Understanding and Managing the Soils of the Big Island

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Soil Nutrient Management for Maui County

College of Tropical Agriculture and Human Resources (CTAHR)

Home Soil Basics Soils of Maui Nutrient Management References

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.

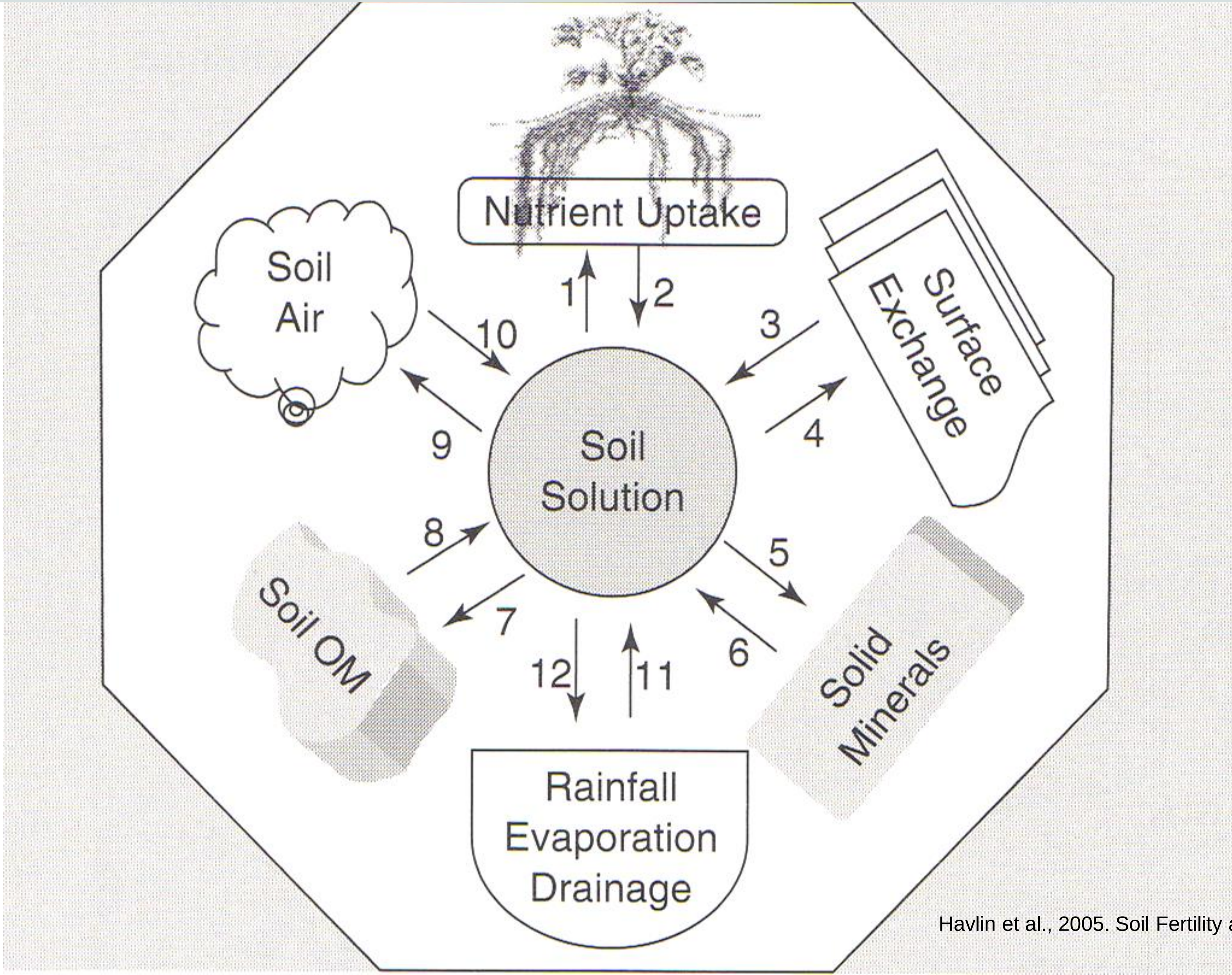
Much of the information provided in this website is unique to Maui. We aim to provide the College of Tropical Agriculture and Human Resources' (CTAHR) clients with resources, knowledge and tools that are easily accessible, comprehensible and useful for properly managing their crops. Despite the localized 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

