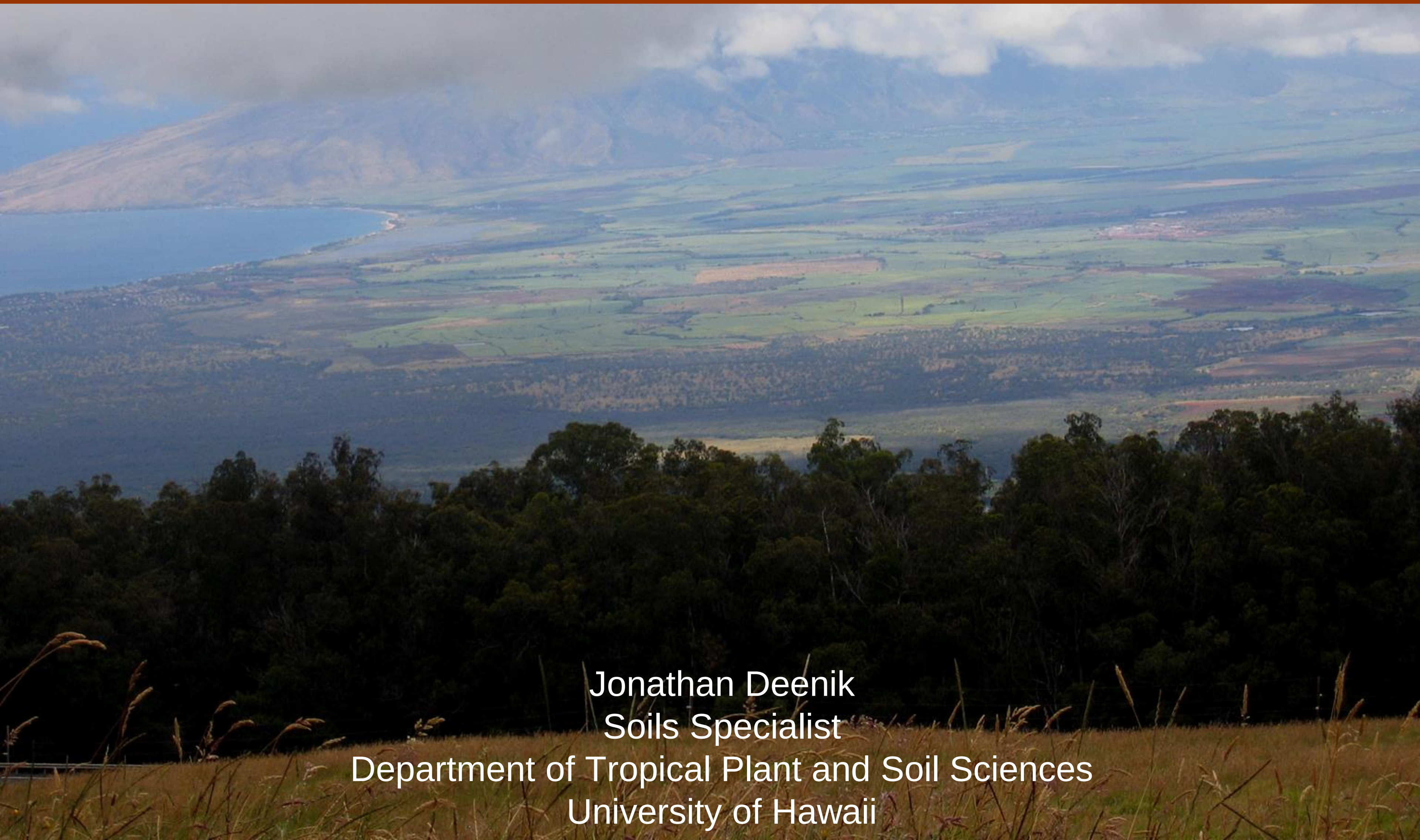
Understanding and Managing Soils for a Healthy Landscape



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University of Hawaii

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:

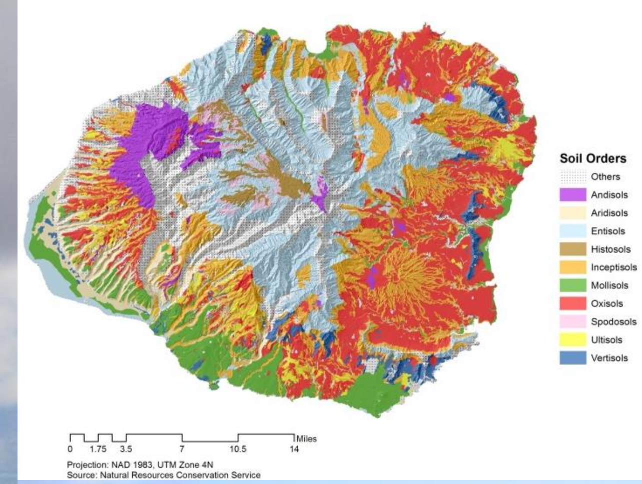
- Section 1 explores the basic principles that govern crop performance in tropical soils.
- Section 2 discusses the diversity of soils which make up the island of Maui.
- Section 3 focuses on the proper management techniques for maintaining or enhancing the nutrition of tropical soils.
- Section 4 introduces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

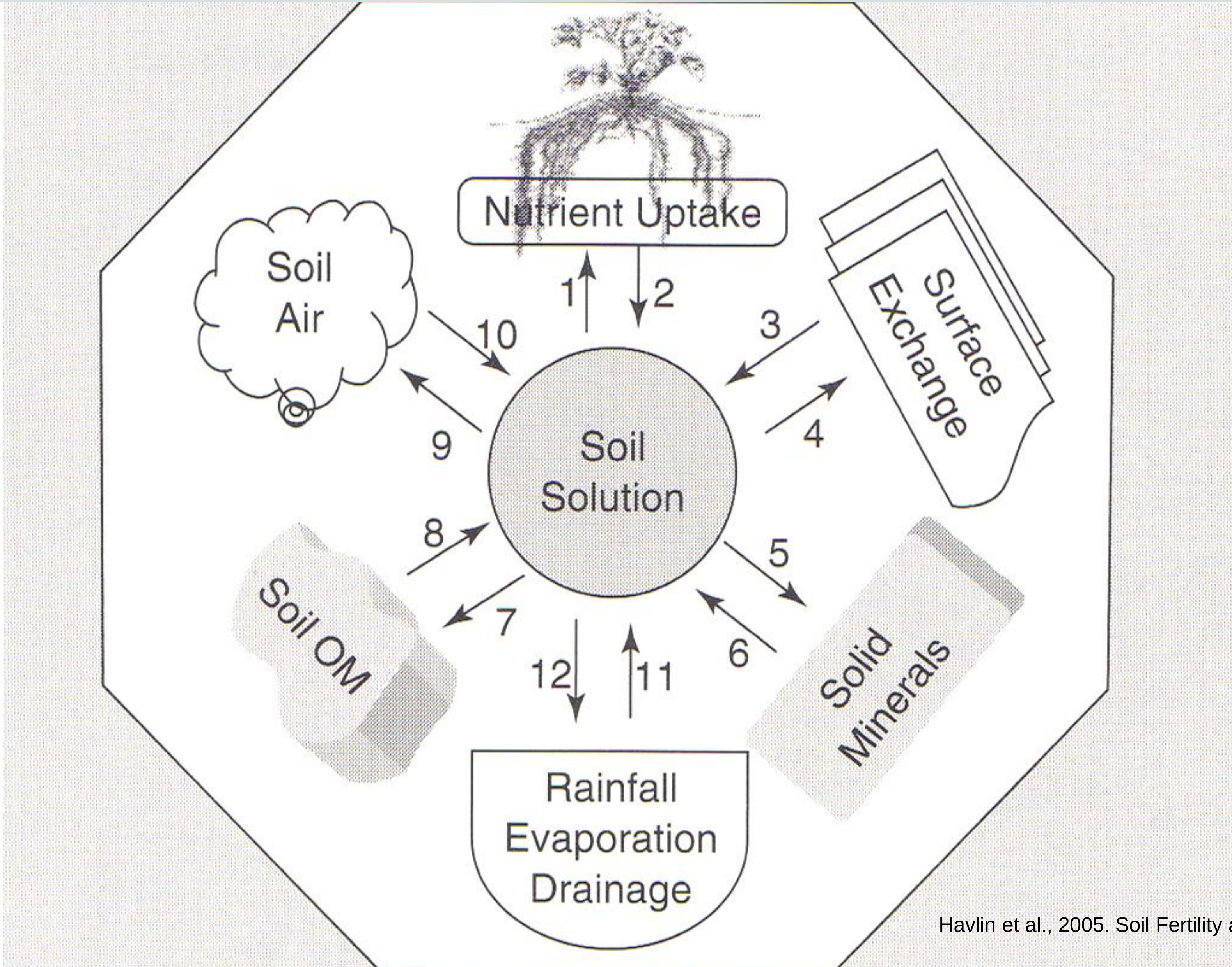
http://www.ctahr.hawaii.edu/mauisoil/

Outline

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



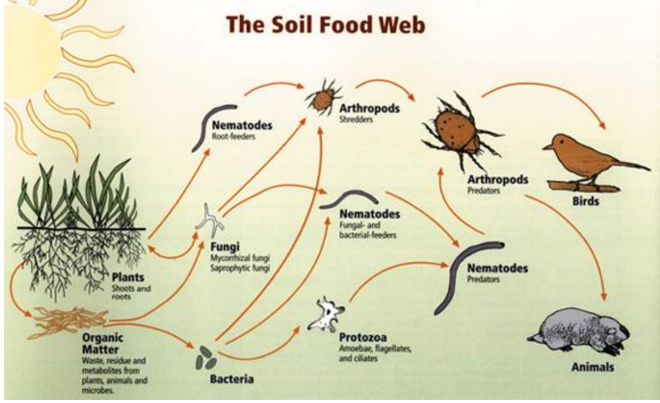
Soil Plant Relationships



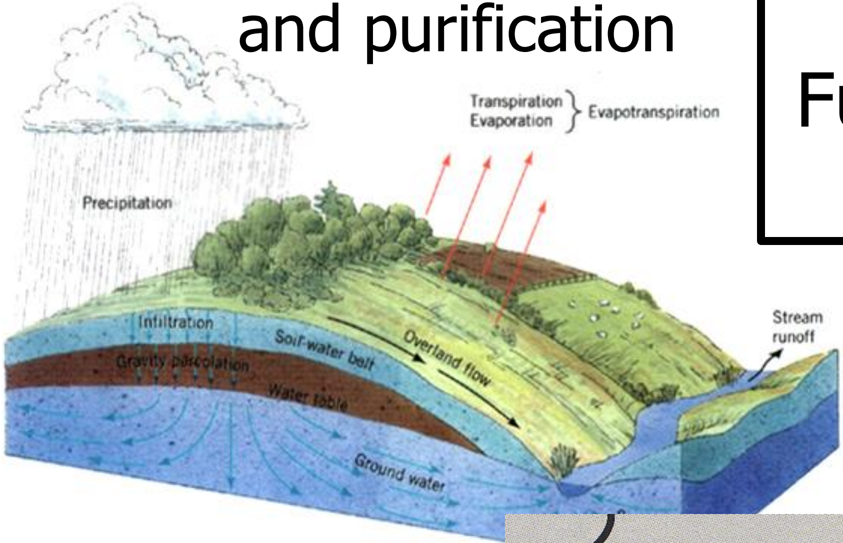
Havlin et al., 2005. Soil Fertility and Fertilizers

Medium for Plant growth

Habitat for Soil organisms



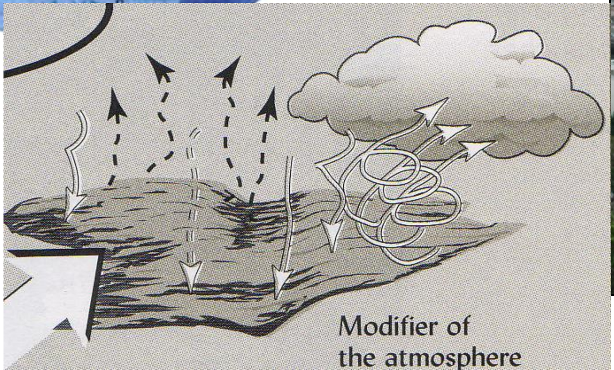
Water supply and purification

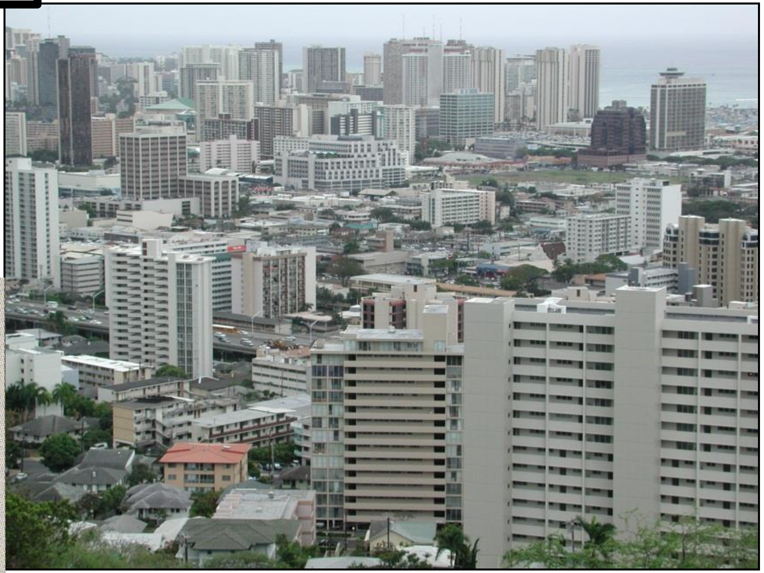


6 Functions of Soil

Recycling system

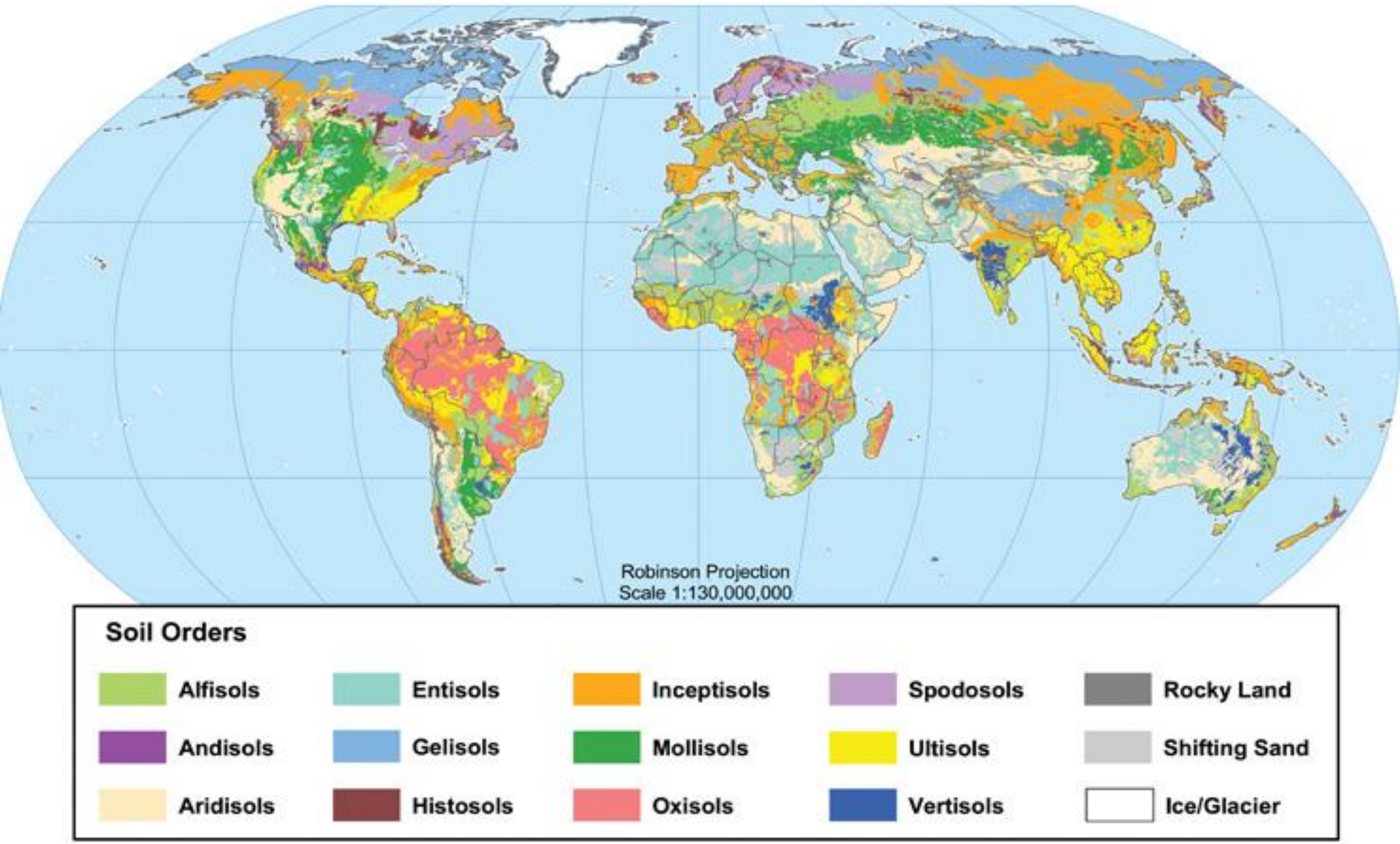
Modifier of the atmosphere





Engineering Medium

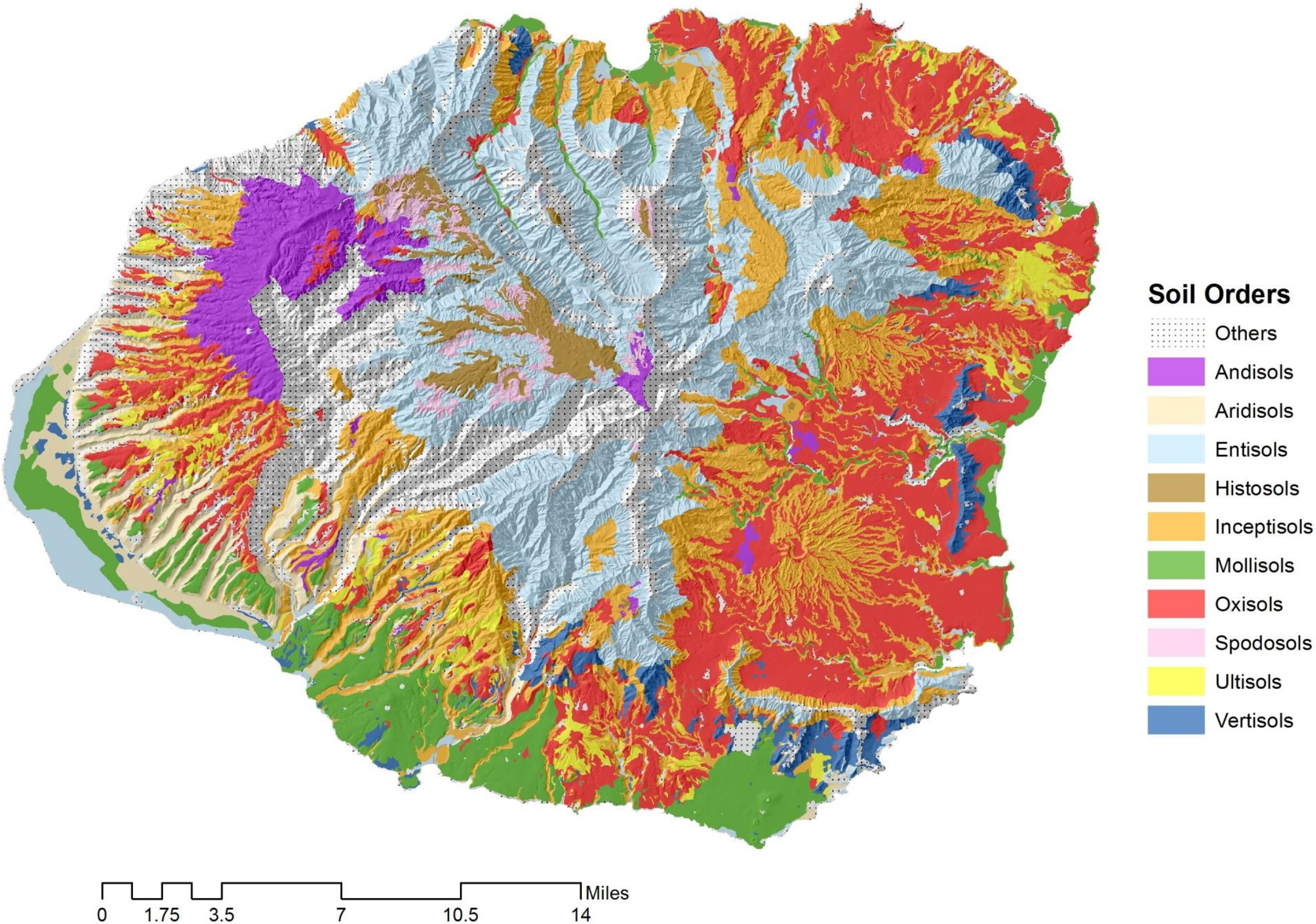
Global Soil Regions



USDA NRCS US Department of Agriculture
Natural Resources
Conservation Service

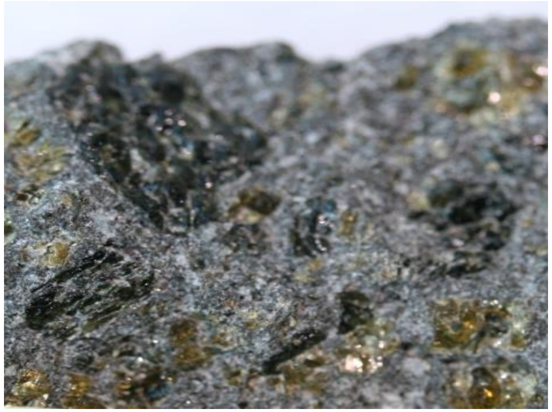
Soil Survey Division
World Soil Resources
soils.usda.gov/use/worldsoils

