

Understanding and Managing the Soils of Kona



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Soil Nutrient Management for Maui County

College of Tropical Agriculture and Human Resources (CTAHR)

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Soil Basics

Soils of Maui

Nutrient Management

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Home

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.

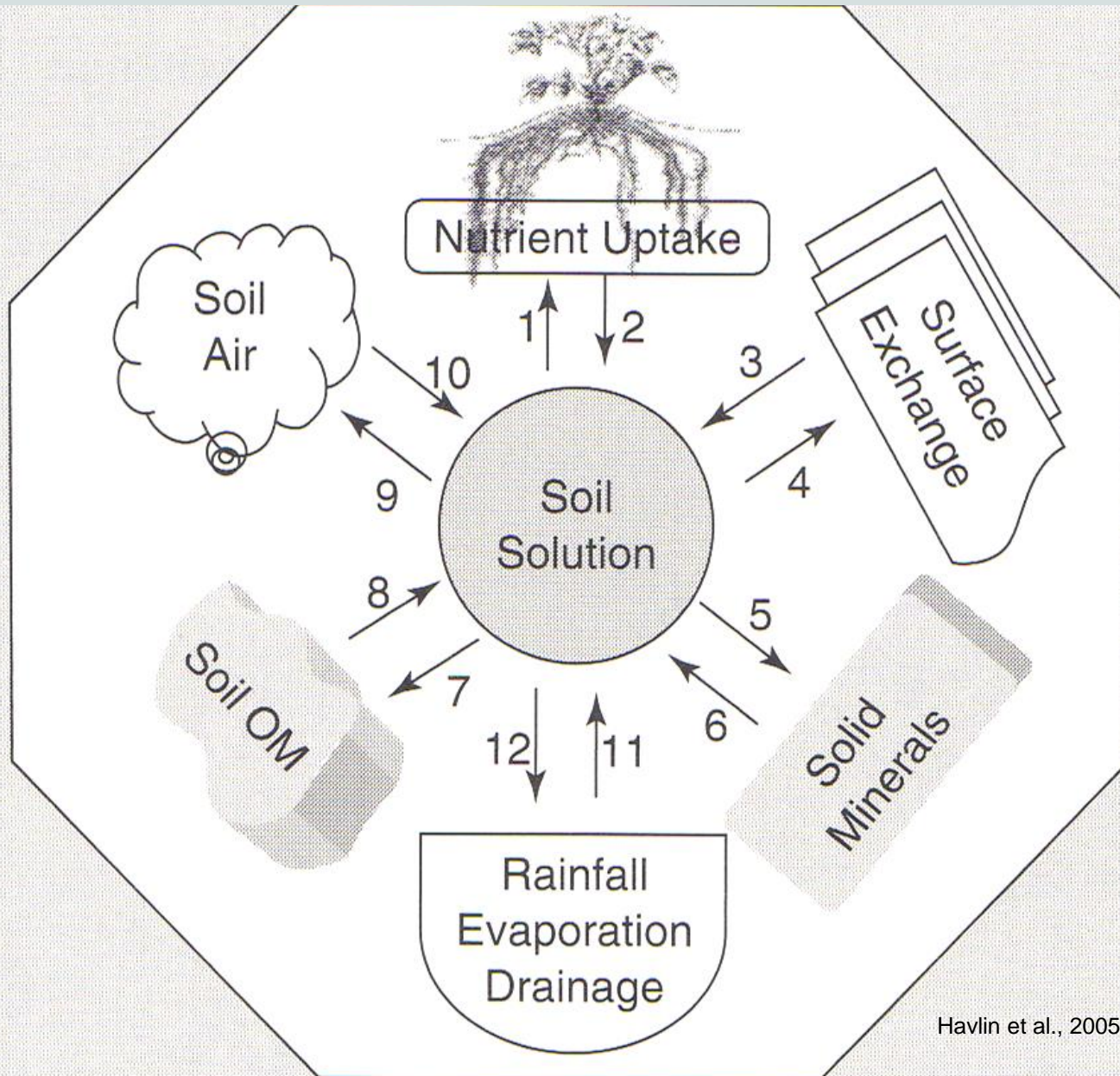
<http://www.ctahr.hawaii.edu/mauisoil/>

Outline

- Importance of Soils
- Soil Diversity
- Clay Minerals and Soil Behavior
- Soil Acidity/Alkalinity
- Soil Organic Matter
- Soil Management