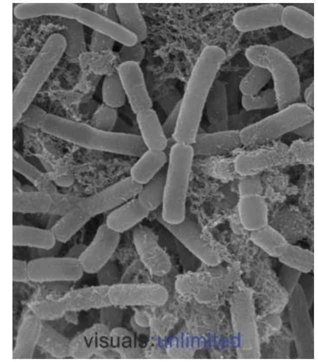
Soil Plant Relationships



Havlin et al., 2005. Soil Fertility and Fertilizers

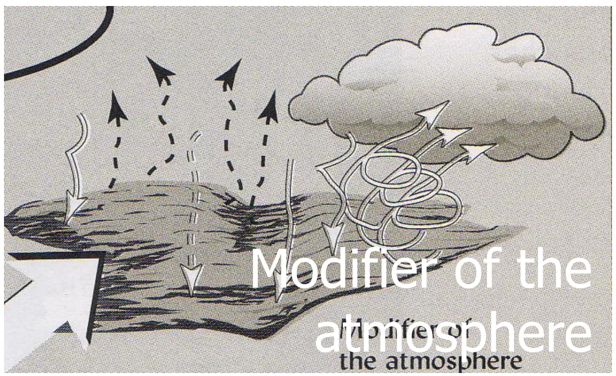
Medium for
Plant growth

Habitat for
Soil organisms



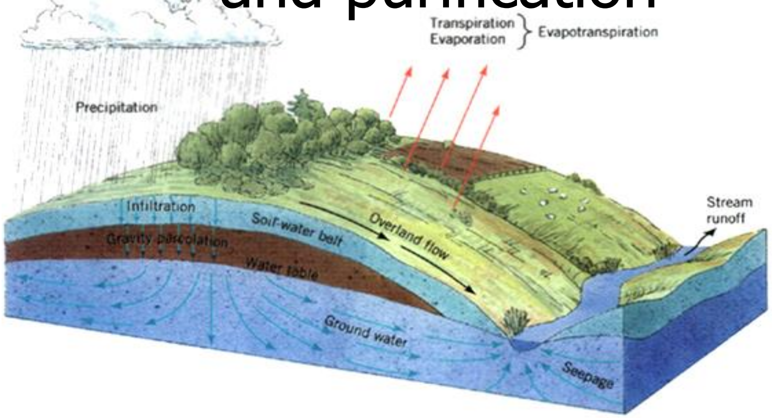
Recycling
system

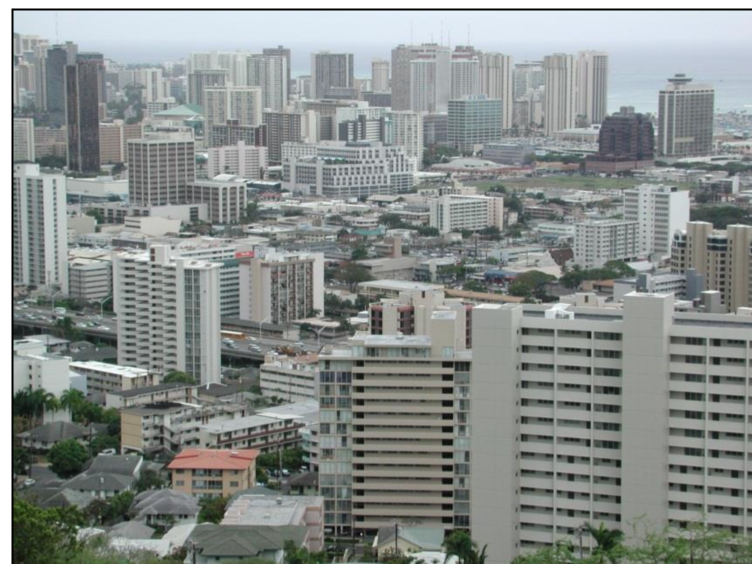
6 Functions of Soil



Modifier of the atmosphere

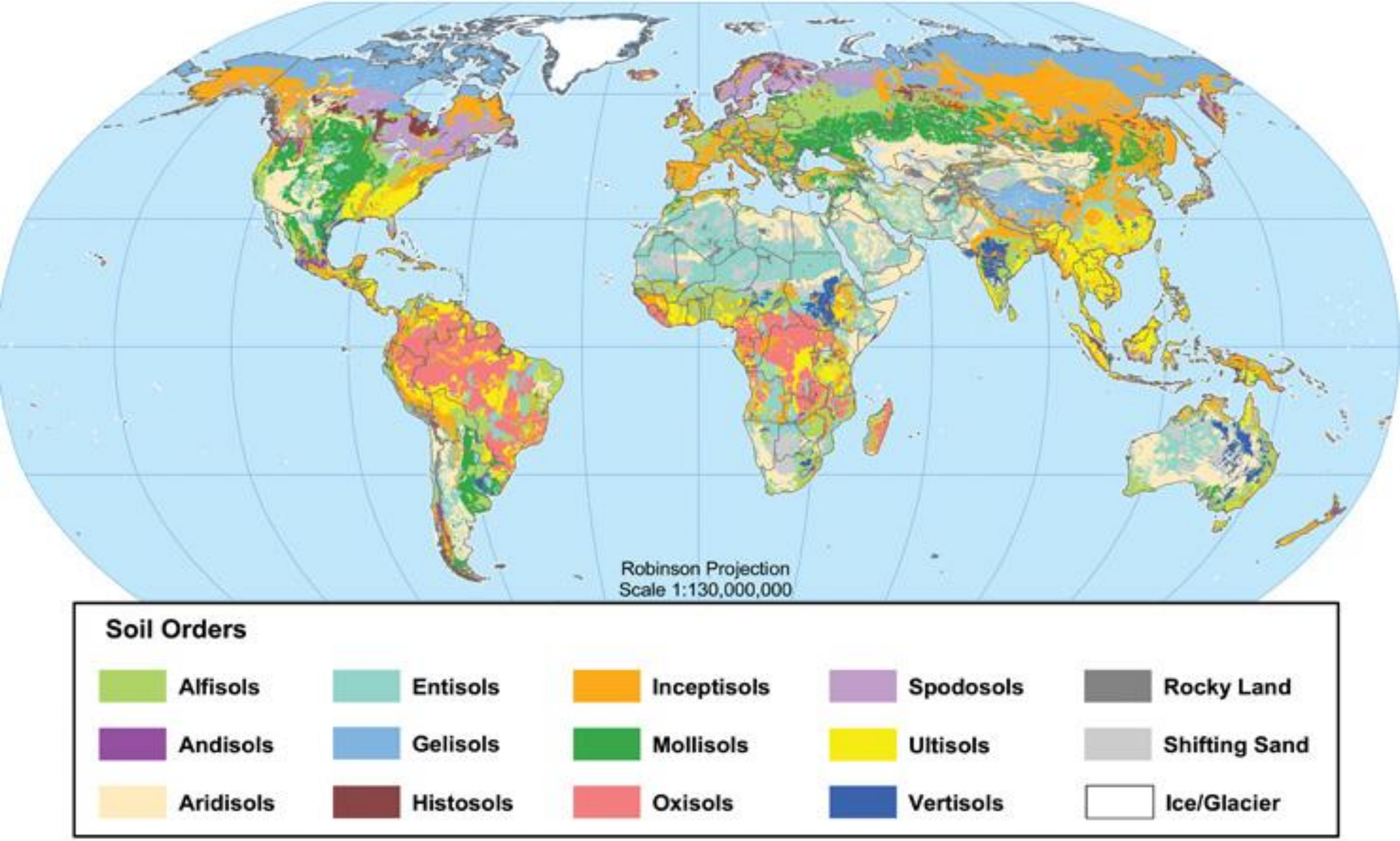
Water supply
and purification





Engineering Medium

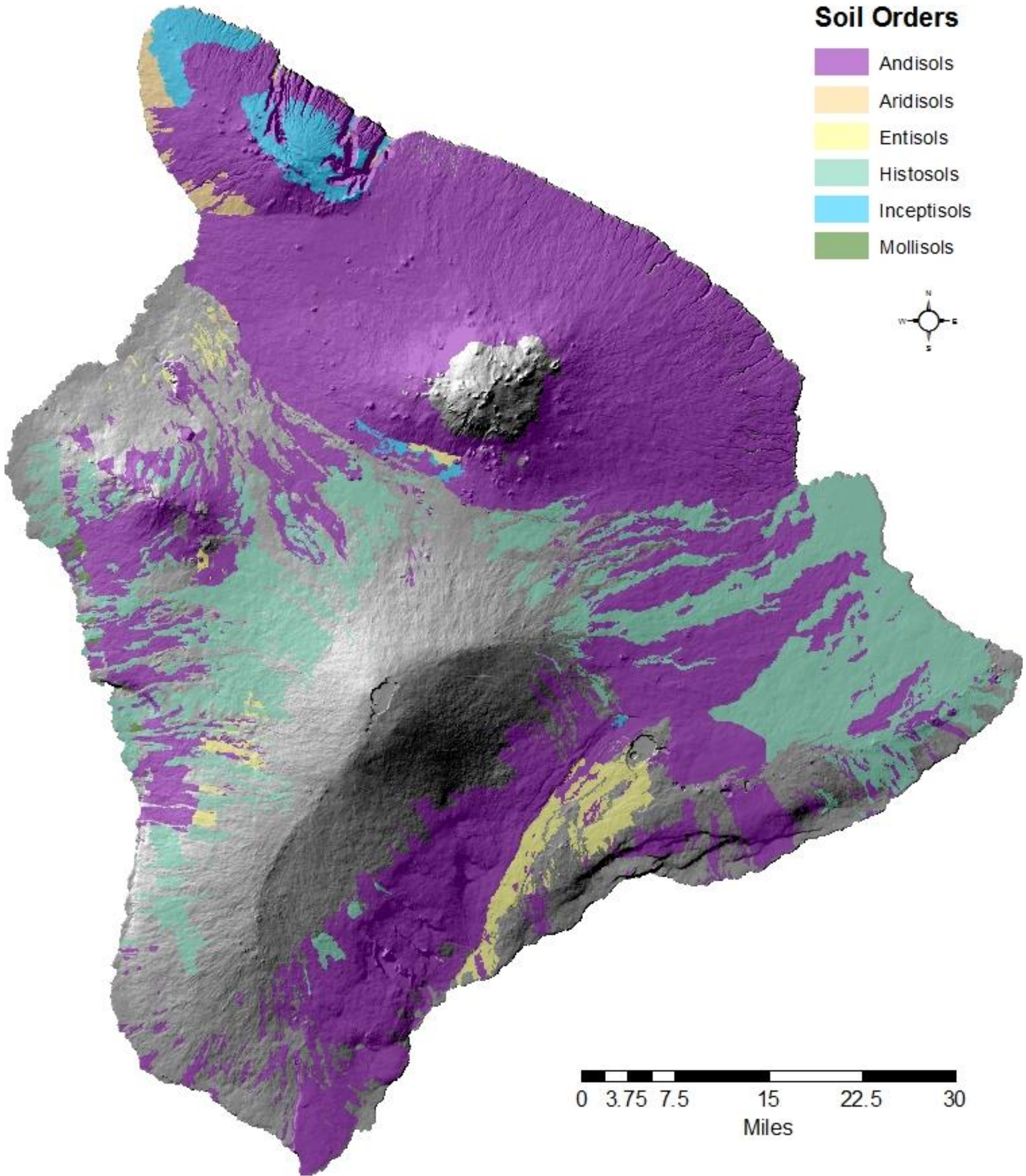
Global Soil Regions



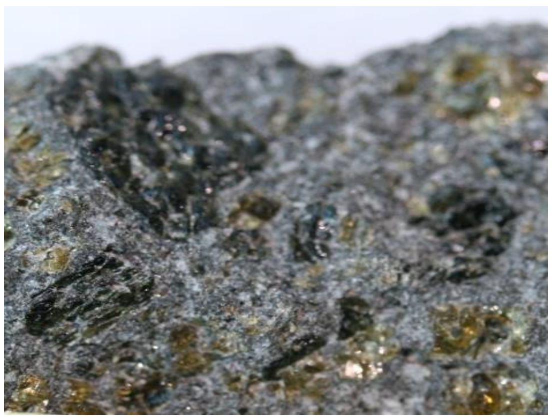
USDA NRCS
US Department of Agriculture
Natural Resources
Conservation Service

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

November 2005


Soil Orders
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
0 3.75 7.5 15 22.5 30
Miles

Soil Formation

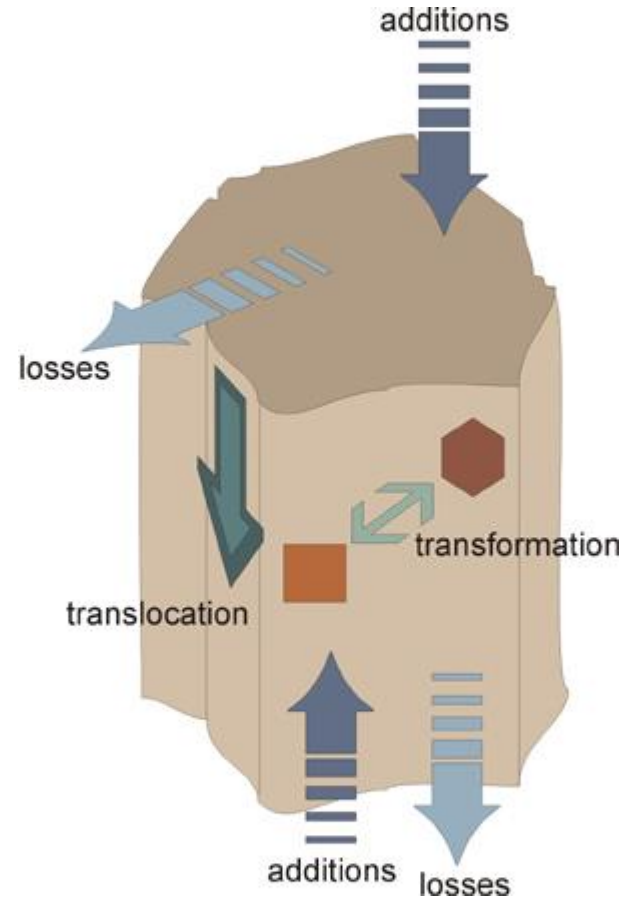


Factors

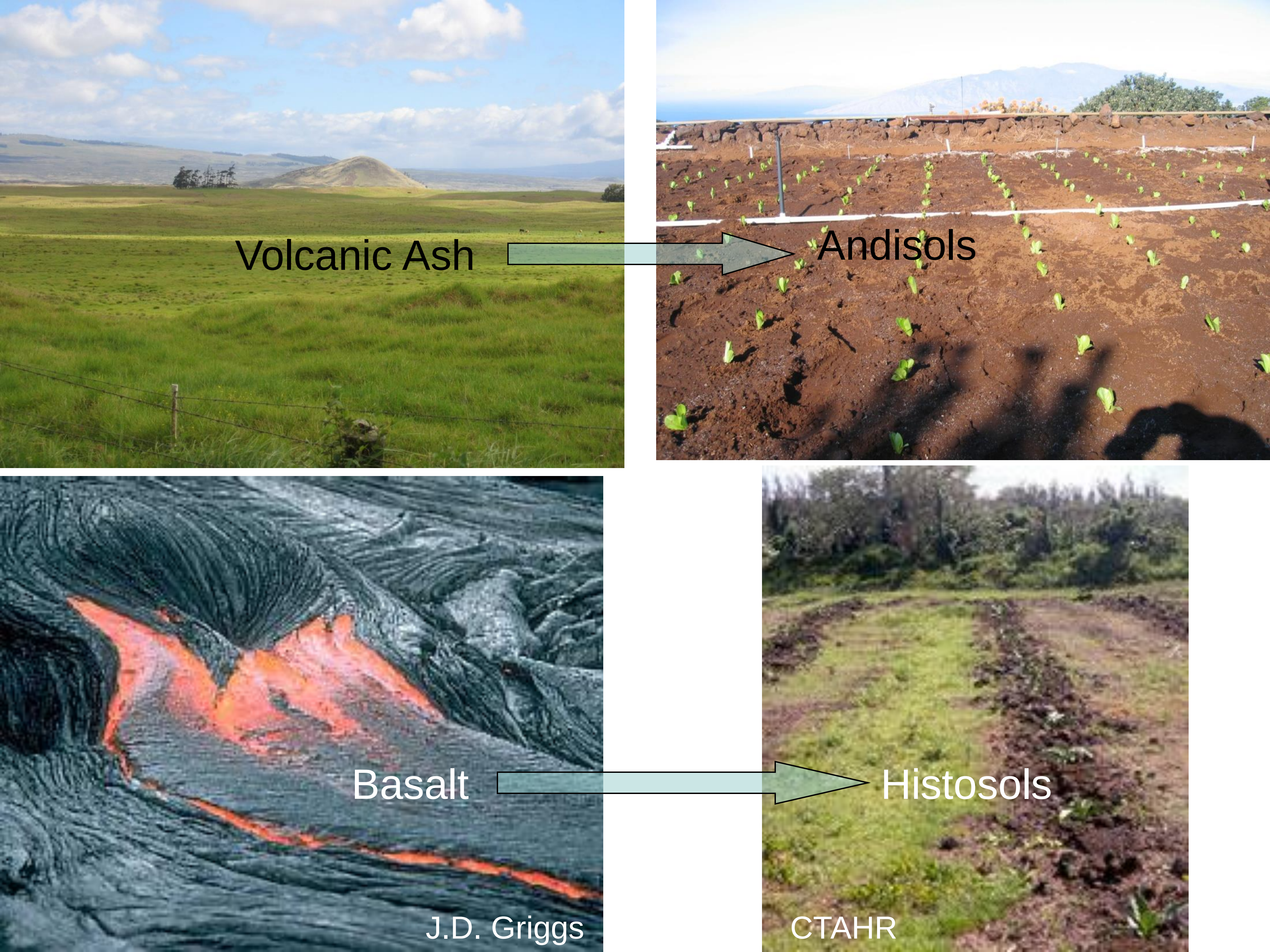
- Parent material
- Age
- Climate
- Biota
- Topography