November 2005



Projection: NAD 1983, UTM Zone 4N
Source: Natural Resources Conservation Service

Soil Formation

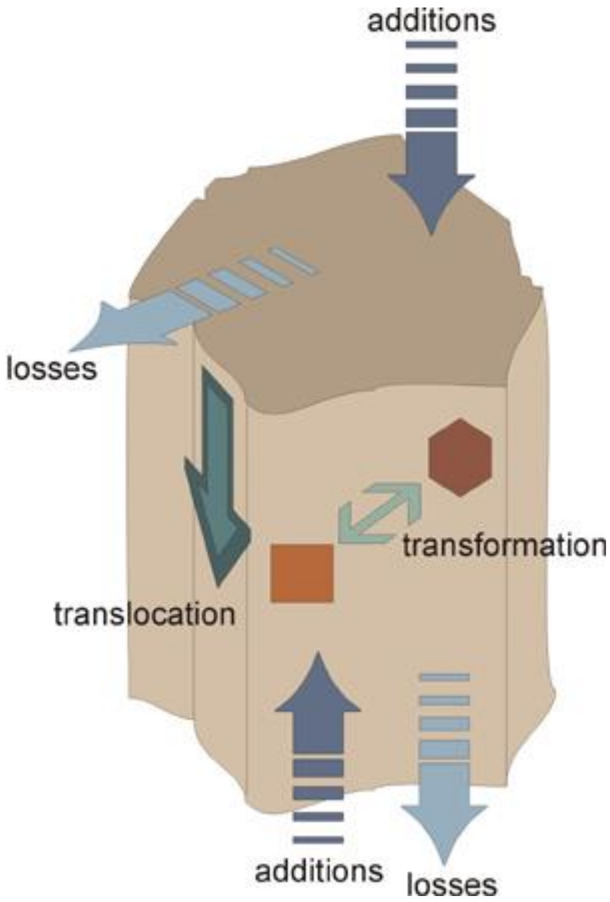


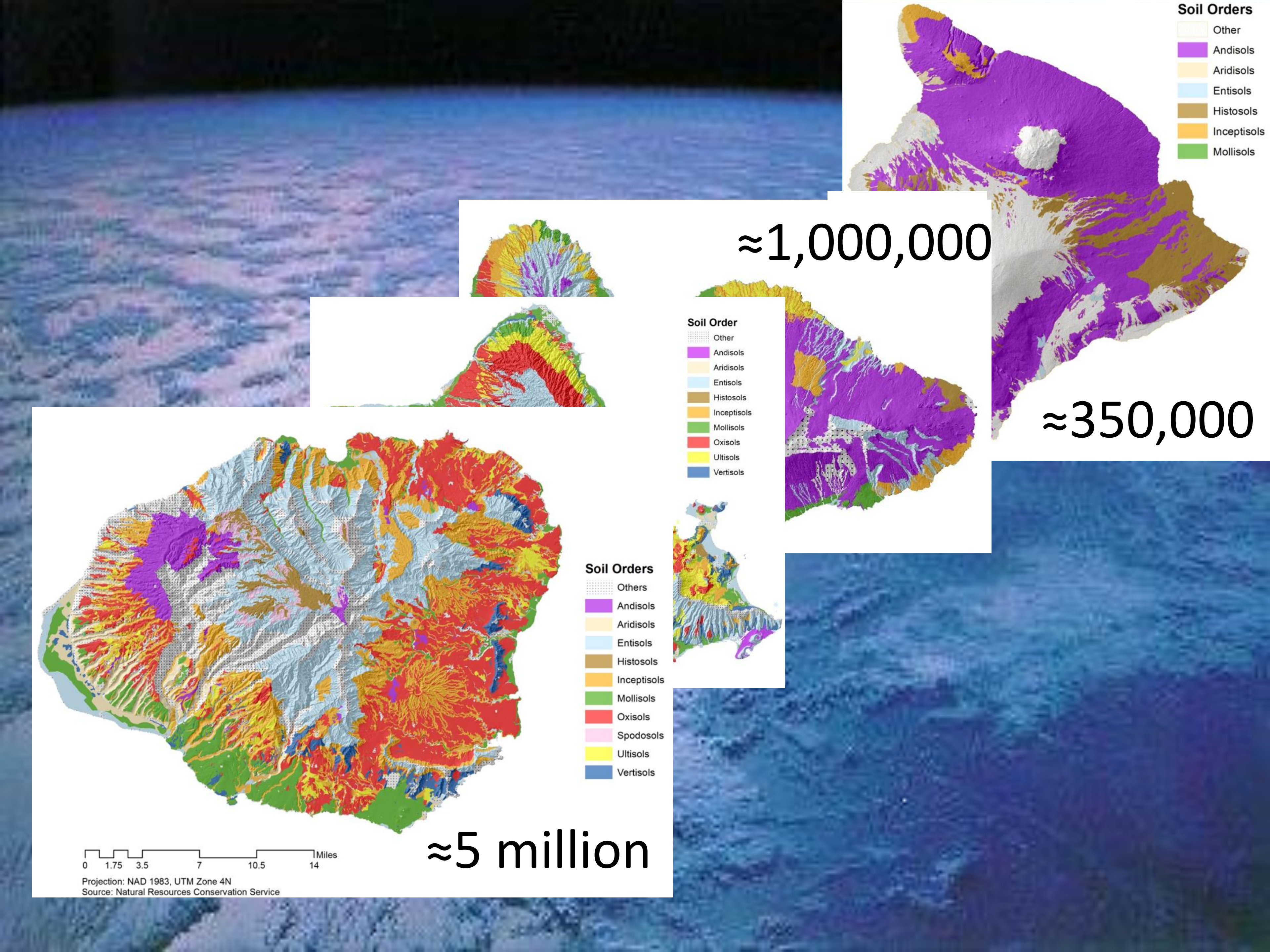
Factors

- Parent material
- Age
- Climate
- Biota
- Topography

Processes

- Additions
- Transformations
- Translocations
- Losses

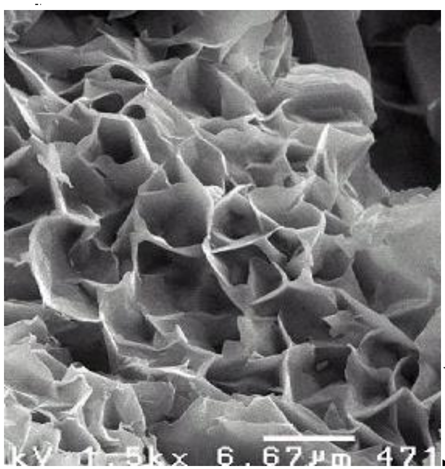



Soil Orders
Other
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
≈350,000
≈1,000,000
Soil Order
Other
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols
Soil Orders
Others
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
Oxisols
Spodosols
Ultisols
Vertisols
0 1.75 3.5 7 10.5 14 Miles
Projection: NAD 1983, UTM Zone 4N
Source: Natural Resources Conservation Service
≈5 million

Weathering of Parent Rock

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

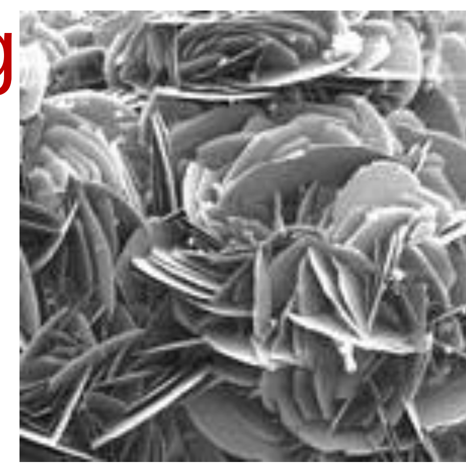
Olivine $(Mg,Fe)_2SiO_4$



Chemical Weathering

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

Hematite Fe_2O_3



Mollisols

Forming Factors

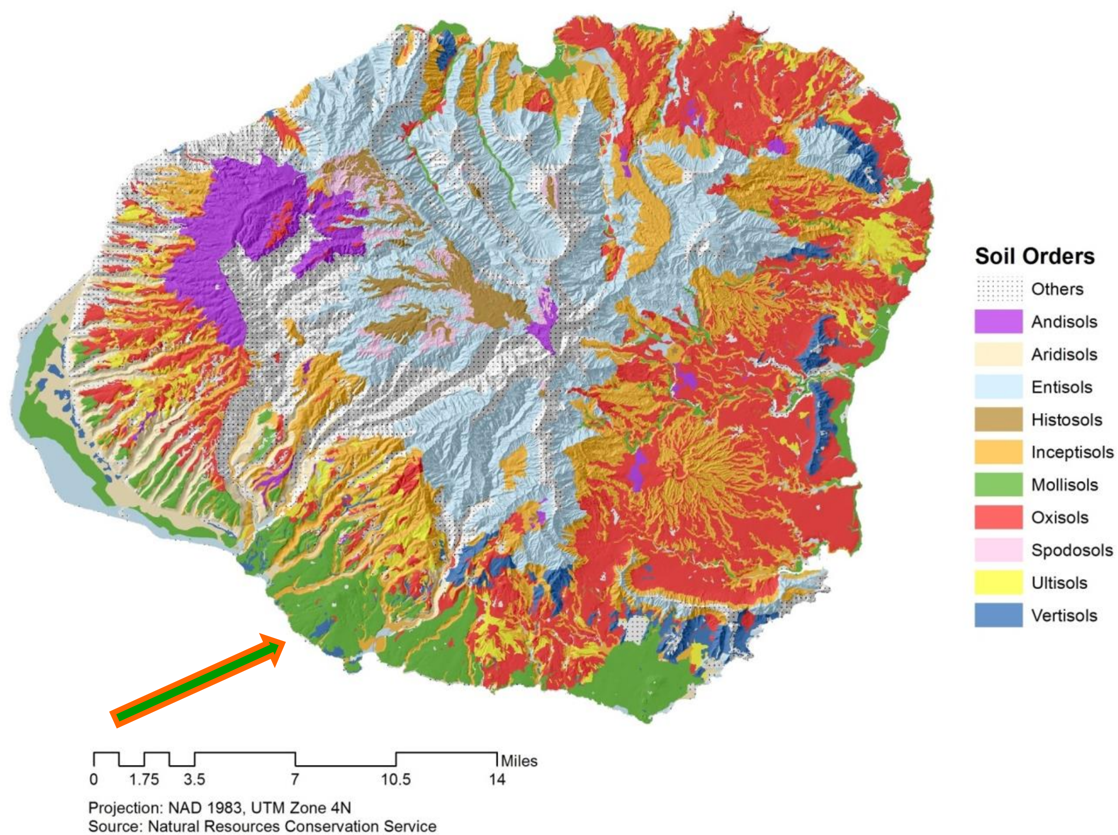
- Parent material
  - Alluvial
- Climate
  - Low rainfall
- Vegetation
  - Grassland open savanna

Processes

- Minimal leaching
- Moderate weathering

Soil Characteristics

- Fertile soil, high nutrient status
- Clay rich, some shrink swell potential



Vertisols

Forming Factors

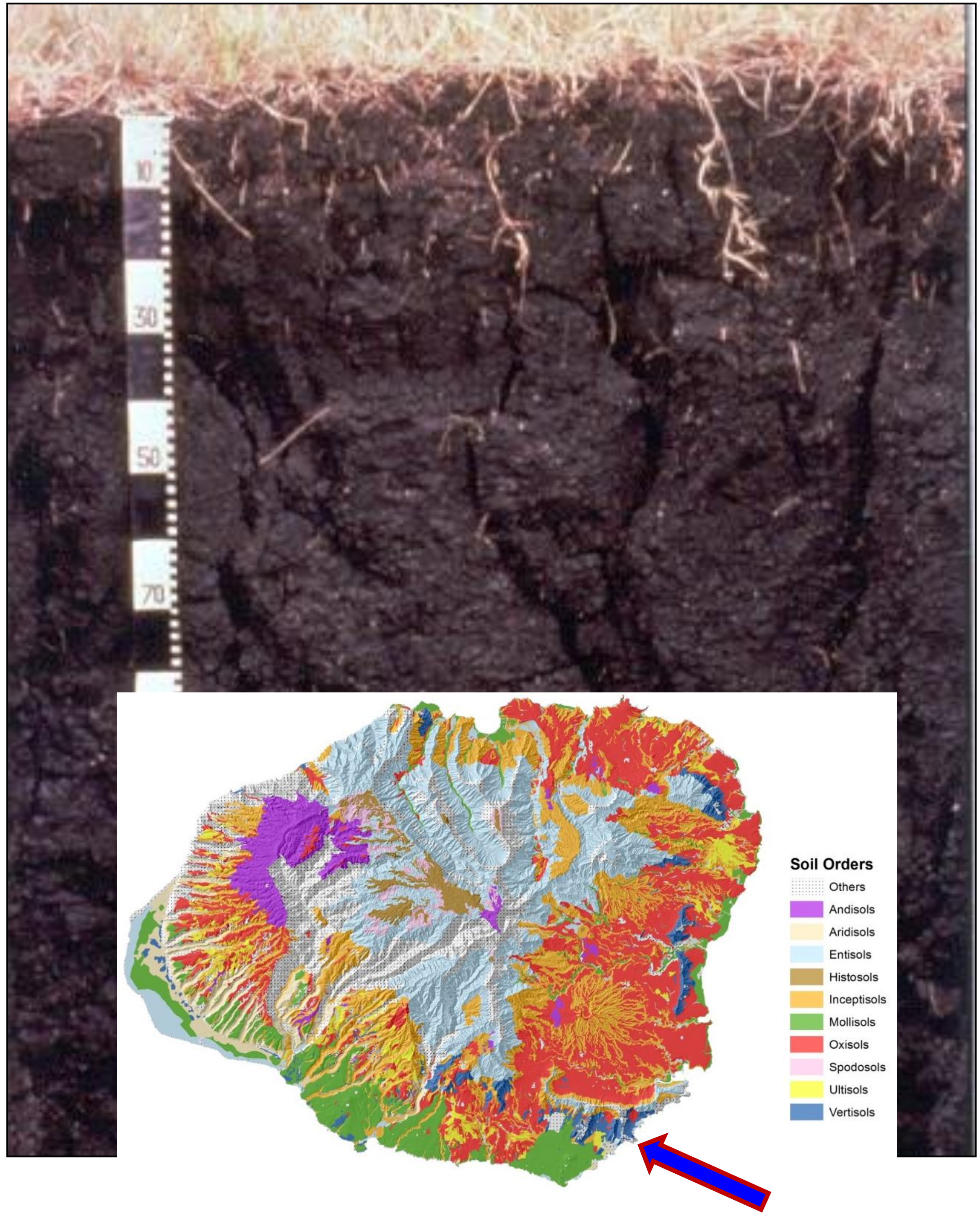
- Parent material
  - Alluvium, coral
- Climate
  - Low rainfall
- Vegetation
  - Grass and scrub land

Processes

- Transformation
- Moderate weathering

Soil Characteristics

- Very fertile
- Neutral to alkaline
- High shrink-swell potential



Oxisols

Forming Factors

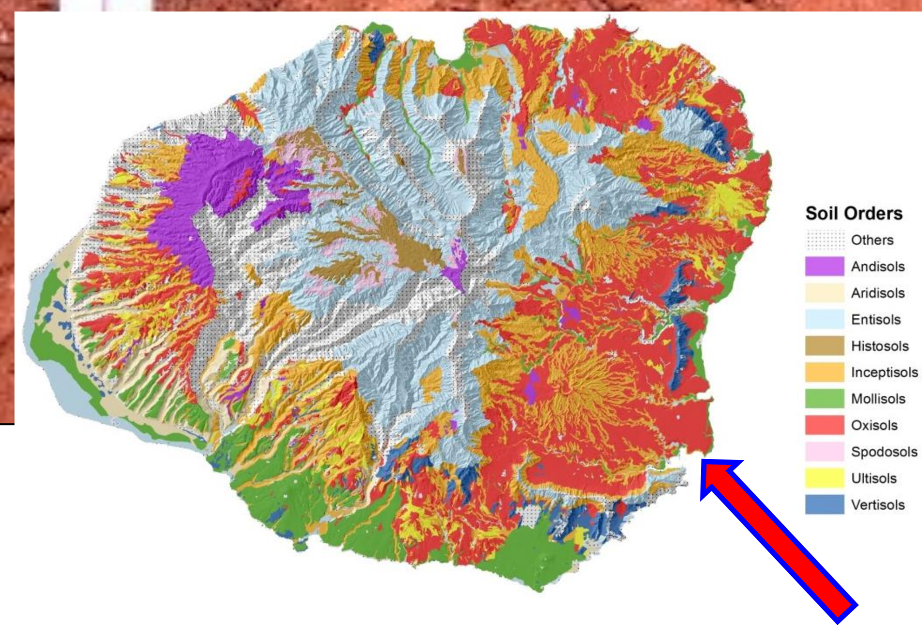
- Parent material
  - Residuum (basalt lava)
- Climate
  - Moderate to high rainfall
- Vegetation
  - Forest/grassland

Processes

- High leaching
- Highly weathered

Soil Characteristics

- Infertile soil, low nutrient status
- Acidic
- Good physical properties



Ultisols

Forming Factors

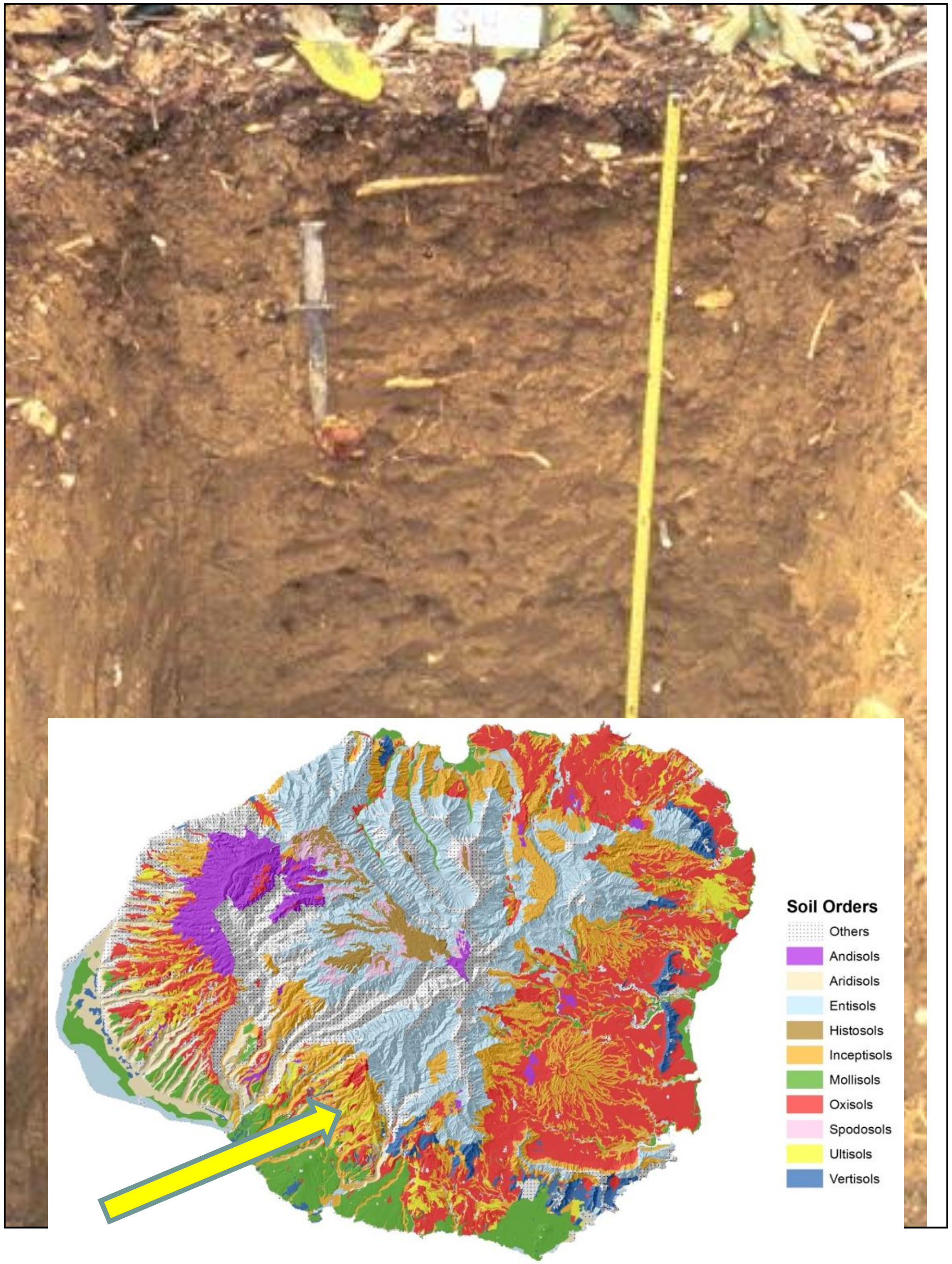
- Parent material
  - Residuum (basalt lava)
- Climate
  - High rainfall
- Vegetation
  - Forest

