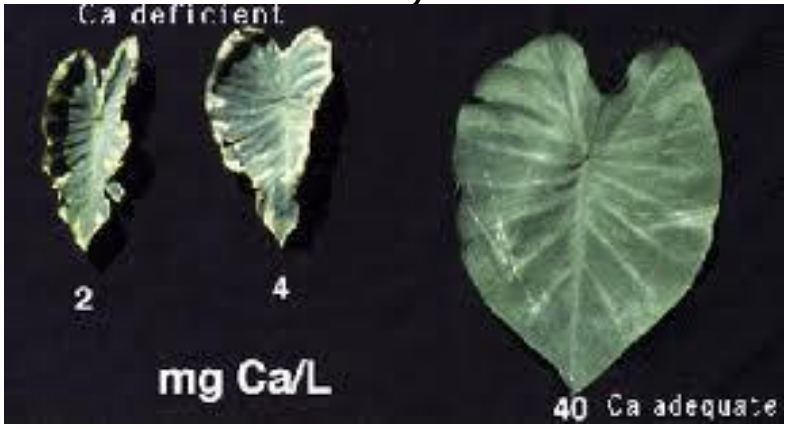
Negative Effects of Soil Acidity

- Low nutrient retention (CEC)
- Nutrient deficiencies
  - P deficiency

P Fixation



  - Ca deficiency



Soil Acidity Problems in Maui County

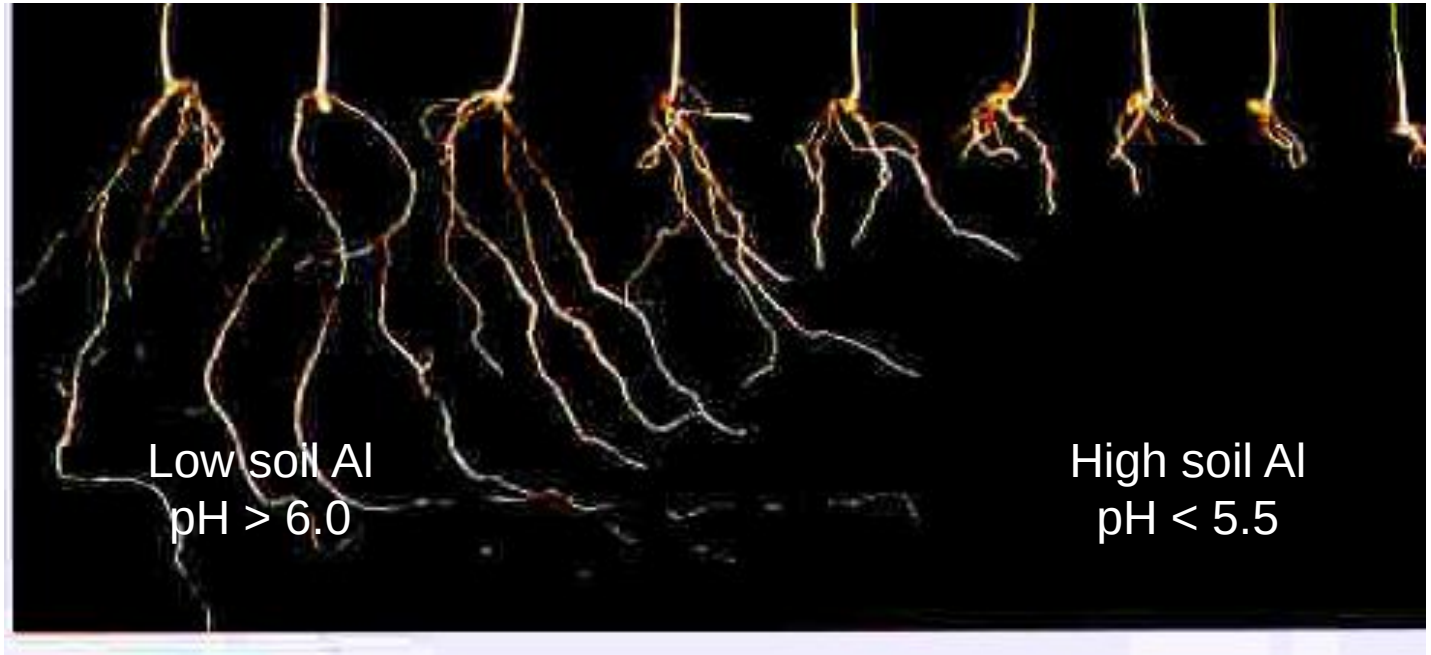
The primary problems related to soil acidity in Hawaii are aluminum and manganese toxicities.