Processes

- Additions
- Transformations
- Translocations
- Losses

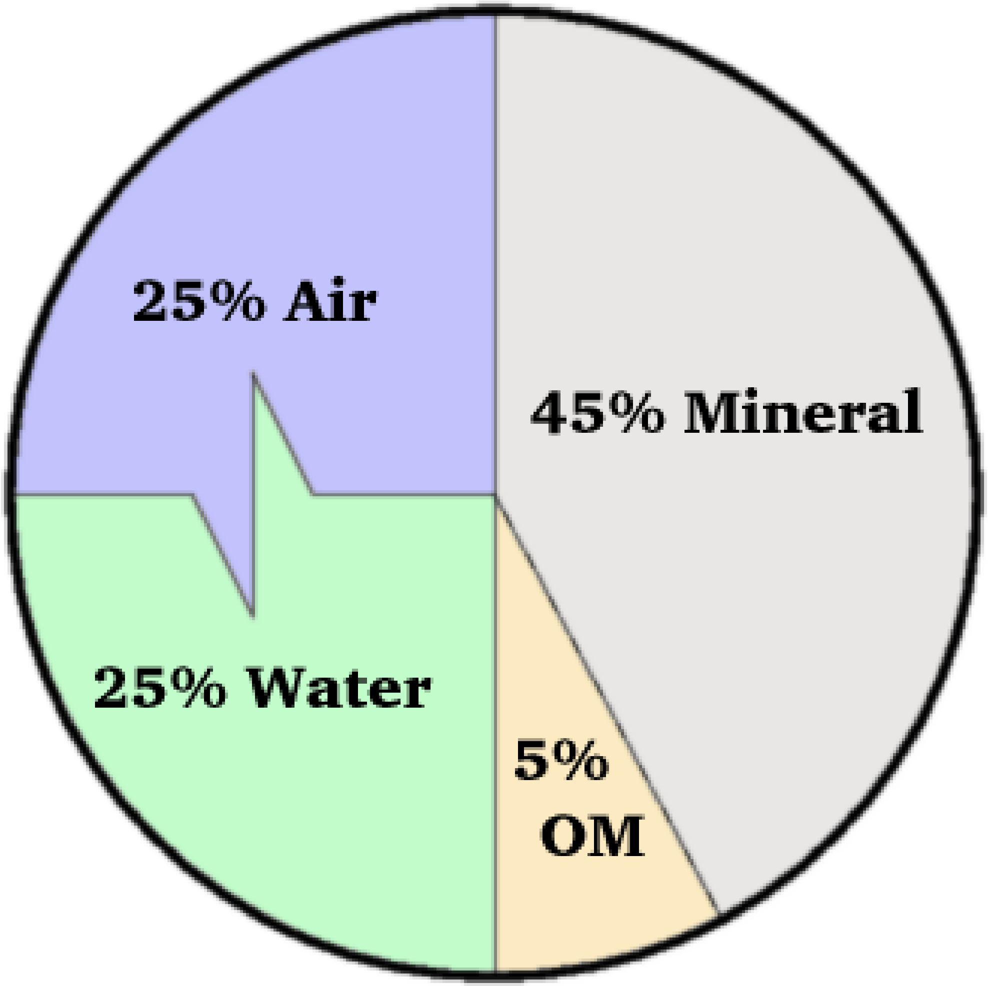


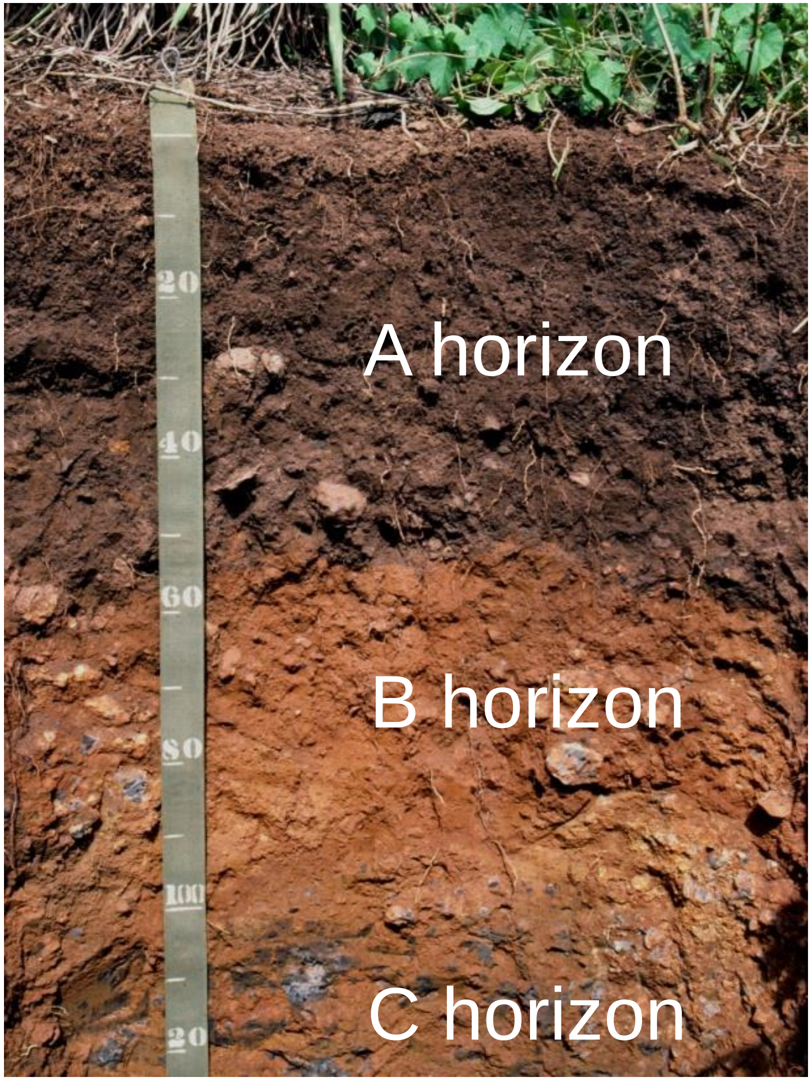
Soil Diversity



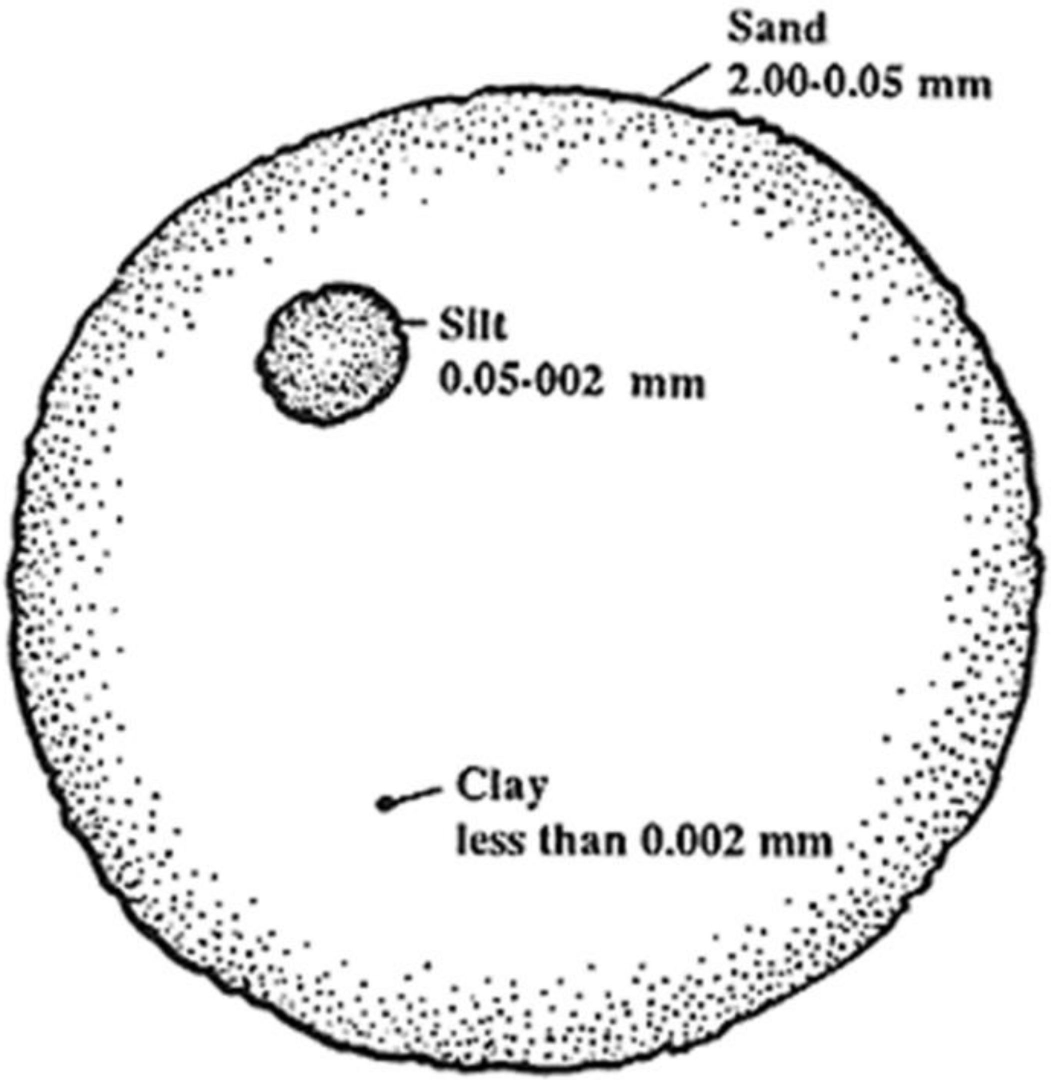
Volcanic Ash
Andisols
Basalt
Histosols
J.D. Griggs
CTAHR

What is Soil?





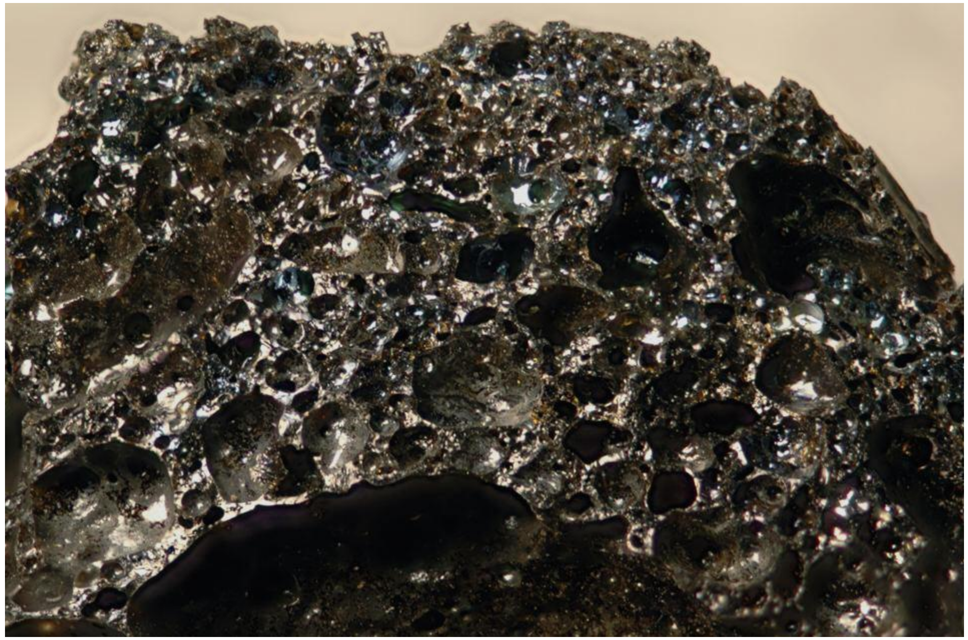
Soil Texture



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

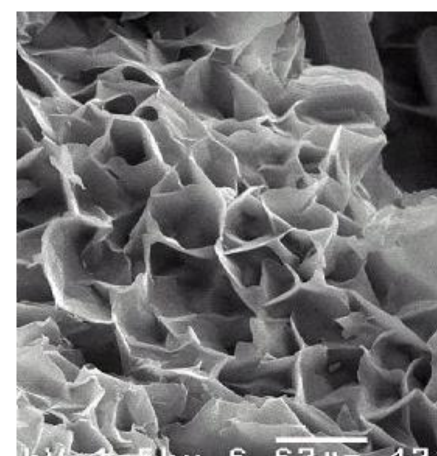


Chemical Weathering

$CaAl_2Si_2O_8$

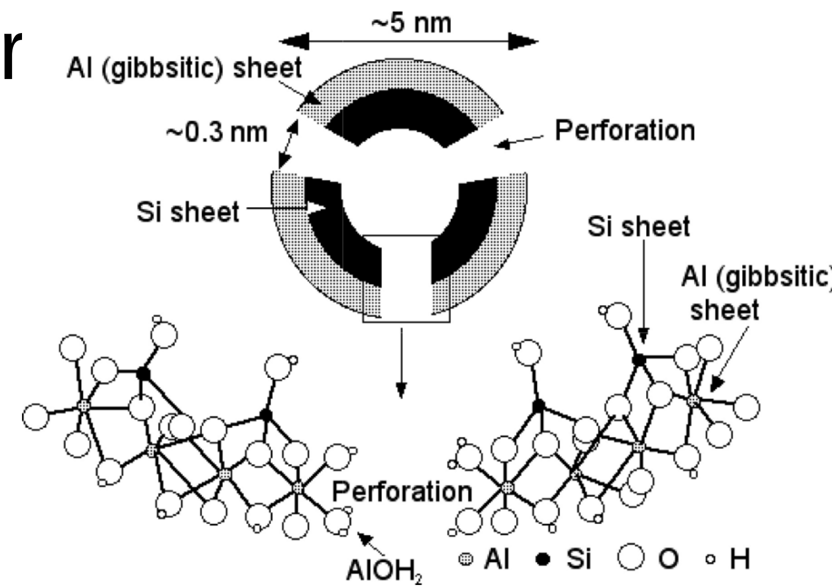
Allophane

Montmorillonite



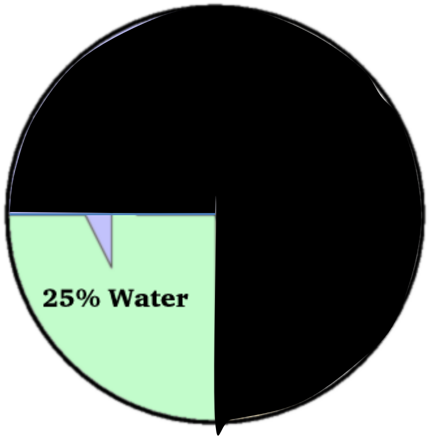
Properties of Allophane

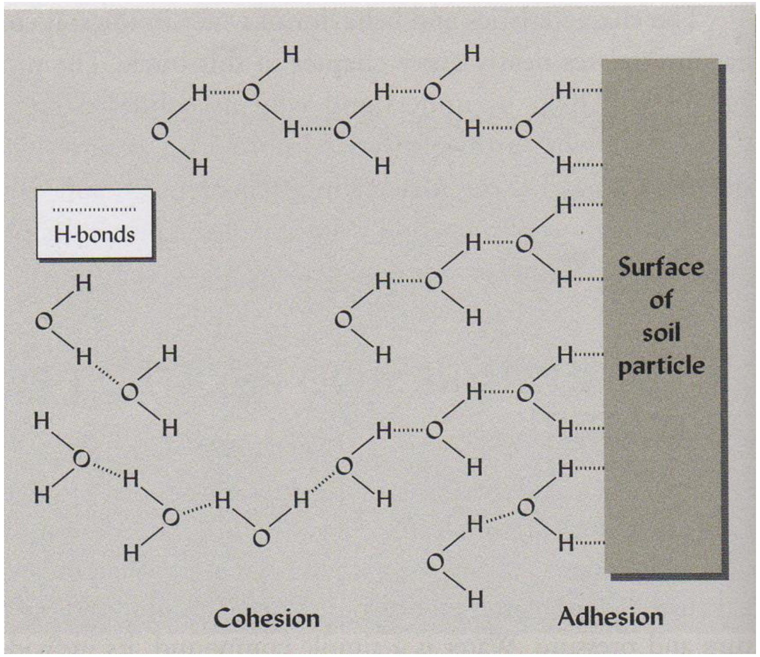
- Tubular structure with both exterior and interior surfaces
- Extremely high surface area >1,000 m^2 per gram
- Very high water holding capacity
- Excellent structure
- High surface charge
- High chemical reactivity