Processes

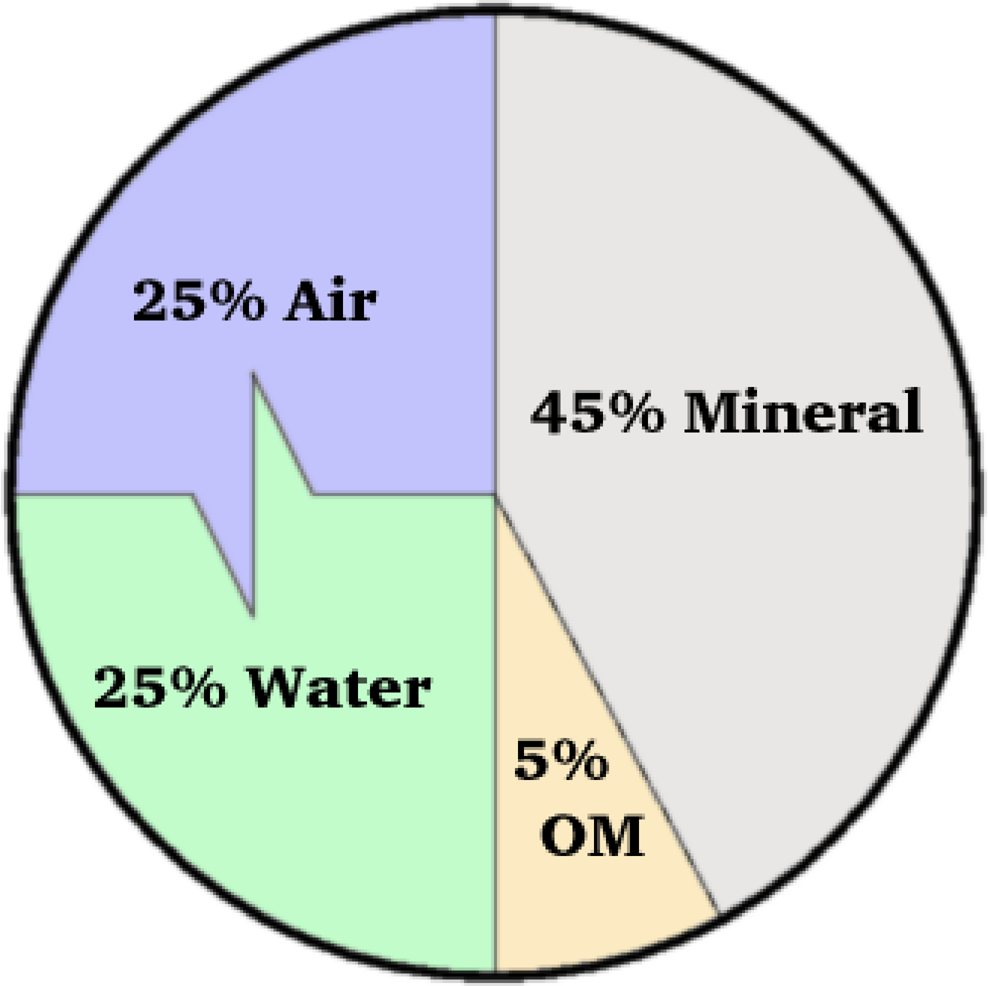
- High leaching
- Highly weathered

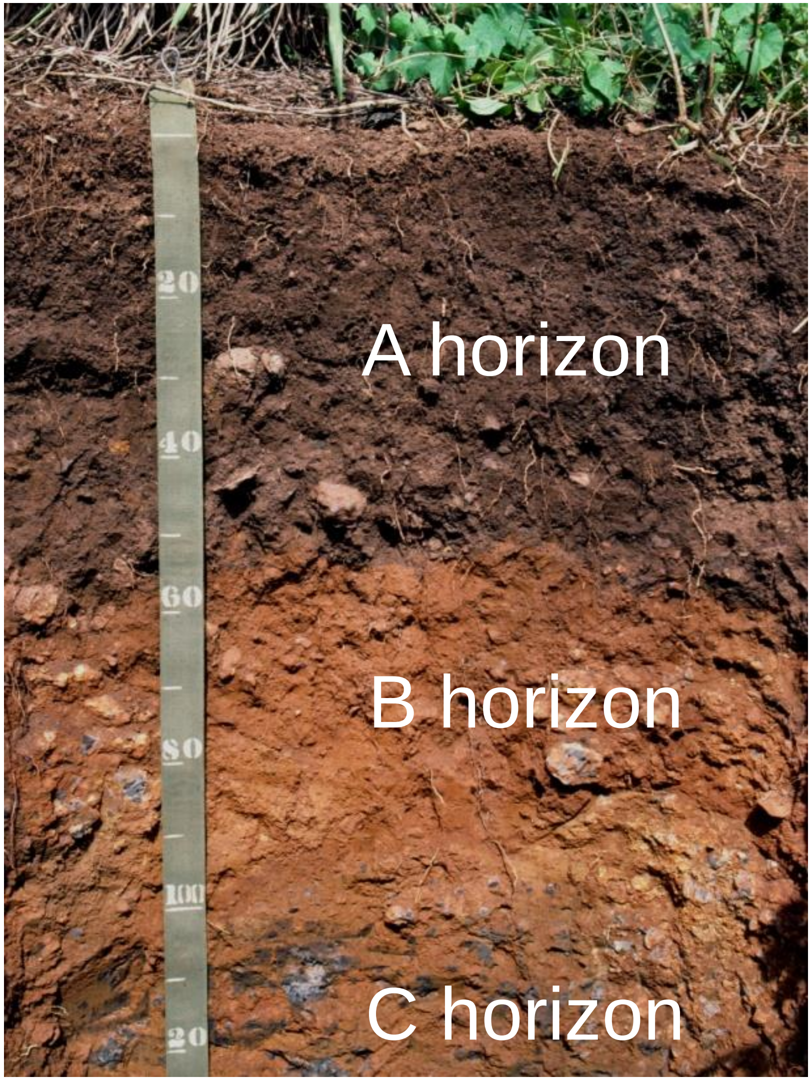
Soil Characteristics

- Infertile soil, nutrient deficient
- Very acidic
- Good physical properties

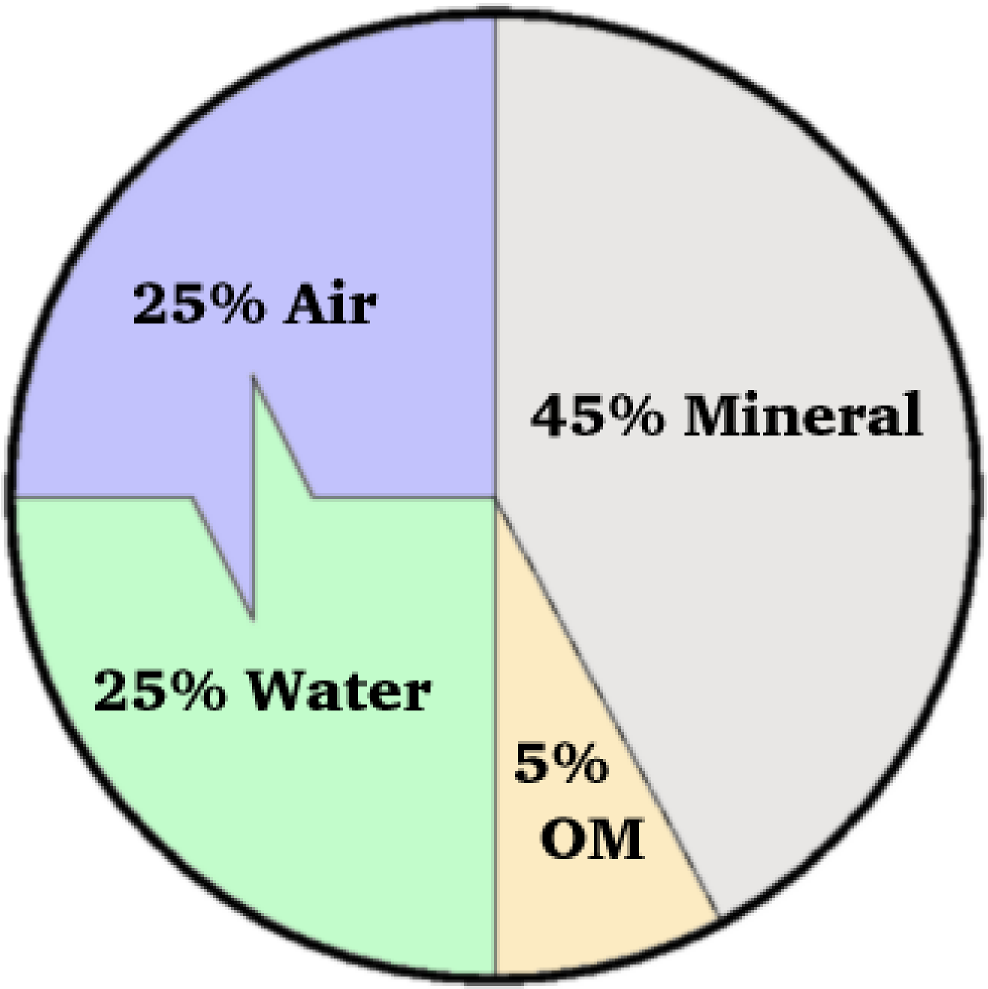


What is Soil?



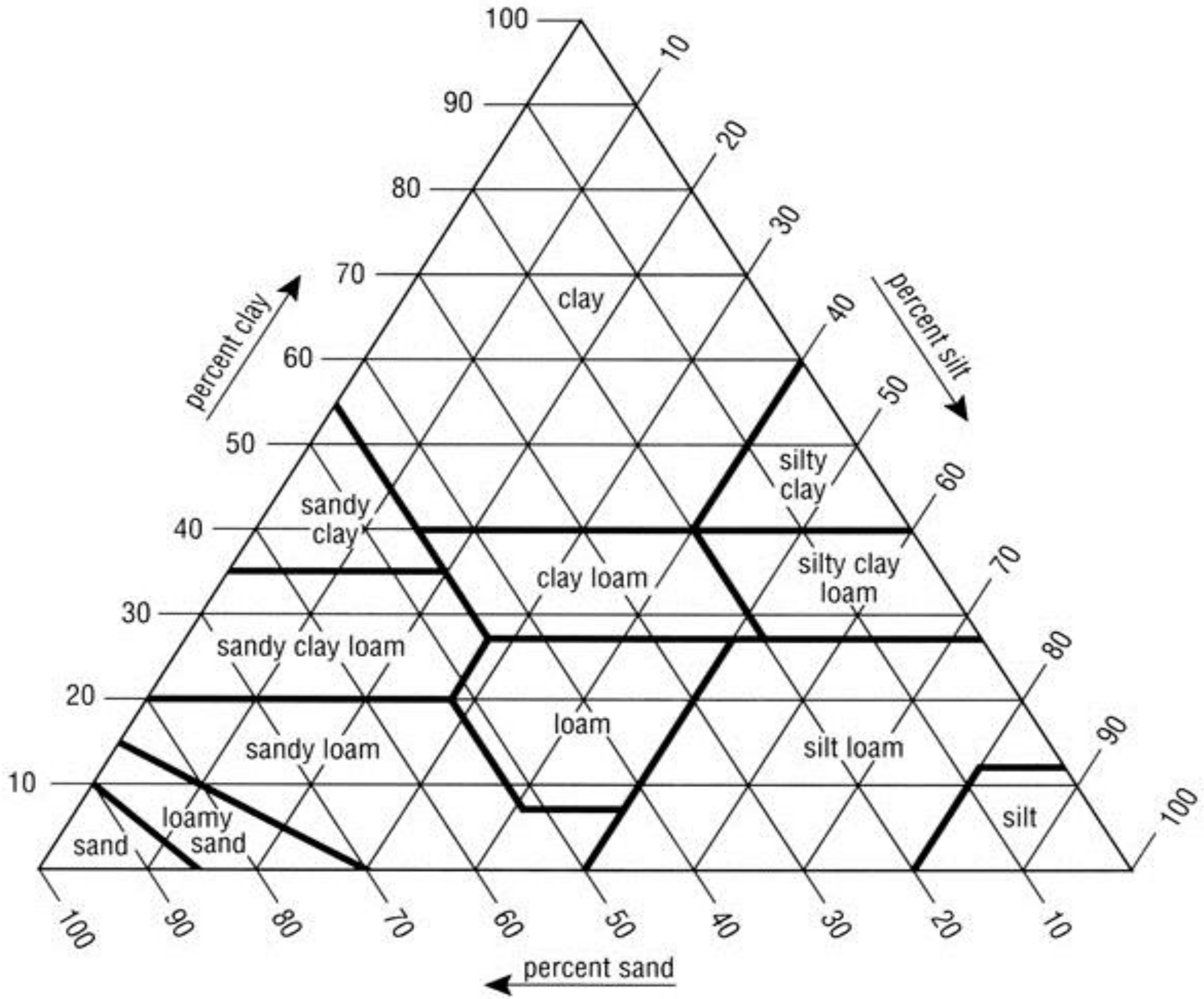


Soil Physical Properties

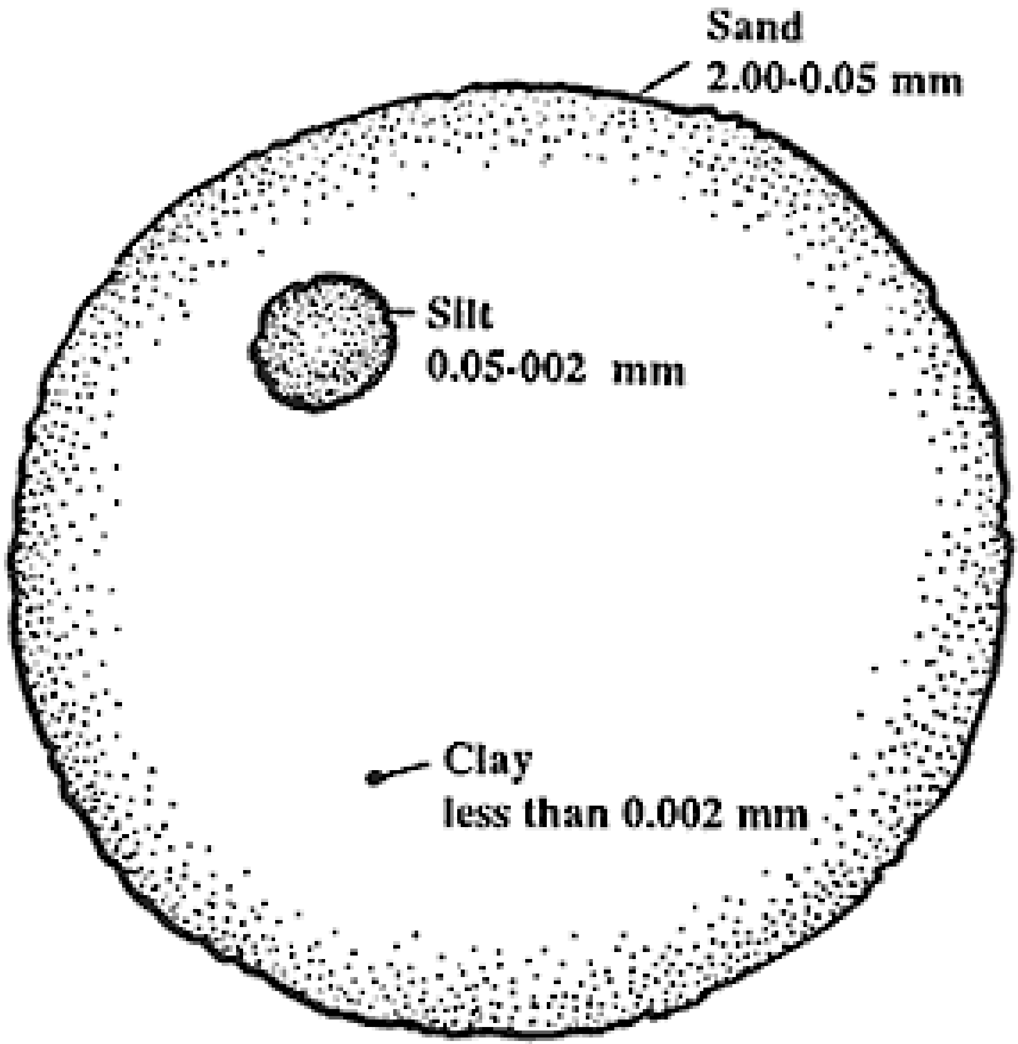


1. Soil texture/structure
2. Soil Water
3. Soil Organic Matter

Soil Texture



Soil Texture

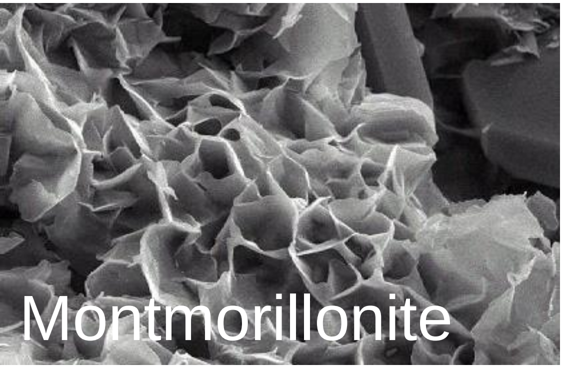


Important Clay Minerals

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

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

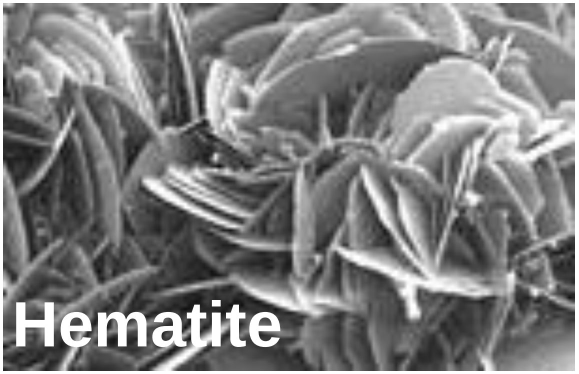
Some Important Clay Minerals



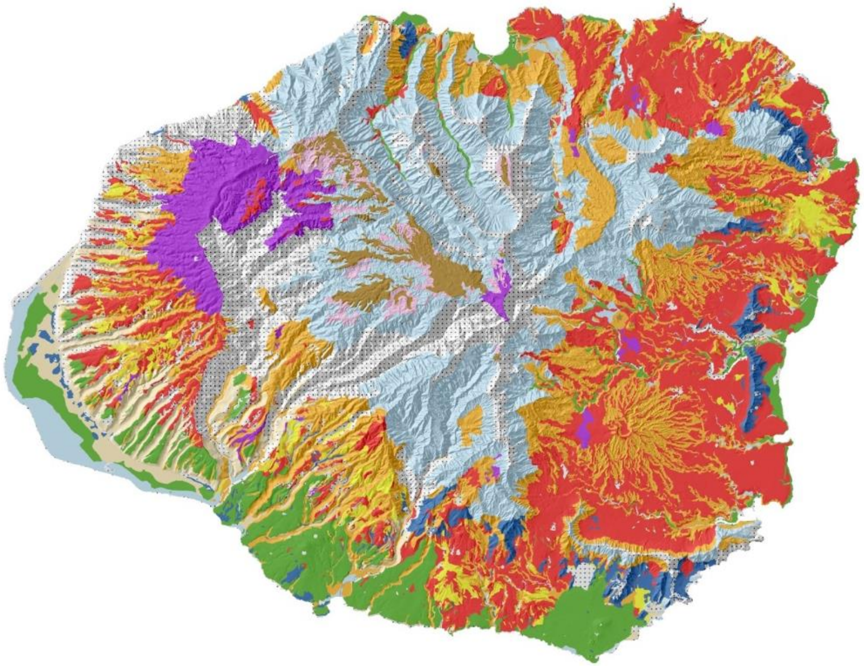
<u>Properties</u>:

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

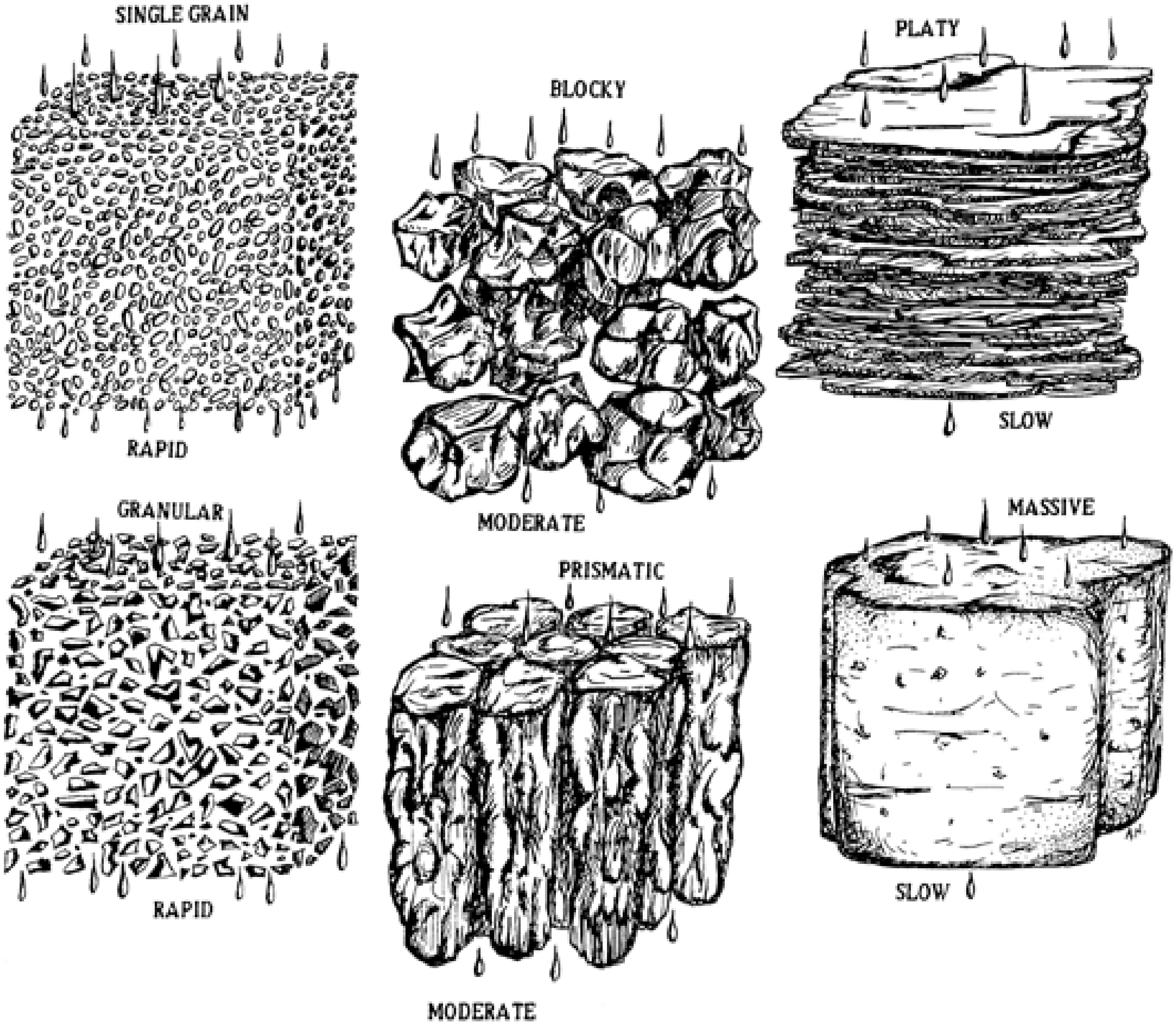
- Non-expanding
- Variable charge
- Low surface are
- Low CEC
- Non-sticky

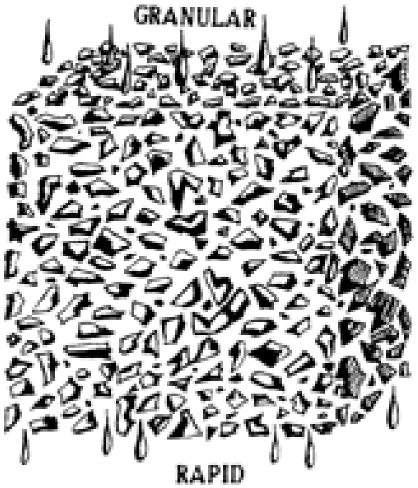


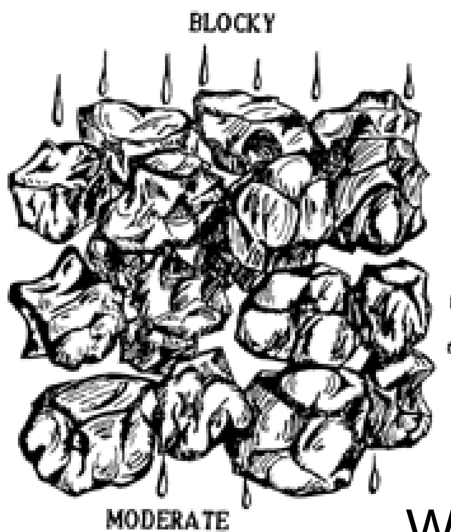
- Non-expanding
- Variable charge
- Low surface are
- Very low CEC
- Non-sticky

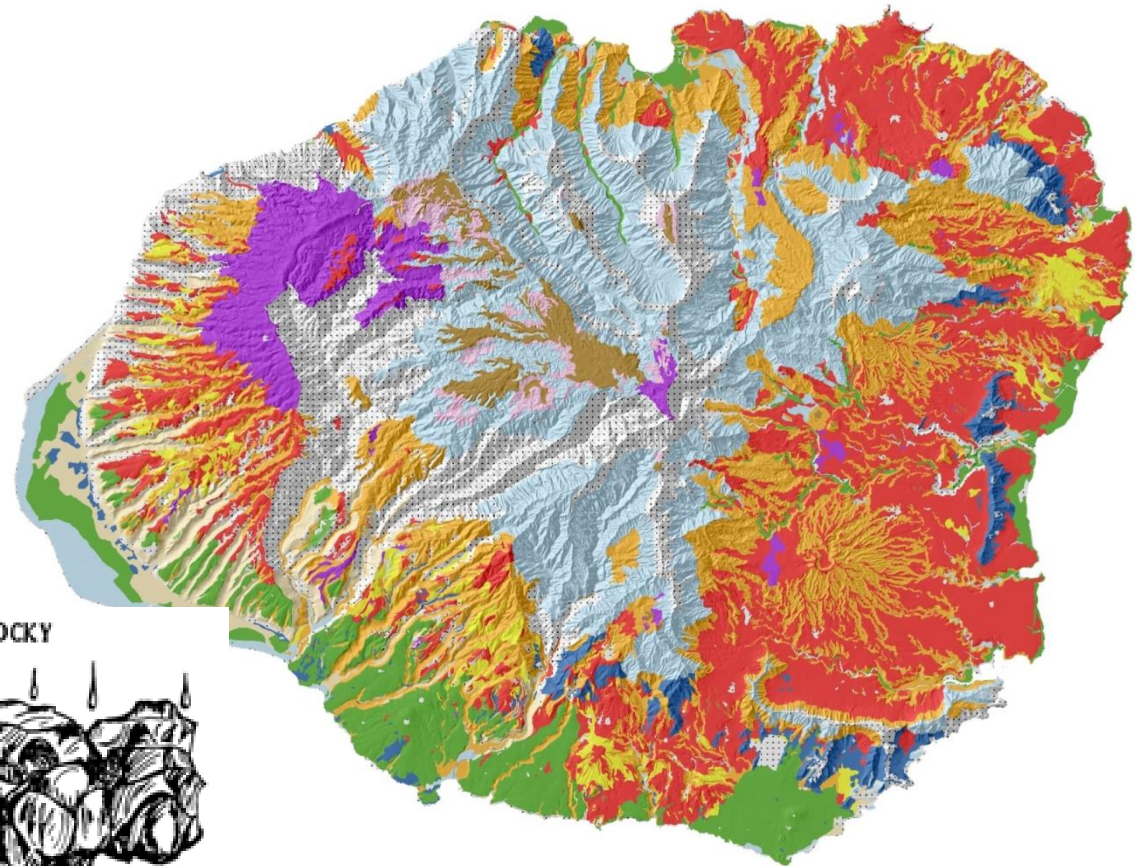


Soil Structure



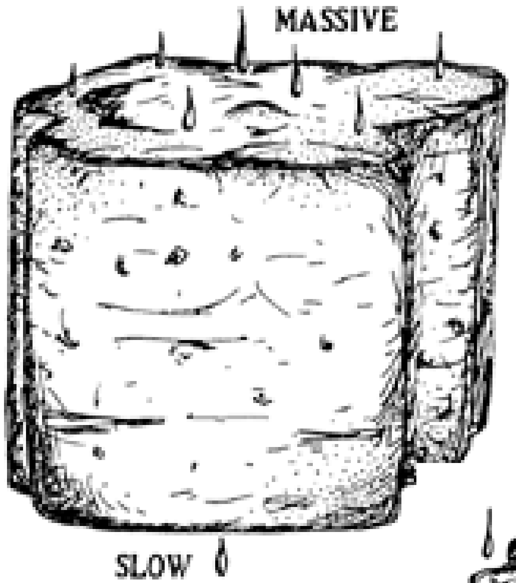


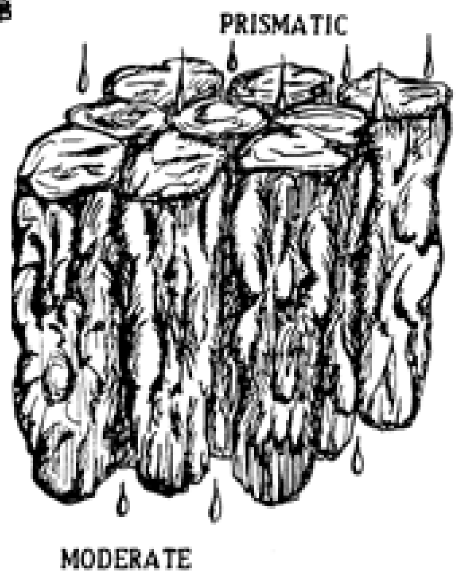


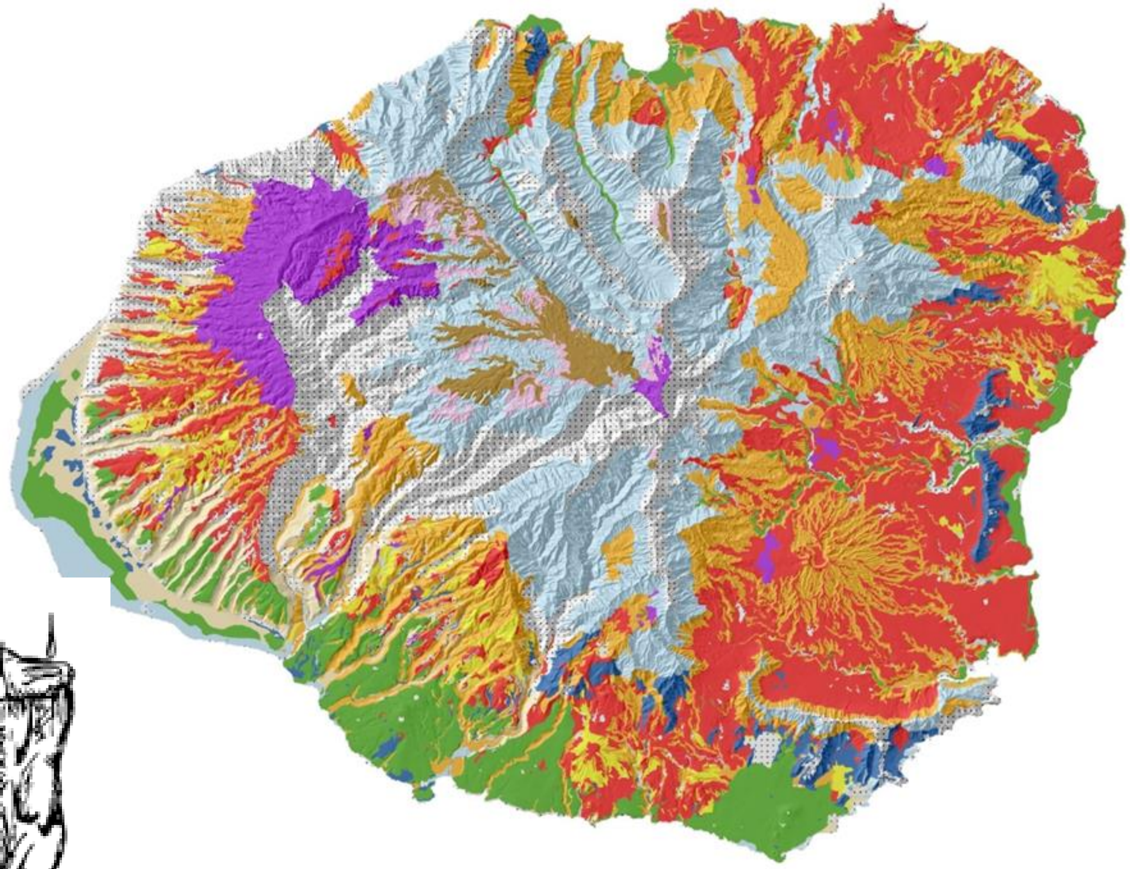


Well-drained soils that resist compaction

Andisols
Ultisols
Oxisols
Entisols





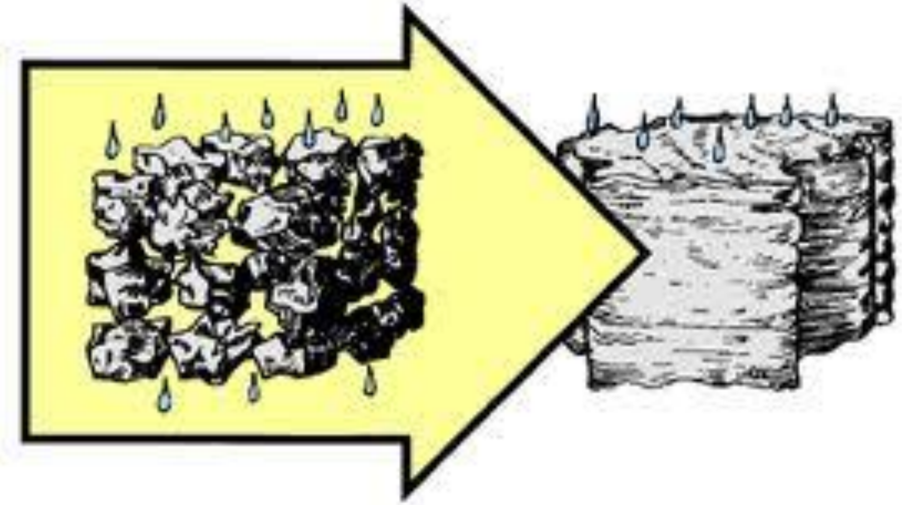


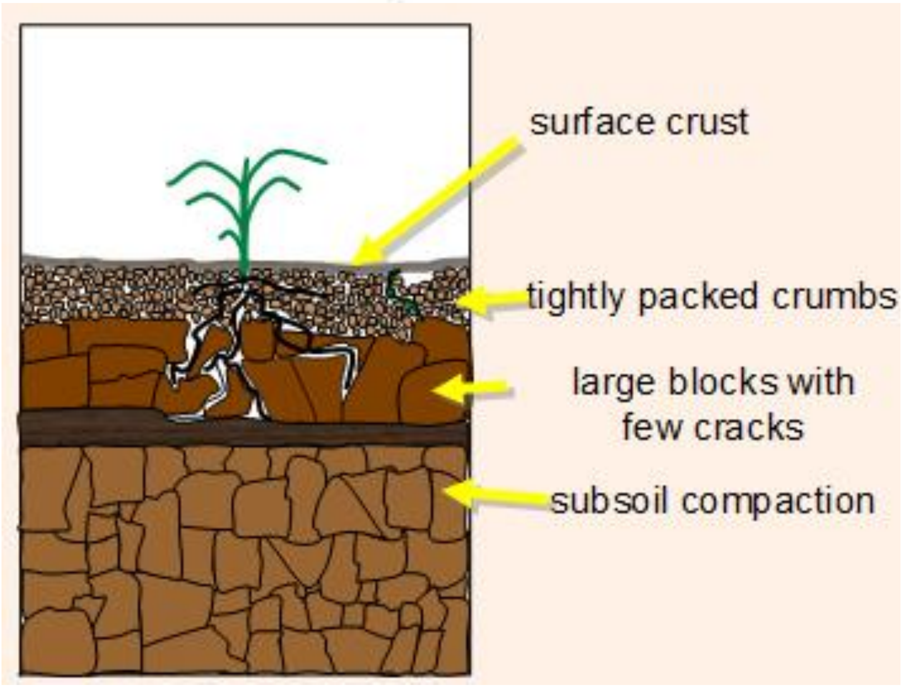
<u>Poorly-drained soils that compact easily</u>

- Mollisols
- Vertisols

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

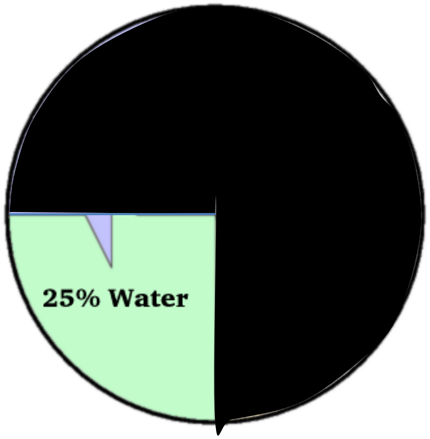


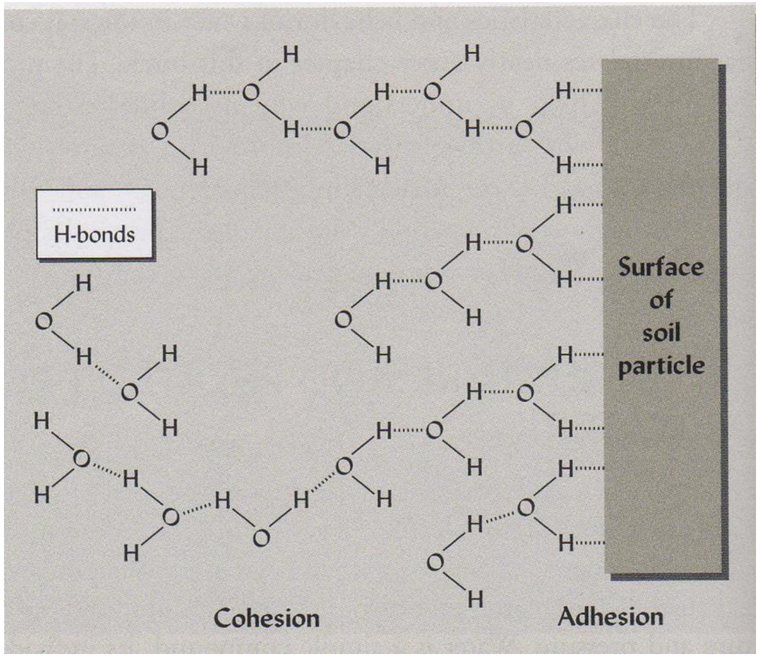


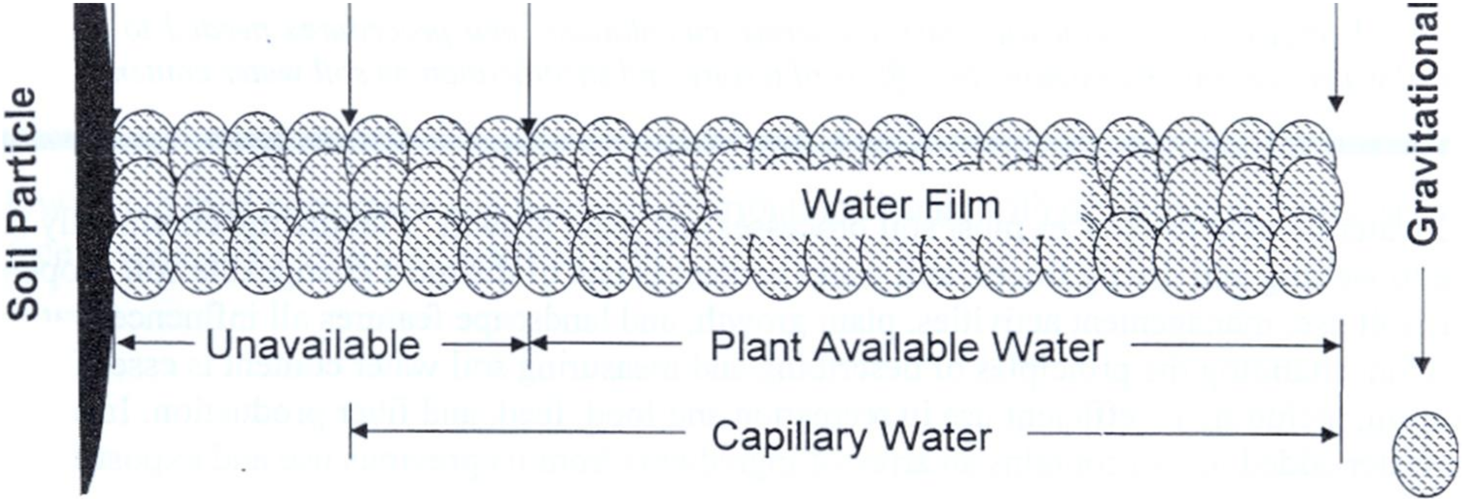
Improving Drainage

- Add organic matter
  - glueing action
  - Binding by soil fungi
- Add gypsum ($CaSO_4$)
  - Polyvalent Ca2+ pulls negatively charged clay particles together