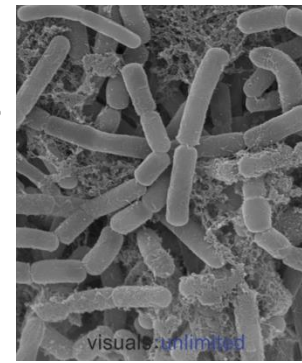
Soil Plant Relationships



Medium for
Plant growth



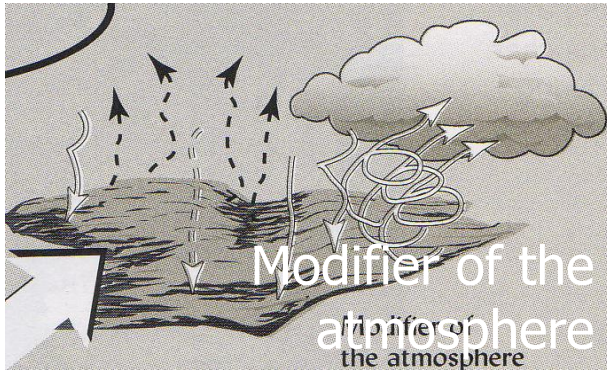
Habitat for
Soil organisms



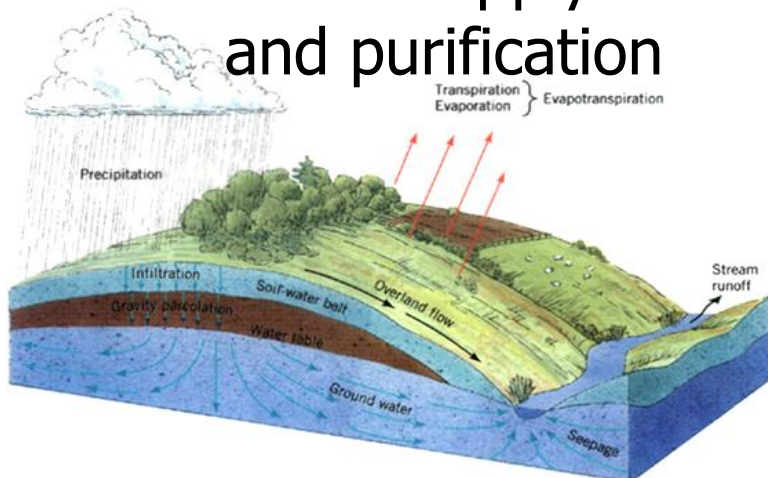
Recycling
system



6 Functions
of Soil

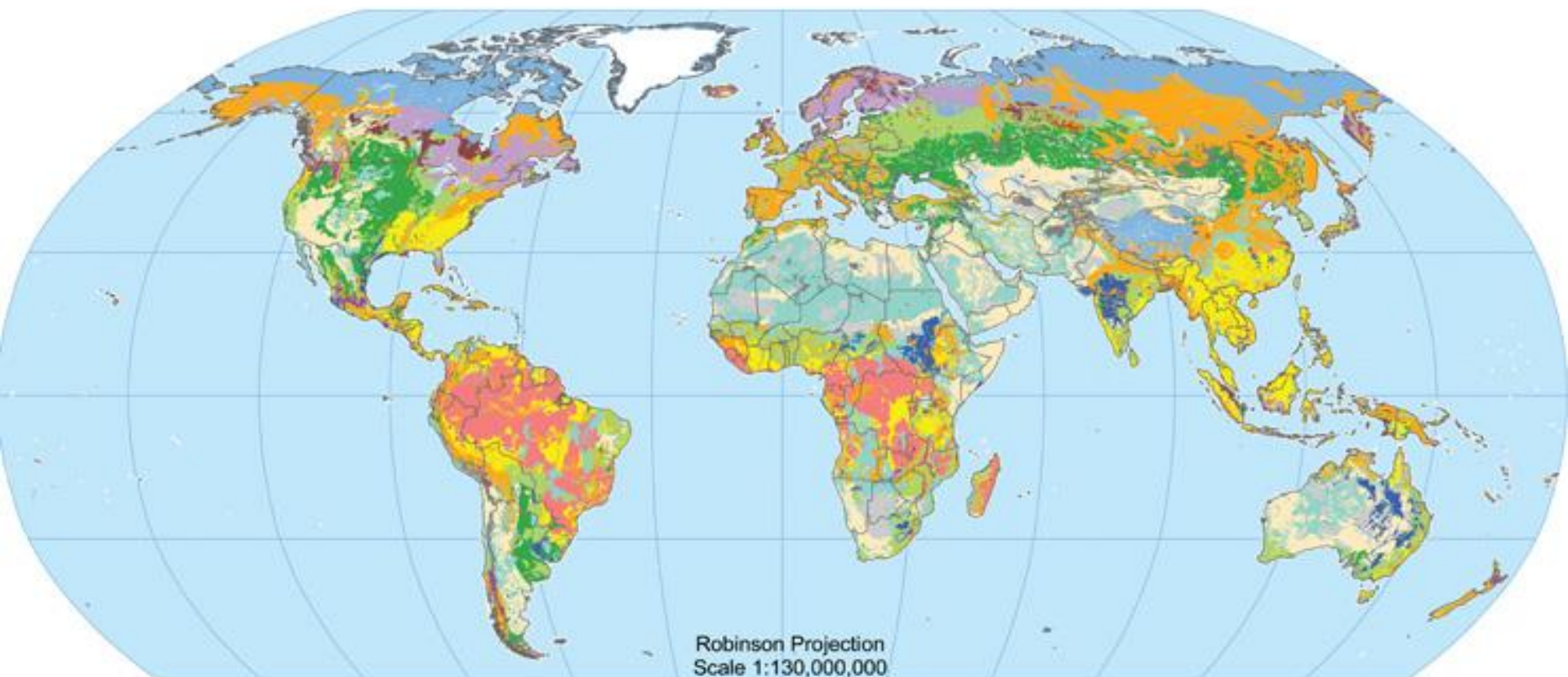


Water supply
and purification



Engineering Medium

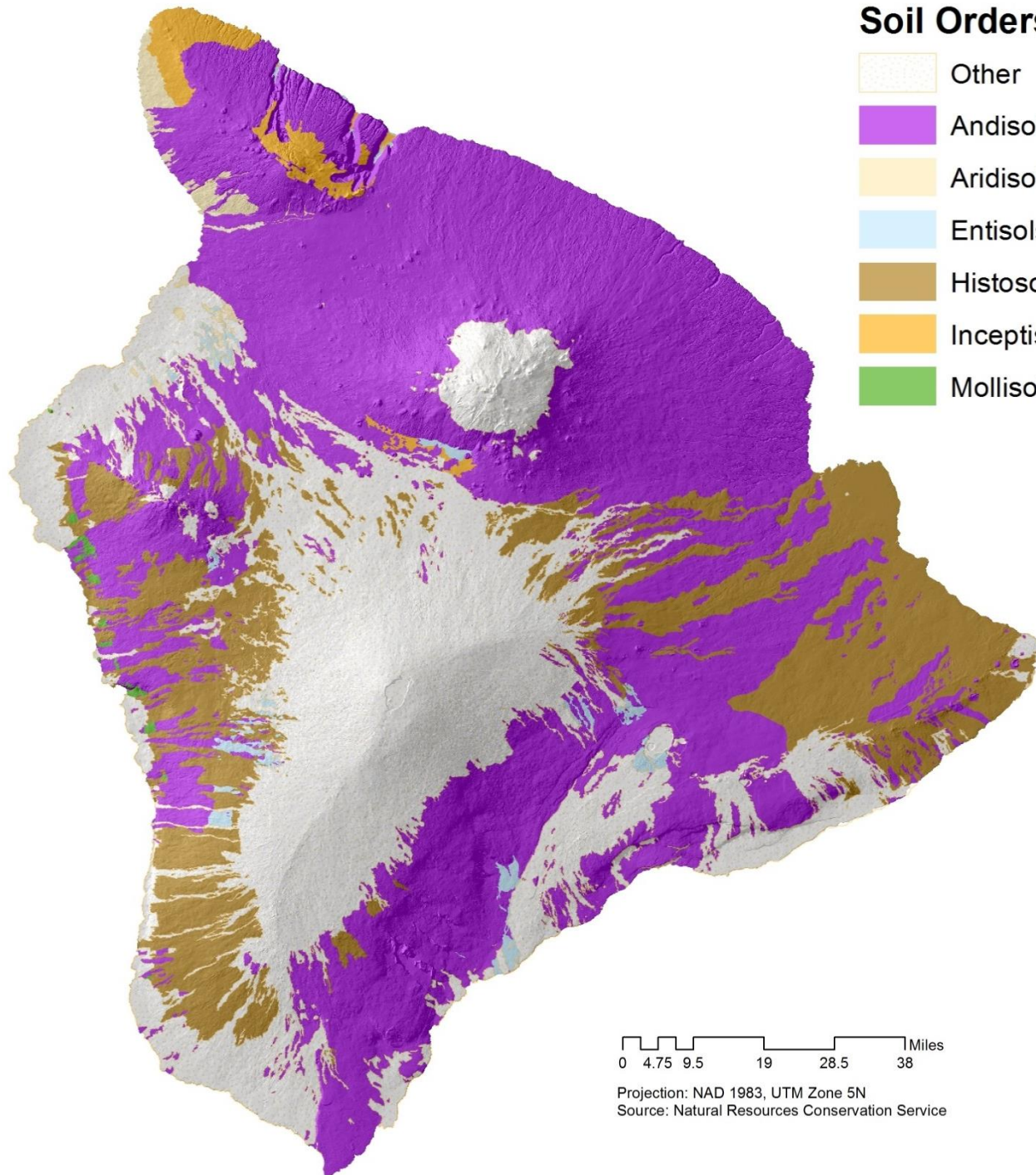
Global Soil Regions



Soil Orders

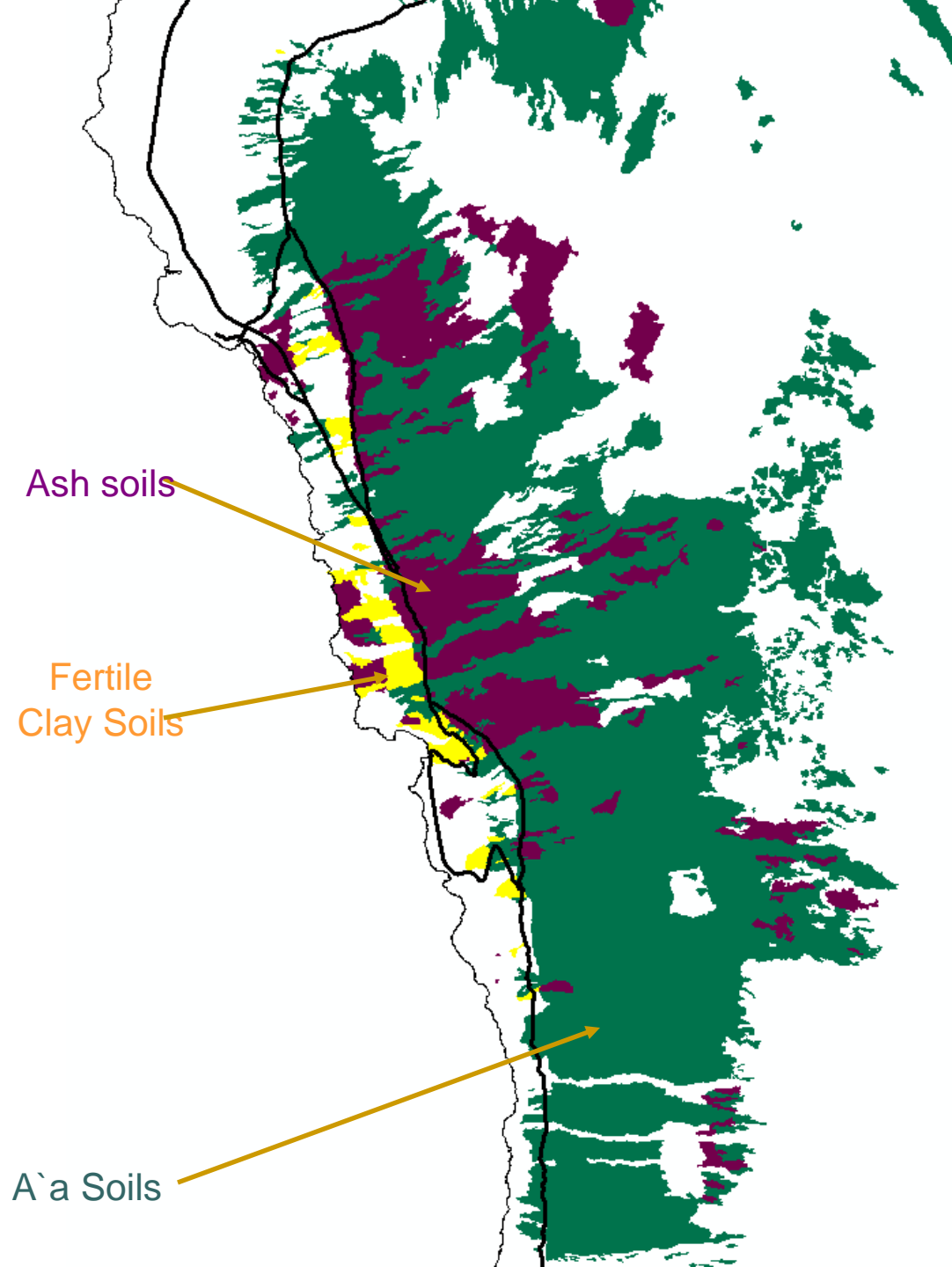
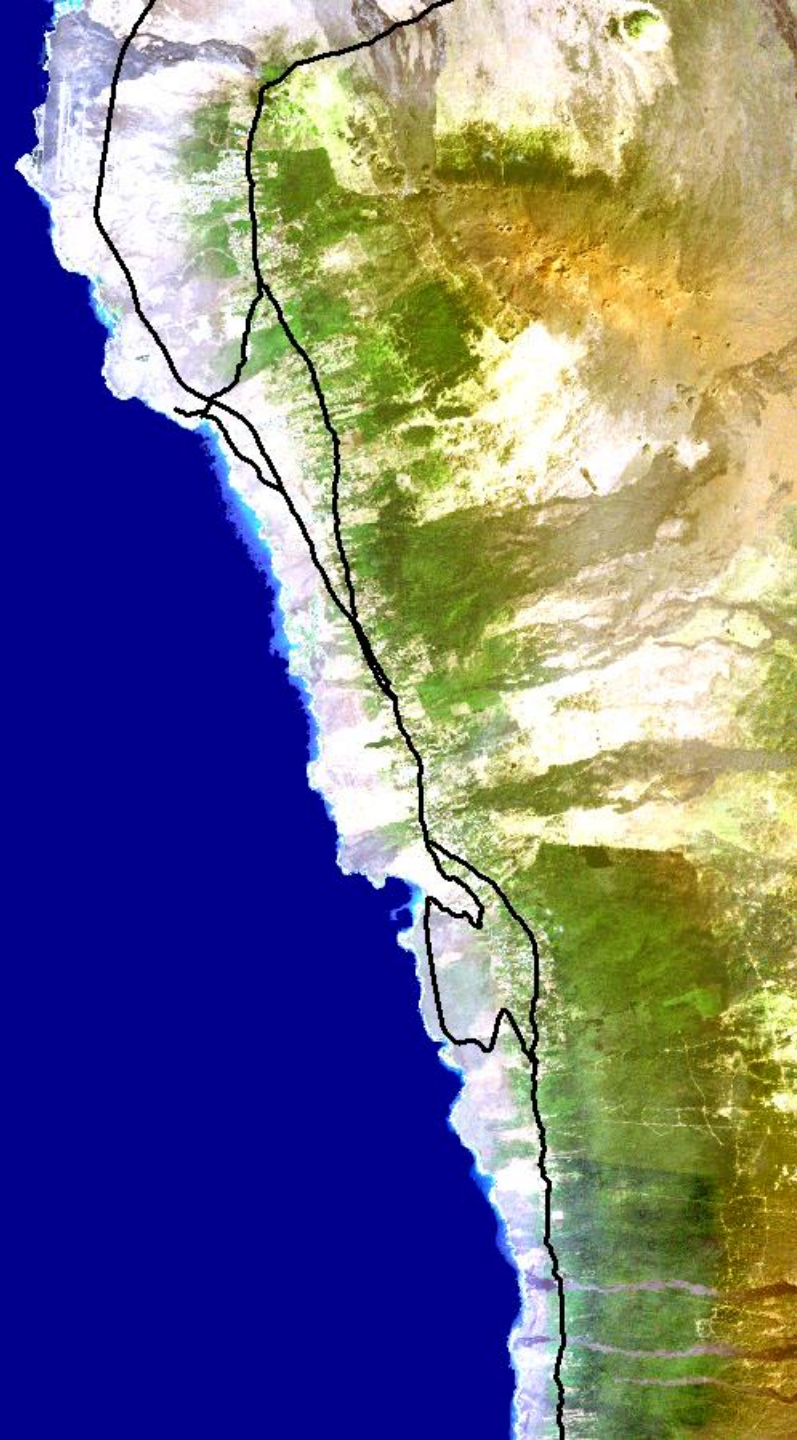
Alfisols	Entisols	Inceptisols	Spodosols	Rocky Land
Andisols	Gelisols	Mollisols	Ultisols	Shifting Sand
Aridisols	Histosols	Oxisols	Vertisols	Ice/Glacier

Soil Orders



0 4.75 9.5 19 28.5 38 Miles

Projection: NAD 1983, UTM Zone 5N
Source: Natural Resources Conservation Service



Soil Formation

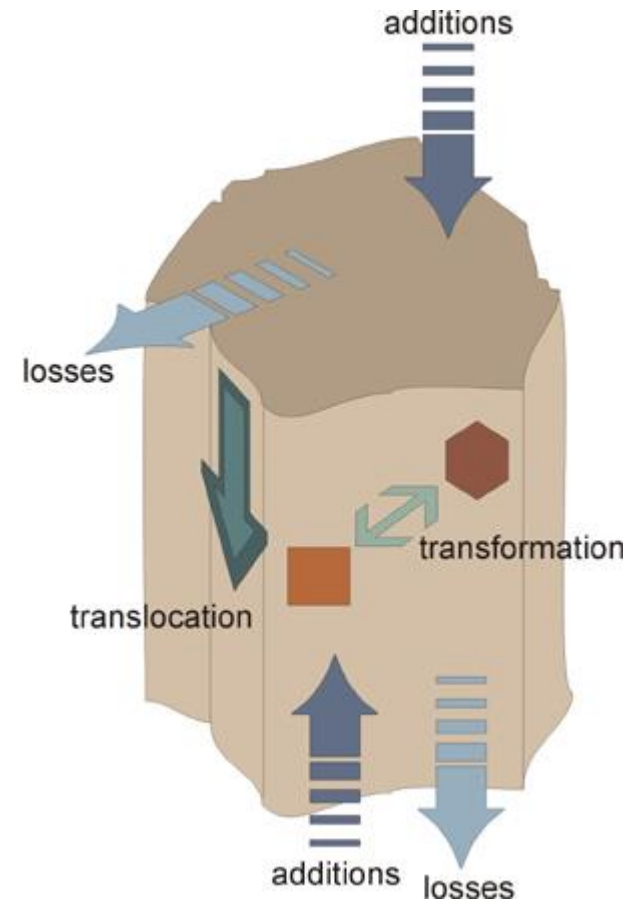


Factors

- Parent material
- Age
- Climate
- Biota
- Topography

Processes

- Additions
- Transformations
- Translocations
- Losses

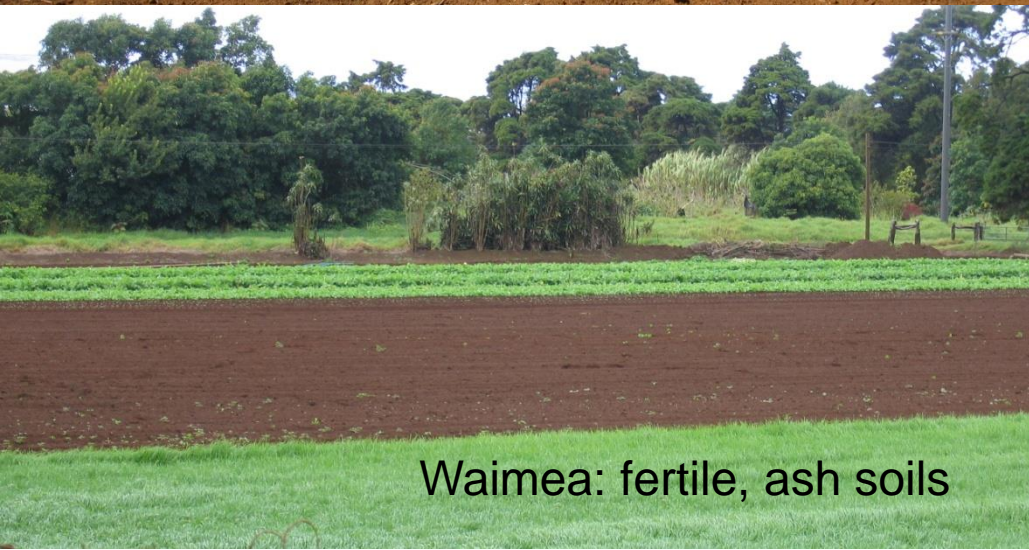


Soil Diversity

Hamakua: infertile ash soil



Kohala: fertile clay soils
infertile ash soils

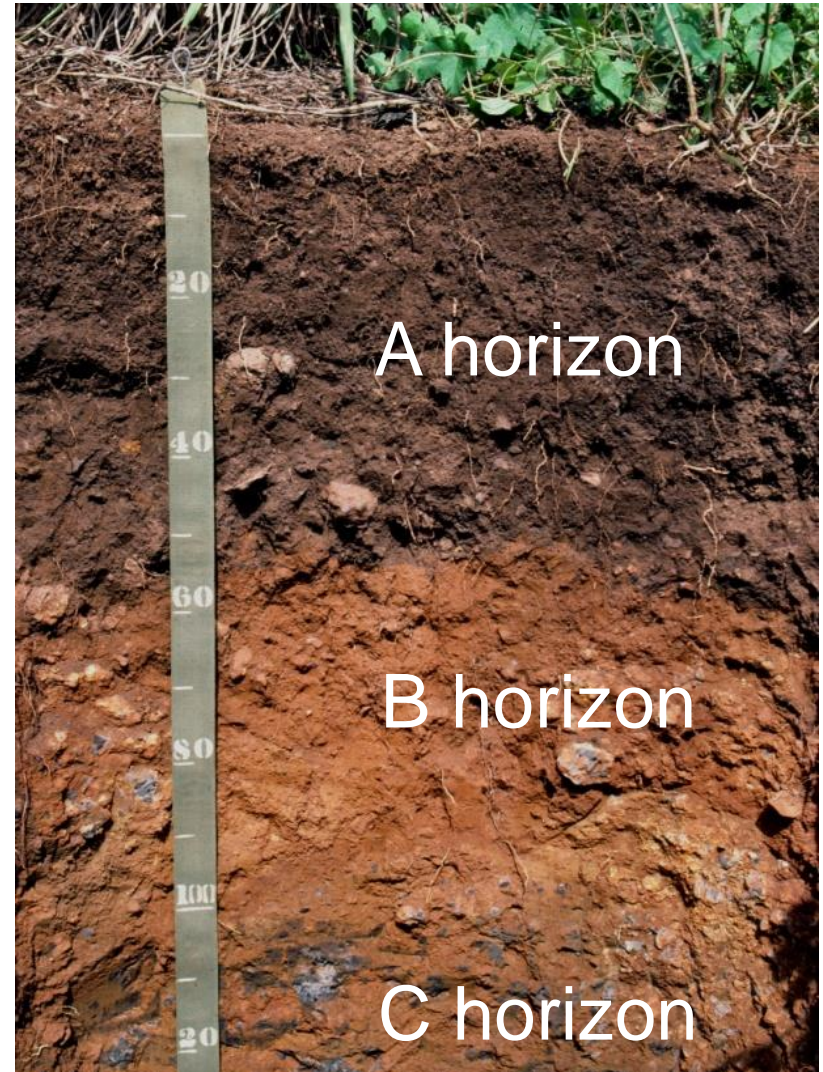
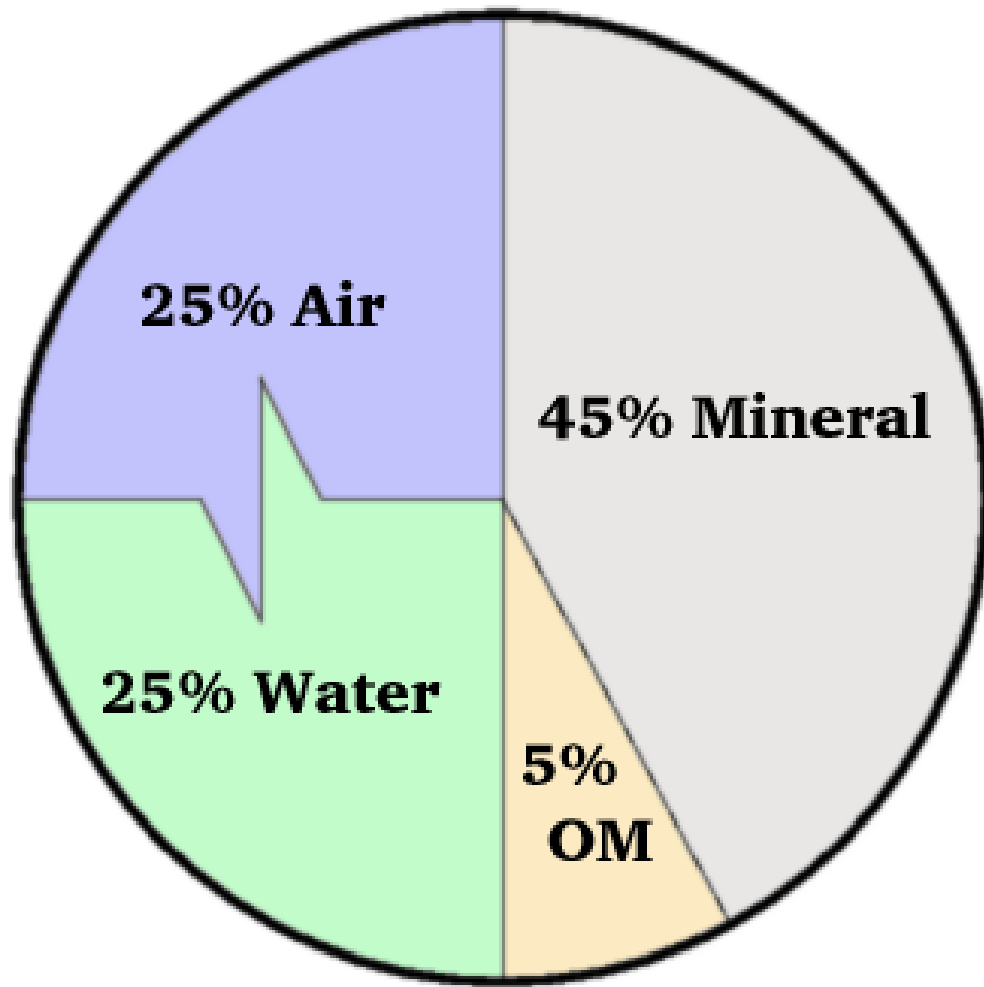


Waimea: fertile, ash soils

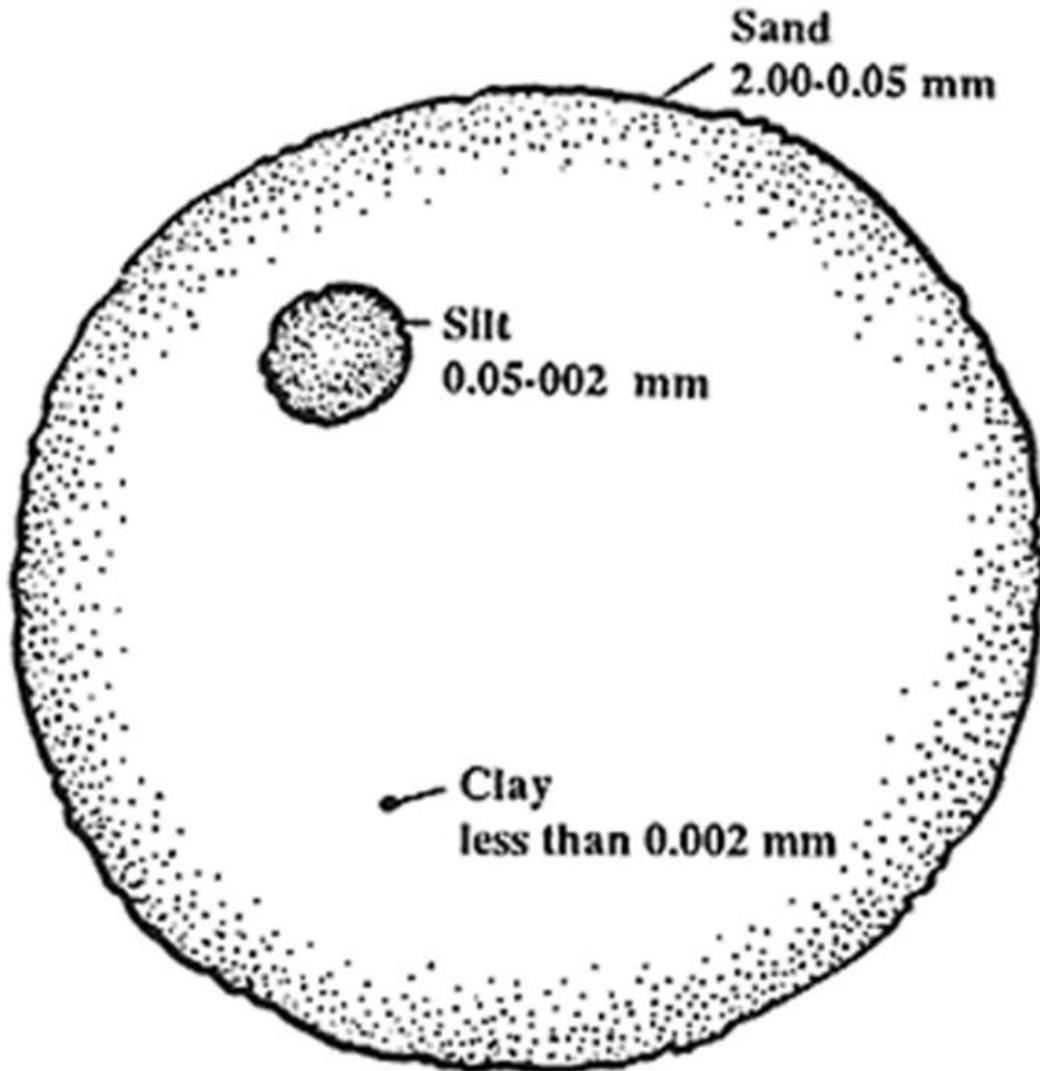


Puna/ka`u: a'a/pahoehoe soils

What is Soil?