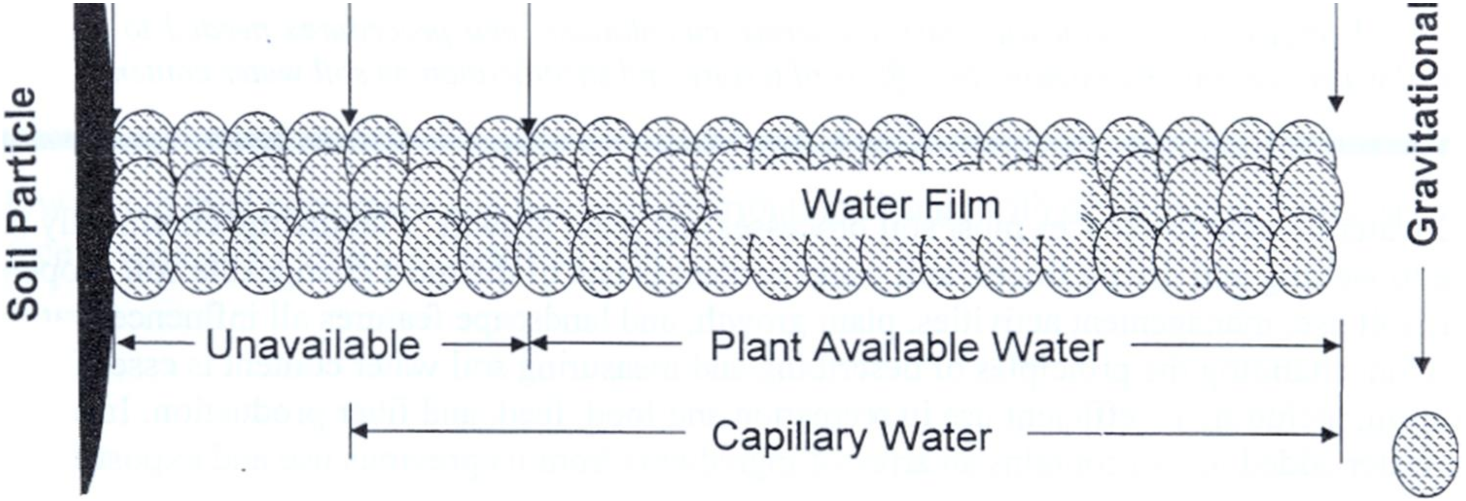


Allophane is the clay mineral in ash soils. It has extermely high surface area

Soil Water

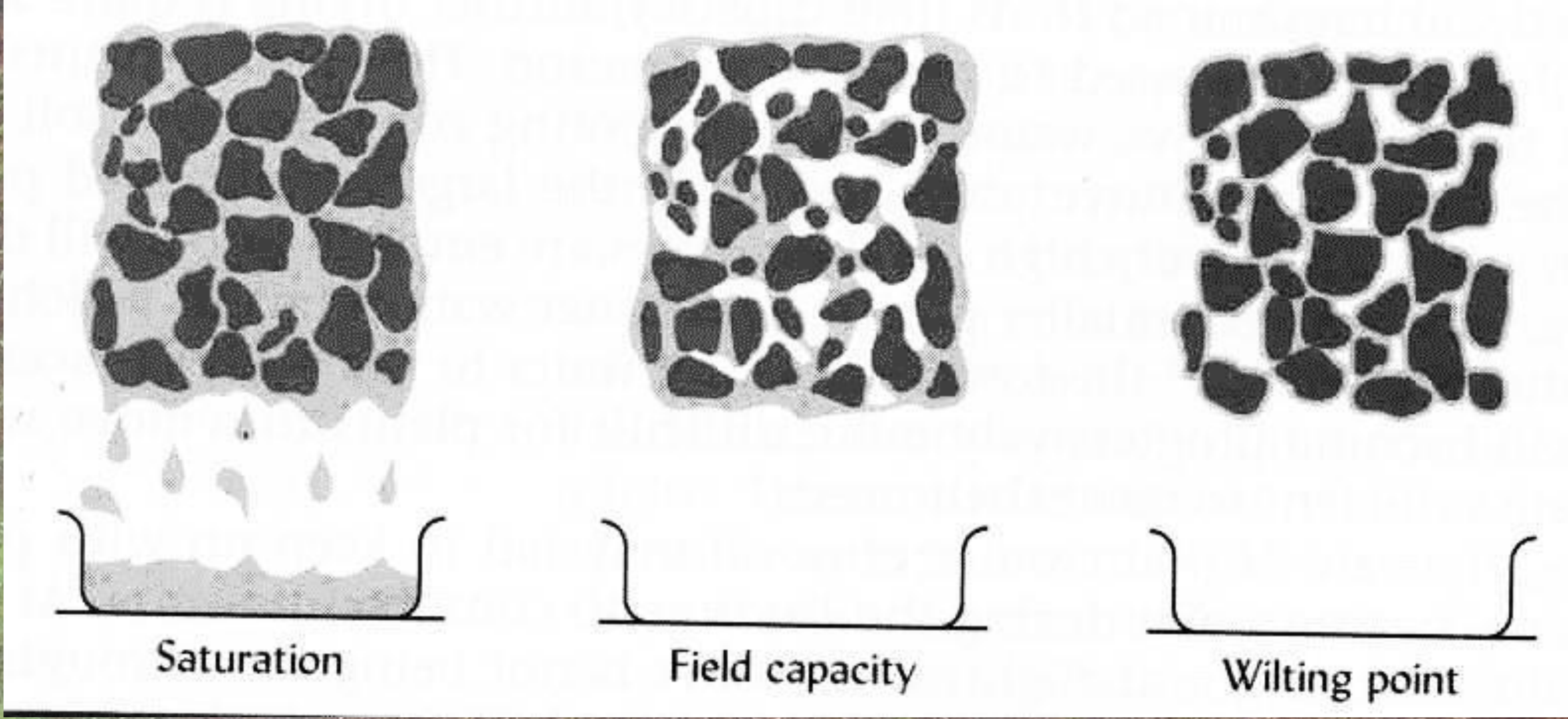

25% Water


H-bonds
Surface of soil particle
Cohesion
Adhesion


Soil Particle
Water Film
Gravitational
Unavailable
Plant Available Water
Capillary Water

Soil Water Availability

Soil water holding capacity depends on texture



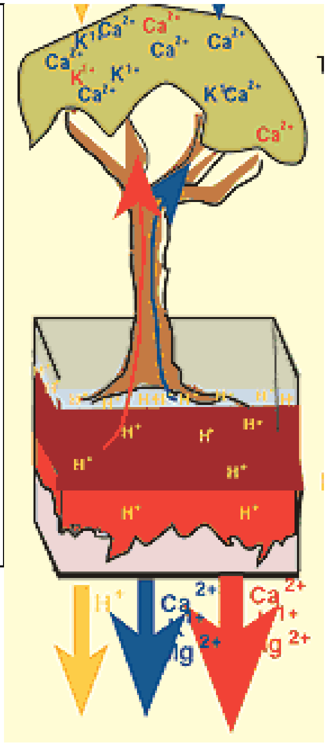
Too Little Water

- Drought
- Low nutrient availability
- Poor plant growth

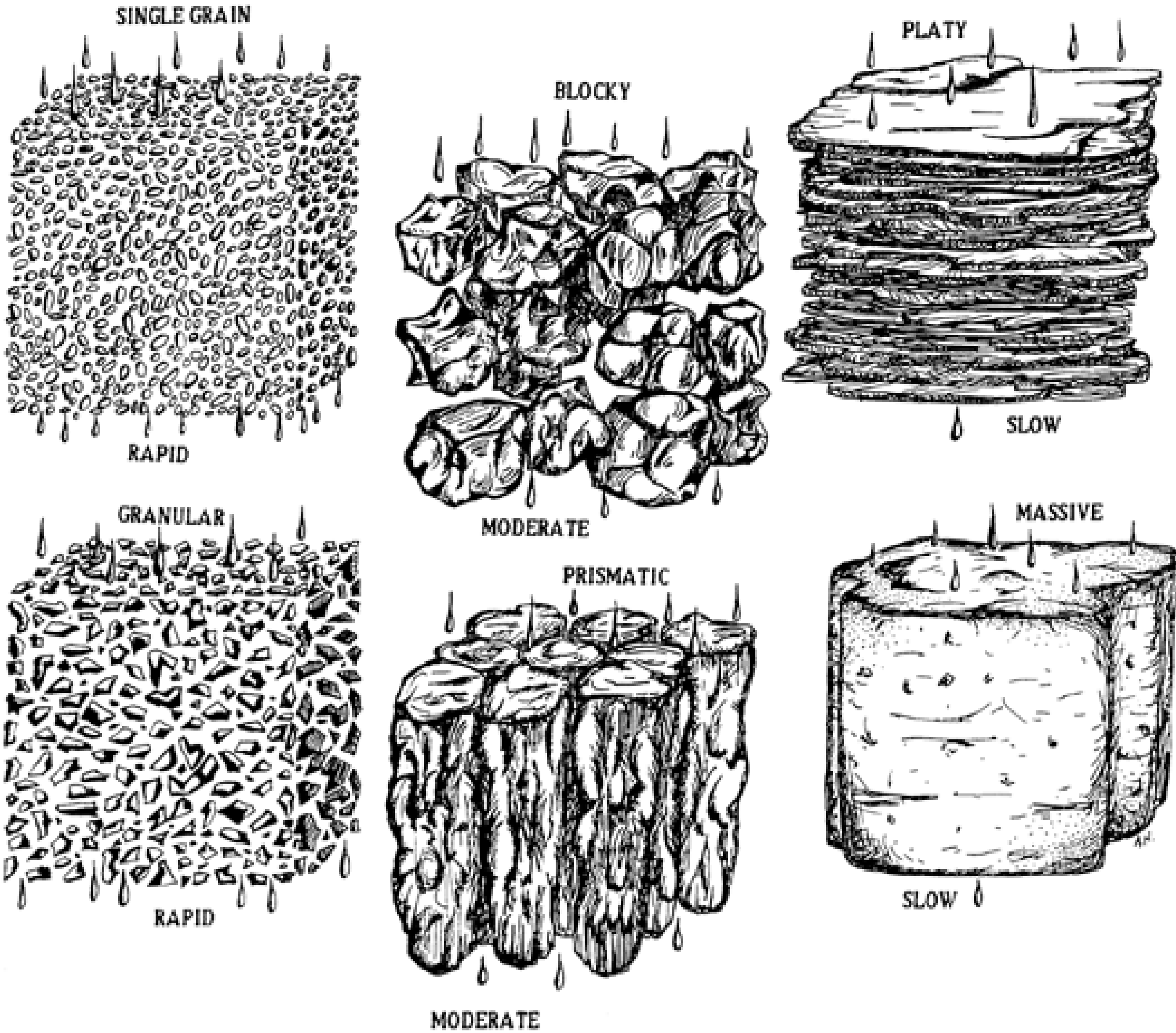
Too Much Water

- Nutrient leaching
- Nitrogen loss as gas

  $NO_3^- \longrightarrow N_2O \uparrow$



Soil Structure and Water Flow

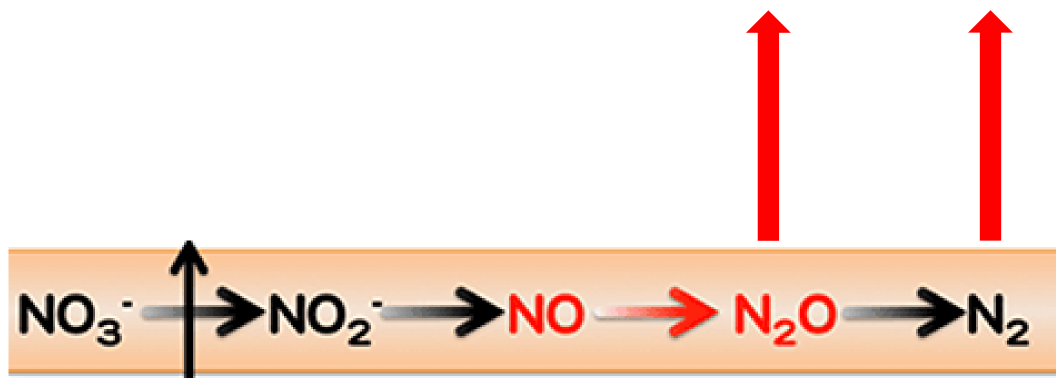


- Soils with strong stable aggregates have good drainage
- Aggregate stability depends on clay mineralogy
- Oxide-rich red soils have strong aggregates with good physical properties

Soil air

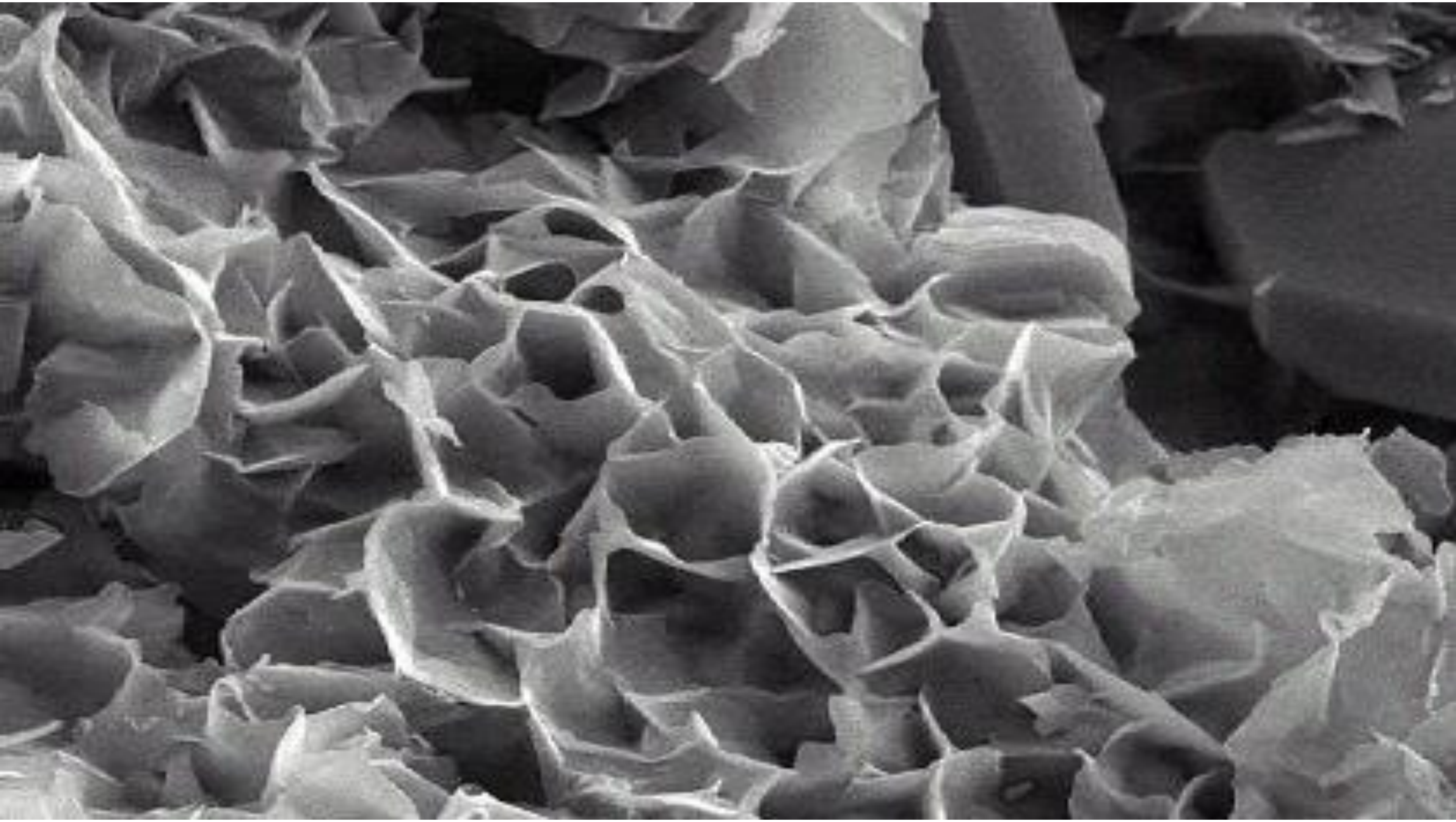
- Oxygen is essential for most life forms. In soil it supports a diverse microbial population and is required for root metabolism