Soil Water

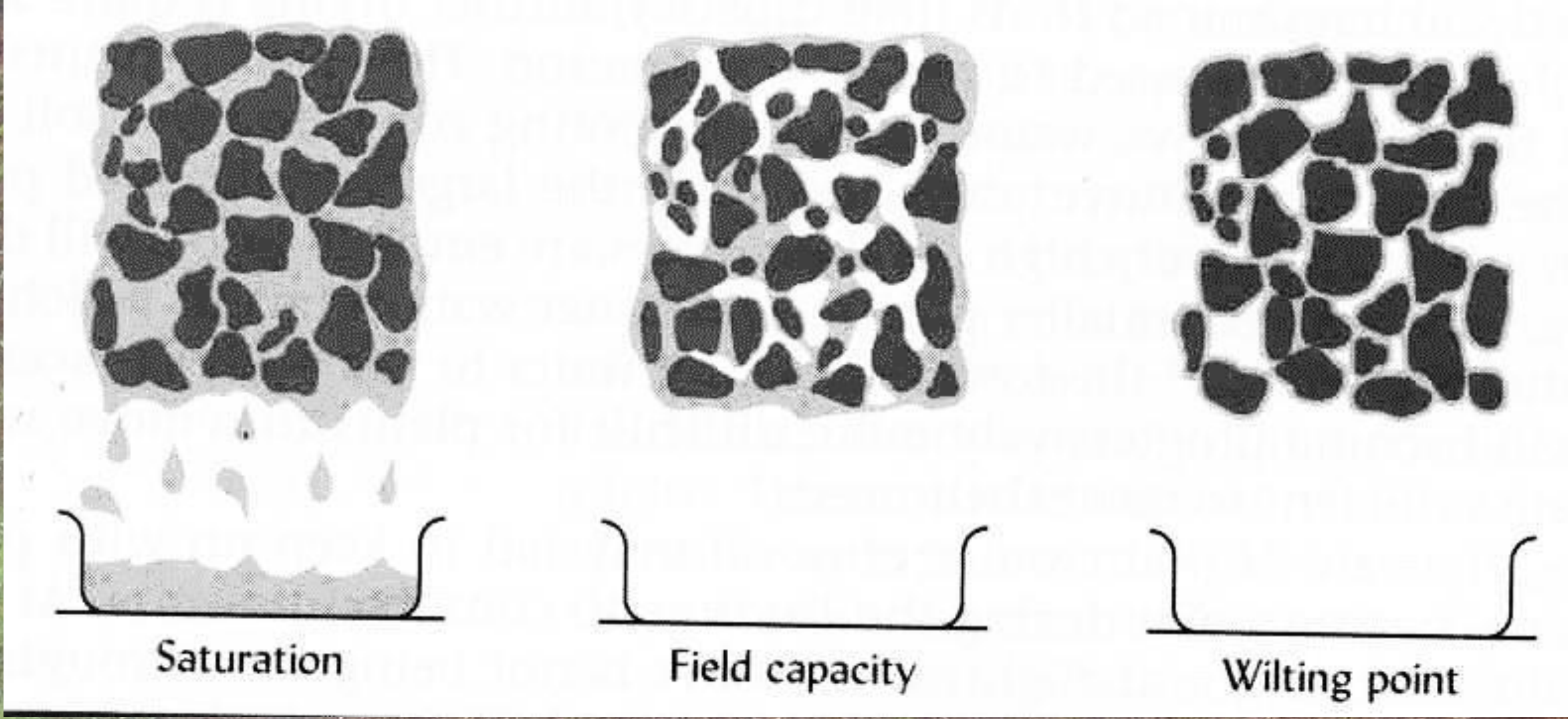

25% Water


H-bonds
Surface of soil particle
Cohesion
Adhesion


Soil Particle
Water Film
Gravitational
Unavailable
Plant Available Water
Capillary Water

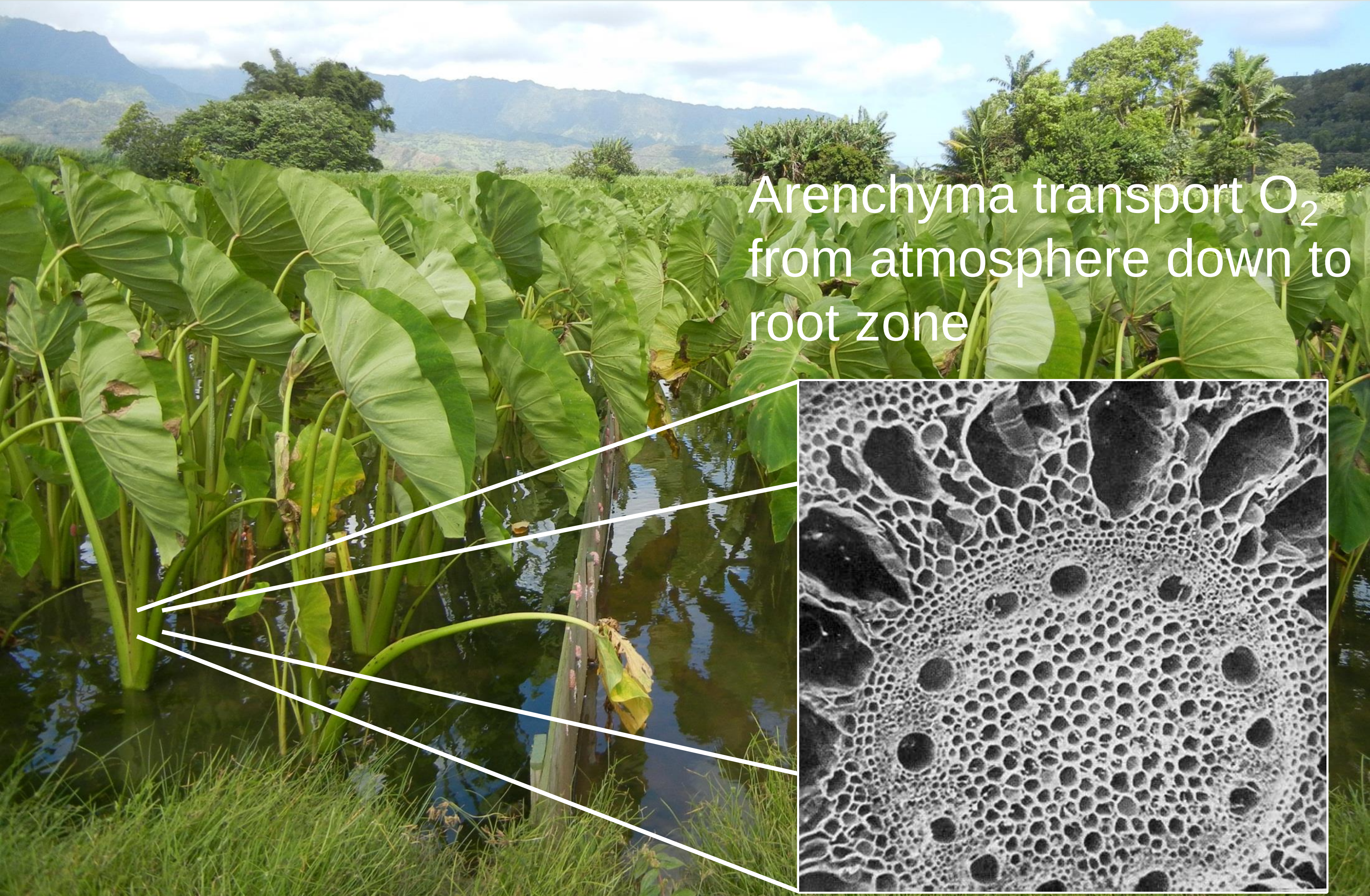
Soil Water Availability

<u>Soil water holding capacity depends on texture</u>



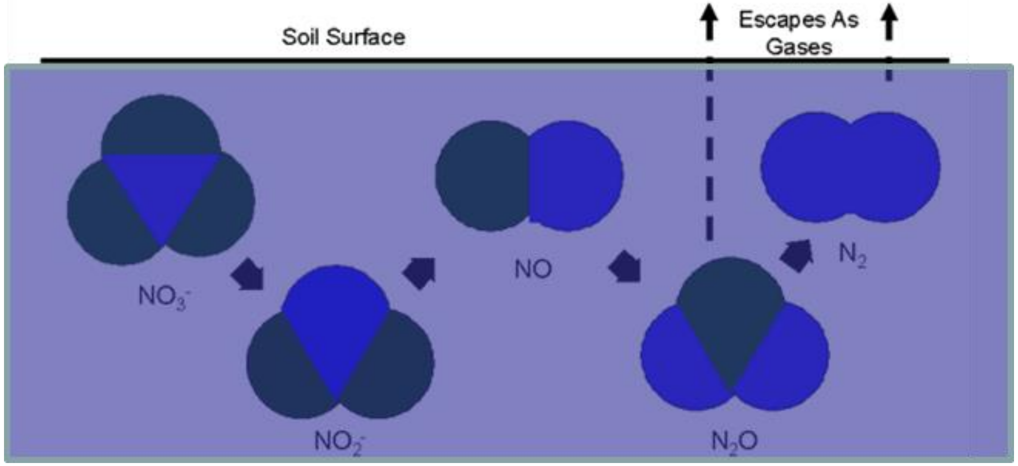
Soil Air

Soil Air



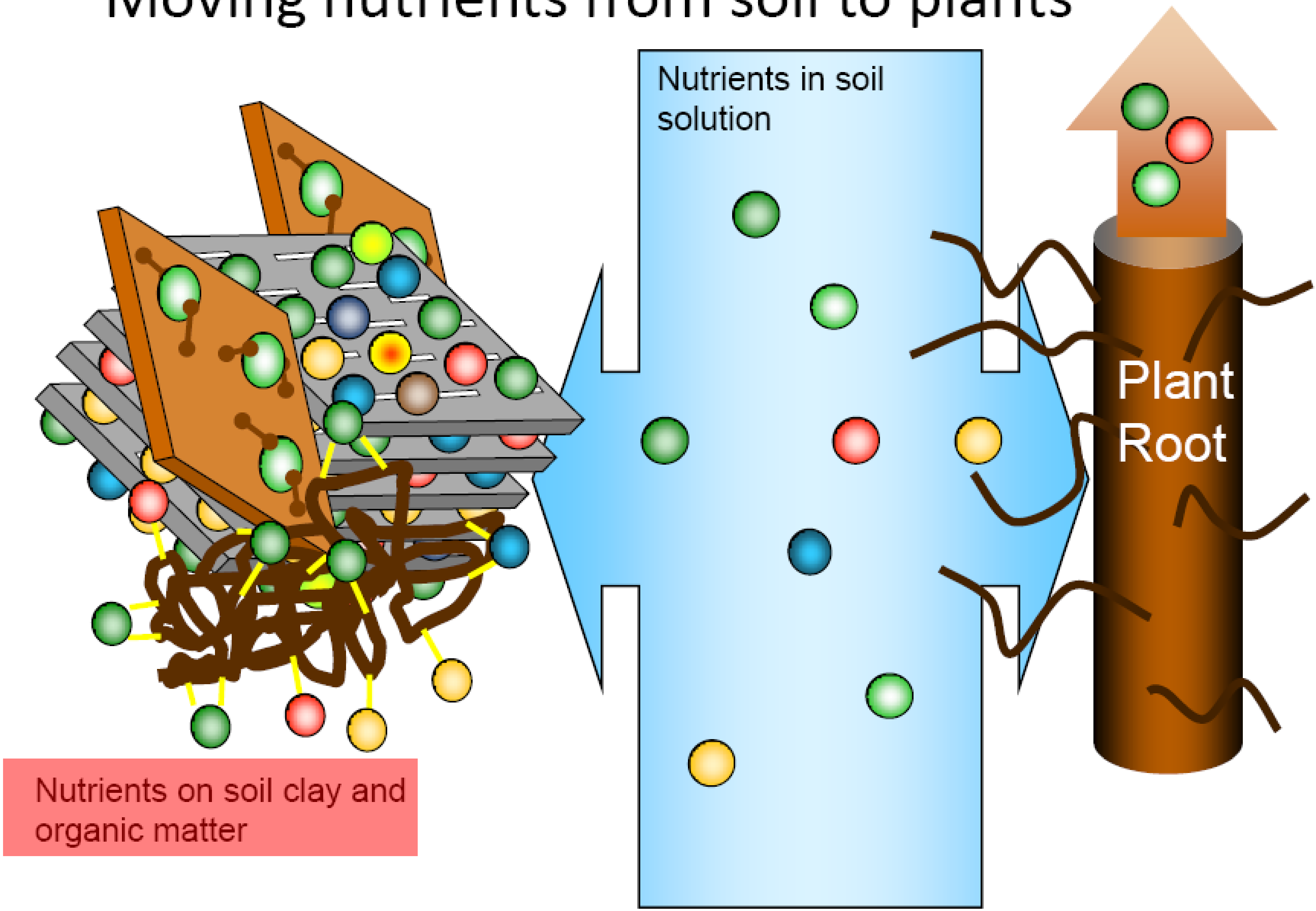
Importance of Soil Air

- 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

Moving nutrients from soil to plants



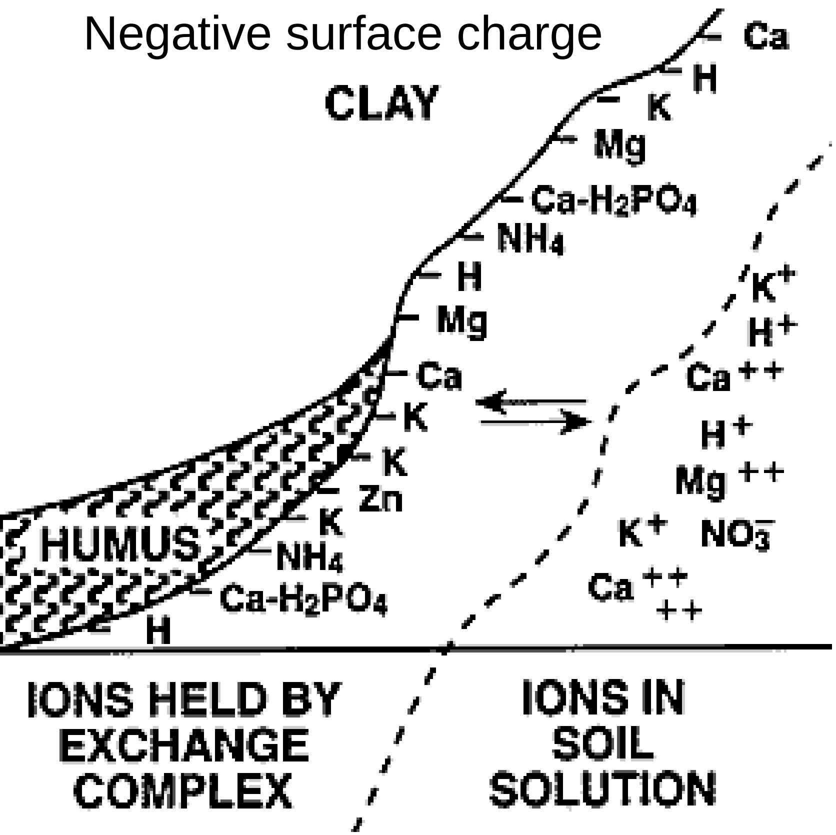
Soil Chemical Properties

Cation Exchange Capacity

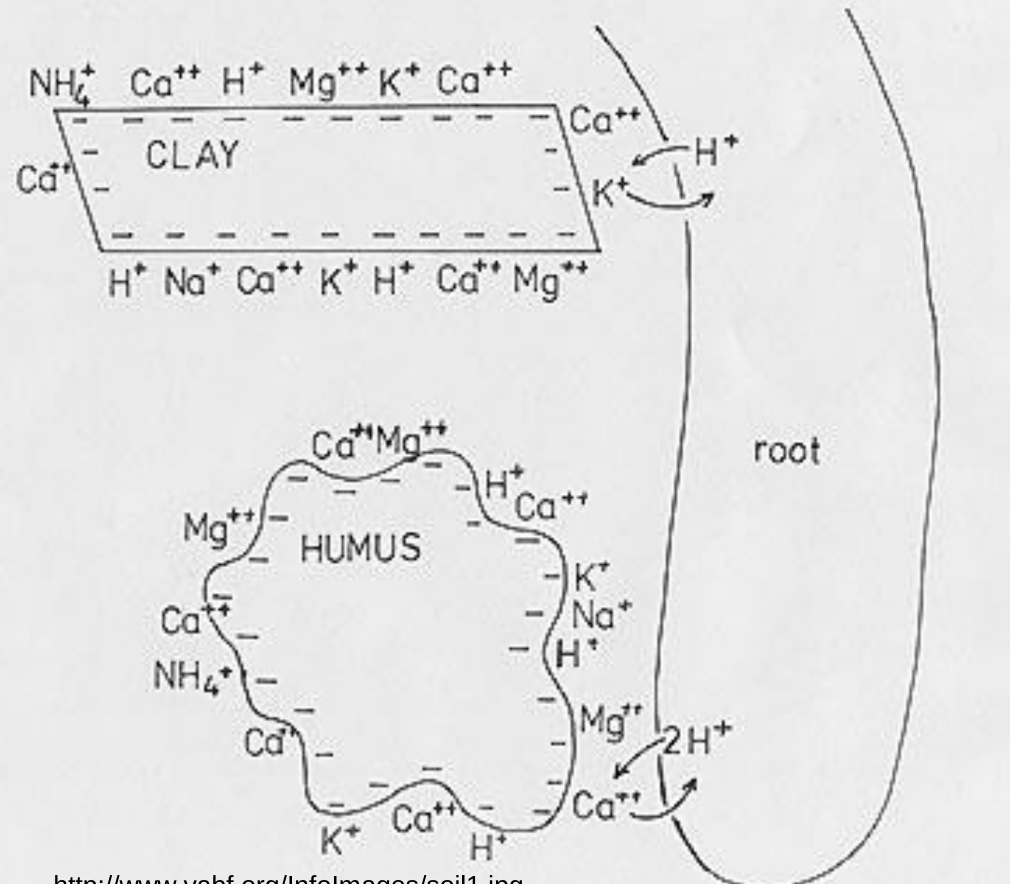
CEC is defined as the degree to which a soil can adsorb and exchange cations

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

Negative surface charge



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

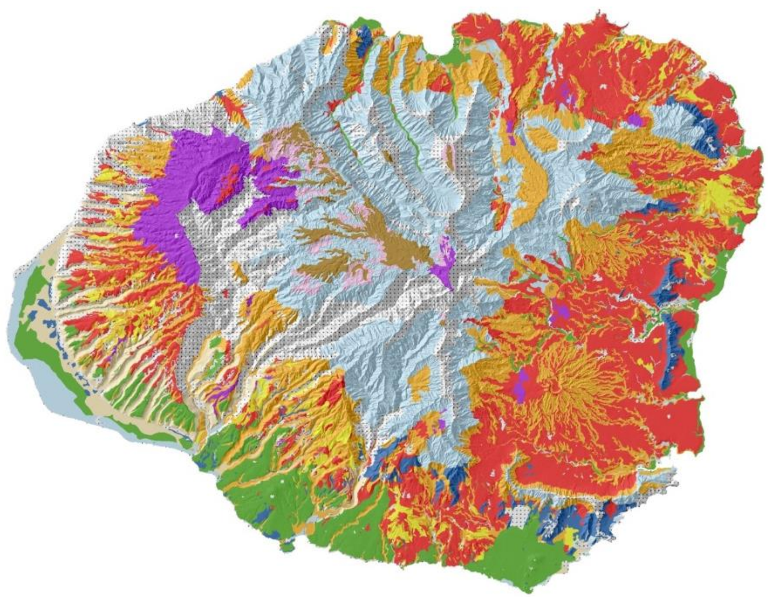


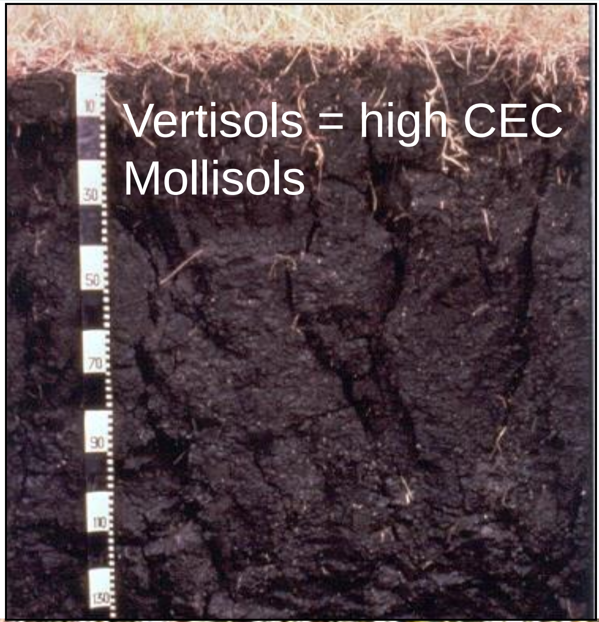
http://www.vabf.org/InfoImages/soil1.jpg