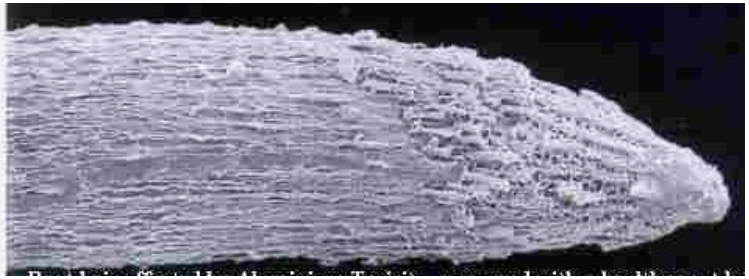
Aluminum toxicity can occur in soils that have large amounts of aluminum containing minerals. In such soils, aluminum can dissolve into the soil solution as the soil pH drops below 5.4.

Manganese toxicity can become a problem in soils with manganese-containing minerals. When these minerals dissolve, manganese ions are released into the soil solution. Although manganese is an essential plant nutrient, excessive quantities of manganese may be detrimental to plant growth.

Both can be ameliorated by addition of lime to raise the pH

High Soil Aluminum Causes Root Damage



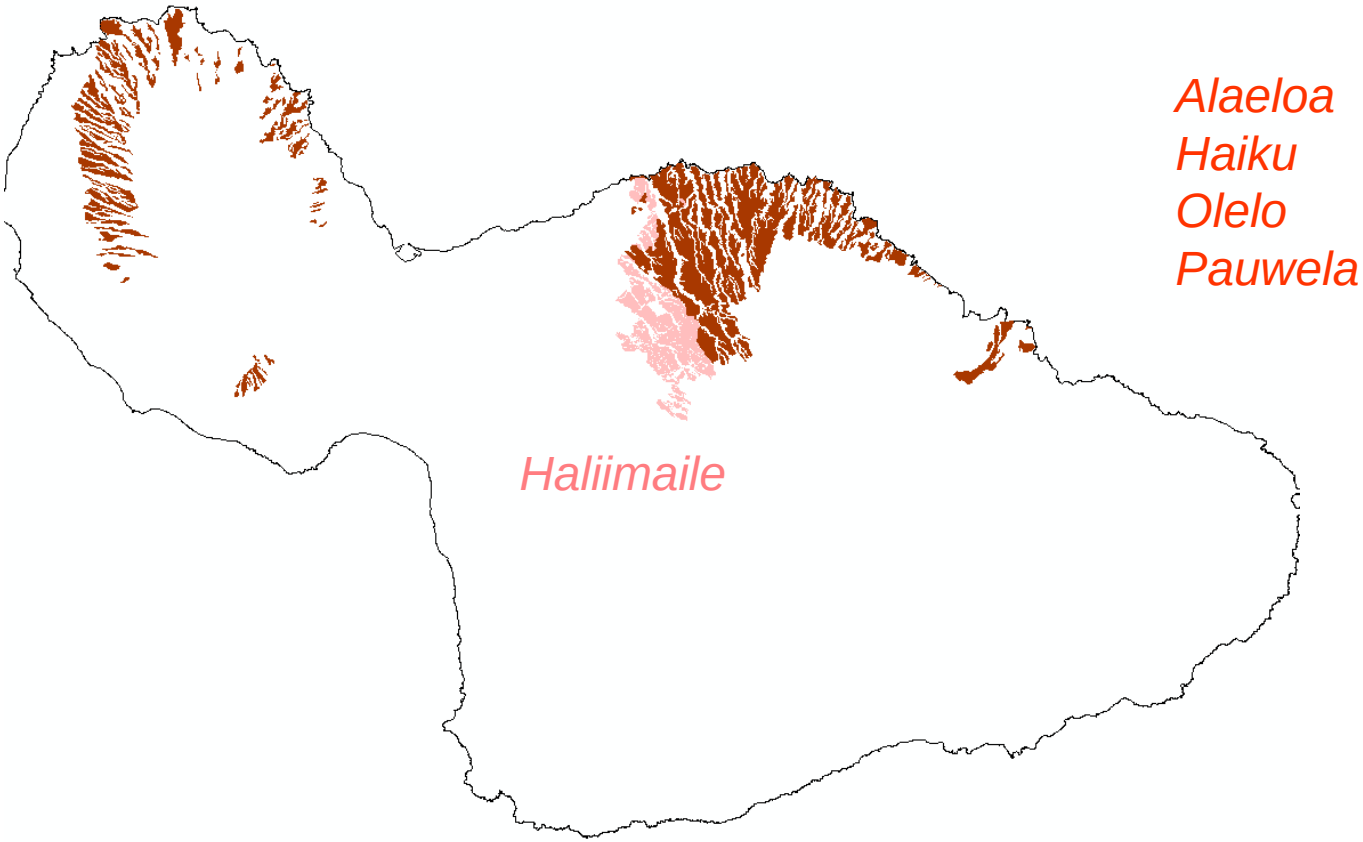


Healthy root hair in soil with low Al

Deformed root hair in soil with high Al

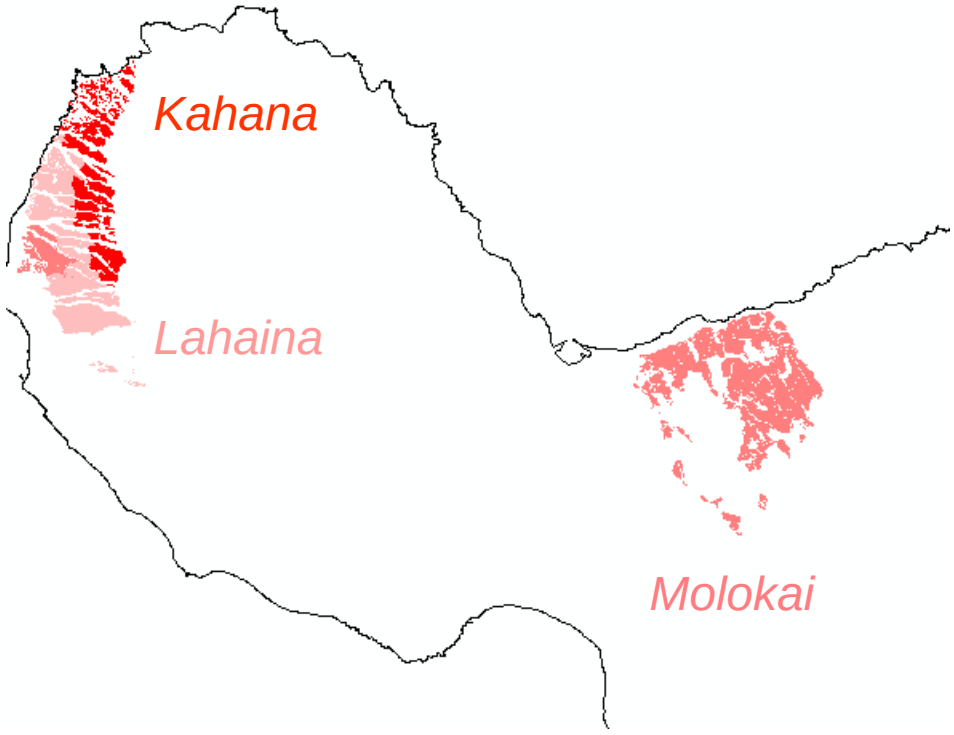
Soils with Potential Al Toxicity

- Ultisols/Inceptisols exisiting at low to moderate elevation (200-750 ft) with high rainfall (60-100 in/yr)