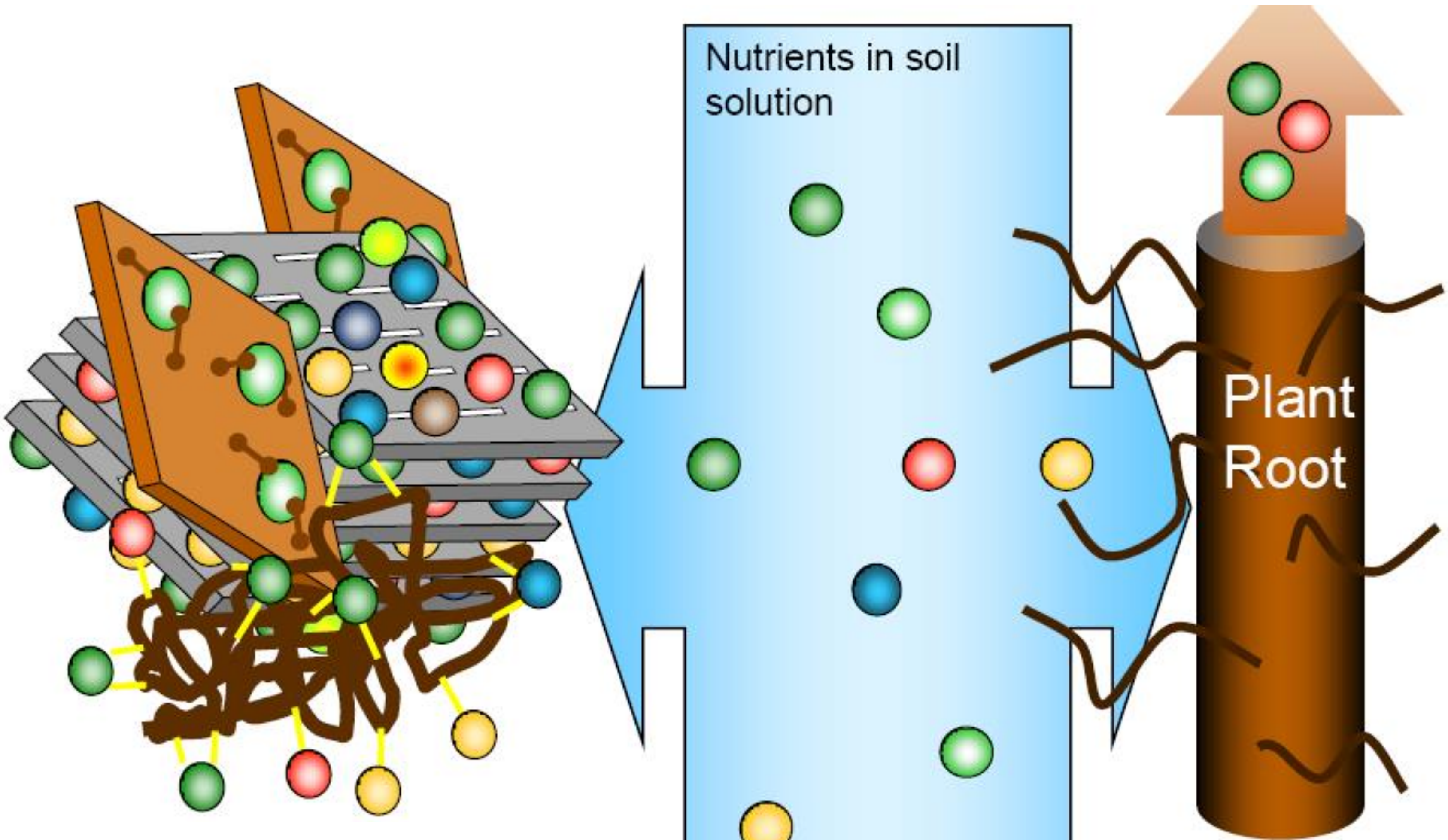
- In waterlogged soil, O_2 is present in very low concentrations creating reducing conditions
  - Gaseous loss of plant available N
  - Increase in toxic levels of Manganese in some soils
  - Fermentation and production of toxic by-products of anaerobic respiration



Loss of plant available N in saturated soils

Clay Minerals & Soil Chemical Properties





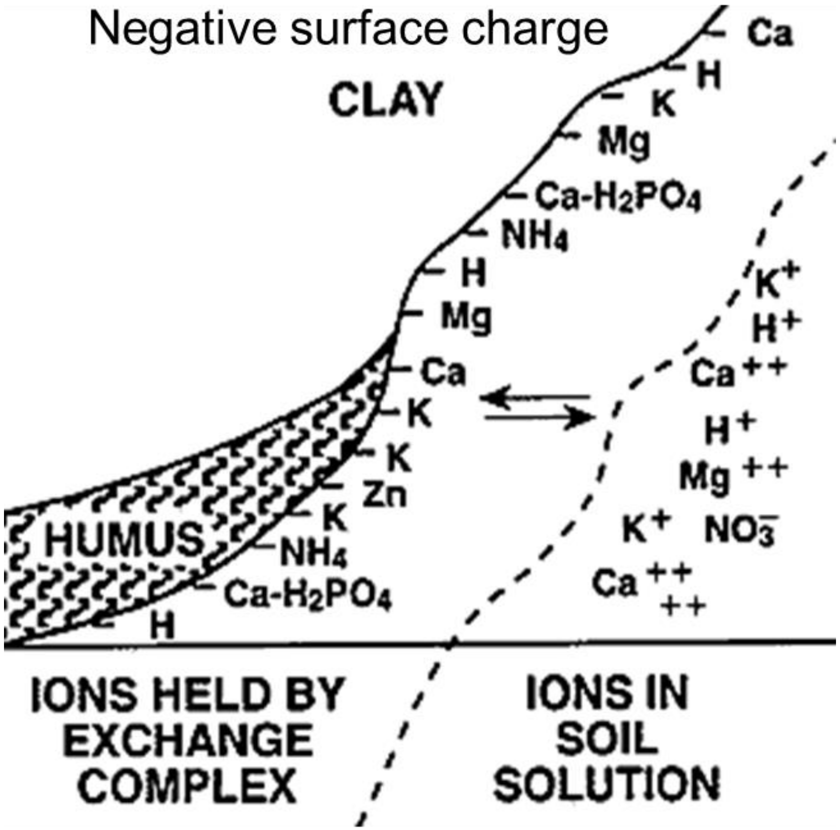
- Clay minerals
  - CEC/AEC
  - P fixation

Cation Exchange Capacity

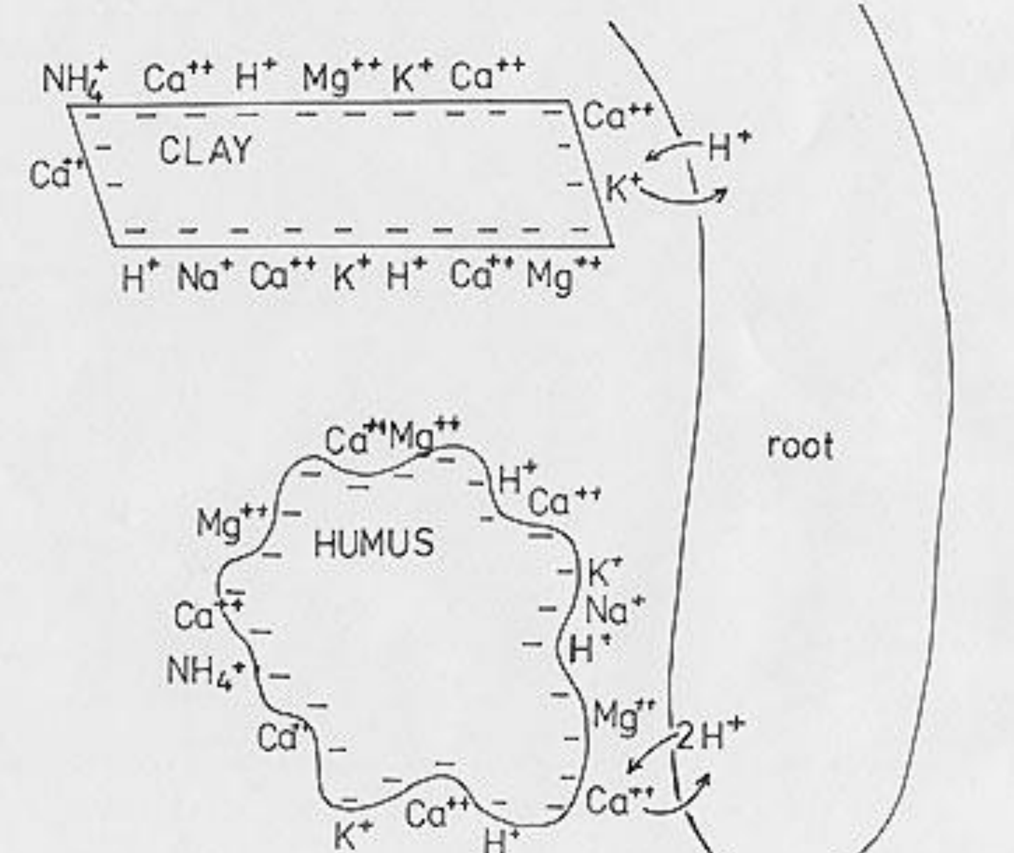
Cation Exchange Capacity

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

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

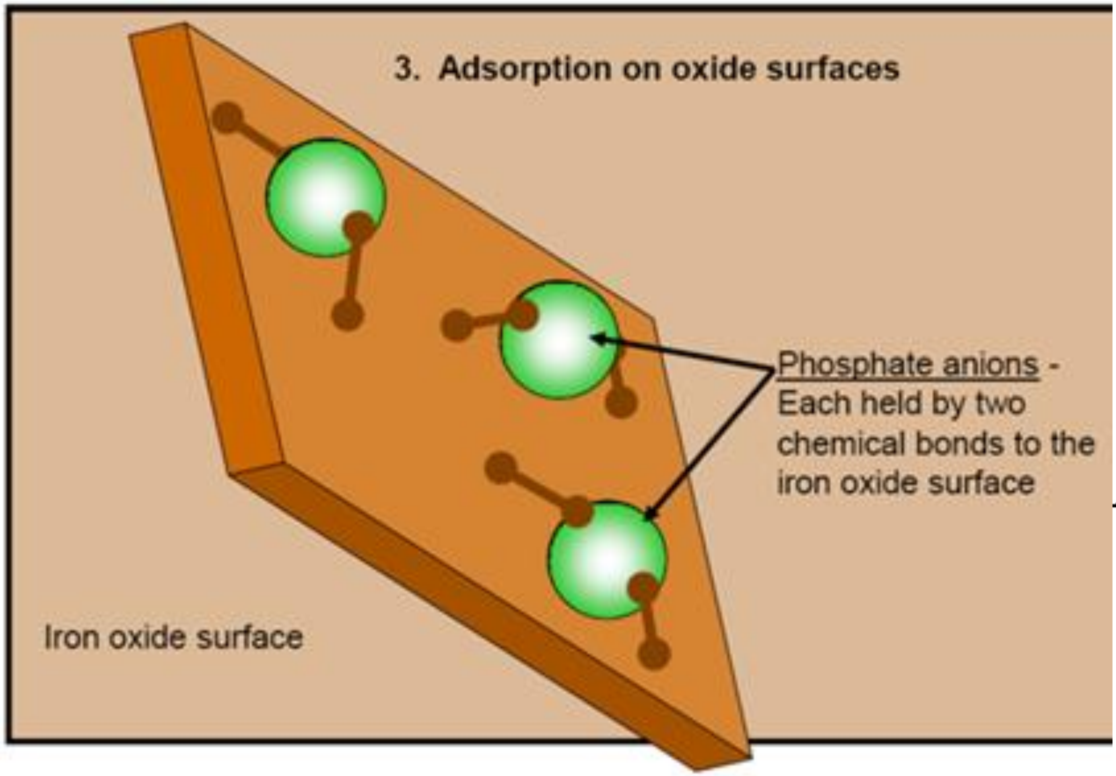


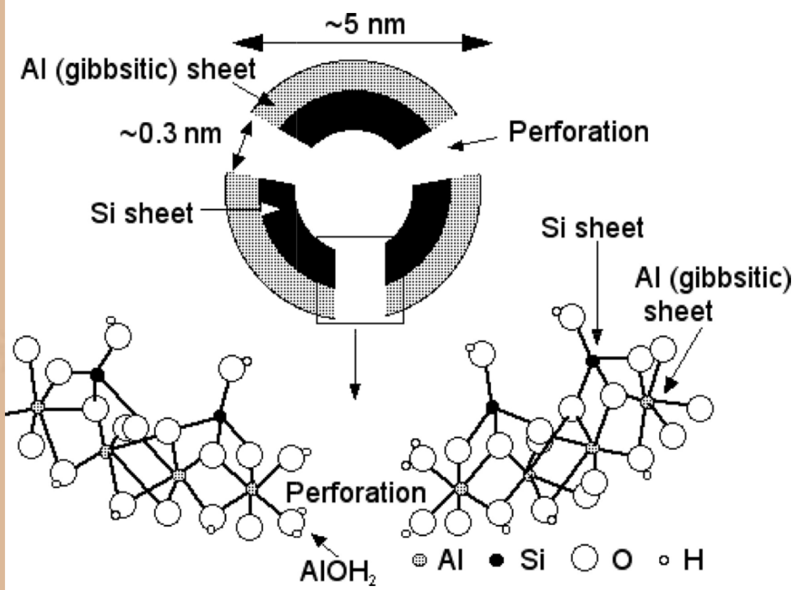
http://www.extension.umn.edu/distribution/cropsystems/images/6437f01.gif