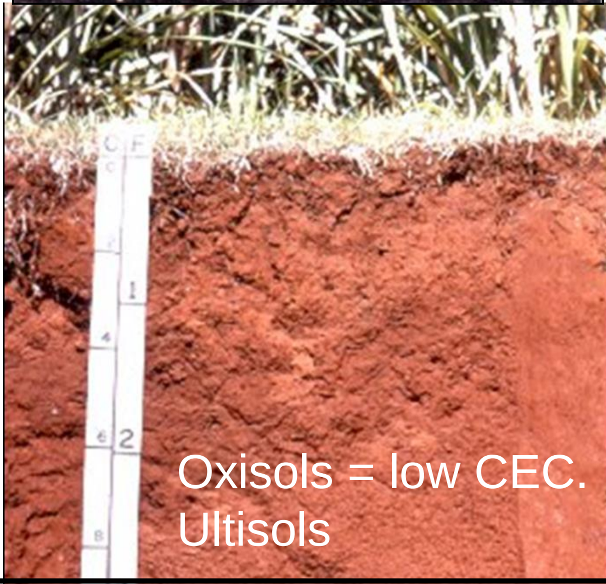
Cation Exchange Capacity

Cation Exchange Capacity

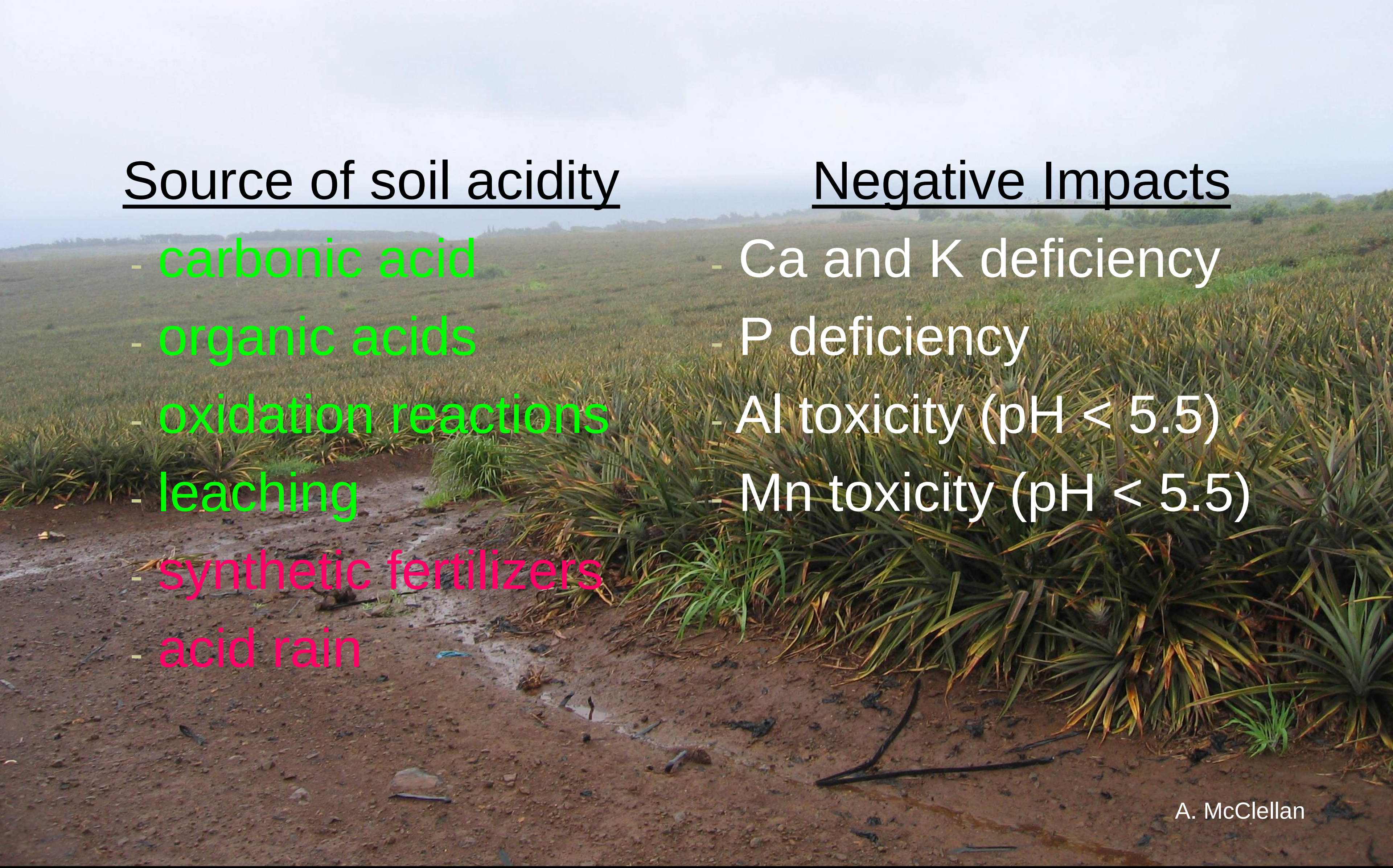
1. Clay surfaces
   - Smectite: 80 – 100 $cmol_c kg^{-1}$
   - Kaolinite: 3 – 15 $cmol_c kg^{-1}$
   - Al/Fe oxides: 0 $cmol_c kg^{-1}$
2. Organic matter
   - Humus: 200 $cmol_c kg^{-1}$







Soil Acidity



Source of soil acidity

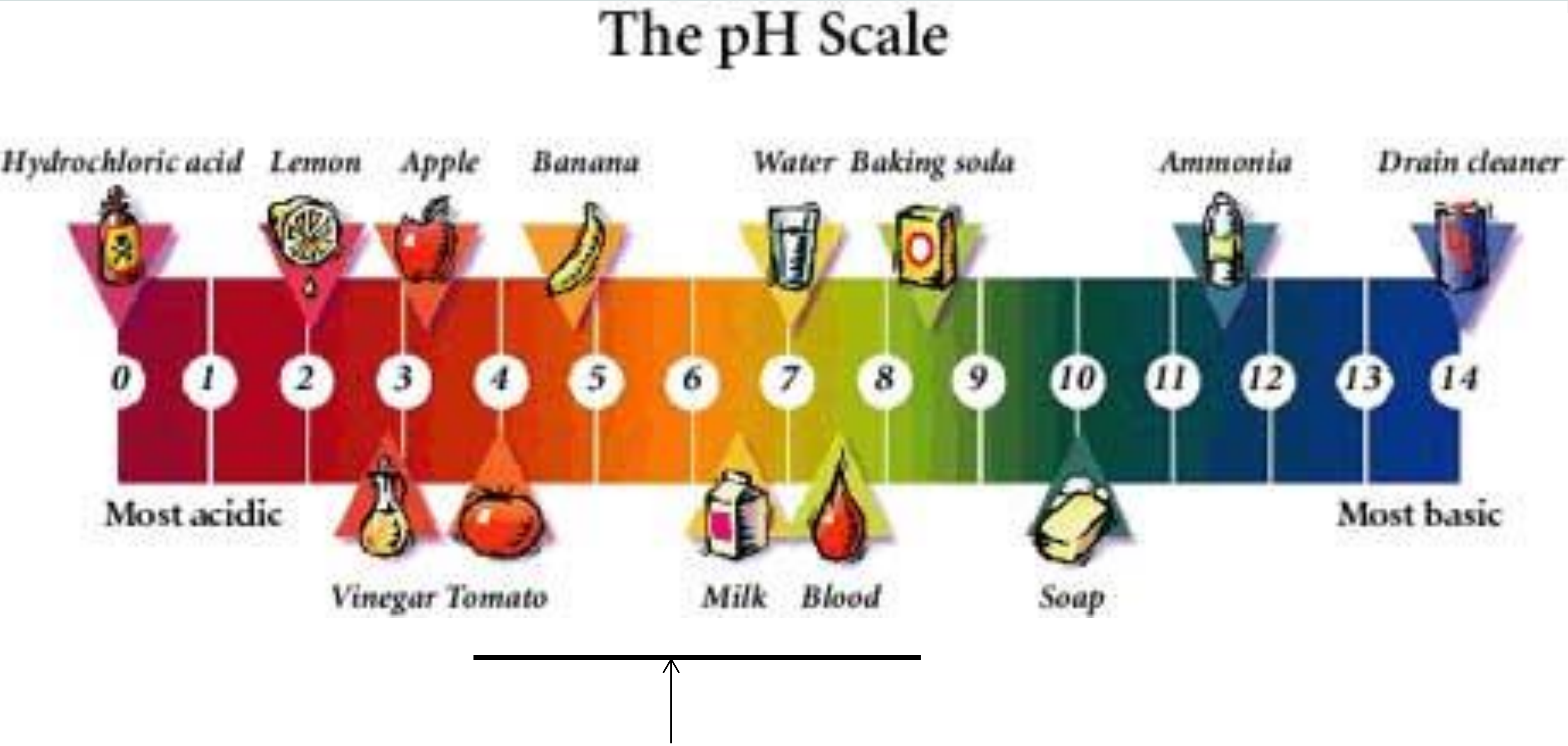
- carbonic acid
- organic acids
- oxidation reactions
- leaching
- synthetic fertilizers
- acid rain