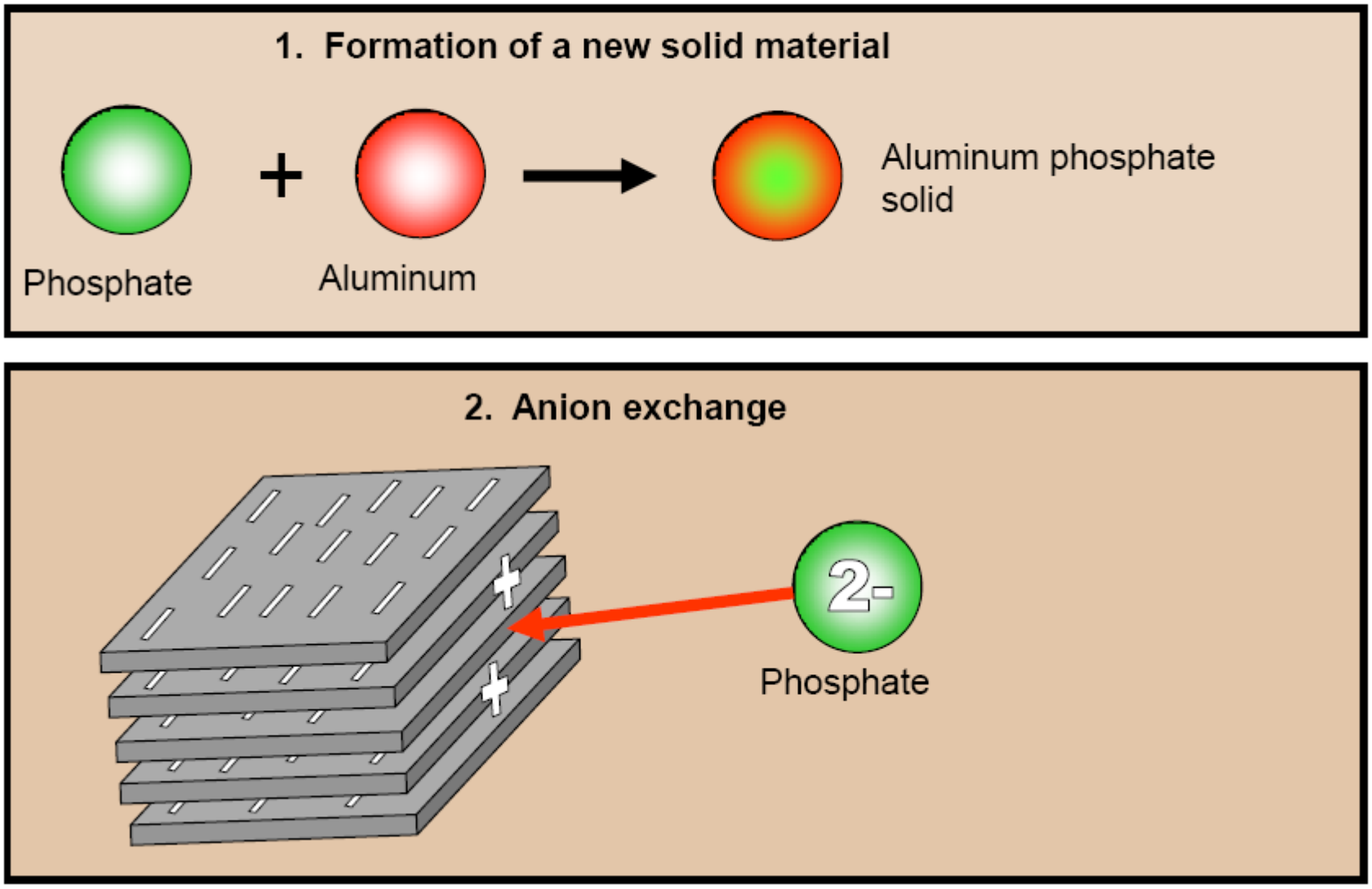


Soils with Potential Mn Toxicity

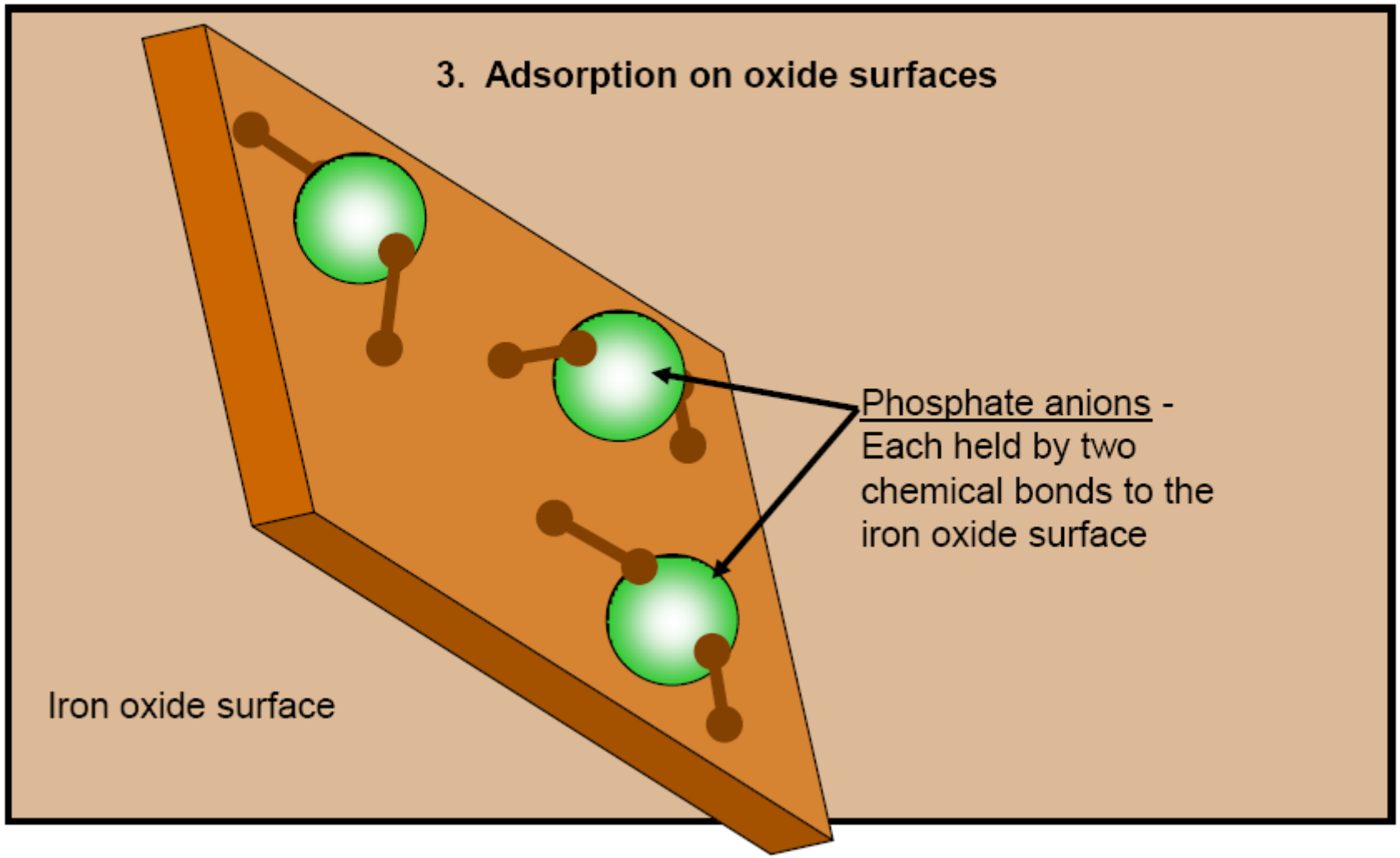
- Oxisols/Inceptisols exisiting at low to moderate elevation (200-750 ft) with moderate rainfall (20-60 in/yr)