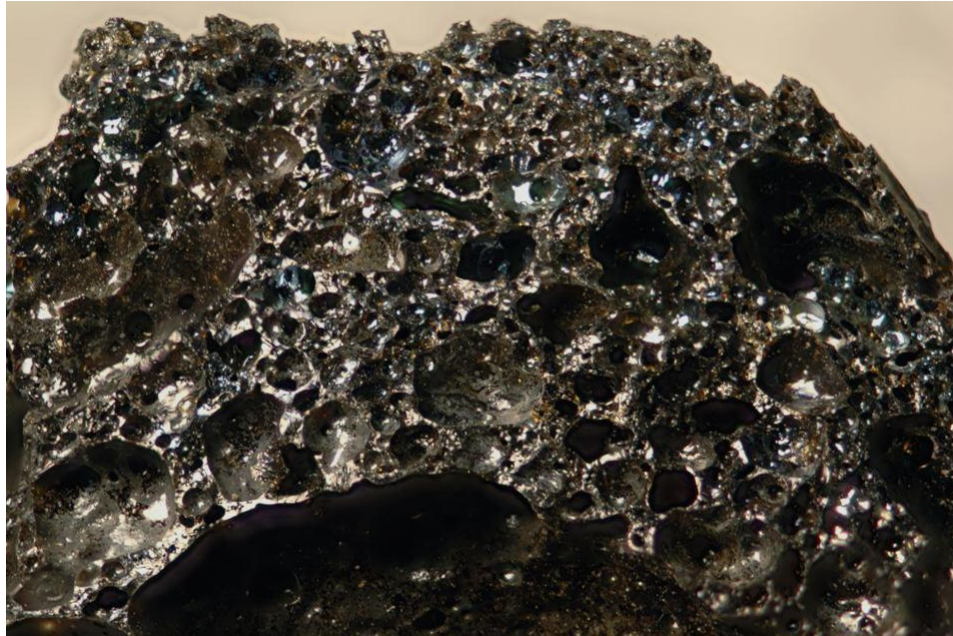
Soil Texture



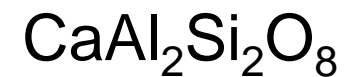
Clay Properties:

- Microscopic size (<0.002 mm)
- Extremely high surface area
 - water retention
 - chemical reactions
 - biological activity
- Clay surfaces carry charge (-/+)

Weathering of Parent Rock

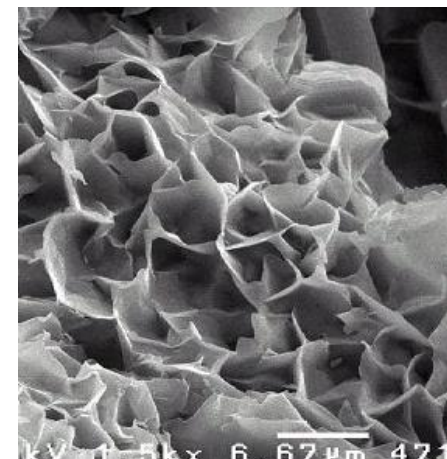


Chemical Weathering



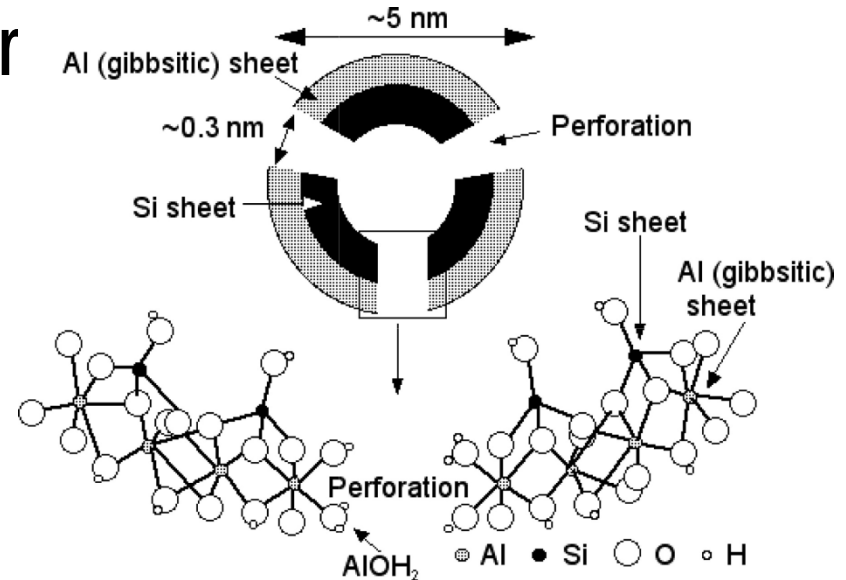
Allophane

Montmorillonite



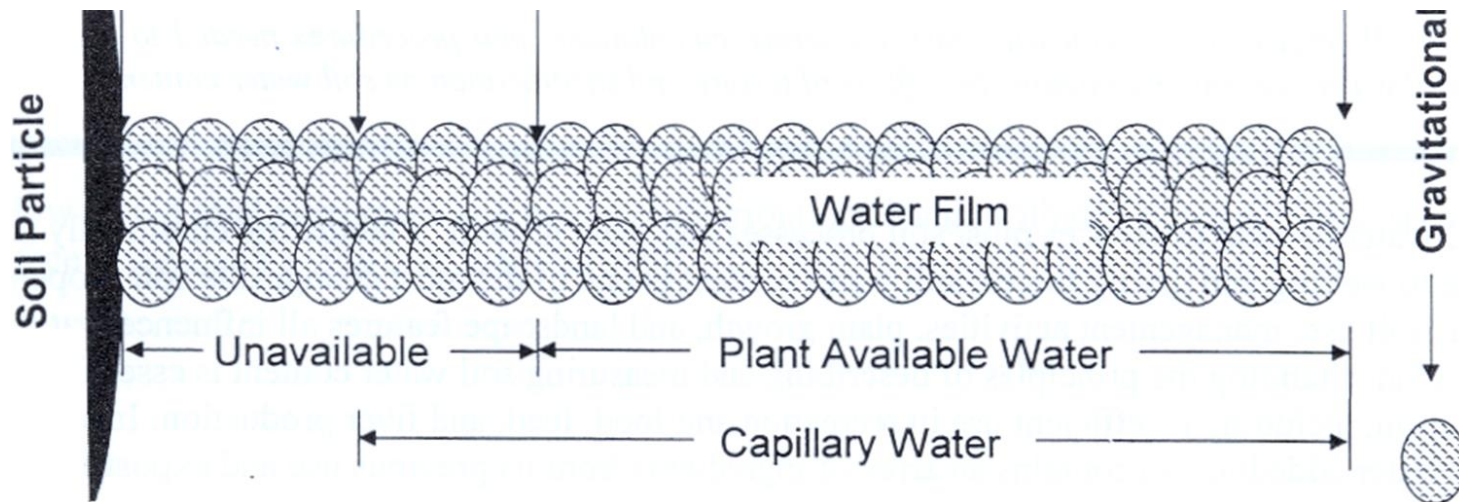
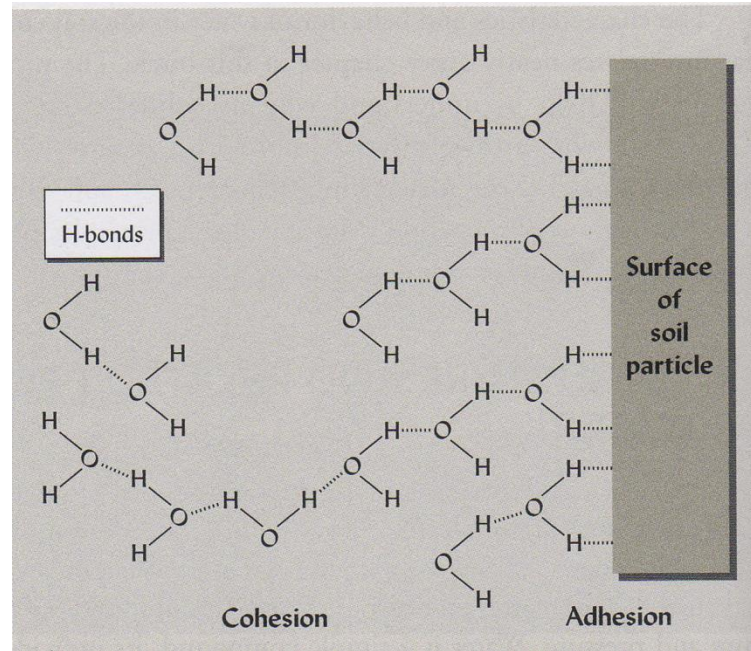
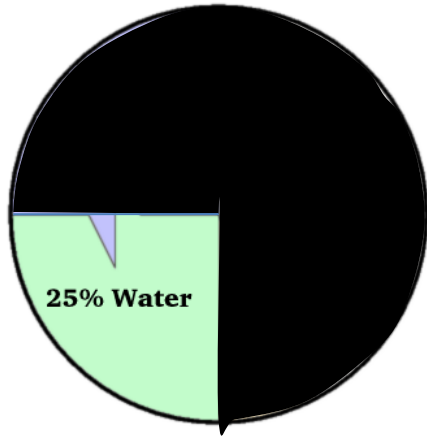
Properties of Allophane

- Tubular structure with both exterior and interior surfaces
- Extremely high surface area $>1,000 \text{ m}^2$ per gram
- Very high water holding capacity
- Excellent structure
- High surface charge
- High chemical reactivity



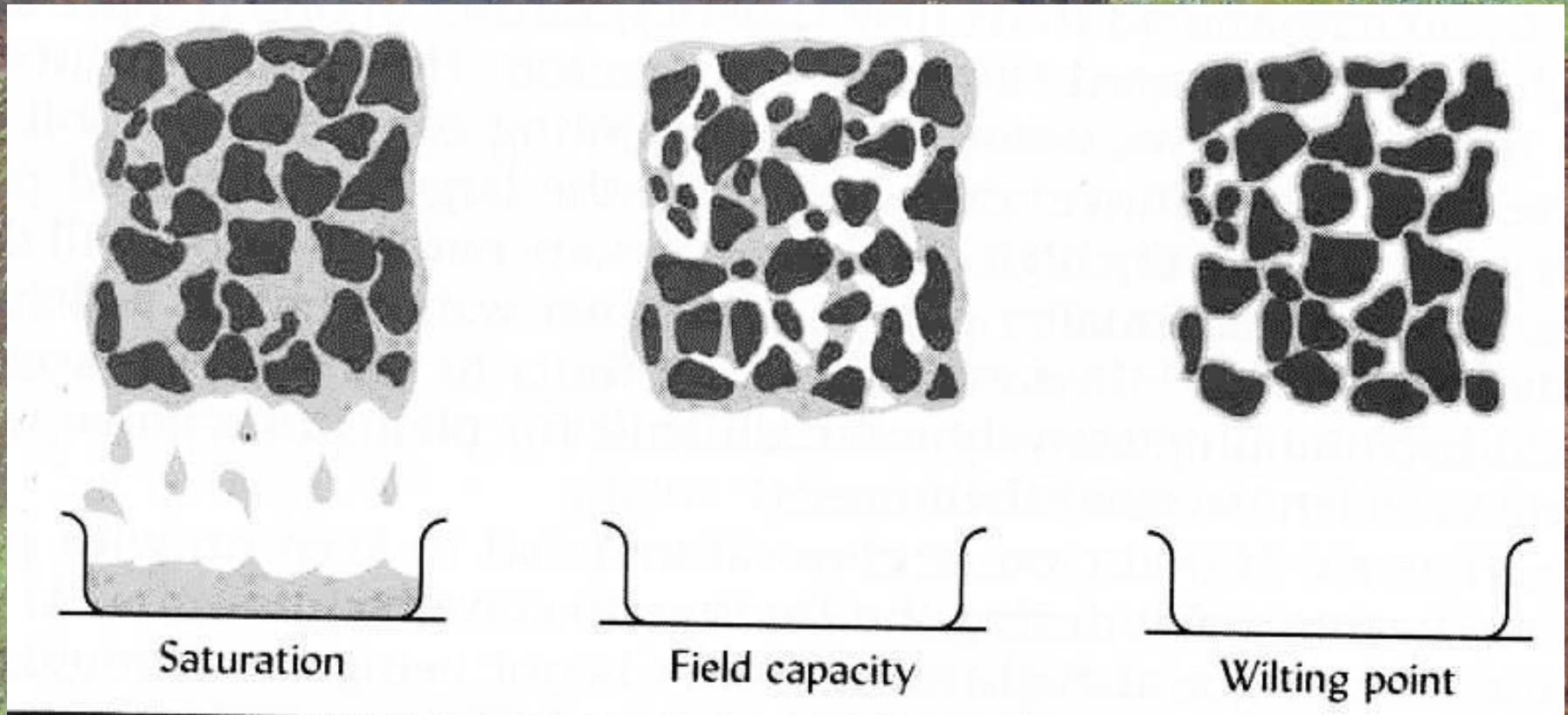
Allophane is the clay mineral in ash soils. It has extremely high surface area

Soil Water



Soil Water Availability

Soil water holding capacity depends on texture





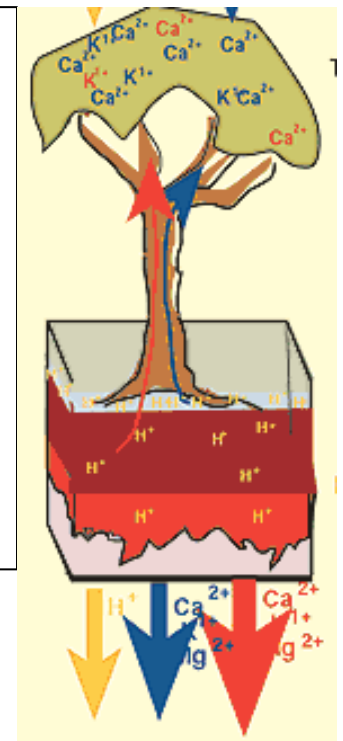
Too Little Water

- Drought
- Low nutrient availability
- Poor plant growth

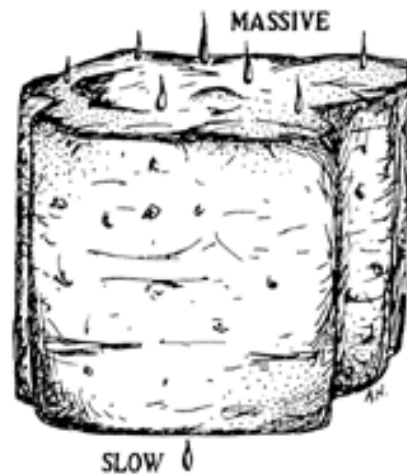
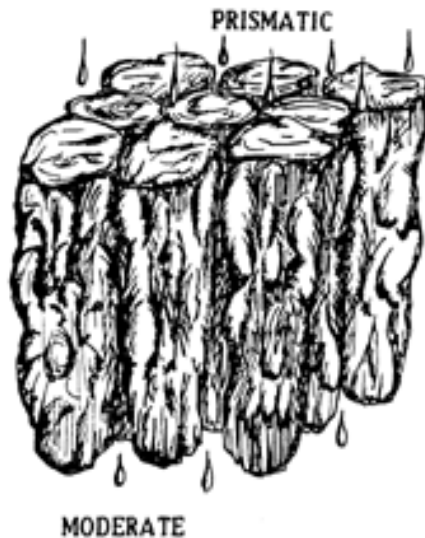
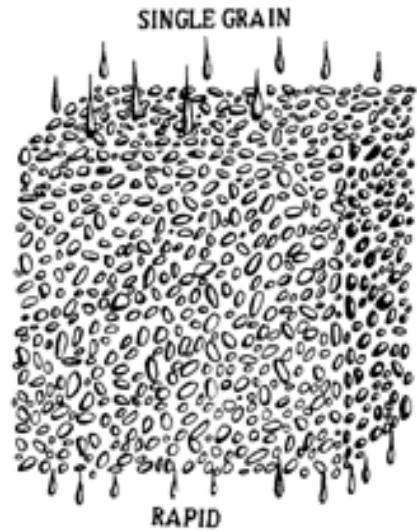
Too Much Water