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

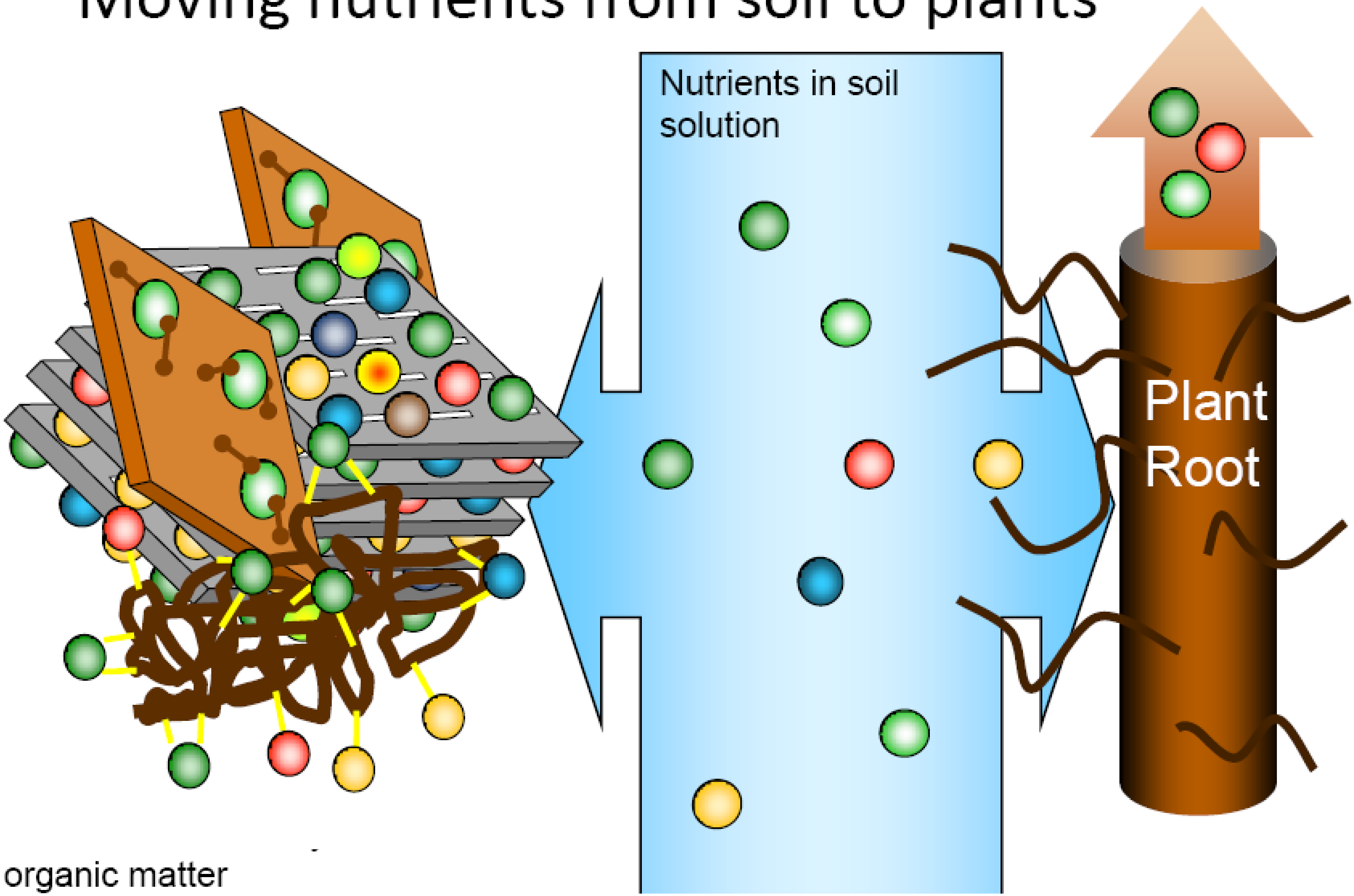
Phosphorus Fixation





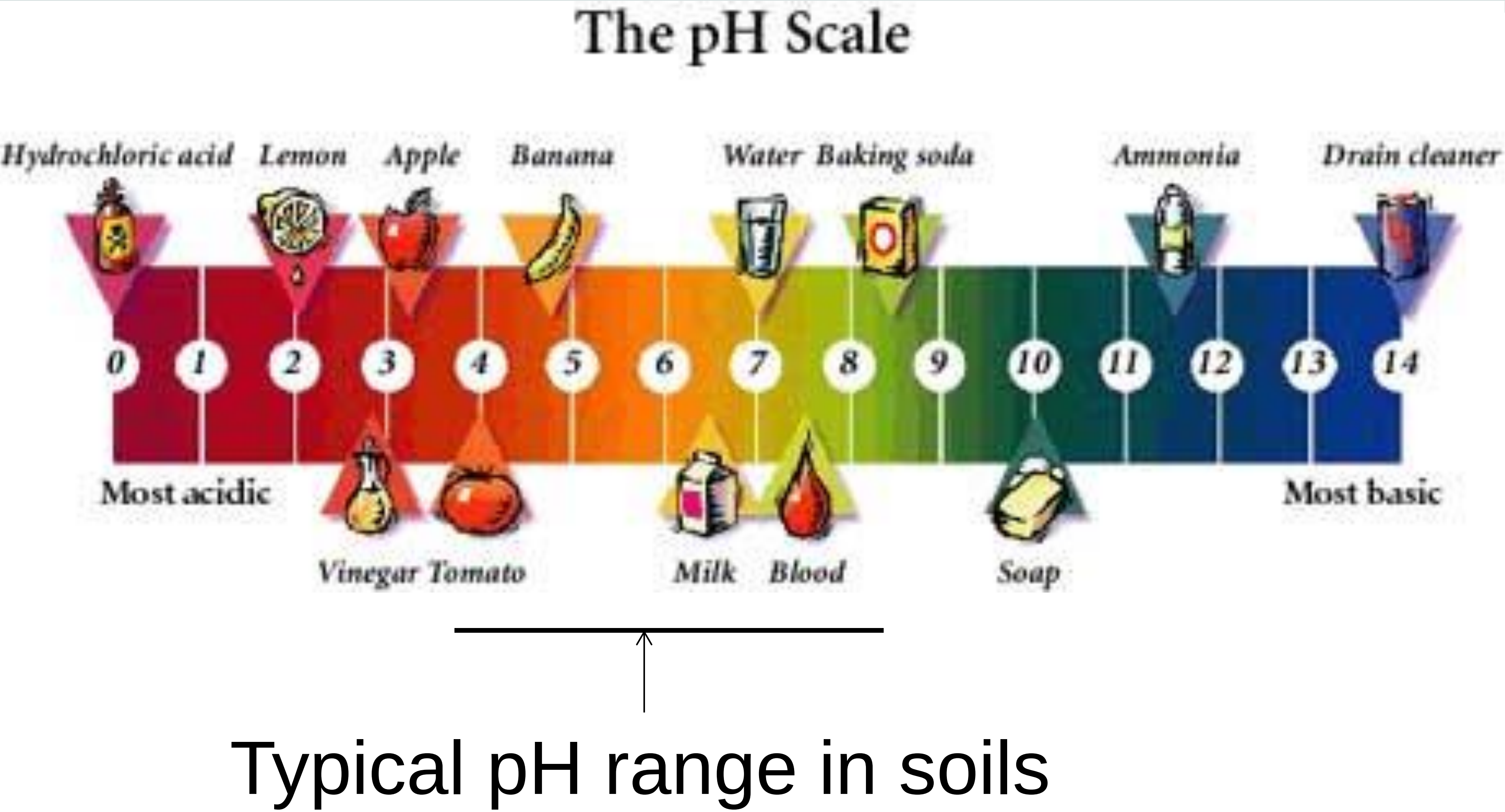
- ➢Under acidic conditions P forms strong bonds with Fe and Al clay surfaces
- ➢P is not available for plant use

Moving nutrients from soil to plants

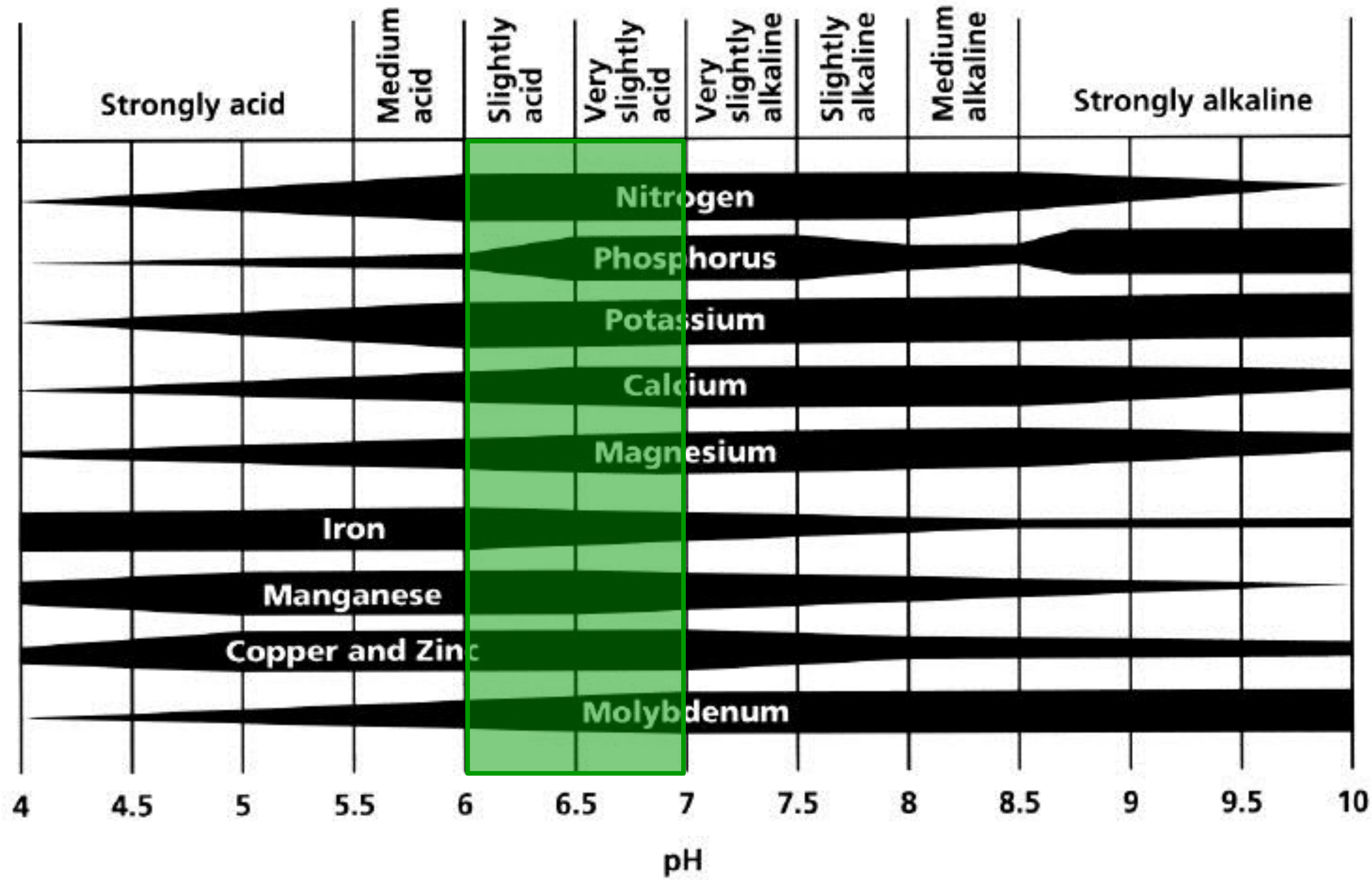


- Soil acidity/alkalinity

Soil pH is an Expression of Acidity/Alkalinity



Soil pH Affects Nutrient Availability



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 (pH < 5.5)
- Mn toxicity (pH < 5.5)