Phosphate retention in soil

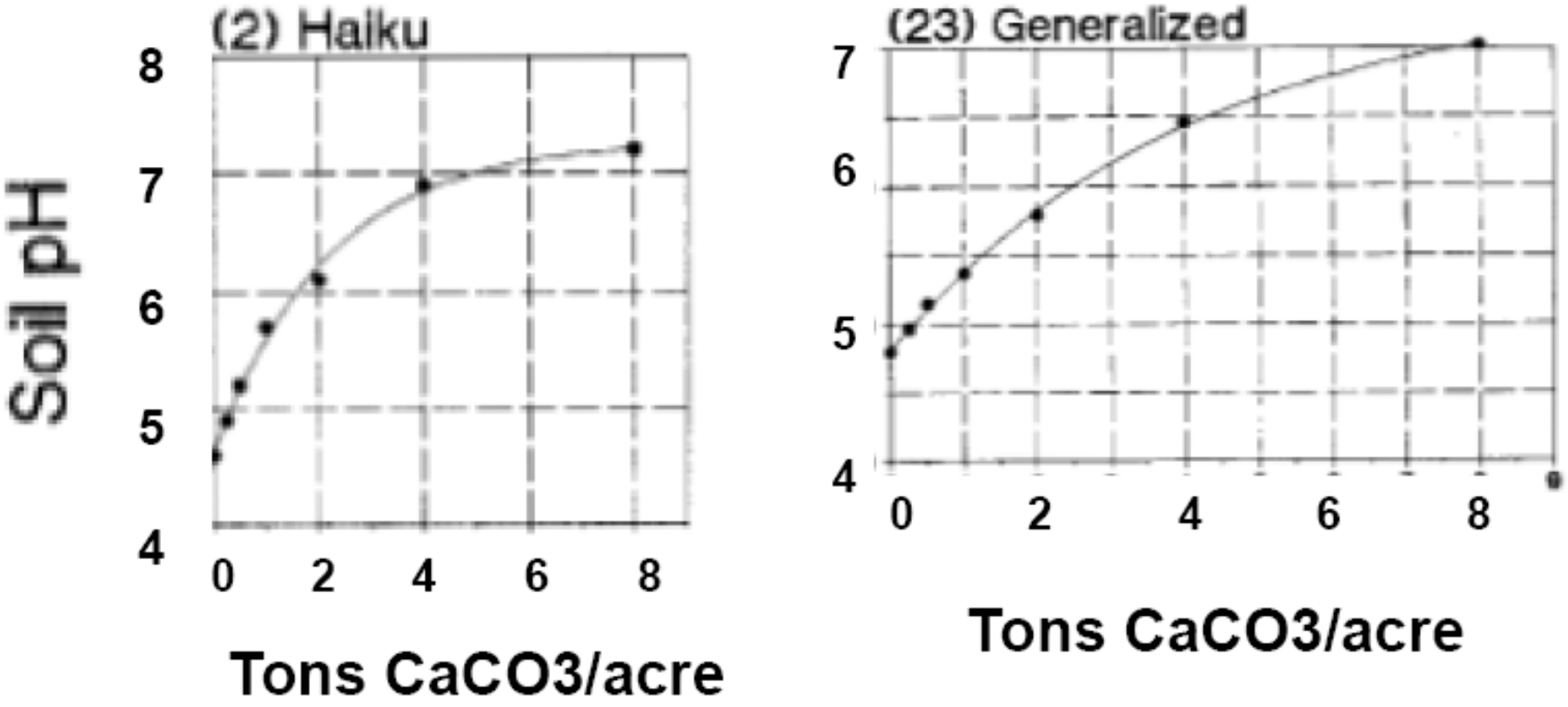


Phosphate retention in soil



Liming Materials

Liming material	Chemical name	Relative neutralizing value
Calcitic limestones	calcium carbonate ($CaCO_3$)	100
Quicklime	calcium oxide (CaO)	150–175
Hydrated lime	calcium hydroxide ($Ca(OH)_2$)	120–135
Dolomitic lime	calcium-magnesium carbonate	95–108
Slag	calcium silicate ($CaSiO_3$)	50–70