- Nutrient leaching
- Nitrogen loss as gas

$\text{NO}_3^- \longrightarrow \text{N}_2\text{O} \uparrow$



Soil Structure and Water Flow



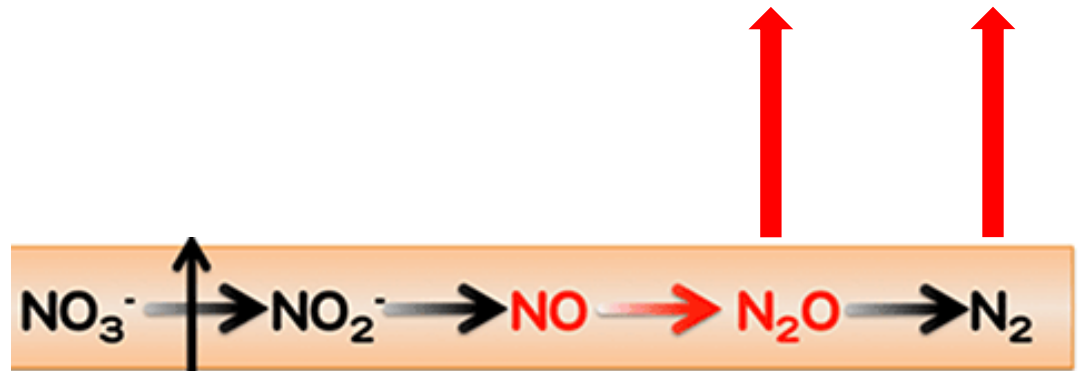
- Soils with strong stable aggregates have good drainage
- Aggregate stability depends on clay mineralogy
- Oxide-rich red soils have strong aggregates with good physical properties

Soil air

- Oxygen is essential for most life forms. In soil it supports a diverse microbial population and is required for root metabolism

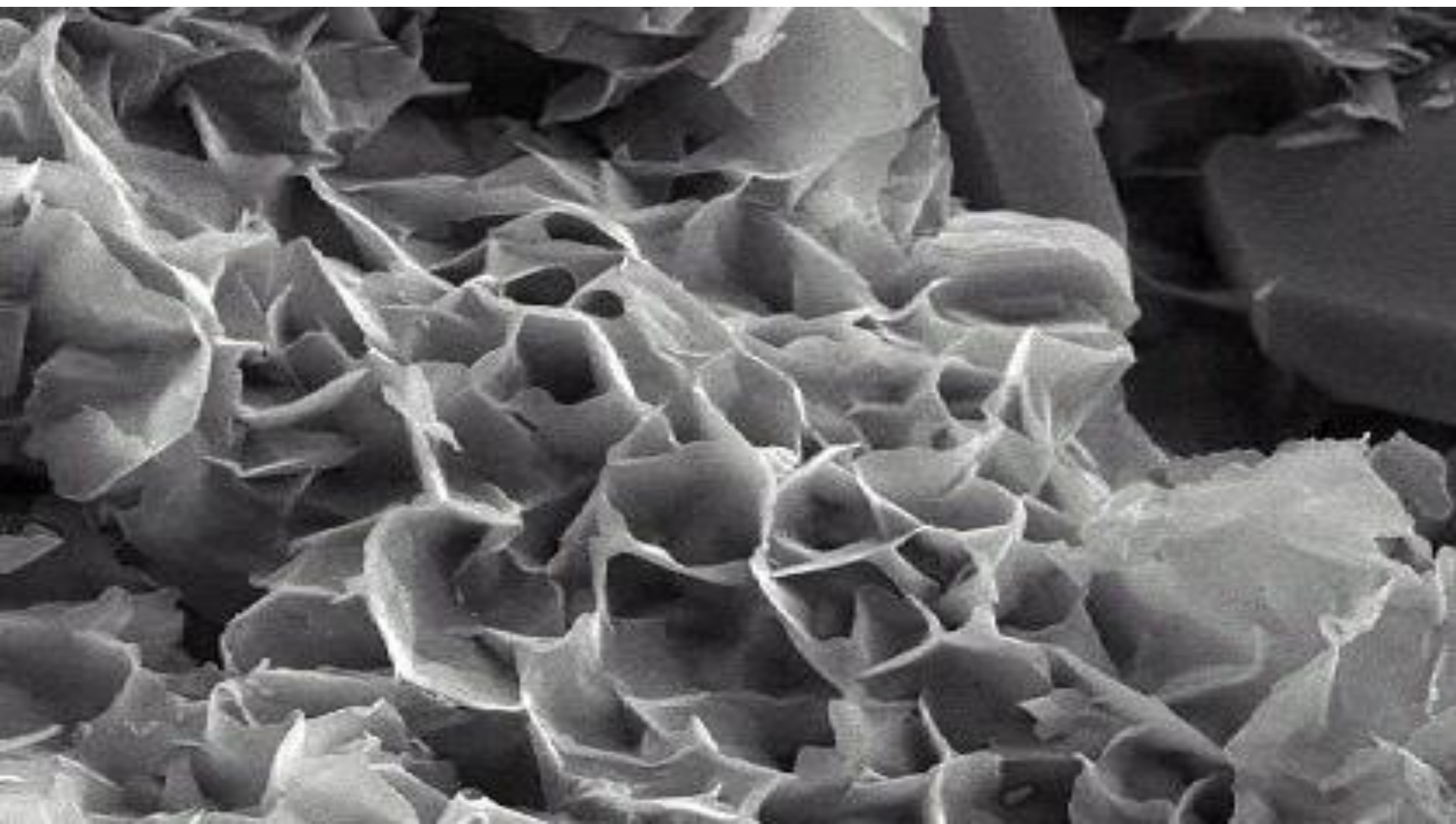


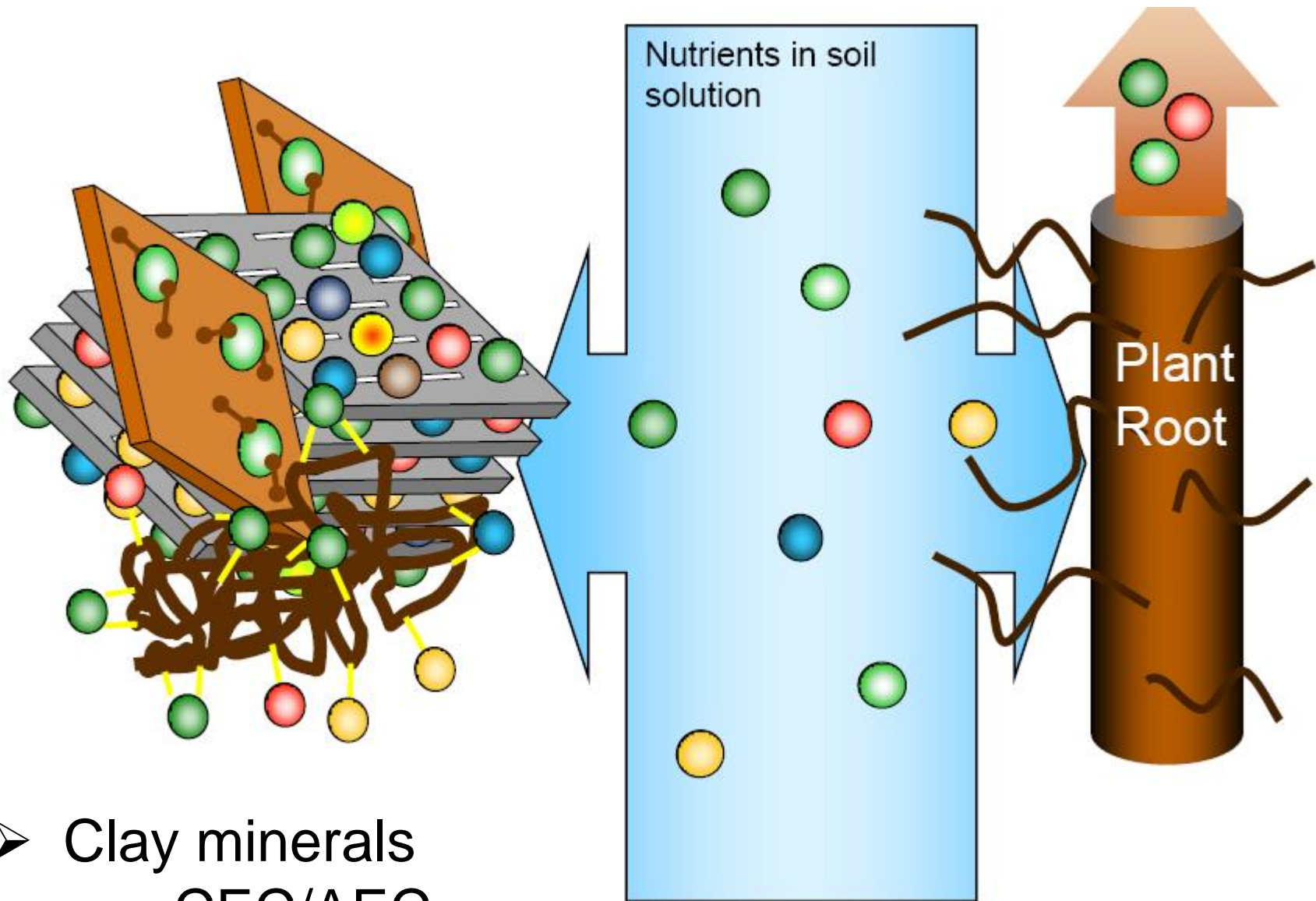
- In waterlogged soil, O_2 is present in very low concentrations creating reducing conditions
 - Gaseous loss of plant available N
 - Increase in toxic levels of Manganese in some soils
 - Fermentation and production of toxic by-products of anaerobic respiration



Loss of plant available N in saturated soils

Clay Minerals & Soil Chemical Properties





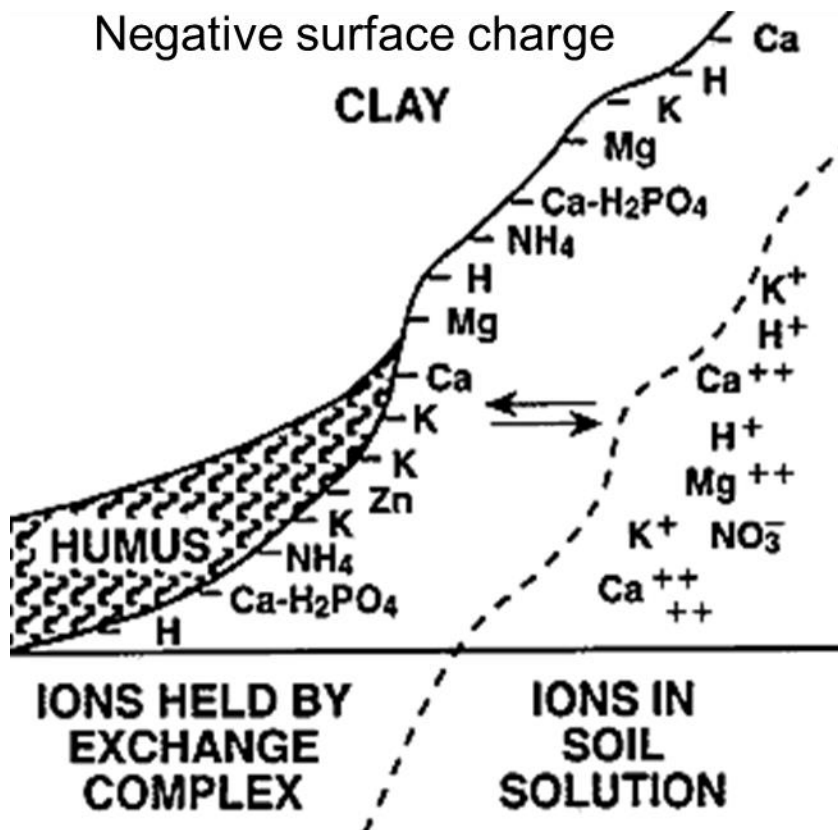
- Clay minerals
 - CEC/AEC
 - P fixation

Cation Exchange Capacity

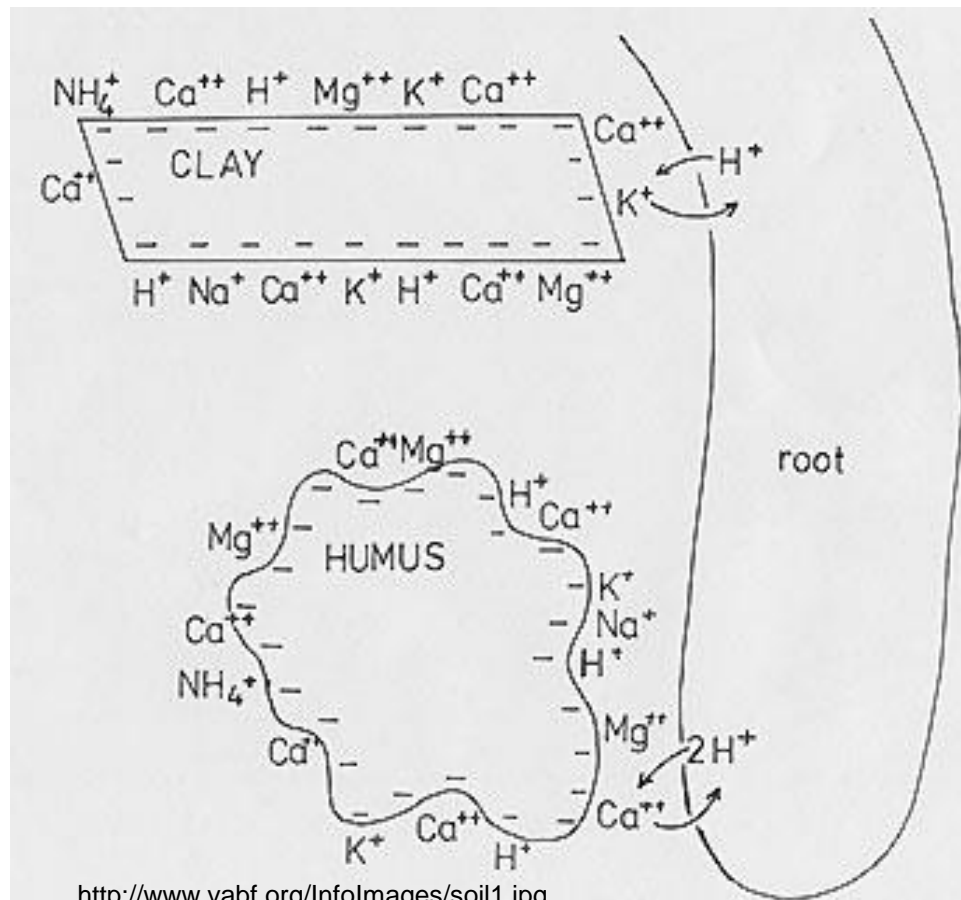
Cation Exchange Capacity

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

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

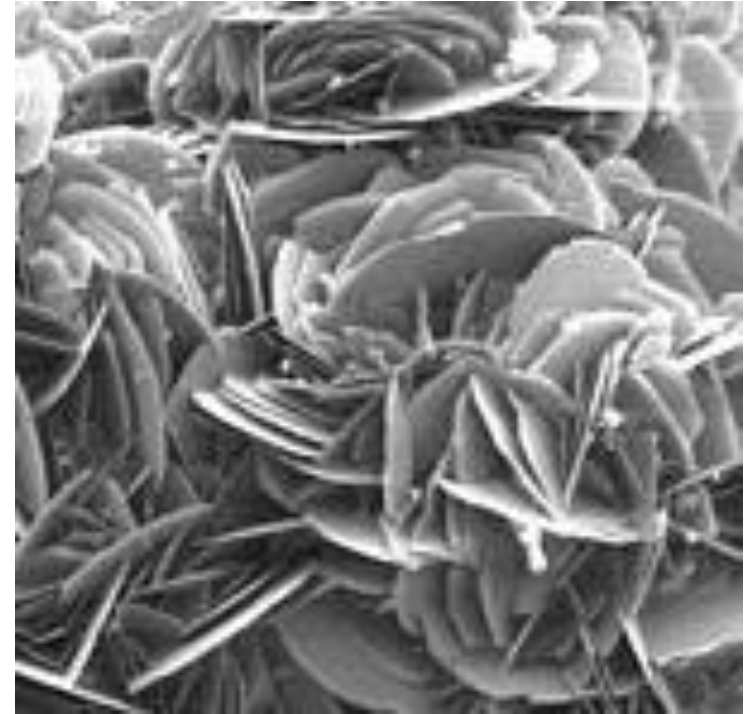
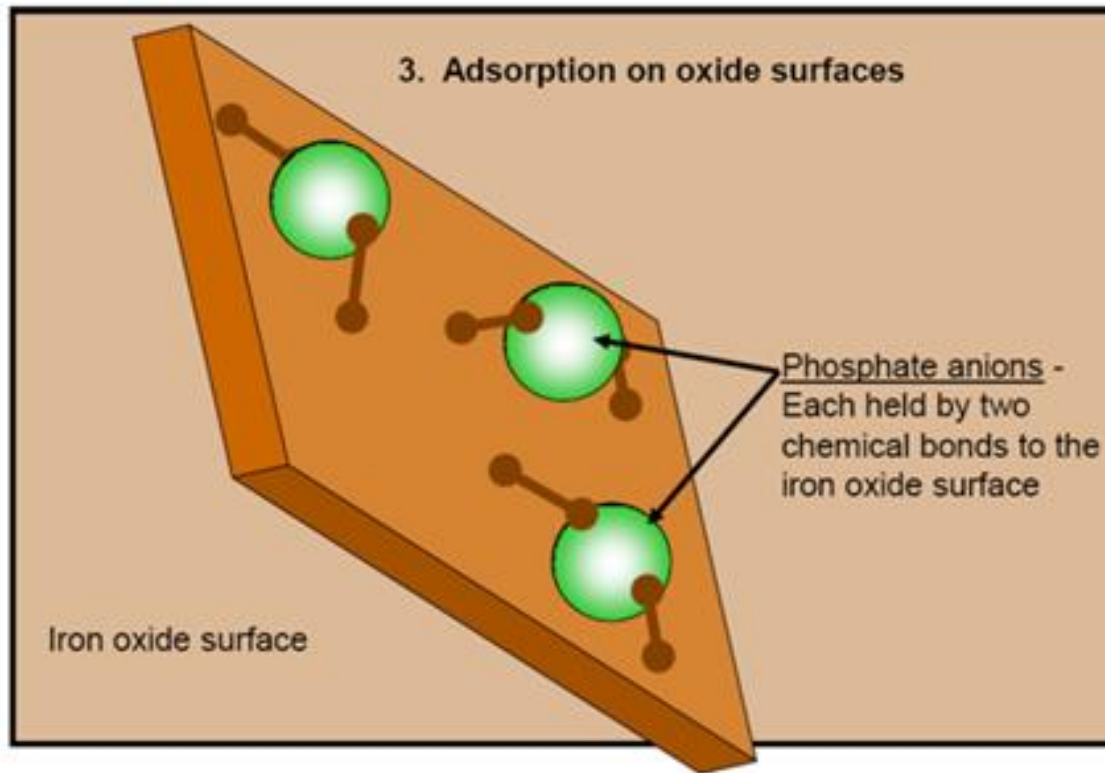