Negative Impacts

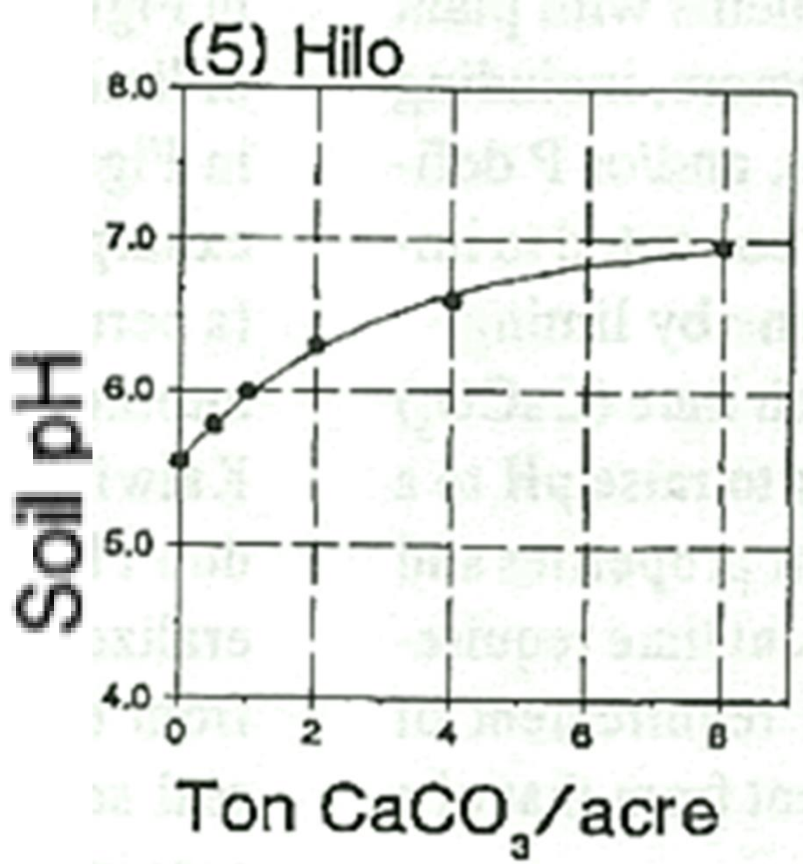
- micronutrient deficiencies
- P deficiency
- high salinity
- poor drainage

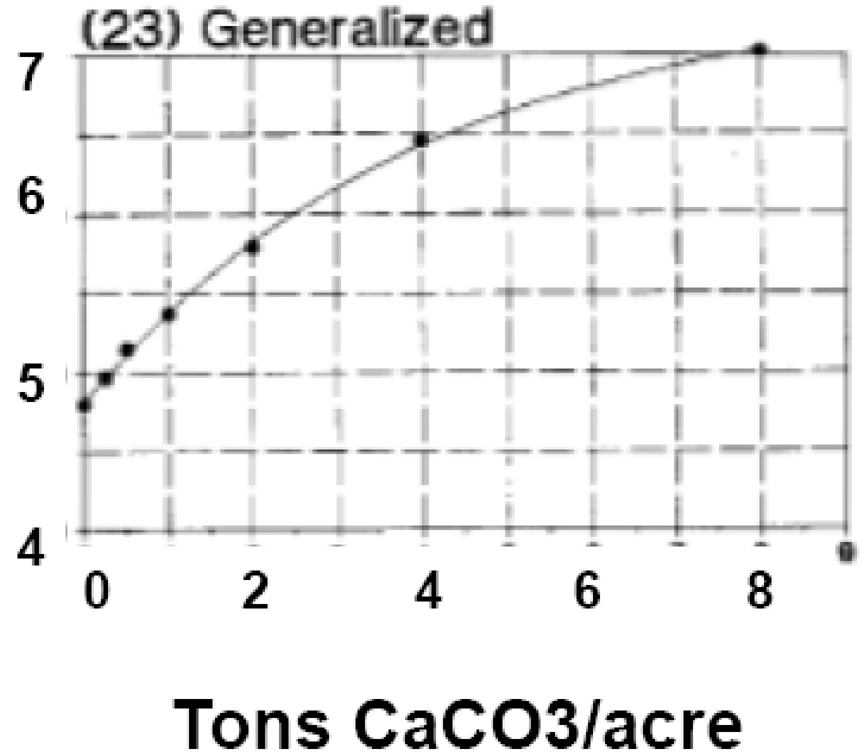
Liming Corrects Soil Acidity

- 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

Common name of liming material	*Chemical formula (of pure materials)*	*% $CaCO_3$ equivalent*
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_2O, $K(OH)$, etc.	40
Misc. lime-containing by-products	Usually $CaCO_3$ with various impurities	20–100

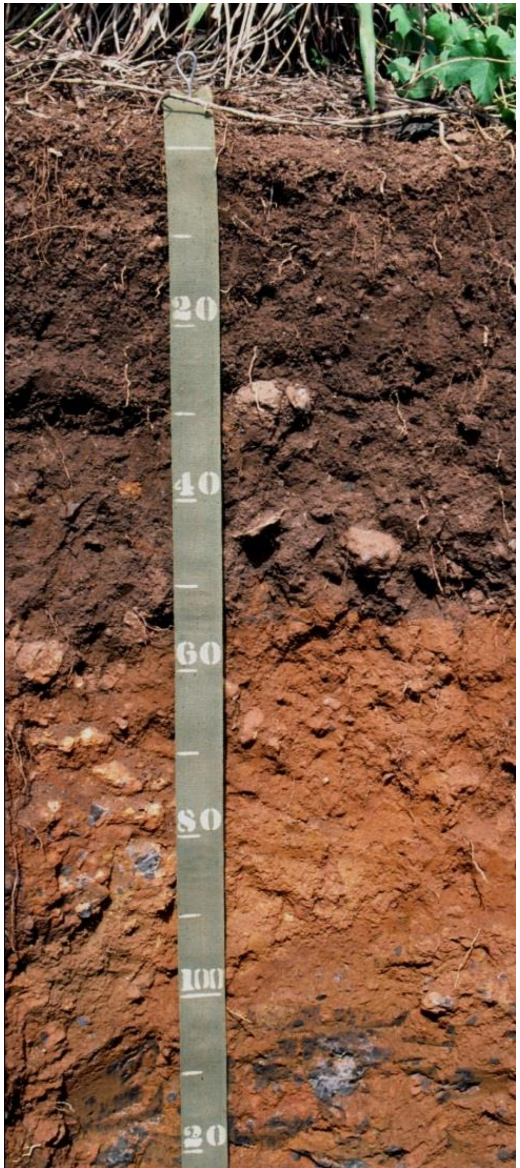




Liming curves for many soil series in Hawaii available online

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

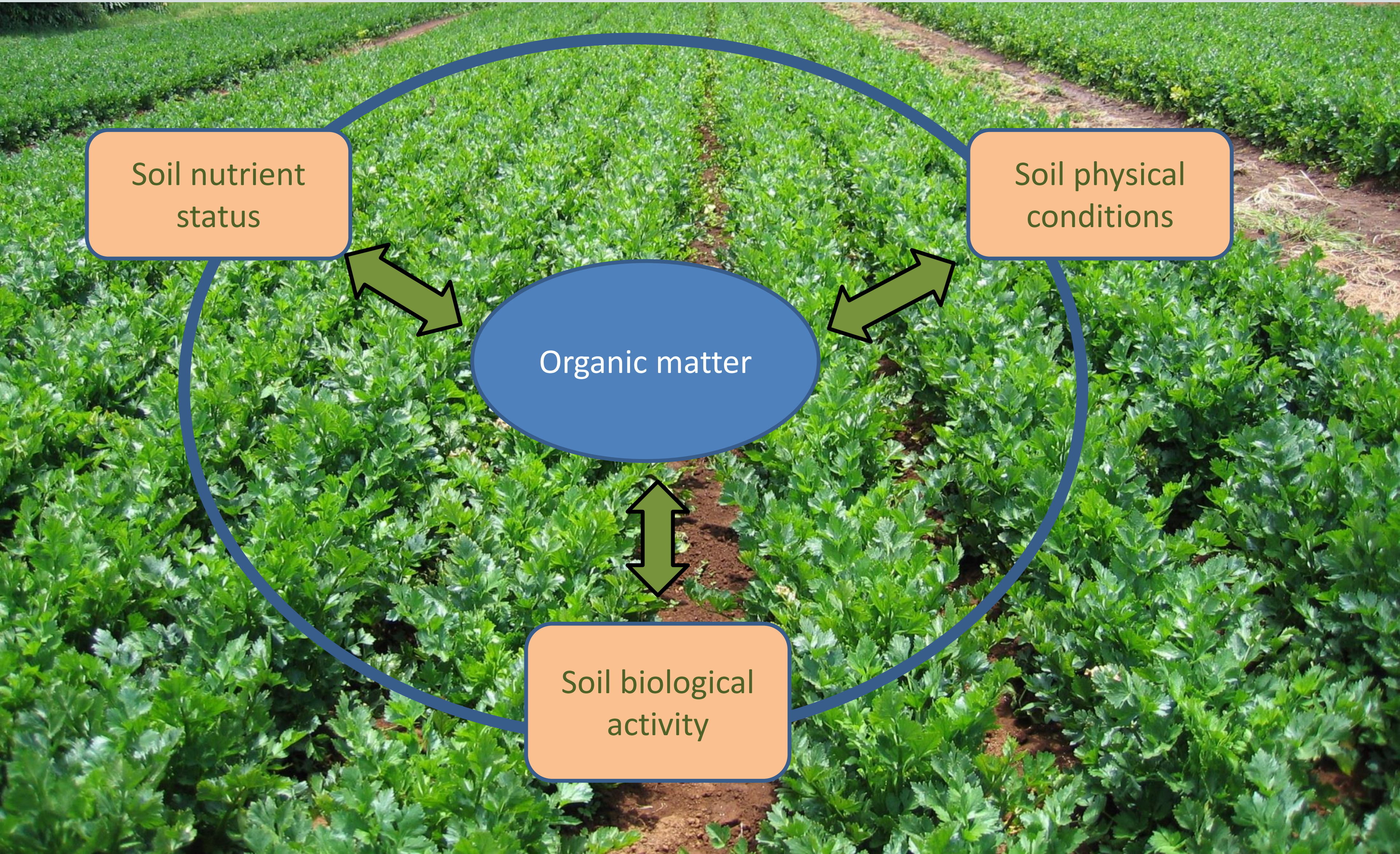
Soil Organic Matter



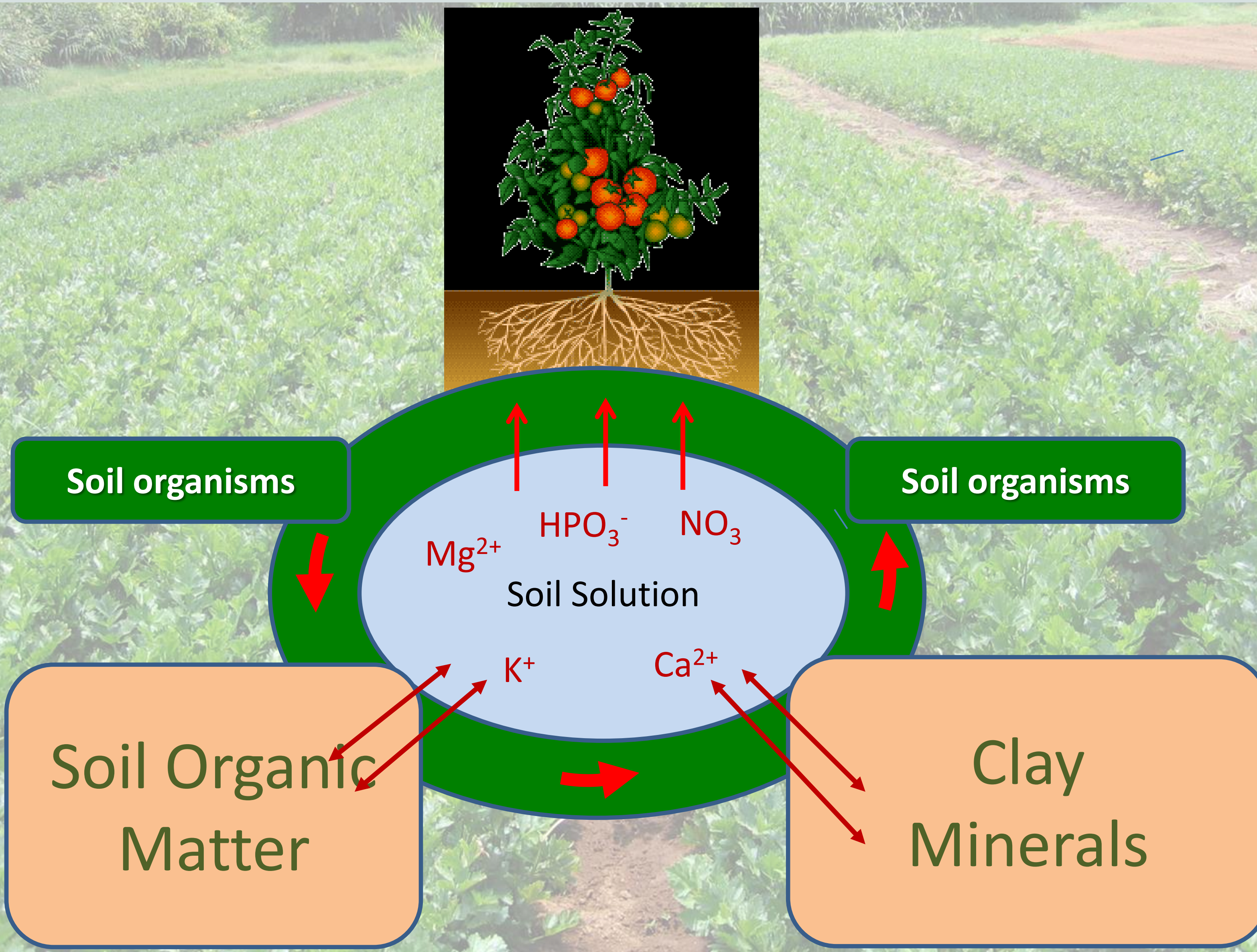
Nutrients present

Nutrients absent

Organic Matter Quantity and Quality Central to Fertility



Soil Nutrient Pools



Improves Soil Physical Properties

- Enhances soil structure
- Increases water infiltration
- Increases water retention
- Decreases bulk density