Negative Impacts

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

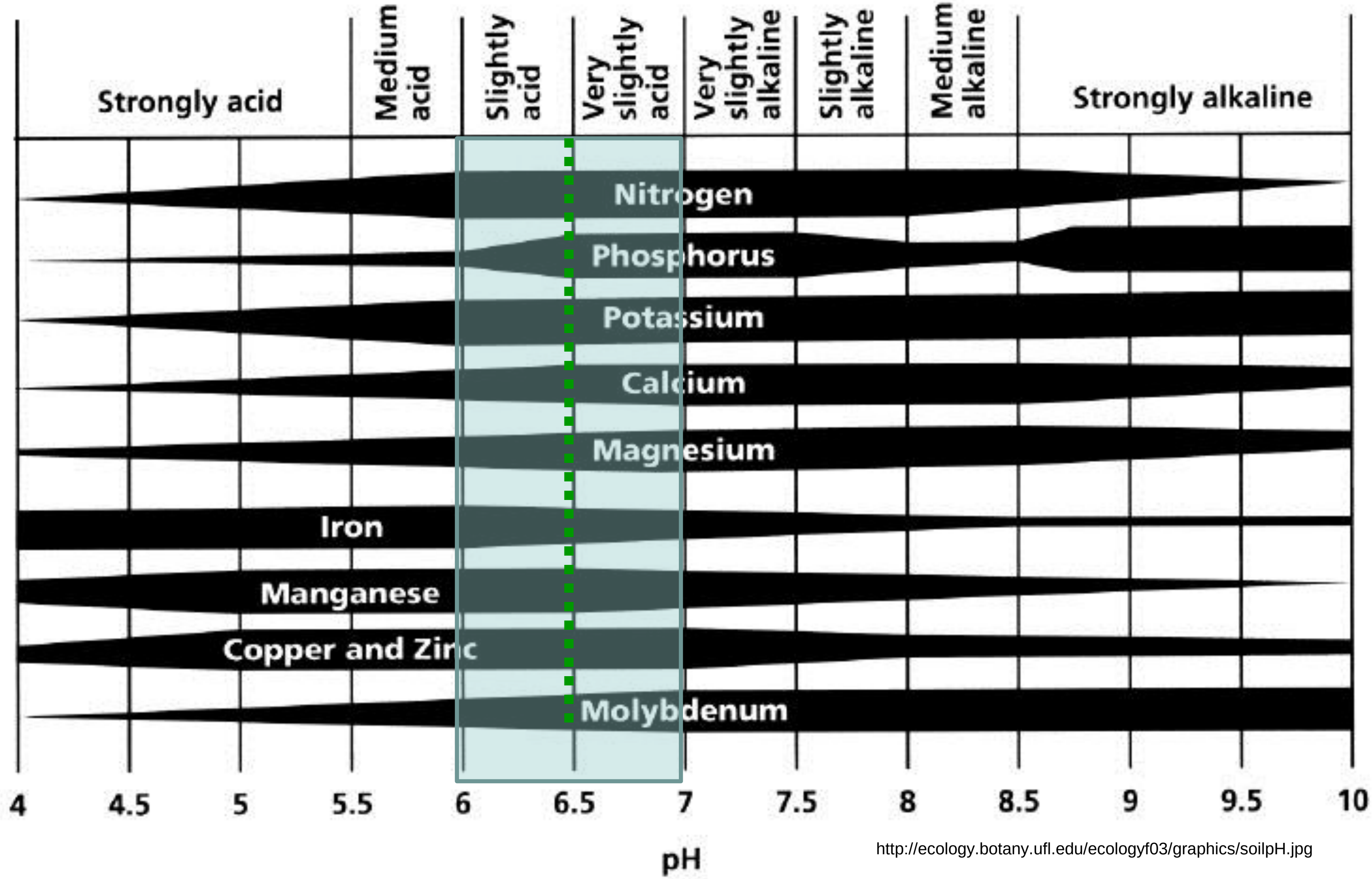
A. McClellan

Soil pH is an Expression of Acidity/Alkalinity



Typical pH range in soils

Soil Acidity

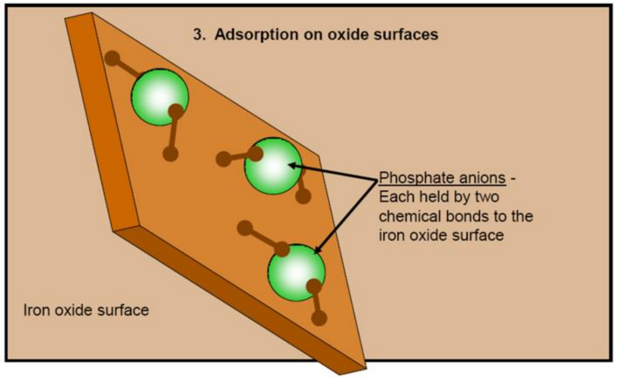


http://ecology.botany.ufl.edu/ecologyf03/graphics/soilpH.jpg

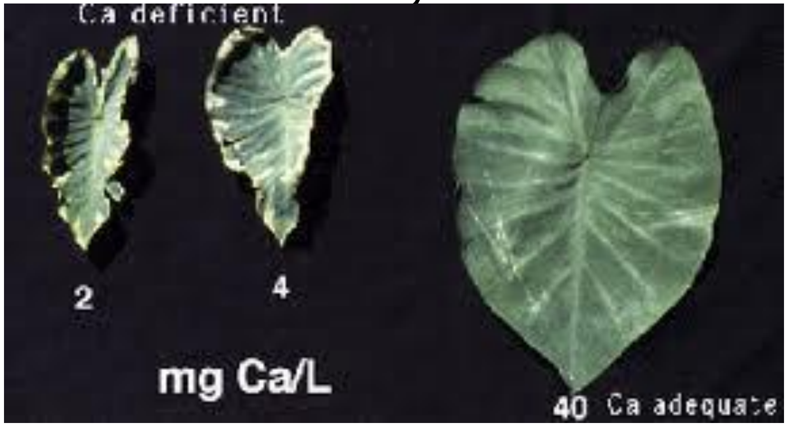
Negative Effects of Soil Acidity

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

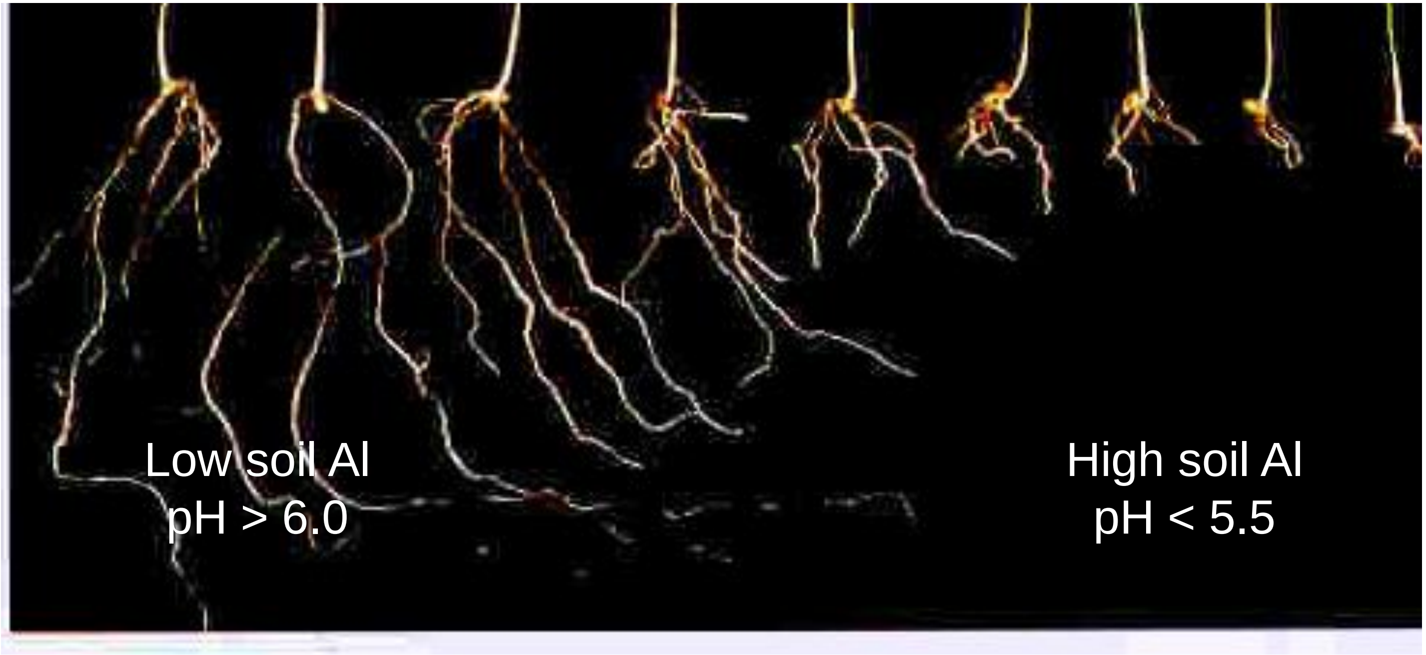
P Fixation

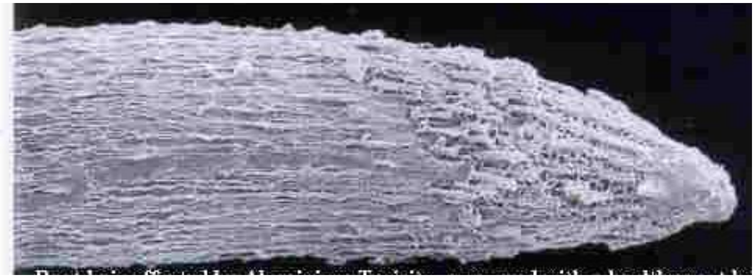


  - Ca deficiency



High Soil Aluminum Causes Root Damage

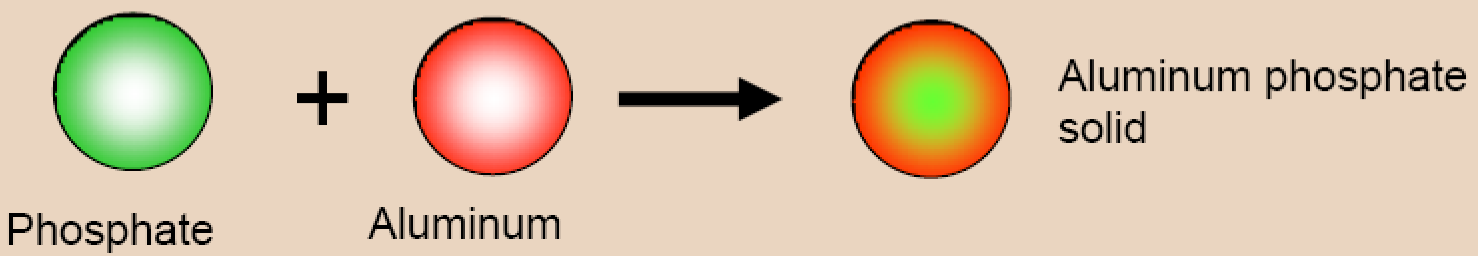



Healthy root hair in soil with low Al

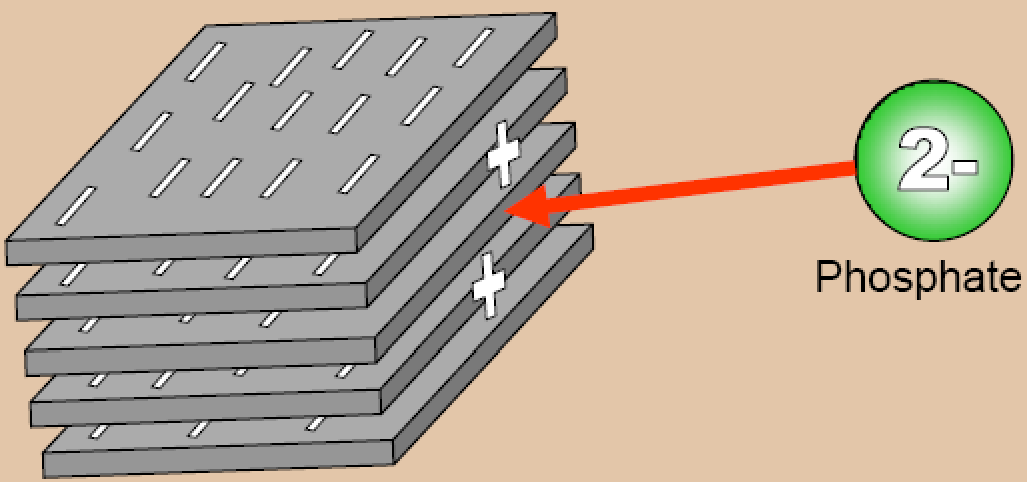
Deformed root hair in soil with high Al

Phosphate retention in soil

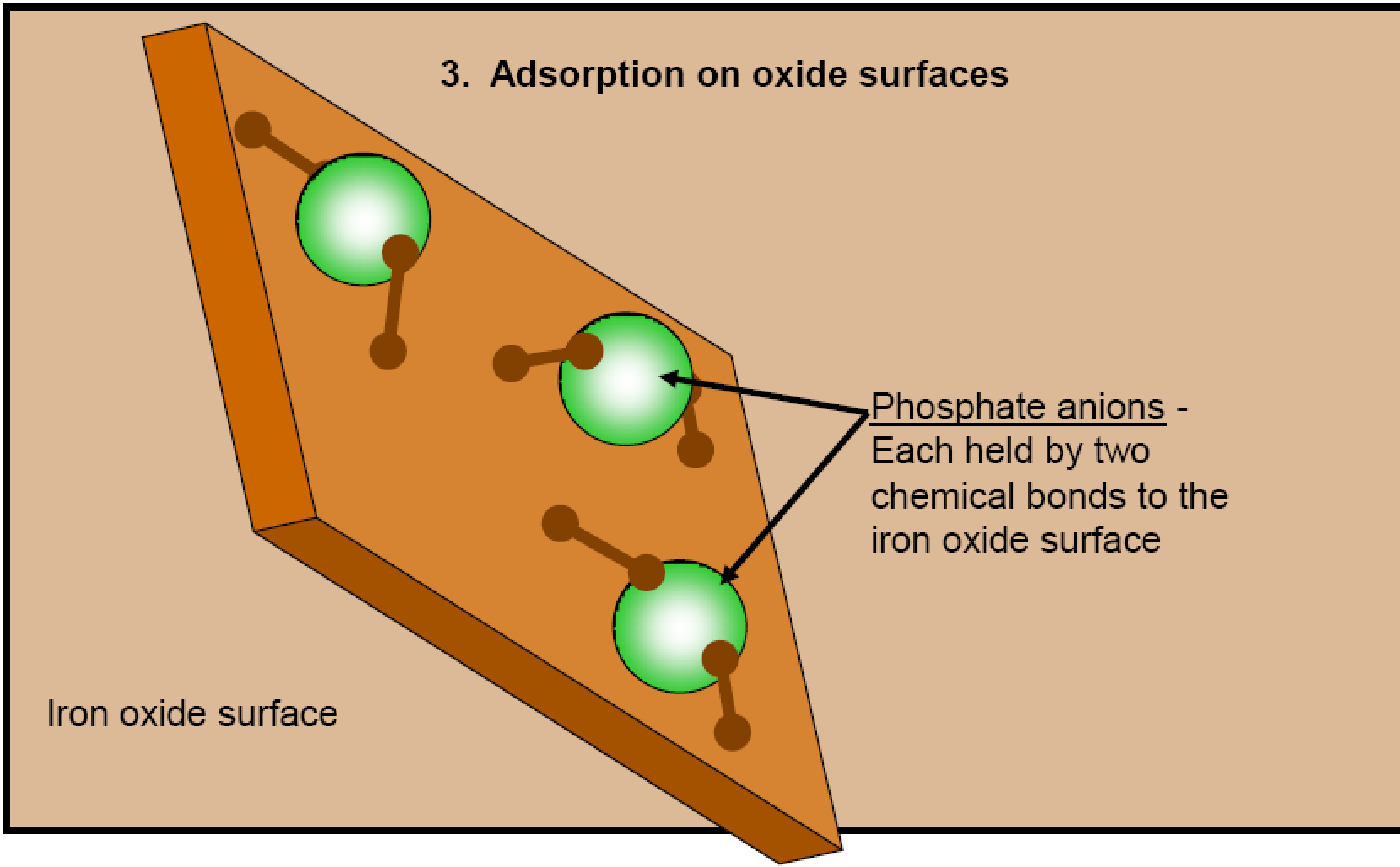
1. Formation of a new solid material



2. Anion exchange

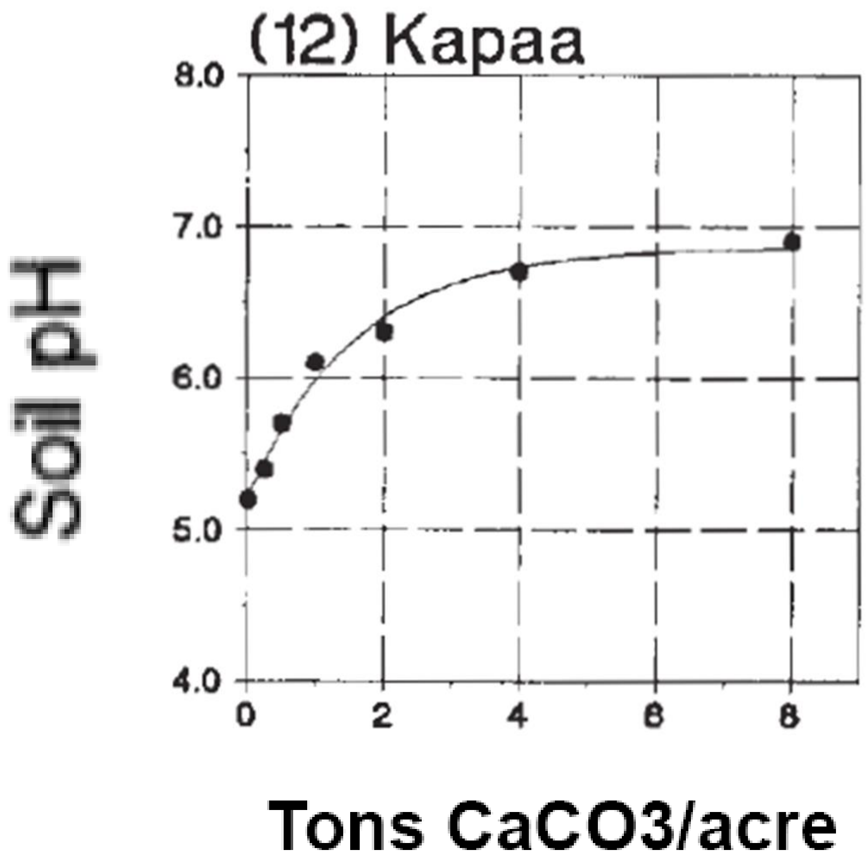


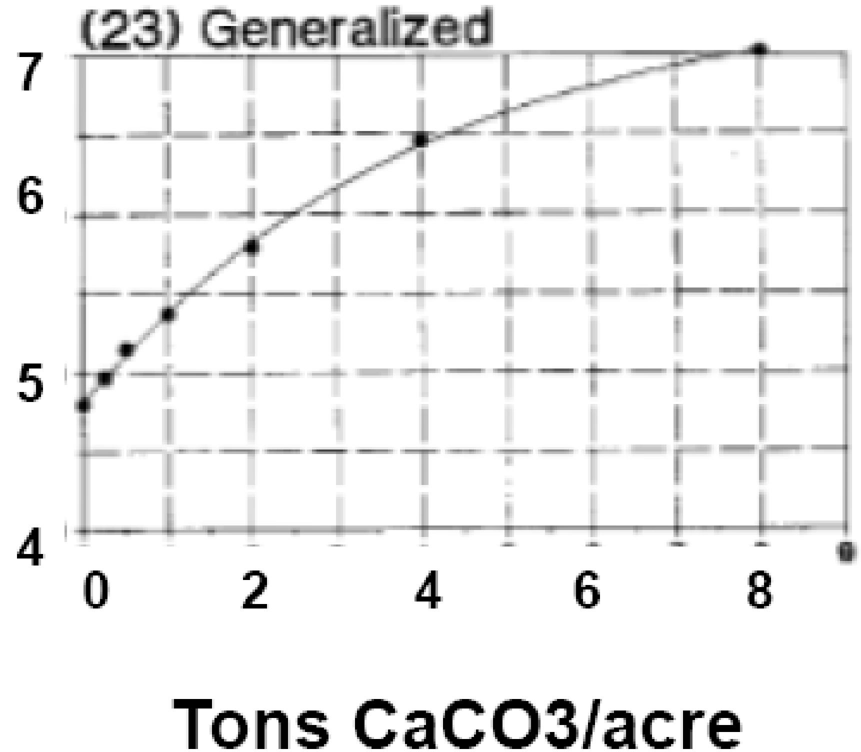
Phosphate retention in soil



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



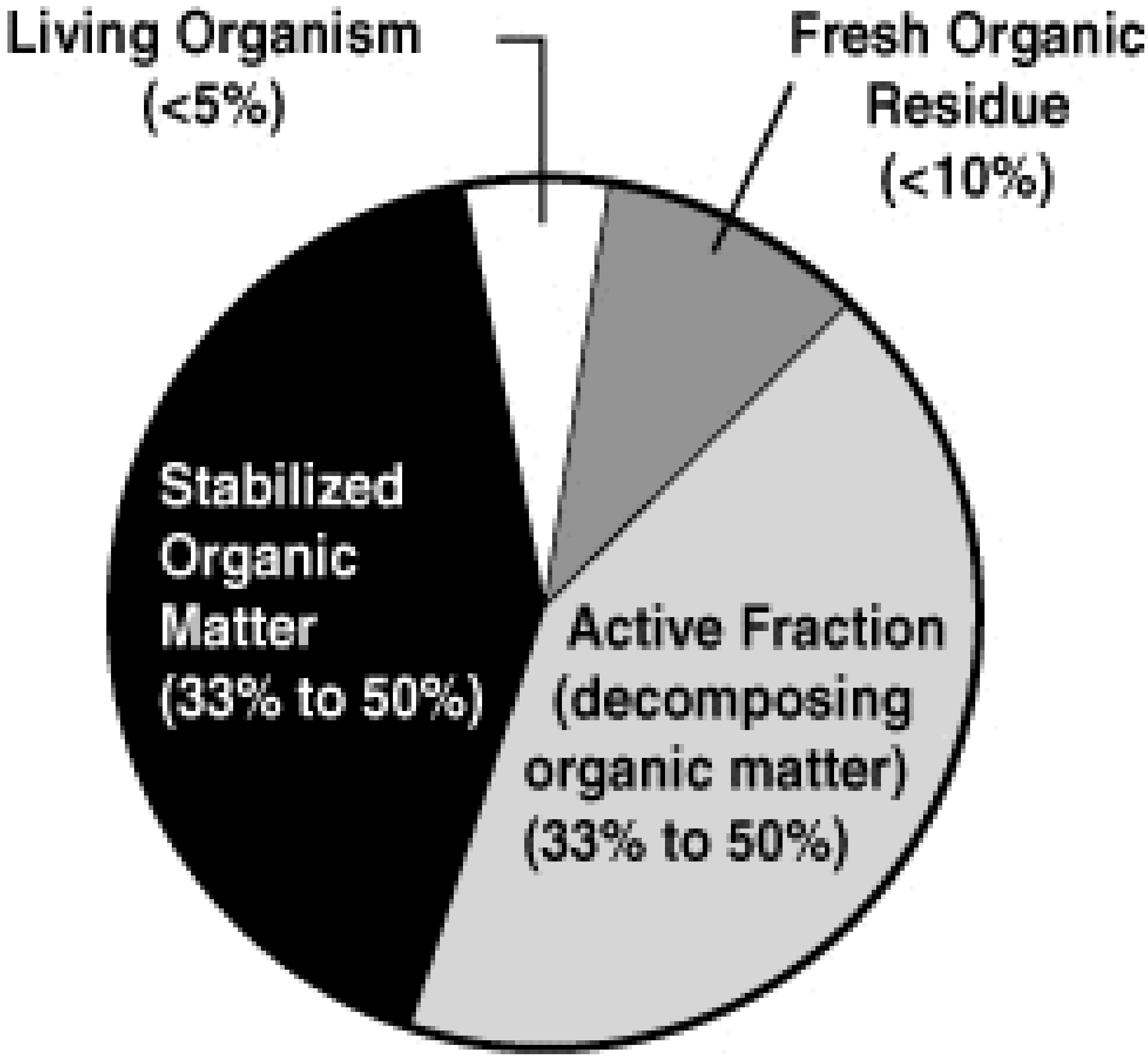


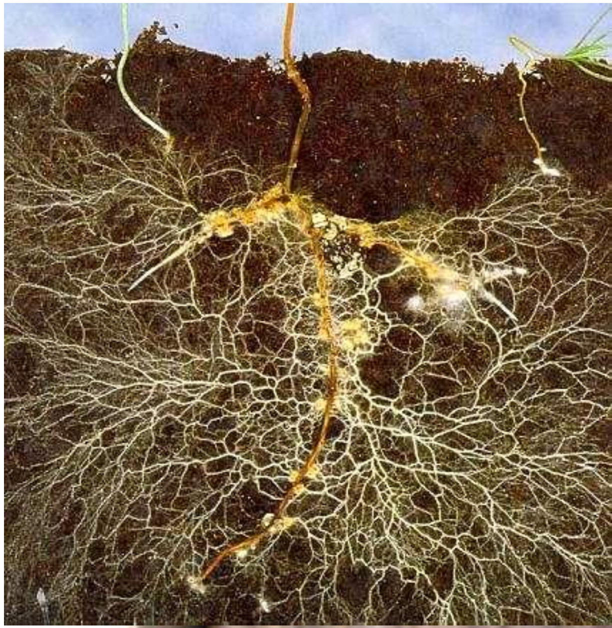
Liming curves for many soil series in Hawaii available online

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

Soil Organic Matter is the Primary Source of Fertility in Low Activity Clay Tropical Island Soils

Soil Organic Matter





Organic Matter Improves Soil Physical Properties

- OM promotes clay aggregation increasing H_2O infiltration and aeration
- OM decreases soil bulk density
- OM increases soil porosity
- OM increases water retention

Organic Matter Improves Soil Chemical Properties

- OM increases nutrient availability (N cycling, P and micronutrient solubility)
- OM increases CEC (200 cmolc kg-1)
- OM buffers the soil against pH changes
- OM detoxifies Al

Organic Matter Improves Soil Biology

- OM is the food for soil organisms
- OM increases microbial diversity
- Microbial diversity ensures nutrient cycling
- Microbial diversity promotes pathogen suppression through competition

Soil OM & Root Symbioses

Rhizobium

Mycorrhizae


Part II

Outline

- Diagnosis of Nutrient Deficiencies
- Soil tests
- Nutrient Management

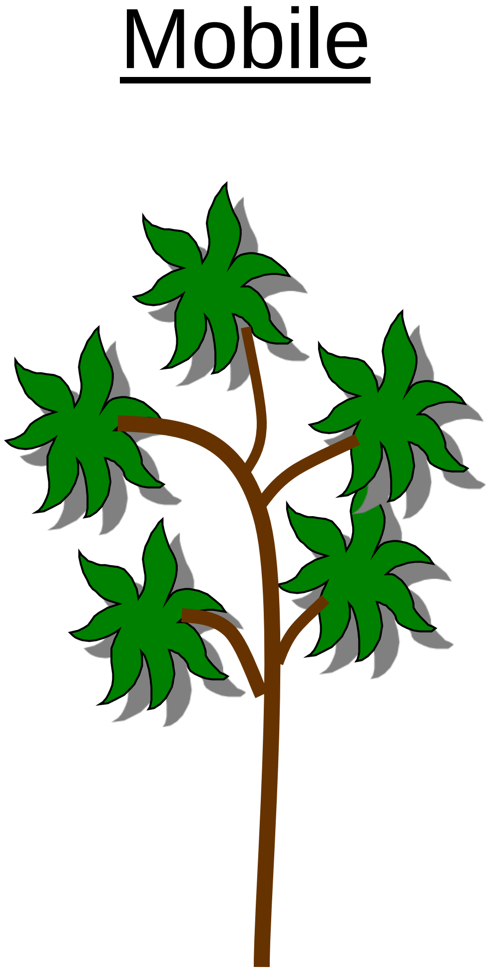
Essential Plant Nutrients

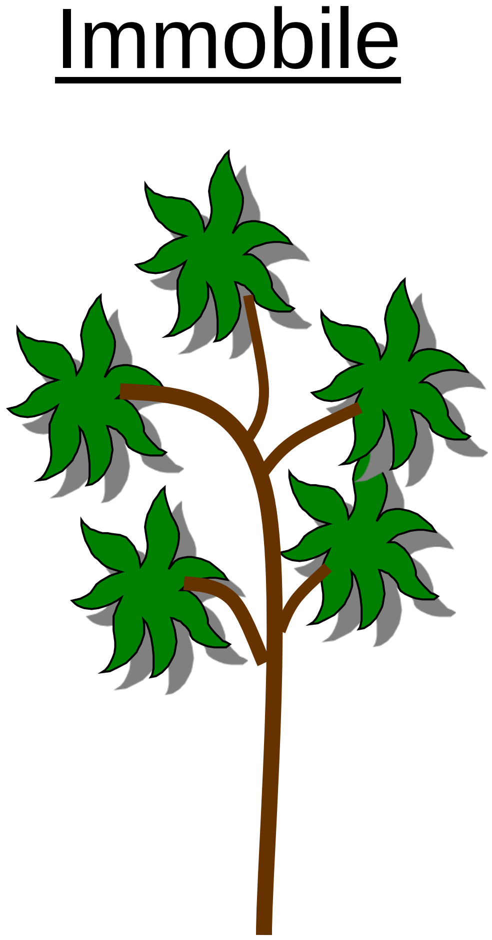
Macronutrients

Mineral/ Element	Chemical symbol	Main requirement/use by the plant
Macronutrients		
Nitrogen	N	Plant growth; proteins; enzymes; hormones; photosynthesis
Sulphur	S	Amino acids and proteins; chlorophyll; disease resistance; seed production
Phosphorus	P	Energy compounds; root development; ripening; flowering
Potassium	K	Fruit quality; water balance; disease resistance
Calcium	Ca	Cell walls; root and leaf development; fruit ripening and quality
Magnesium	Mg	Chlorophyll (green colour); seed germination

Micronutrients: B, Cu, Fe, Mn, Zn, Mo, Ni, Co, Cl

Nutrient Mobility in Plants





Nutrient Deficiency Symptoms in Plants

9 Nutrient Management Module No. 9

CCA
1.5 NM
CEU

Plant Nutrient Functions and Deficiency and Toxicity Symptoms

by Ann McCauley, Soil Scientist;
Clain Jones, Extension Soil Fertility Specialist; and
Jeff Jacobsen, College of Agriculture Dean

Introduction

This module is the ninth in a series of extension materials designed to provide extension agents, Certified Crop Advisers (CCAs), consultants, and producers with pertinent information on nutrient management issues. To make the learning 'active,' and to provide credits to CCAs, a quiz accompanies this module. In addition, realizing that there are many other good information sources including previously developed extension materials, books, web sites, and professionals in the field, we have provided a list of additional resources and contacts for those wanting more in-depth information about plant nutrient functions and deficiency and toxicity symptoms.

Objectives

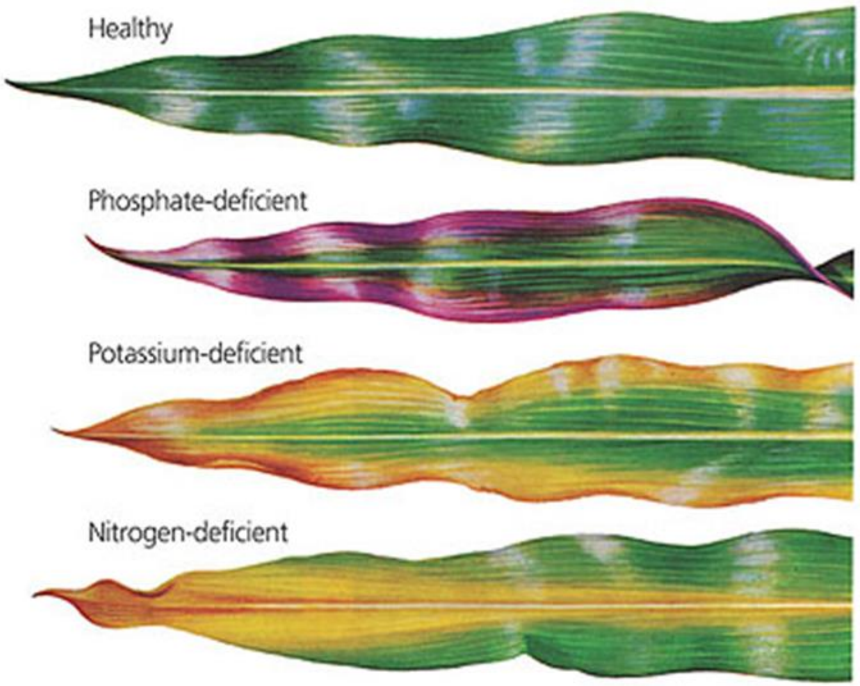
After reading this module, the reader should be able to:

1. Identify and diagnose common plant nutrient deficiency and toxicity symptoms
2. Know potential limitations of visual diagnosis
3. Understand how to use a key for identifying deficiency symptoms
4. Distinguish between mobile and immobile nutrient deficiencies

Nutrient Management

a self-study course from the MSU Extension Service Continuing Education Series

MONTANA STATE UNIVERSITY
EXTENSION
4449-9
May 2009



http://landresources.montana.edu/NM/Modules/Module9.pdf

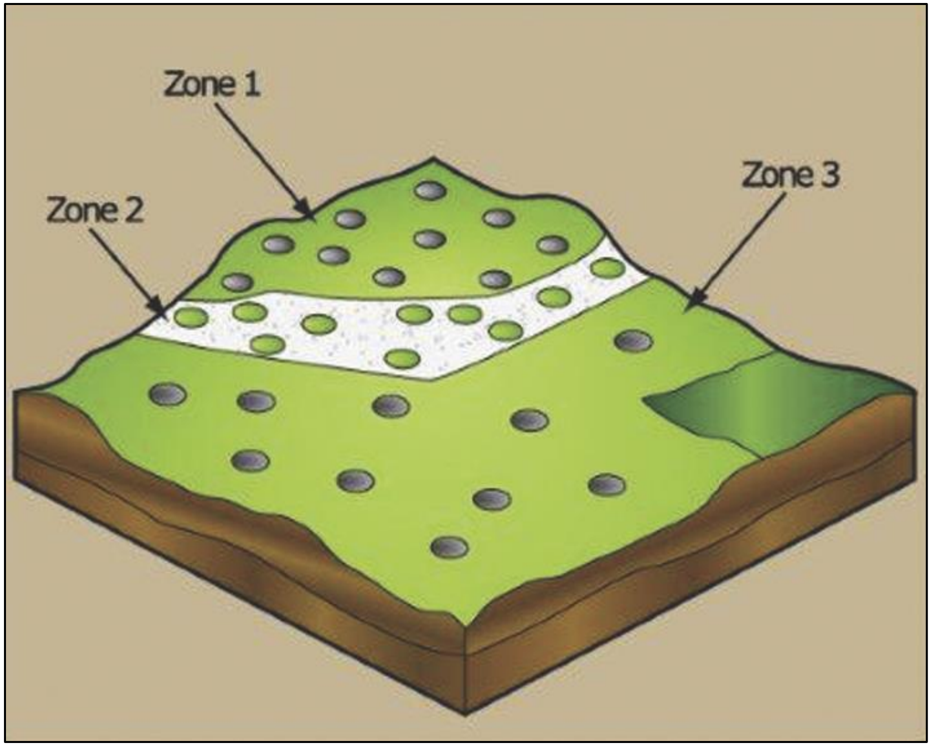
Soil Tests

What is a soil test?