<http://www.extension.umn.edu/distribution/cropsystems/images/6437f01.gif>



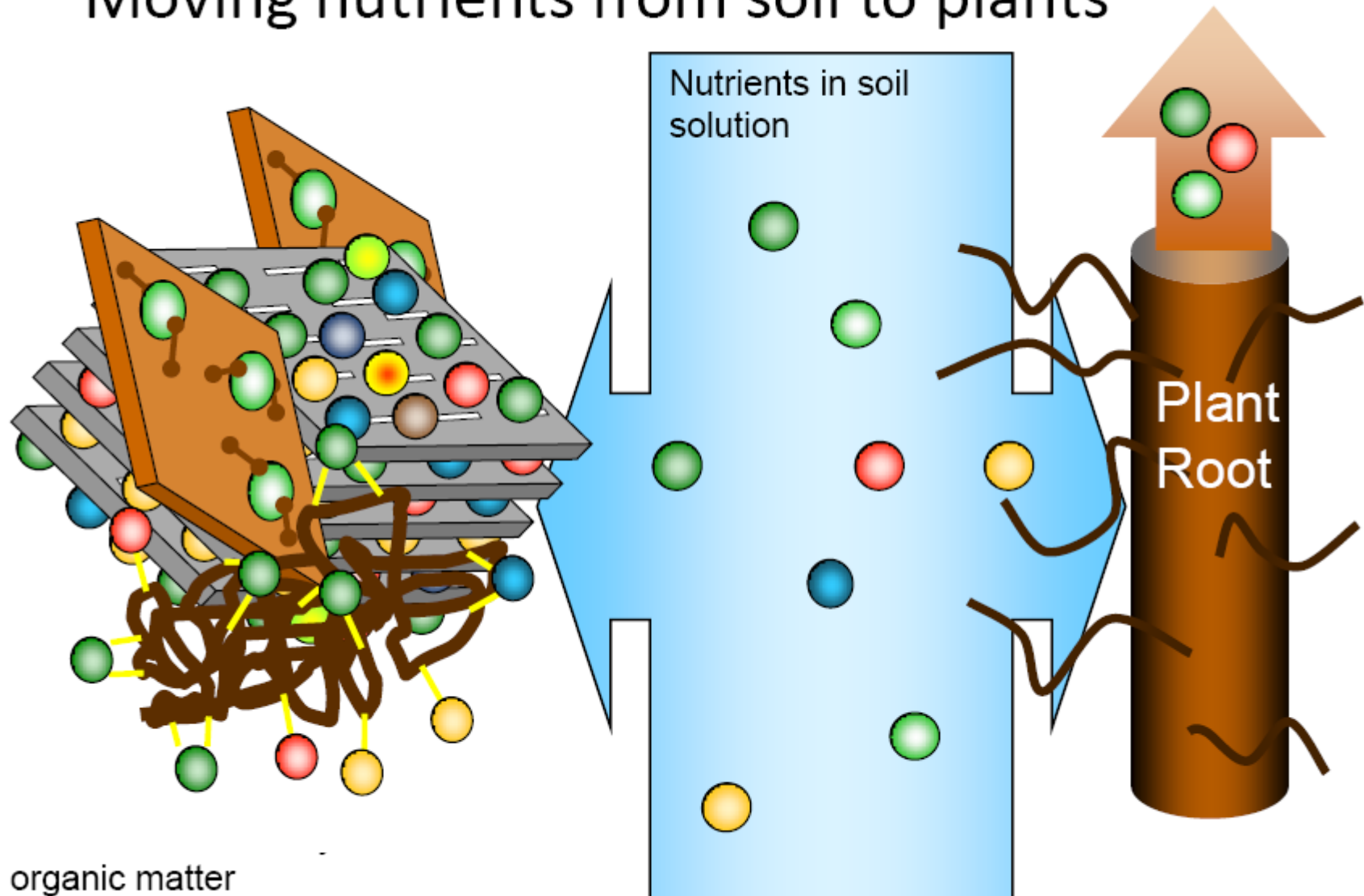
<http://www.vabf.org/InfImages/soil1.jpg>

Phosphorus Fixation



- Under acidic conditions P forms strong bonds with Fe and Al clay surfaces
- P is not available for plant use

Moving nutrients from soil to plants



➤ Soil acidity/alkalinity

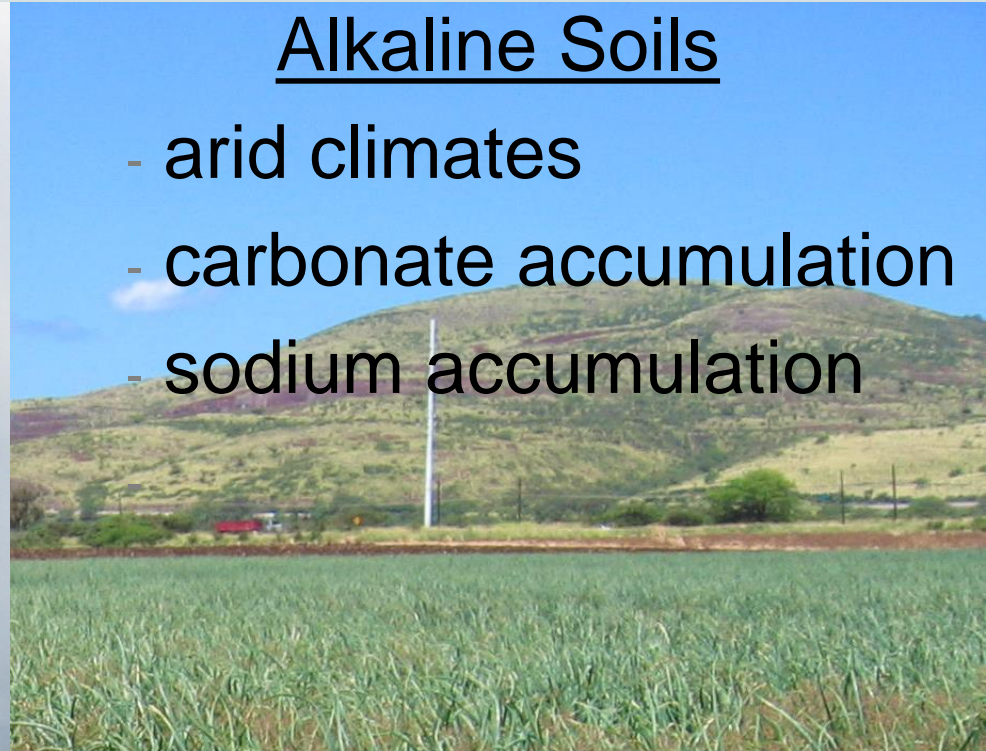
Soil Acidity and Alkalinity

Acid Soils

- high rainfall/leaching
- carbonic acid
- organic acids
- oxidation reactions
- synthetic fertilizers
- acid rain

Alkaline Soils

- arid climates
- carbonate accumulation
- sodium accumulation



Negative Impacts

- low fertility (i.e., Ca and P deficiency)
- Al toxicity ($\text{pH} < 5.5$)
- Mn toxicity ($\text{pH} < 5.5$)

Negative Impacts

- micronutrient deficiencies
- P deficiency
- high salinity
- poor drainage

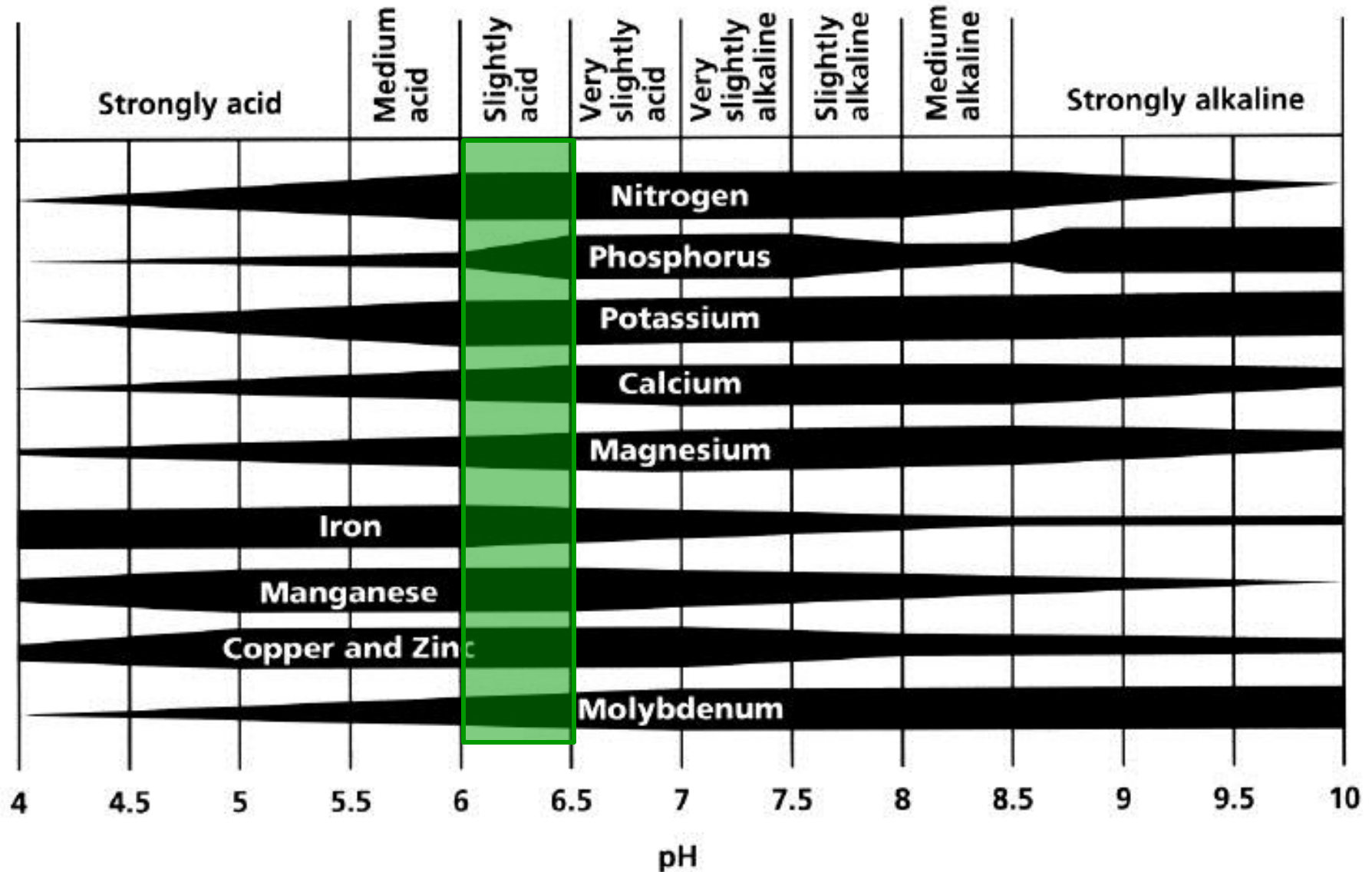
Soil pH is an Expression of Acidity/Alkalinity

The pH Scale



Typical pH range in soils

Soil pH Affects Nutrient Availability

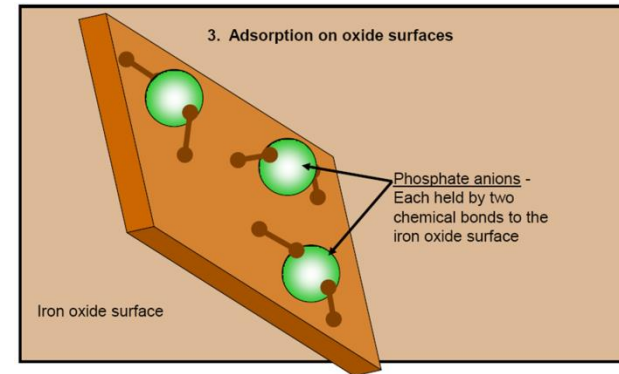


Negative Effects of Soil Acidity

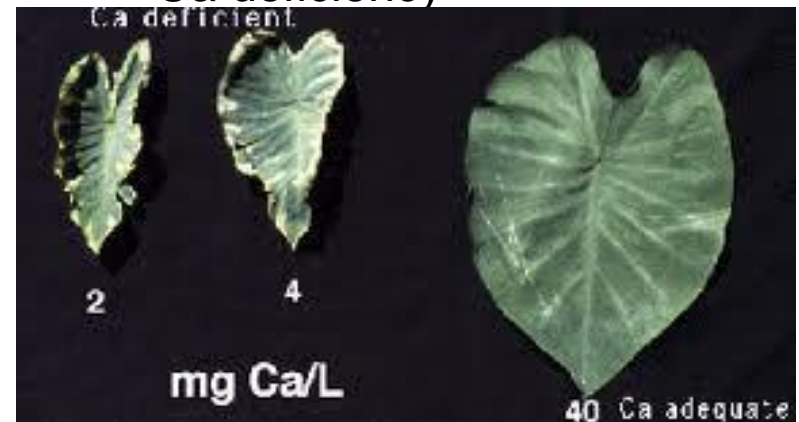


- Low nutrient retention (CEC)
- Nutrient deficiencies
 - P deficiency

P Fixation



- Ca deficiency

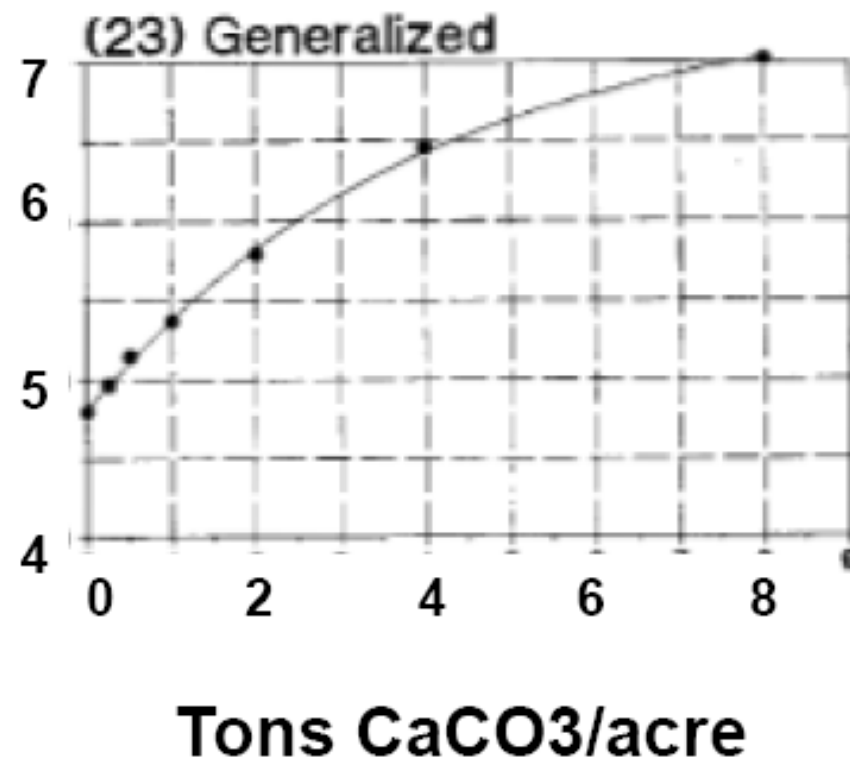
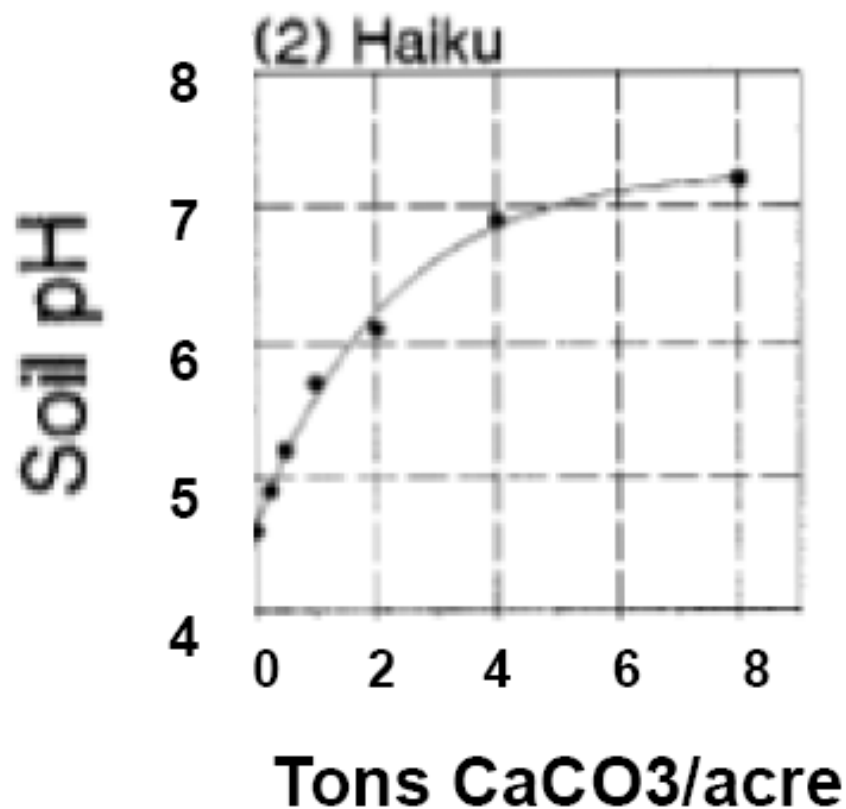