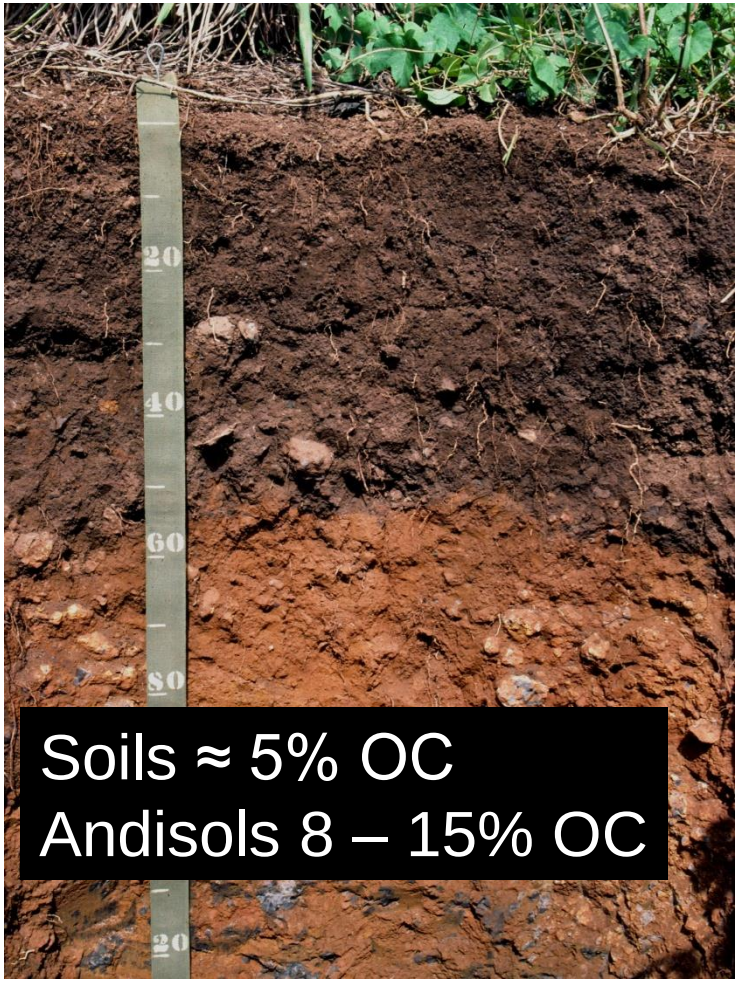


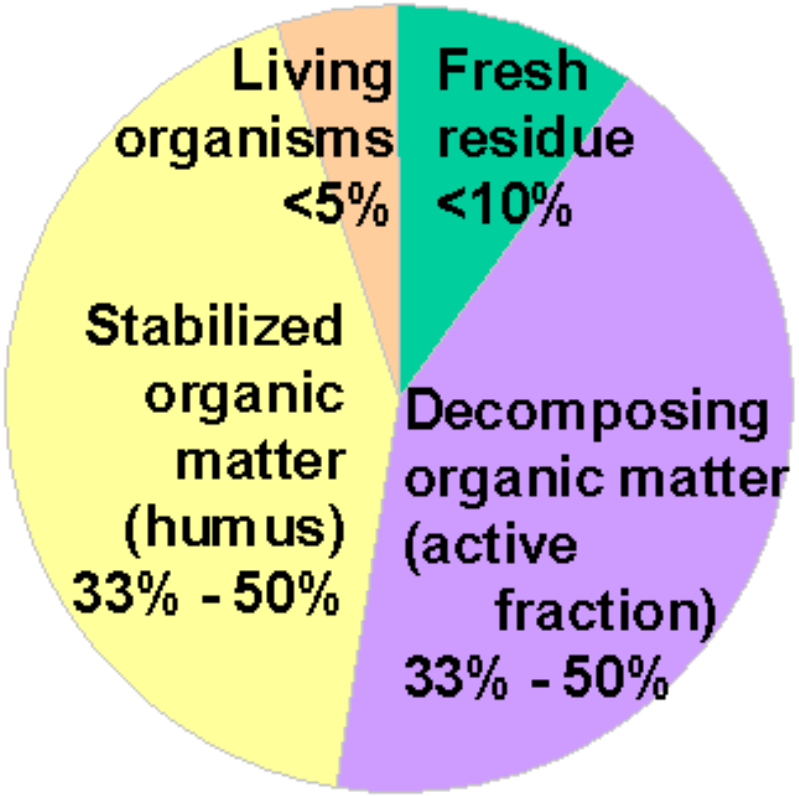
Liming curves for many soil series in Hawaii available online