- a dilute extracting solution that removes “plant available” nutrients.
- extractant is chosen depending on soil chemical properties.
- extractant does <u>not</u> measure total nutrient content
- Result of soil test is the basis for fertilizer recommendation

Collecting a Soil Sample

- Separate sample for distinct management area
- Sample the root zone (0-6" or 0-12")
- Collect multiple samples
  - Samples can be composited

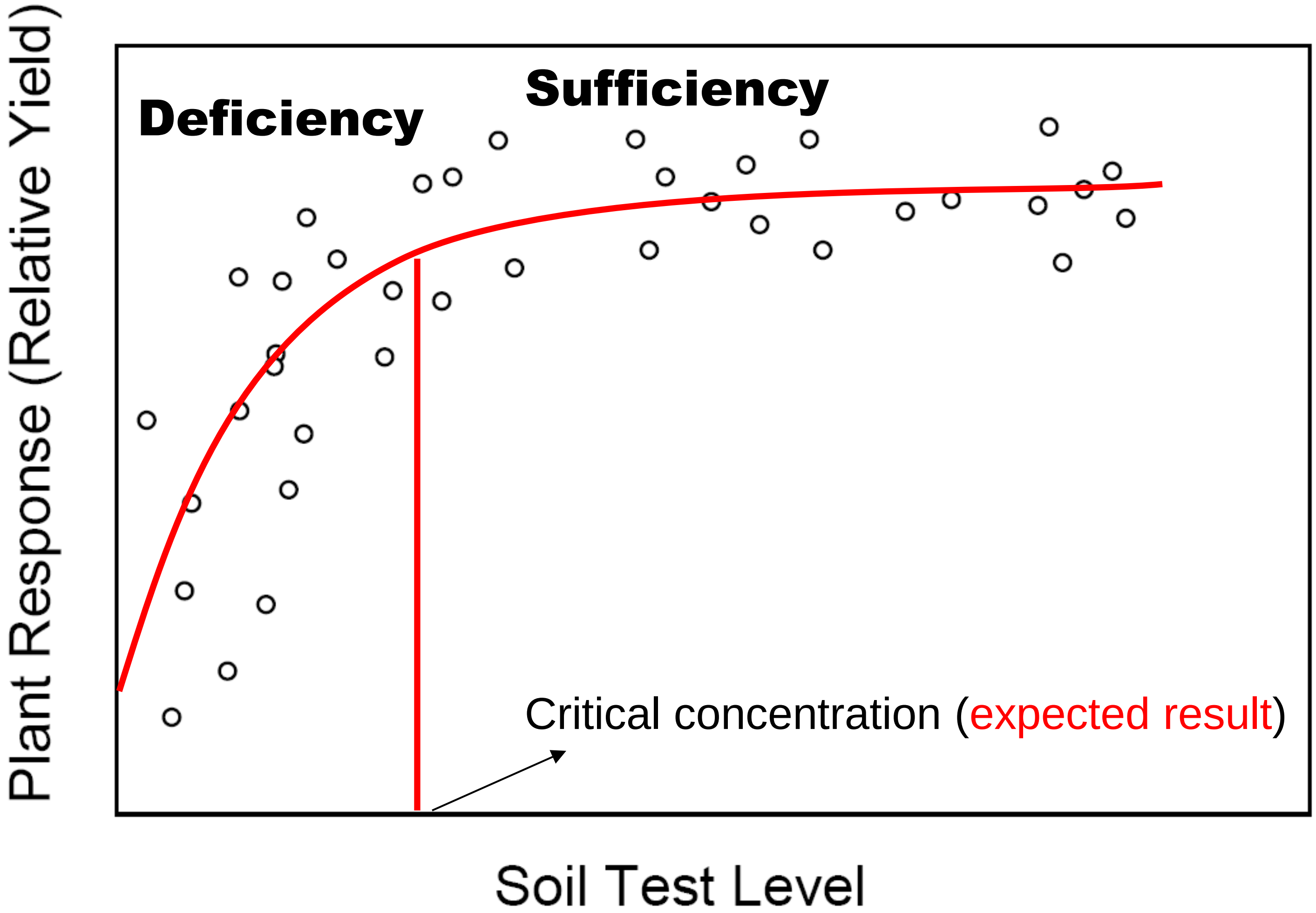


Soil Testing

- Most common method of predicting nutrient deficiencies/toxicities

- Can be used
  - to identify yield limiting factors
  - to indicate soil nutrient supply capacity
  - as part of a nutrient management plan
  - to monitor soil fertility trends over time
  - to manage risk

Soil Test Calibration



Soil Test Printout

CTAHR
College of Tropical Agriculture & Human Resources
University of Hawaii at Manoa

Soil/Plant Analysis Report

Agricultural Diagnostic Service Center
Department of Agronomy and Soil Science
1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-6706/7980 FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Date Reported: 03/15/2006

Client:	PUA LEHUA FARM P.O. Box 959 Attn: Eric Schott Honokaa, Hawaii 96727	Agent:	SATO, DWIGHT, Office: HILO 875 KOMOHANA STREET HILO, HI 96720 981-5199, Fax: 981-5211

Sample Information

Job Control No:	06-036767-001	Map Unit:	KuC	Plant Grown:	OTHER CROP
Sample Label:	1	Soil Series:	KUKAIAU	Plant to be grown:	OTHER CROP
Date Received:	3/15/1906	Soil Category:	LIGHT SOIL	Can you till 4~6 in.?	Yes
Send Copy To		Soil Depth (in):		Test Results Only?	No
Elevation (ft.):		Latitude:		Longitude:	

Test Results and Interpretation

LIGHT SOIL — INTERPRETATION

Soil Analysis	Results	Expected	Very Low | Low | Sufficient | High | Very High
pH	6.8	6.15	
P_ppm	2002	67.5	
K_ppm	374	300	
Ca_ppm	4488	3500	
Mg_ppm	649	700	
OC_%		No criteria found	
Total_N_%		No criteria found	
Salinity_EC		1.25	
S_ppm		No criteria found	
Fe_ppm	48	No criteria found	
Mn_ppm	14	No criteria found	
Zn_ppm	7.9	No criteria found	
Cu_ppm	9.7	No criteria found	
B_ppm		No criteria found	
Mo_ppm		No criteria found	
Al_ppm		No criteria found	

OTHER CROP — INTERPRETATION

Plant Analysis	Results	Expected	Very Low | Low | Sufficient | High | Very High
N_%		No criteria found	
P_%		No criteria found	
K_%		No criteria found	
Ca_%		No criteria found	
Mg_%		No criteria found	
S_%		No criteria found	
Fe_ppm		No criteria found	
Mn_ppm		No criteria found	
Zn_ppm		No criteria found	
Cu_ppm		No criteria found	
B_ppm		No criteria found	
Mo_ppm		No criteria found	
Al_ppm		No criteria found	
NO3_ppm		No criteria found	

Page 1 of 2

Job Control No: 06-036767-001

Problem Description

Peppers to be grown.

Fertilizer and Lime Recommendations

Total Nutrient Requirement (lbs/Acre):	Nitrogen: 175	Phosphorus: 0	Potassium: 0
Fertilizer / Lime Material	Total Amount (lbs/Acre)	Applications	Cost Estimate ($/Acre)
Fertilizer: 46-0-0	389	split into 2 applns.	82

Comments

---- GENERAL INFORMATION ----

o Knowing levels of sulfur and micronutrients in plants is also important. For proper diagnosis, tissue analysis is needed.
o Split the fertilizer into several applications, at planting and thereafter once every 3~4 weeks until the total amount has been applied.
o We recommend that you adopt a nutrient monitoring approach by retaining this sample report for comparison with future samples.

NOTE:

The interpretations are based on Fact Sheet No. 3 "Adequate Nutrient Levels in Soils and Plants in Hawaii."
To help improve future recommendations, please answer the following questions, photocopy this form and return it to above address.
1. Did you need to modify the recommendation? if so, how?
2. Did your plants improve? Please give unit area yield before and after the recommendation was applied.

FEEDBACK

Page 2 of 2

Soil Test Printout

Test Results and Interpretation

LIGHT SOIL

Soil Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
_pH	5.6	6.15					
P_ppm	9.8	67.5					
K_ppm	223	300					
Ca_ppm	795	3500					
Mg_ppm	280	700					
OC_%		No criteria found					
Total_N_%		No criteria found					
Salinity_EC		1.25					

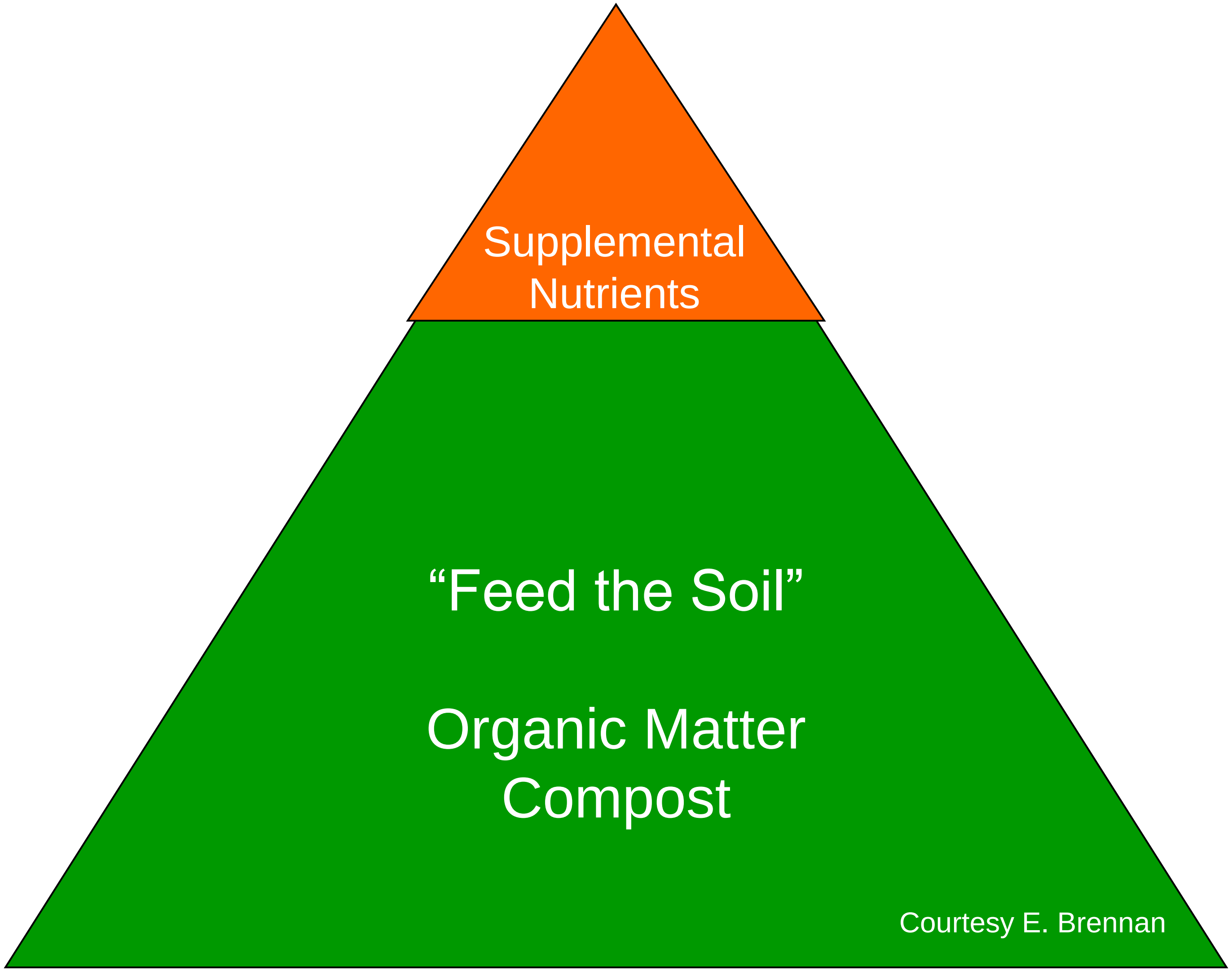
INTERPRETATION

Fertilizer and Lime Recommendations

Total Nutrient Requirement (lbs/Acre): Nitrogen: 300 Phosphorus: 989 Potassium: 92

Fertilizer / Lime	Material	Total Amount (lbs/100sq-ft.)	Applications	Cost Estimate ($/100sq-ft.)
Fertilizer:	10-30-10	6.88	split into 5 applns.	1.38
Lime Material:	Dolomite	3.33	split into 1 applns.	0.734
Ca Material:	Gypsum	16.5	split into 1 applns.	2.98
Mg Material:	Mg-Sulfate	4.52	split into 1 applns.	1.81

Management for Soil Quality



Compost

- Improves physical, chemical, and biological properties
- Need to add in large quantities (> 20 T/acre)
- Relatively low N content (< 2.0%)
- Slow-release nutrients

http://compost.tamu.edu/demos/palopinto/compost.jpg

Benefits of Compost

Soil Physical Properties

1. Improves soil structure
2. Reduces soil density
3. Increases porosity
4. Increases water infiltration
5. Increases water retention

Soil Chemical Properties

1. Reduces negative effects of acidity
2. Increases nutrient supply
3. Increases nutrient retention
4. Buffers soil

Soil Biological Properties

1. Increases microbial abundance and diversity
2. Promotes natural nutrient cycles
3. Increases soil health and resilience

Applying Compost

- Most of N is stabilized in organic forms, only ≈10% N available in first crop cycle
- High compost rates required to supply total crop N requirement initially (i.e., > 40 tons/acre)
- Compost applications build soil organic matter increasing residual N release over time (N release rate difficult to predict)

N Fertilizers

<u>Organic</u>

- Fish meal (≈10% N)
- Feather meal (12 - 13% N)
- Chicken manure (≈3% N)

<u>Conventional</u>

- Urea (46-0-0)
- Ammonium sulfate (21-0-0)
- 16-16-16
- Calcium nitrate
- Potassium nitrate

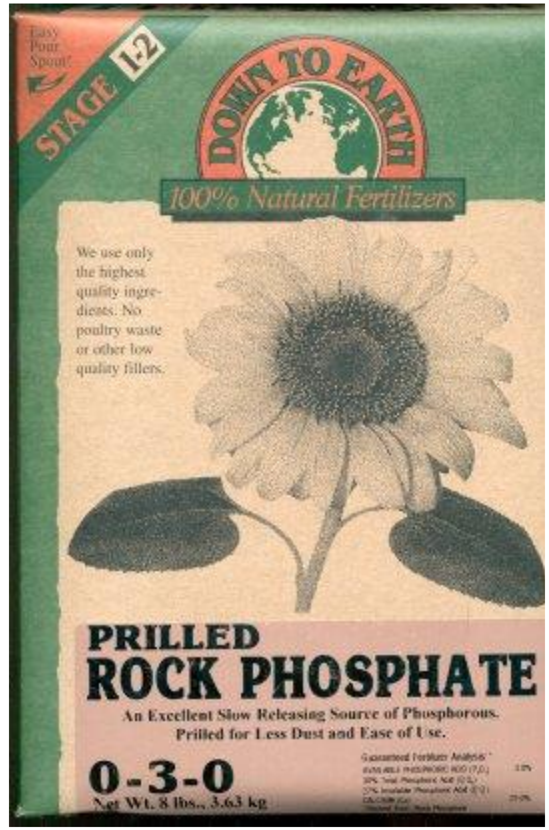
P Fertilizers

Organic

- Bone meal (≈12-15% P)
- Rock phosphate (2-5% P)
- Chicken manure (2-3% P)

Conventional

- TSP (0-45-0)
- DAP (18-46-0)
- 10-30-10



K Fertilizers

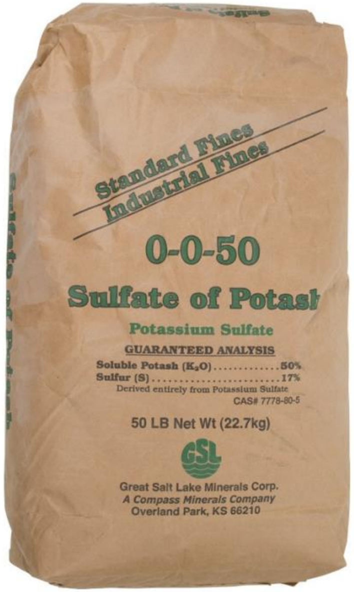
Organic

- Hardwood ashes
- Seaweed
- Sulfate of potash (0-0-50)

Conventional

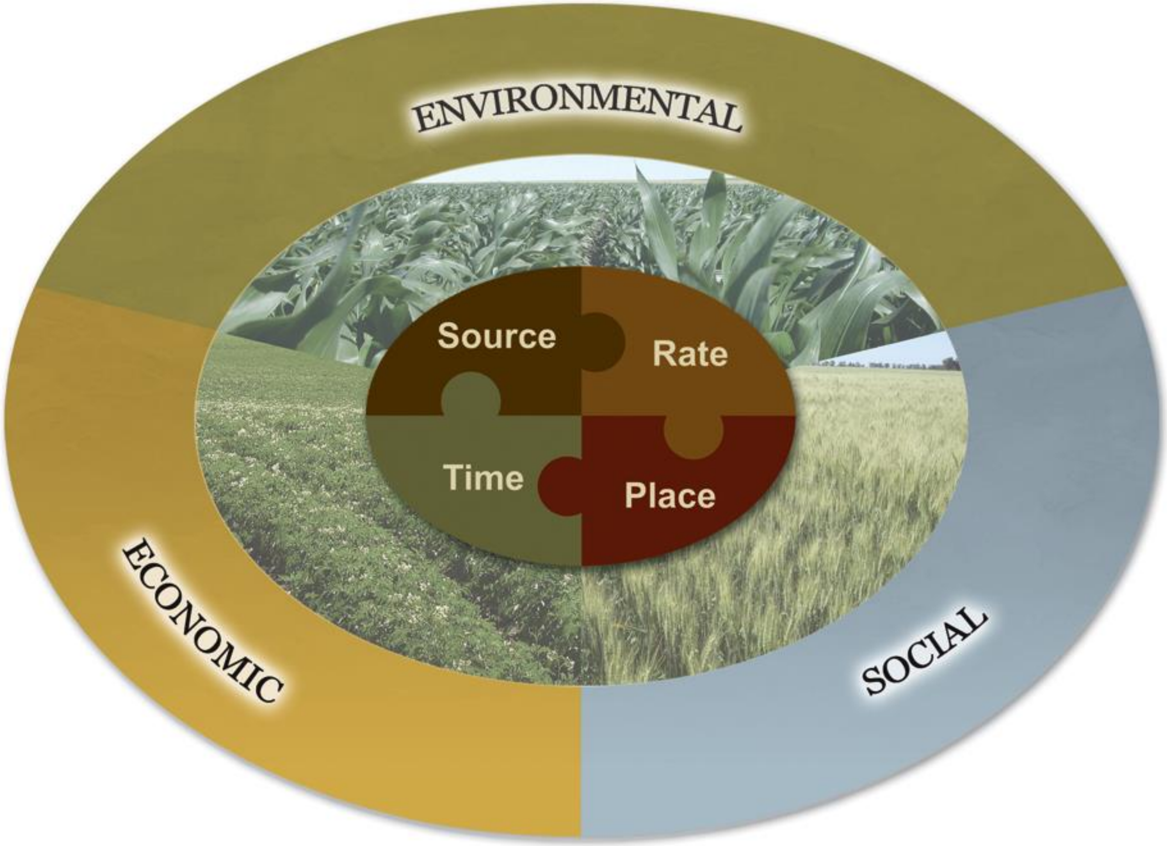
- Muriate of potash (0-0-60)

Hardwood ashes



4R Nutrient Stewardship Concept

1. Right Source
   - What type of fertilizer?
2. Right Rate
   - How much?
3. Right Time
   - When & How often?
4. Right Place
   - Where?



Scientific Principles

	The Four Rights (4Rs)			
	Source	Rate	Time	Place
Key Scientific Principles	• Ensure balanced supply of nutrients • Suit soil properties	• Assess nutrient supply from all sources • Assess plant demand	• Assess dynamics of crop uptake and soil supply • Determine timing of loss risk	• Recognize crop rooting patterns • Manage spatial variability

Practical Choices

	The Four Rights (4Rs)			
	Source	Rate	Time	Place
Practical Choices	• Commercial fertilizer • Livestock manure • Compost • Crop residue	• Test soils for nutrients • Calculate economics • Balance crop removal	• Pre-plant • At planting • At flowering • At fruiting	• Broadcast • Band/drill/inject • Variable-rate application

- Ensure practices are in accord with principles

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!