Liming Corrects Soil Acidity

- To raise pH
 - Reduce existing/potential toxicities (Al & Mn)
 - Increases P availability (reduces P fixation)
 - Supply of Ca & Mg
 - Target pH 6.0 – 6.5
 - Liming can be expensive because soils are buffered (clay content and OM)
- Liming Materials
 - Calcium carbonate (CaCO_3)
 - Dolomite
 - Organic matter detoxifies Al

TABLE 9.2 Common Liming Materials: Their Composition and Use

<i>Common name of liming material</i>	<i>Chemical formula (of pure materials)</i>	<i>% CaCO₃ equivalent</i>
Calcitic limestone	CaCO ₃	100
Dolomitic limestone	CaMg(CO ₃) ₂	95–108
Burned lime (oxide of lime)	CaO (+ MgO) ^a	178
Hydrated lime (hydroxide of lime)	Ca(OH) ₂ (+ Mg(OH) ₂) ^a	134
Basic slag	CaSiO ₃	70
Marl	CaCO ₃	40–70
Wood ashes	CaO, MgO, K ₂ O, K(OH), etc.	40
Misc. lime-containing by-products	Usually CaCO ₃ with various impurities	20–100



Liming curves for many soil series in Hawaii available online

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

Soil Organic Matter



Nutrients
present

Nutrients
absent



Organic Matter Improves Soil Physical Properties

- OM increases H_2O infiltration
- OM decreases soil bulk density and increases aeration
- OM increases water retention



Organic Matter Improves Soil Chemical Properties

- OM increases nutrient availability and supply
- OM increases nutrient retention
- OM detoxifies Al



Organic Matter Improves Soil Biology

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



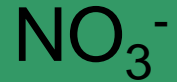
Organic Matter Decomposition

- Decomposition is the physical and chemical breakdown of organic residues
 - Mediated by microbial activity (bacteria/fungi)
 - Source/sink for plant nutrients
 - Creates humus

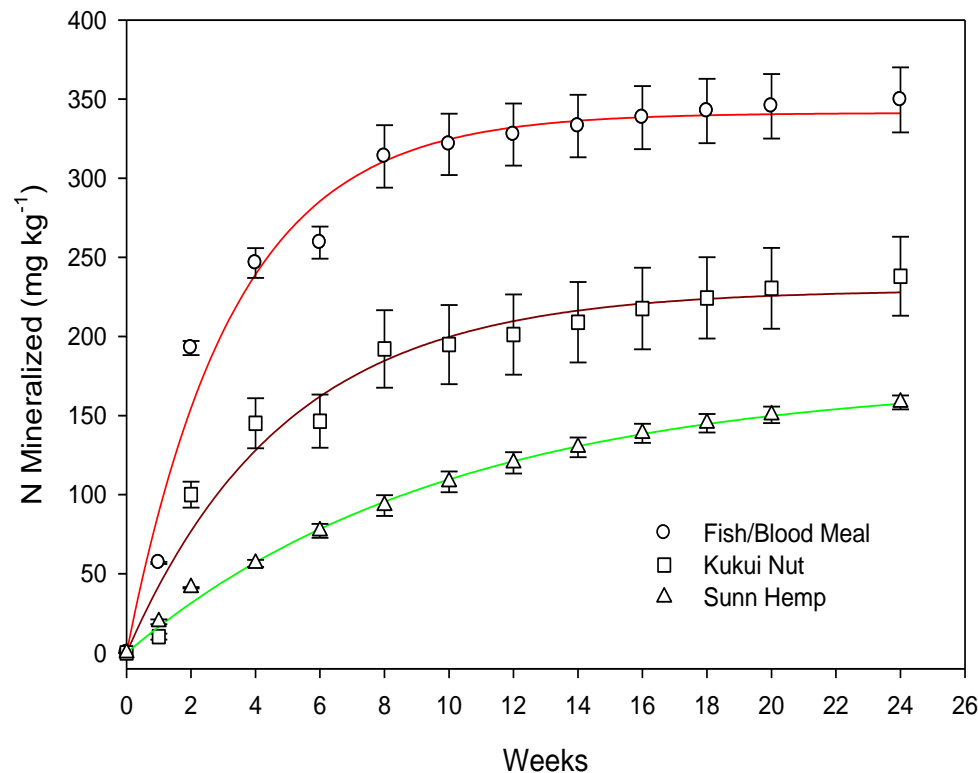


N Mineralization

Organic forms of N
in soil organic matter

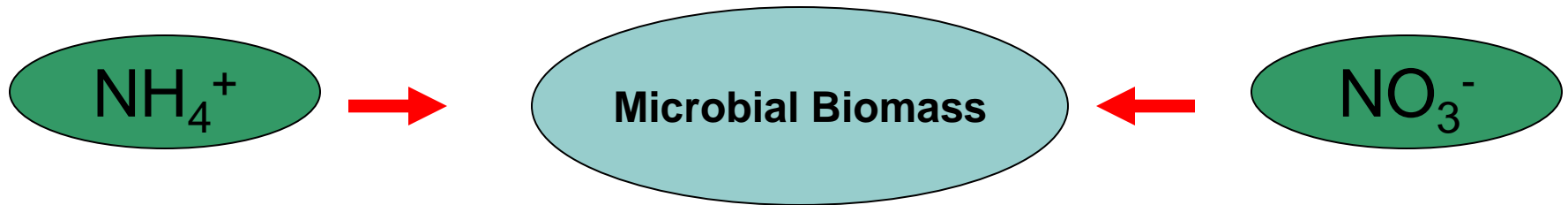


**High N
Materials**
Fish meal
Animal manures
Green leaves



Mineralization: microbial conversion of organic N
into plant available inorganic forms (NH_4^+ , NO_3^-)

N Immobilization



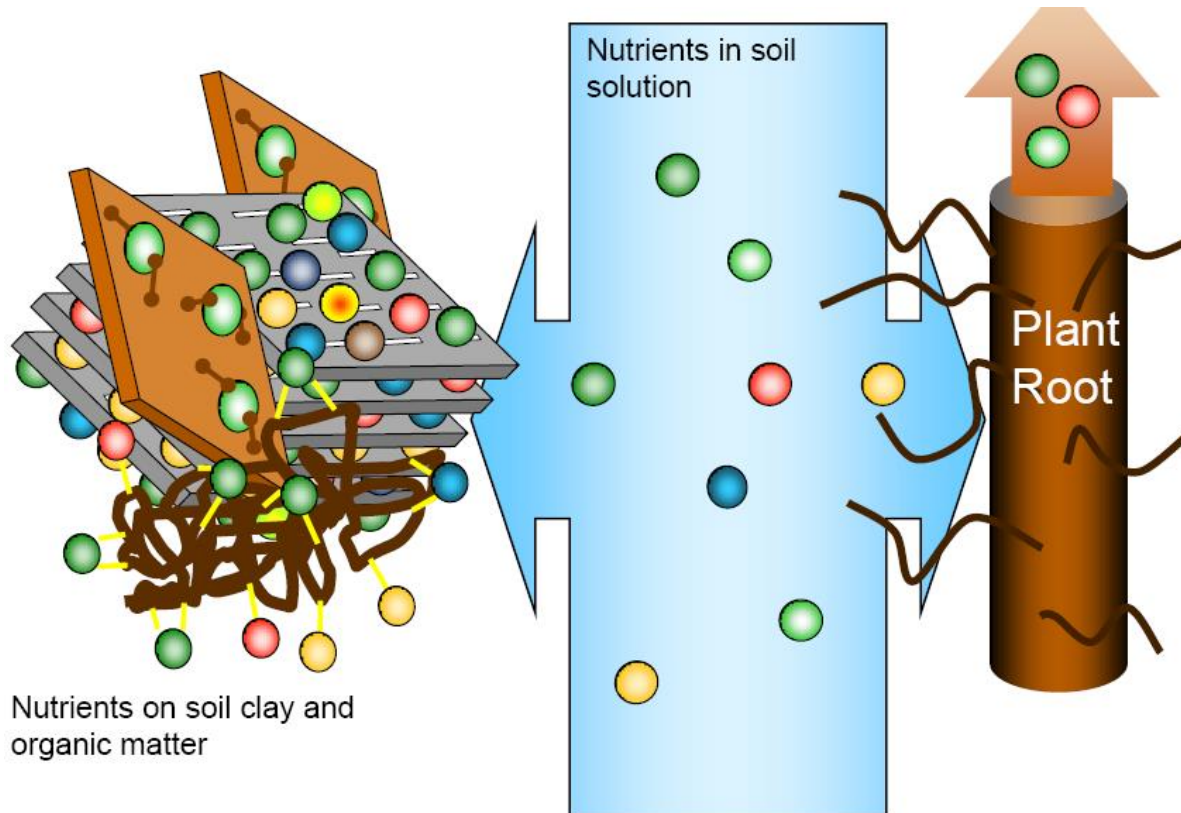
Immobilization: assimilation of inorganic N forms (NH_4^+ , NO_3^-) into the microbial biomass

High C Materials

- Wood chips
- Saw dust
- Coconut husk
- Dried leaves

Soil Fertility Depends on:

- Amount of clay
- Type of clay
- Soil Organic Matter
- Soil Acidity

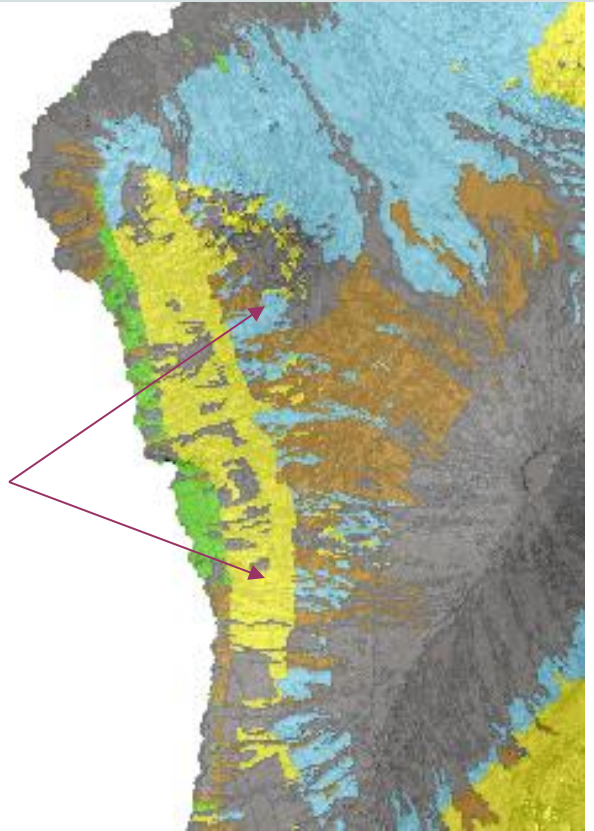


Properties of Ash Soils

Properties

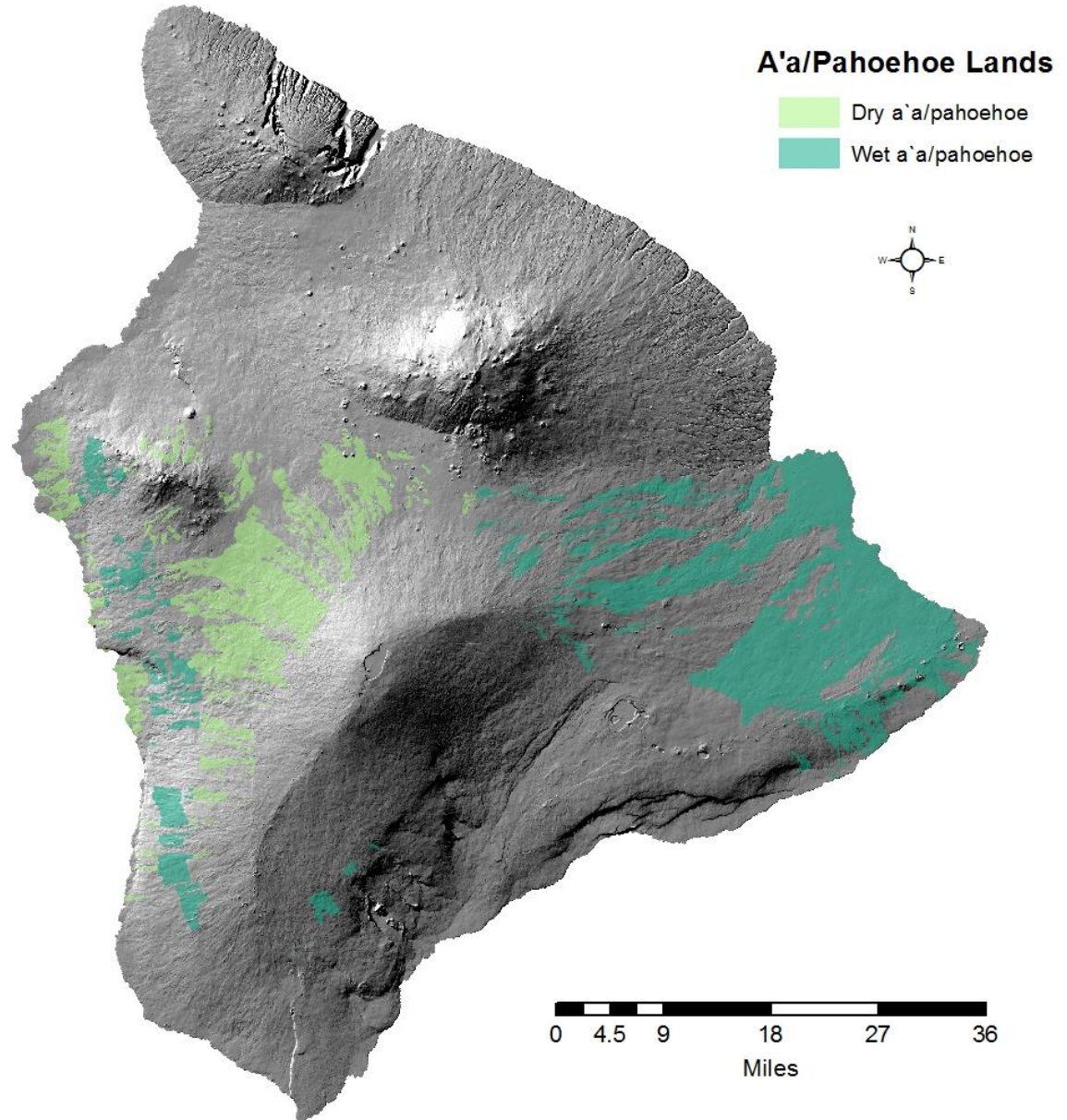
- light (low bulk density)
- high organic matter content
- slightly acidic to acidic
- high P fixing capacity
- soil series: Hanipoe, Honuaulu, Kealakekua, Apakuie, Honaunau

Ash soils



Soil Series	Rainfall (in/yr)	OC %	pH	Ca ppm	Mg ppm	K ppm
Apakuie	30	14.2	6.7	4,320	432	702
Honuaulu	65	19.2	5.6	800	240	273

A`a/Pahoehoe Soils



Physical Properties of A`a Soils

- Dominated by coarse materials (80%)
- Minimal clay content
- Very low water retention capacity (droughty)
- Excessively well-drained
- Extremely difficult to cultivate