http://www.ctahr.hawaii.edu/oc/freepubs/pdf/AS-1.pdf

Soil Biological Properties

Soil Organic Matter

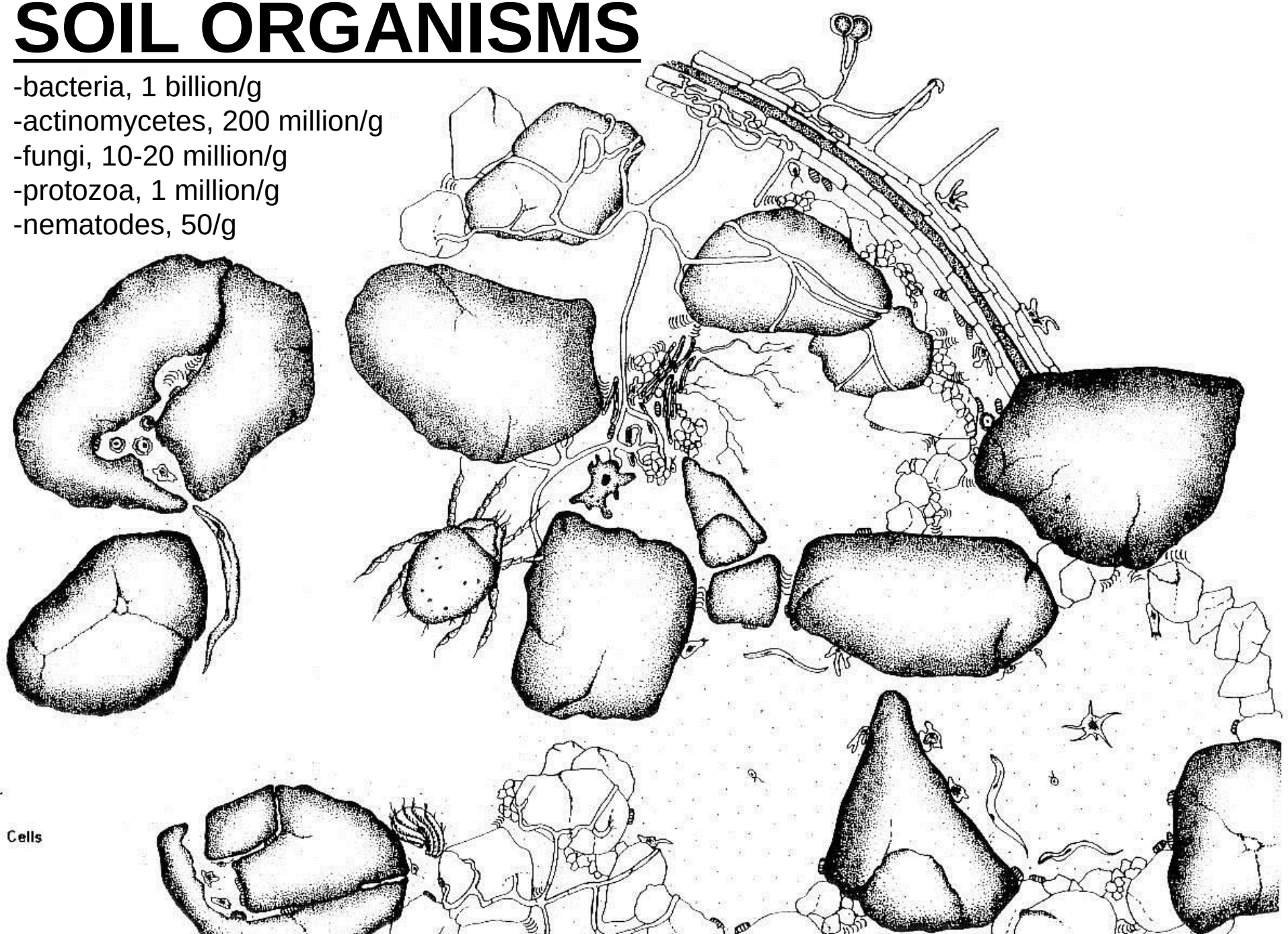




http://www.soilandhealth.org/01aglibrary/ingam/Soil%20Food%20Web%20%20NRCS%20SQ_files/soil_f1.gif

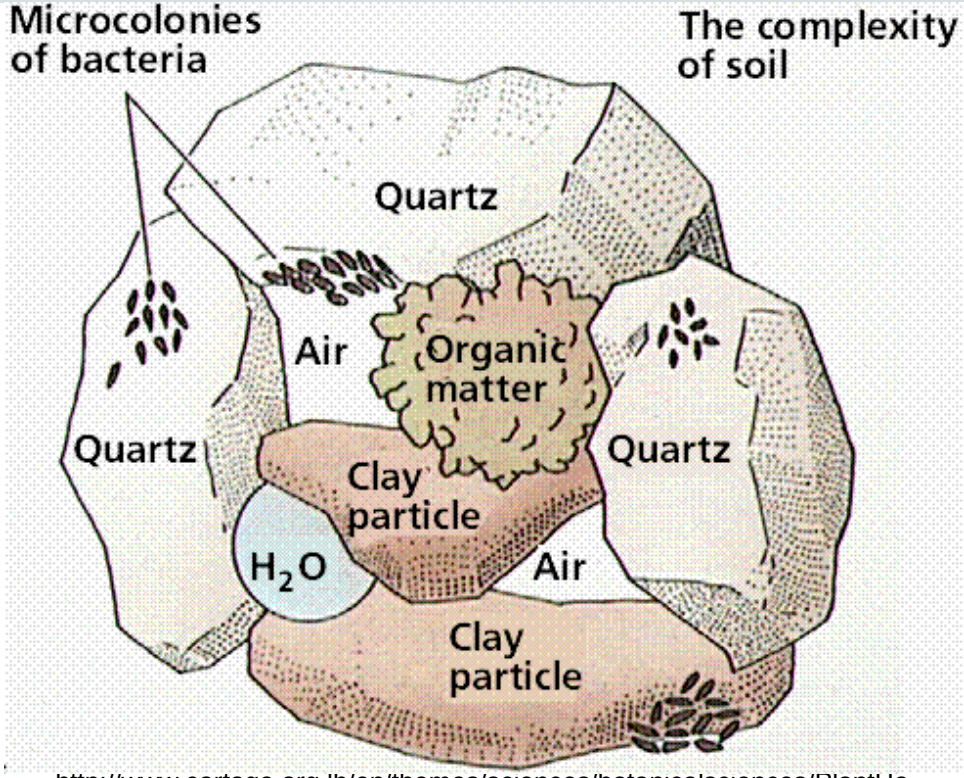
SOIL ORGANISMS

-bacteria, 1 billion/g
-actinomycetes, 200 million/g
-fungi, 10-20 million/g
-protozoa, 1 million/g
-nematodes, 50/g



Soil Organic Matter

- Physical
  - Improves aggregation
  - Improves water holding capacity (surface area)
- Chemical
  - Increases nutrient availability (N & P cycling, solubility)
  - Increases CEC
  - Buffers against pH changes
- Biological
  - Increases microbial diversity
  - N fixation (rhizobia), P availability (myccorhiza)
  - Increases pathogen suppression



http://www.cartage.org.lb/en/themes/sciences/botanicalsciences/PlantHormones/PlantHormones/soil.gif

Soil OM & Root Symbioses

Rhizobium

Mycorrhizae

Summary

- Soils are a critical natural resource to be protected
- Soils vary on the landscape
- Different soils have different physical, chemcial and biological properties
- Organic matter is foundational to soil health and productivity
- Keep soil pH between 6 and 7
- Use soil test to guide soil amendments
- Apply appropriate amendments at the right time

Mahalo!