Chemical Properties of A`a Soils

Soil Series	Rainfall in/yr	pH	Org. C %	TN	Ca	K ppm	Mg
Kaimu	20-50	5.7	13.5	0.97	8,200	273	1,104
Kekake	20-50	4.8	21	1.39	2,900	-	636
Kahaluu	90->150	4.4	55	1.81	2,480	624	636

- Organic matter is the primary source of nutrient supply and retention
- High nutrient leaching

Part II



Essential Plant Nutrients

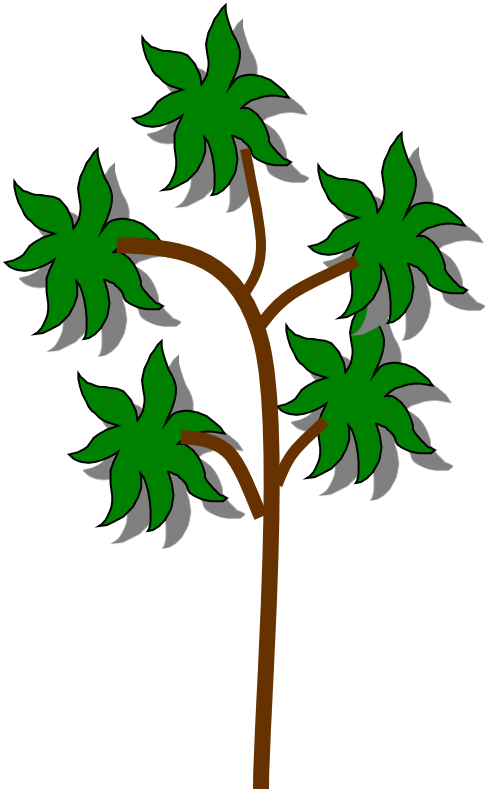
Macronutrients

Mineral/ Element	Chemical symbol	Main requirement/use by the plant
<i>Macronutrients</i>		
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

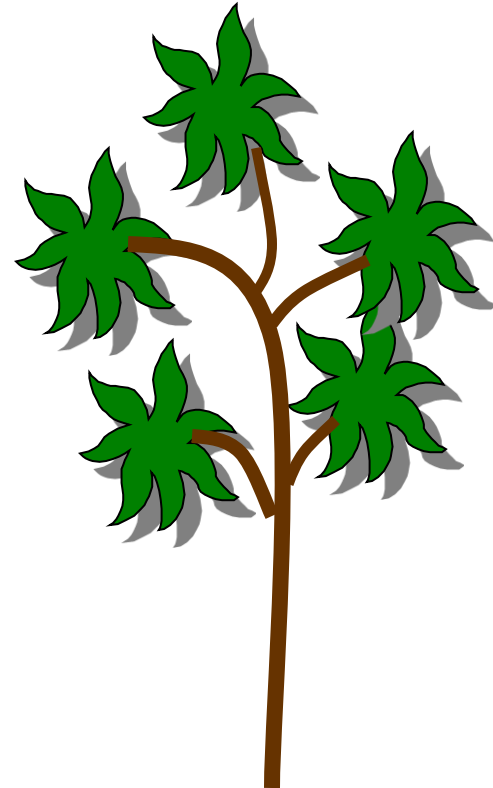
Micronutrients: B, Cu, Fe, Mn, Zn, Mo, Ni, Co, Cl

Nutrient Mobility in Plants

Mobile



Immobile



Nutrient Mobility in Plants

Mobile

Symptoms appear in older leaves first

- nitrogen
- phosphorous
- potassium
- magnesium

Immobile

Symptoms appear in younger leaves first

- sulfur
- calcium
- boron, iron, manganese, zinc, copper, molybdenum, chloride

Nutrient Deficiency Symptoms

Nitrogen – chlorosis older leaves

Phosphorus – purpling on older leaves

Potassium – chlorosis on edges of older leaves

Calcium – necrosis of growing points

Magnesium – interveinal chlorosis on older leaves

Sulfur – chlorosis on new leaves

Iron – interveinal chlorosis on new leaves

Manganese – mottled interveinal chlorosis on new leaves

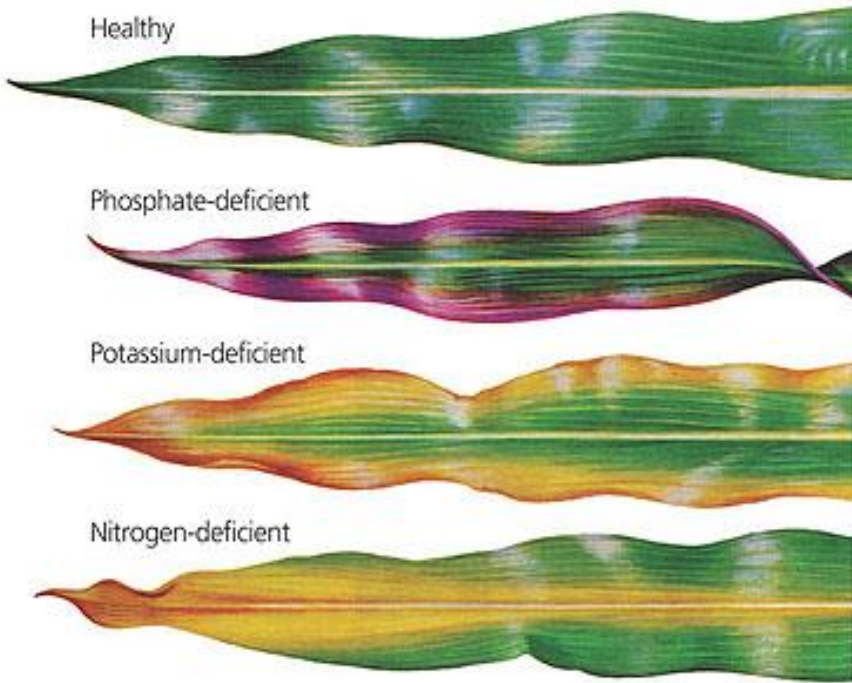
Zinc – interveinal chlorosis in bands on new leaves

Diagnosis

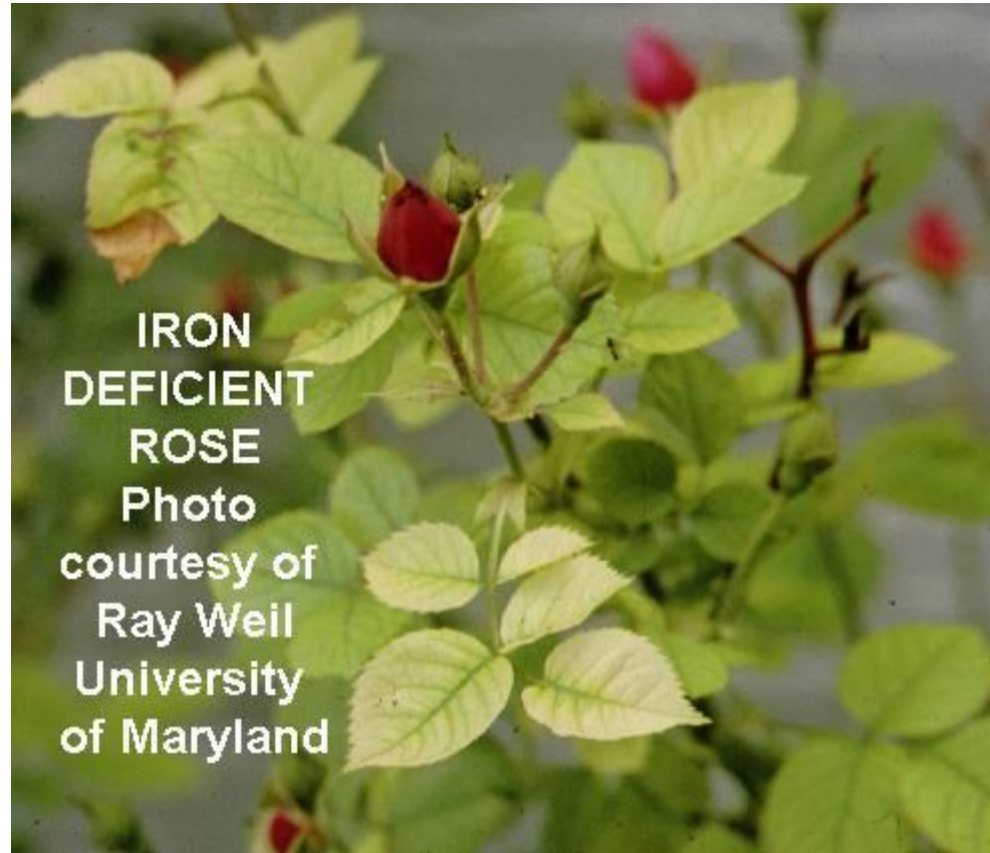
1. Visual symptoms
2. Soil test
3. Tissue test



Deficiency Symptoms



Old Leaves



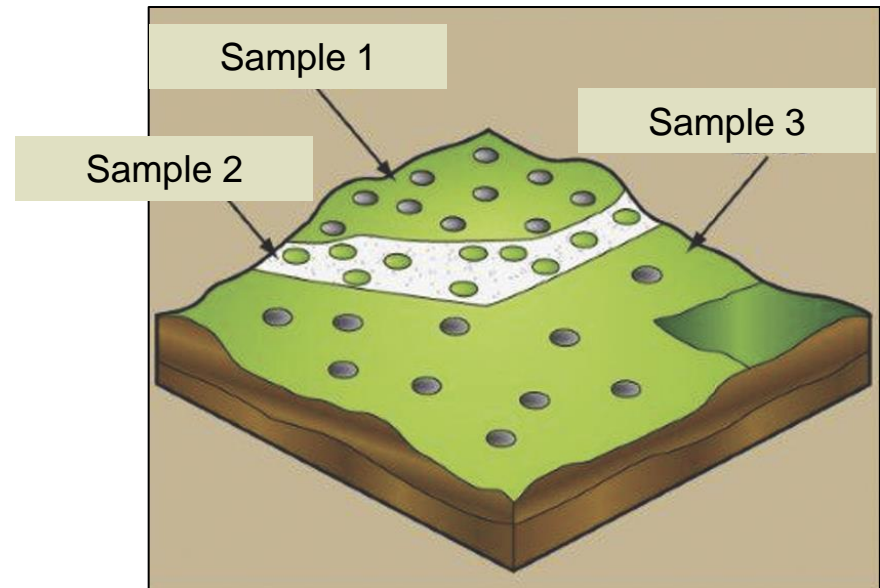
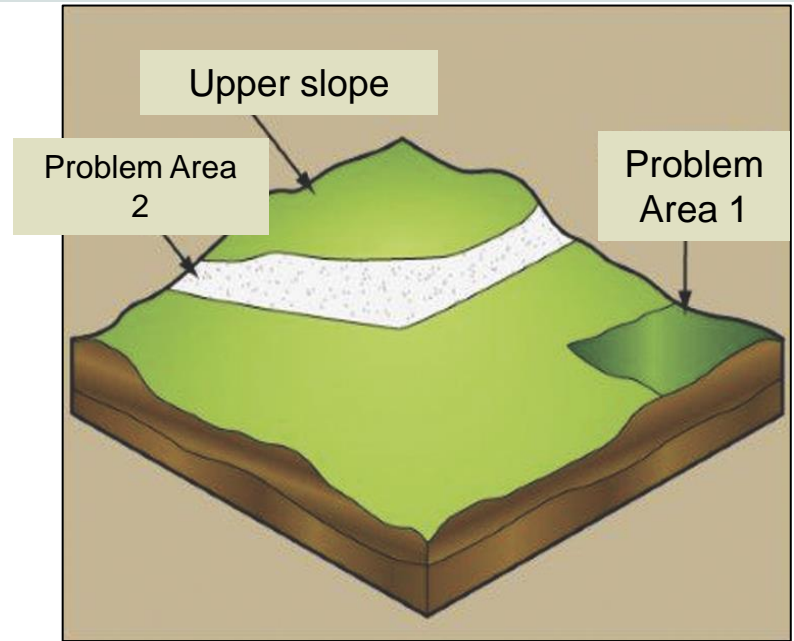
Soil Tests

- Soil tests determine how much nutrients are in the soil
- Soil tests are used to make fertilizer recommendations
- Soil tests improve fertilizer application efficiency

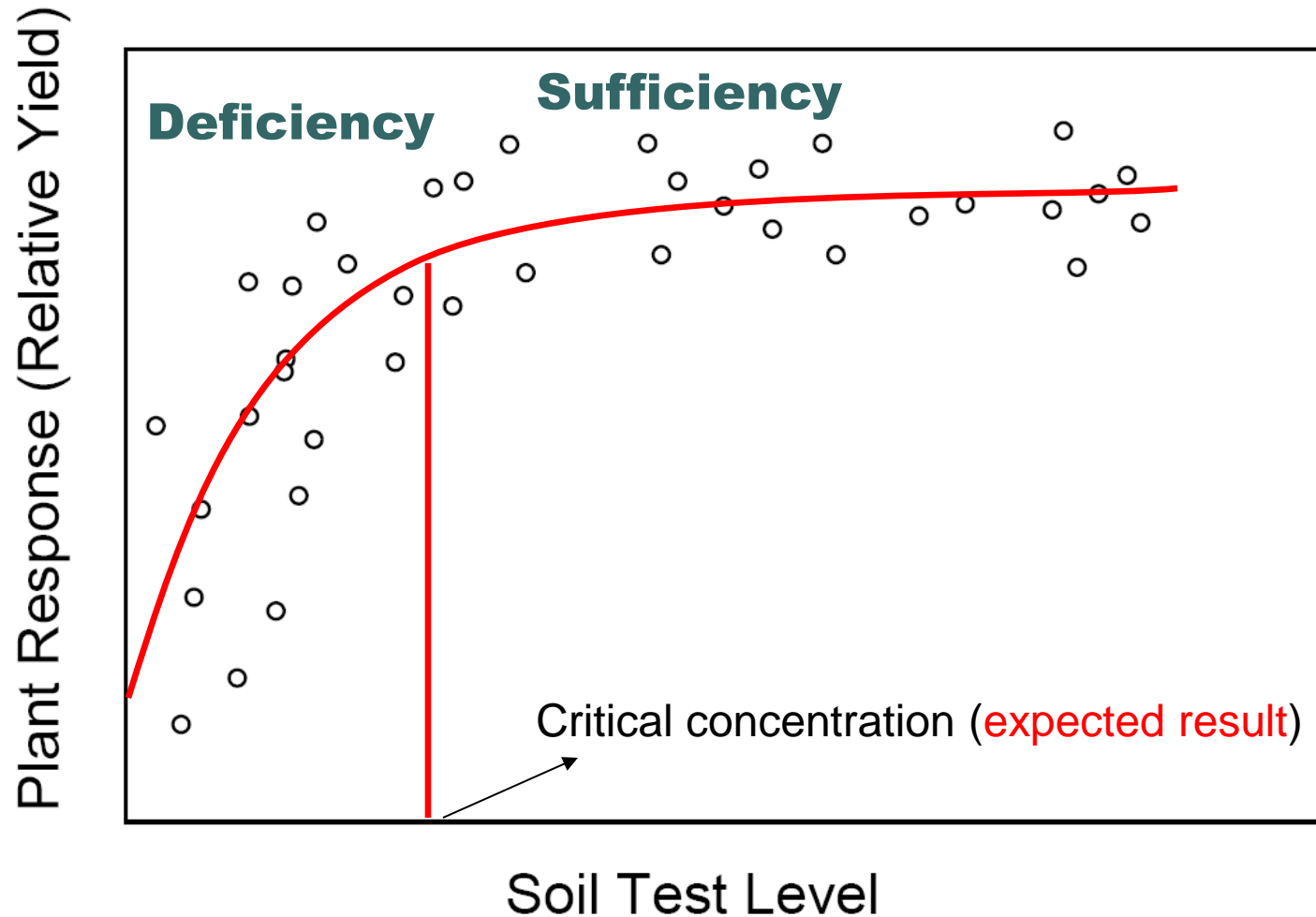


Soil Testing

- Separate samples for distinct management areas
- Proper depth/s
- Usually 15 to 20 cores, mix well, take sub-sample
- Avoid contamination



Soil Test Calibration



Soil Test Printout

CTAHR

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

Agricultural Diagnostic Service Center

Department of Agronomy and Soil Science
1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-8706/7980 FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Soil/Plant Analysis Report

Client:	PUA LEHUA FARM P.O. Box 959 Attn: Eric Schott Honokaa, Hawaii 96727	Date Reported: 03/15/2006 Agent: SATO, DWIGHT, Office: HILO 875 KOMOHANA STREET HILO, HI 96720 981-5199, Fax: 981-5211
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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					

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

Soil Test Printout

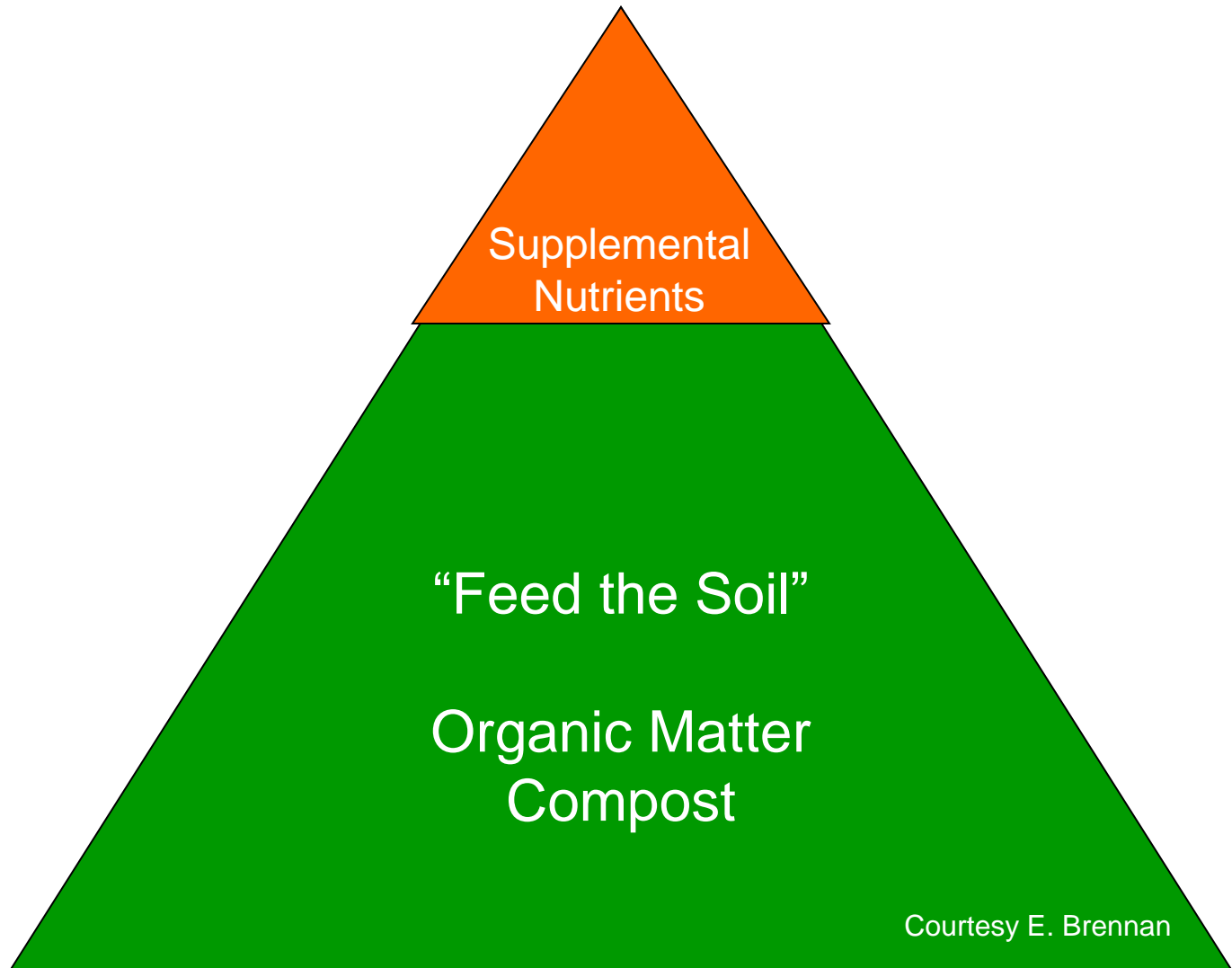
Test Results and Interpretation

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

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 Properties

A large, conical pile of dark brown, moist-looking compost sits in a grassy field. The background shows green trees and a clear sky, suggesting an outdoor agricultural or landscaping setting.

- Decomposed organic materials
- Dark material with particle size < 2.5 cm
- No foul odor
- pH = 6.0 – 7.0
- Balanced nutrient concentrations

Benefits of Compost

Soil Physical Properties

- Improve soil structure
- Increase water retention
- Decrease bulk density

Soil Chemical Properties

- Source of essential nutrients
- Increase nutrient retention (CEC)
- Detoxify AI
- Buffer pH

Soil Biological Properties

- Increase microbial abundance and diversity
- Create disease suppressive soils

N Fertilizers

Organic

- Fish meal ($\approx 10\%$ N)
- Feather meal (12 - 13% N)
- Chicken manure ($\approx 3\%$ N)

Conventional

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



P Fertilizers

Organic

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

Conventional

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



Potassium Fertilizers

Organic

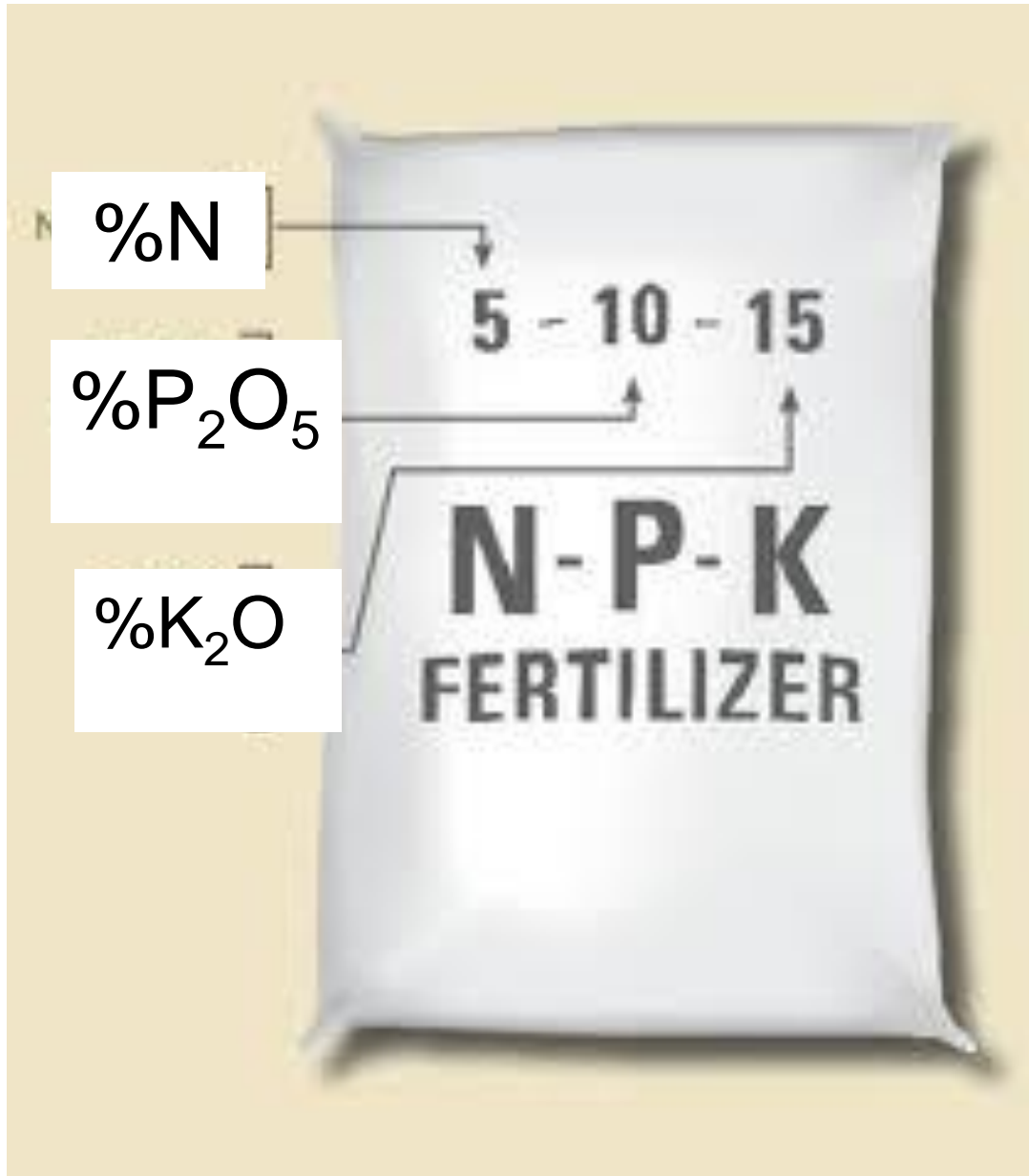
- Wood ash
- Seaweed
- Green sand
- Sulfate of potash (0-0-50)

Conventional

- Muriate of potash: 0-0-60 (49.8% K)
- Sulfate of potash: 0-0-50 (41.5%)



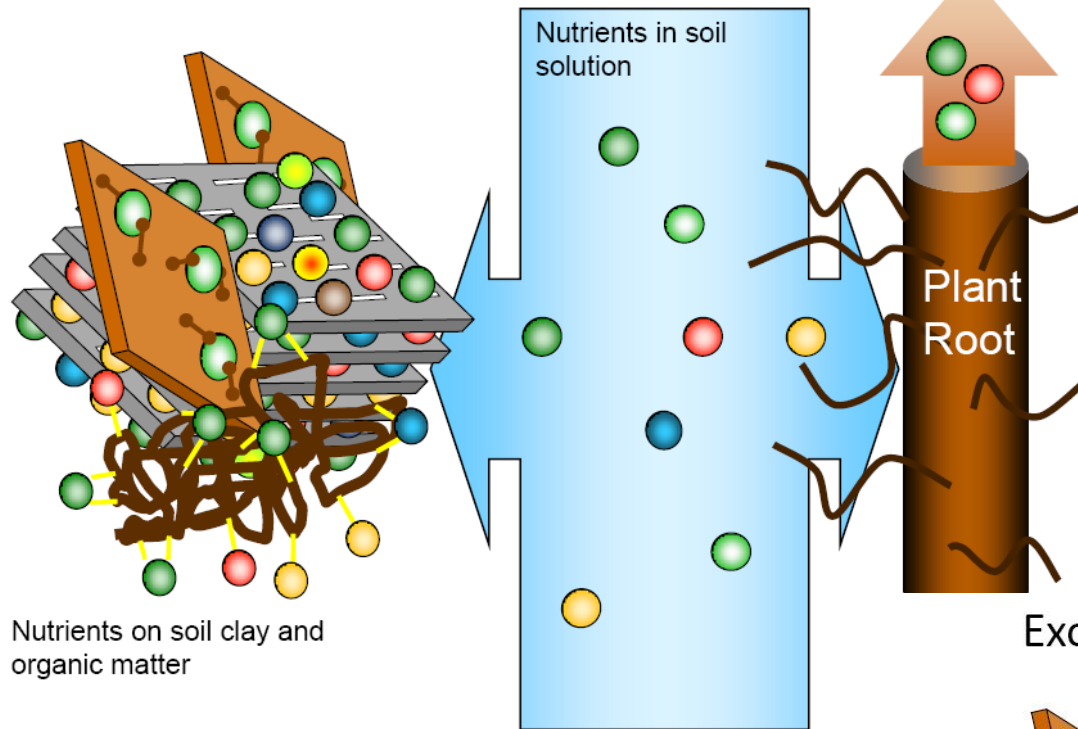
Blended Fertilizers



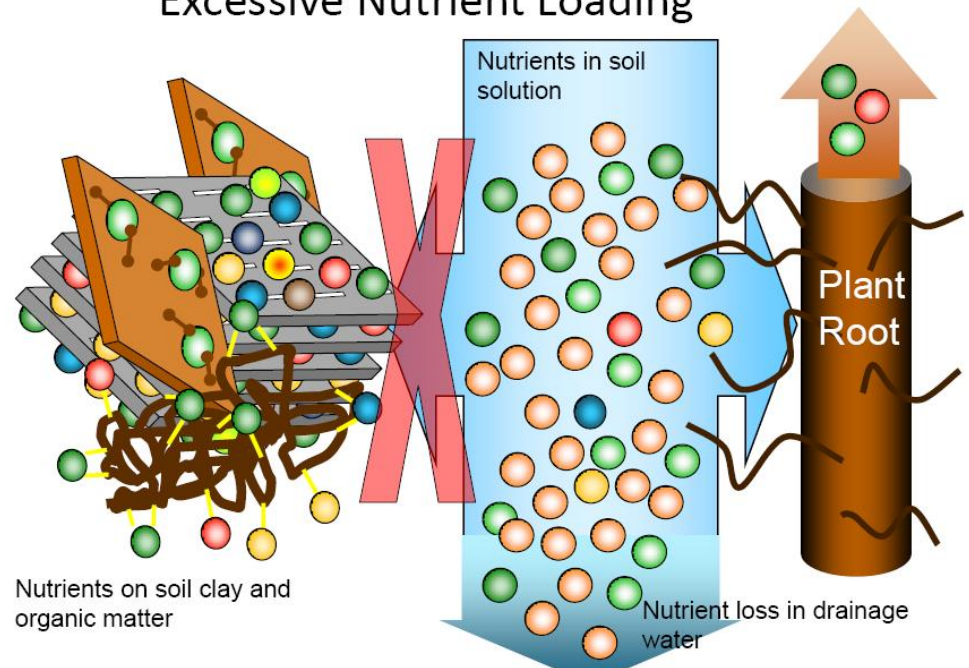
Common Blends

- 10-10-10
- 16-16-16
- 10-30-10

Moving nutrients from soil to plants



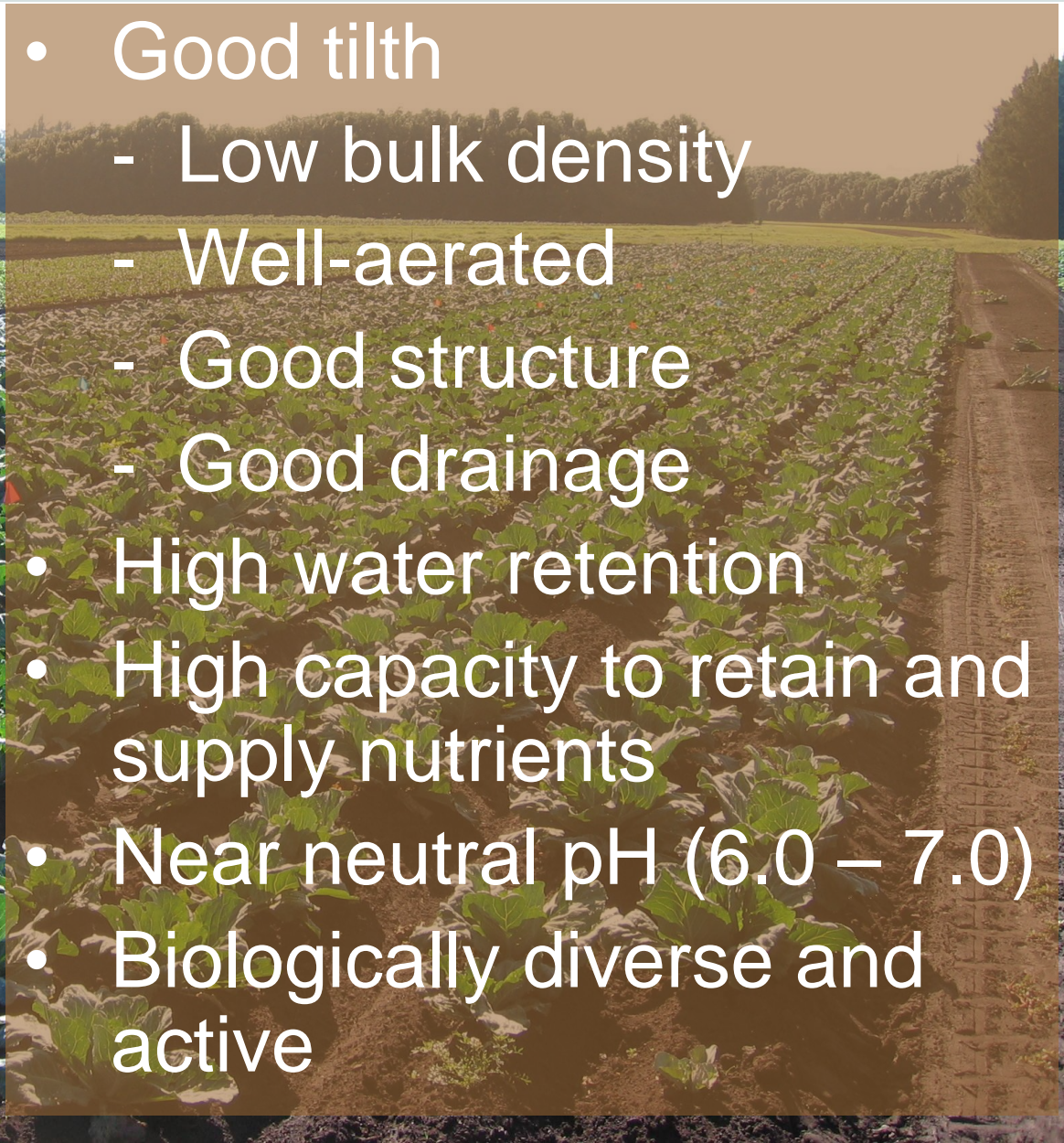
Excessive Nutrient Loading



High Quality Soil



- Good tilth
 - Low bulk density
 - Well-aerated
 - Good structure
 - Good drainage
- High water retention
- High capacity to retain and supply nutrients
- Near neutral pH (6.0 – 7.0)
- Biologically diverse and active



Summary

- Soils provide critical ecosystem services
- Clay mineralogy affects soil behavior
- Soil pH affects nutrient availability
- Organic matter makes a difference
- Soils vary on the landscape
- If we know our soils we can manage them well