Improves Soil Chemical Properties

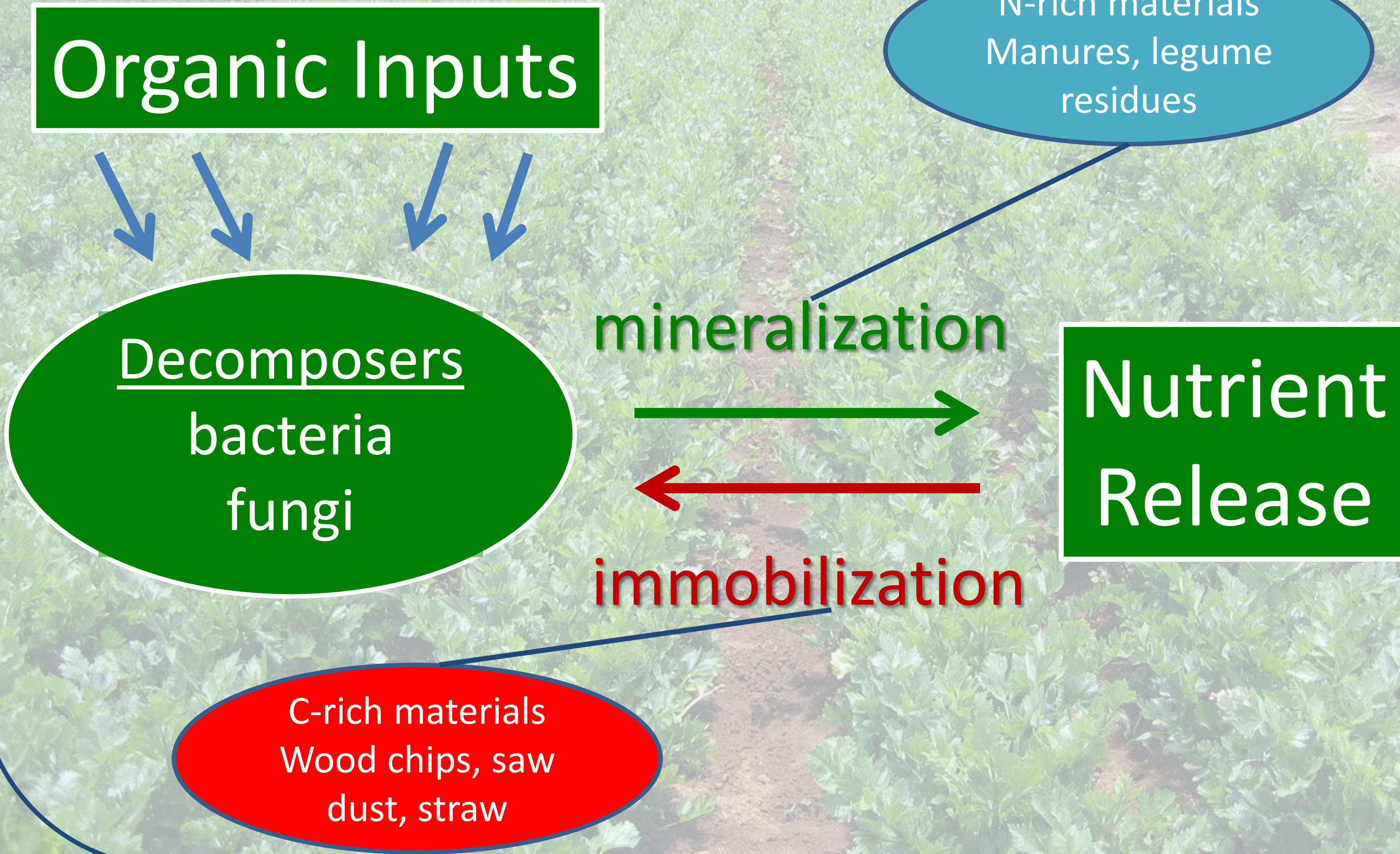
- Essential nutrients
- Increases CEC
- Detoxifies Al
- Buffers pH

Soil Organic Matter

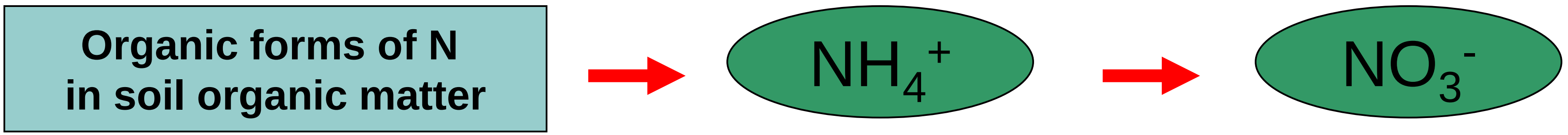
Improves Soil Biological Properties

- Increases microbial abundance and diversity
- Creates disease suppressive soils
- Increases nutrient cycling and availability

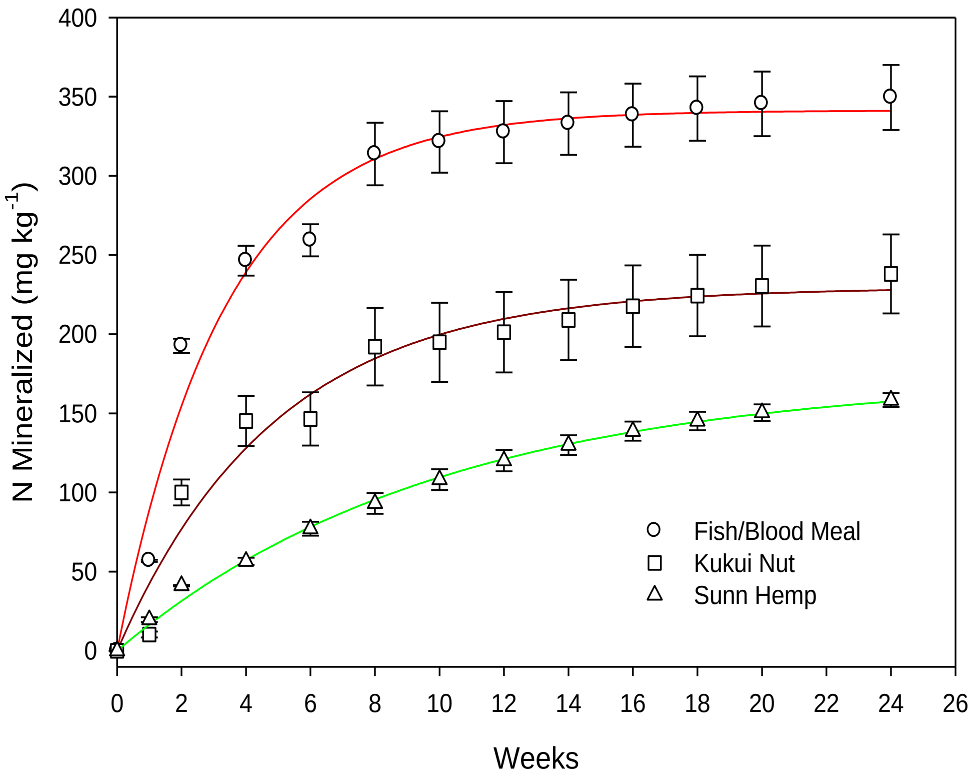
Organic Matter and Nutrient Dynamics



N Mineralization

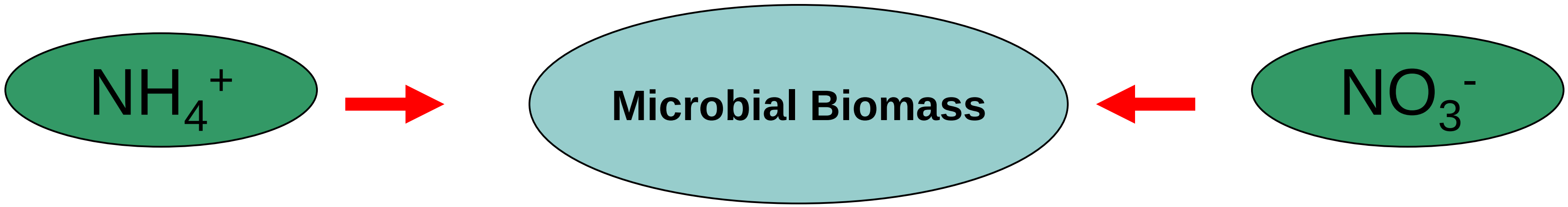


High N Materials
Fish meal
Animal manures
Green leaves



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

N Immobilization



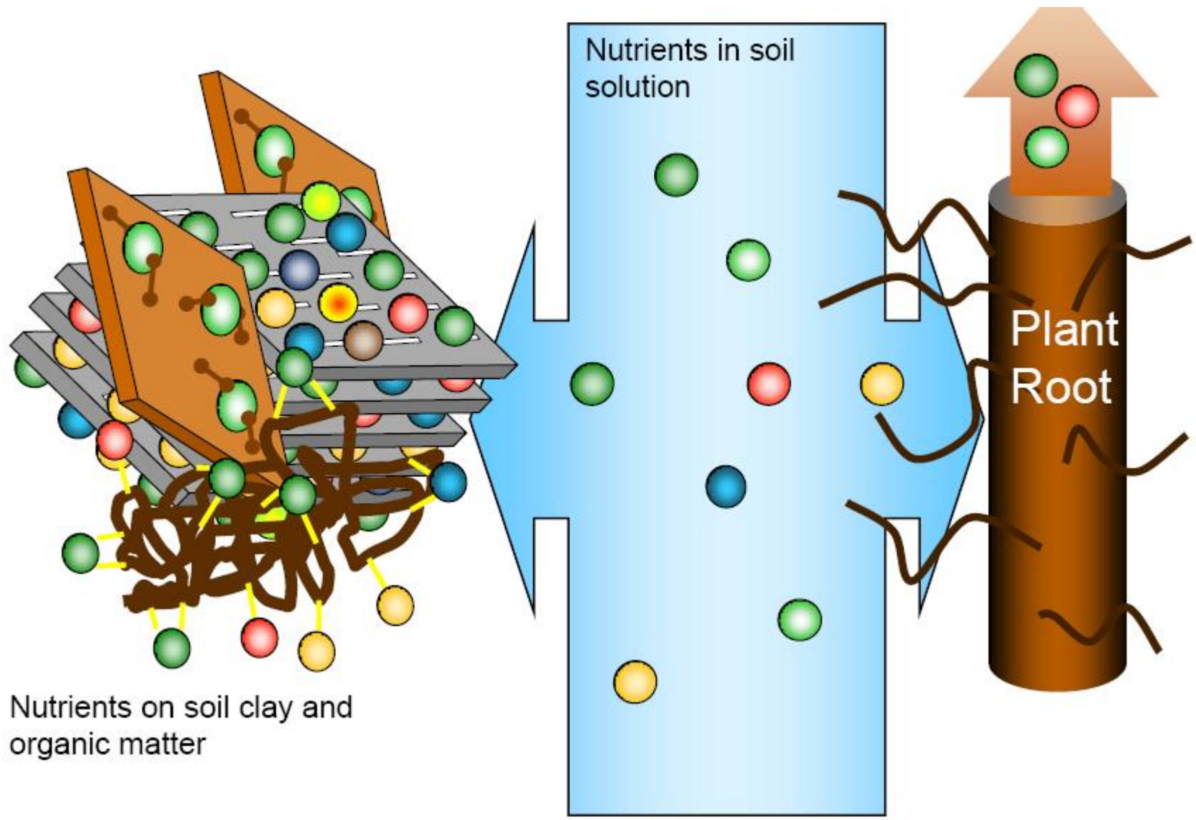
<u>Immobilization</u>: assimilation of inorganic N forms (NH_4^+, NO_3^-) into the microbial biomass

<u>High C Materials</u>

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

Soil Fertility Depends on:

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




Part II

Essential Plant Nutrients

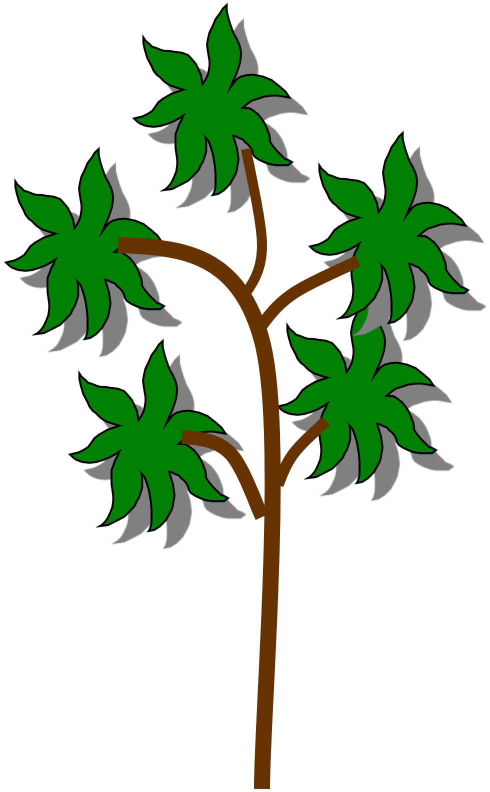
Macronutrients

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

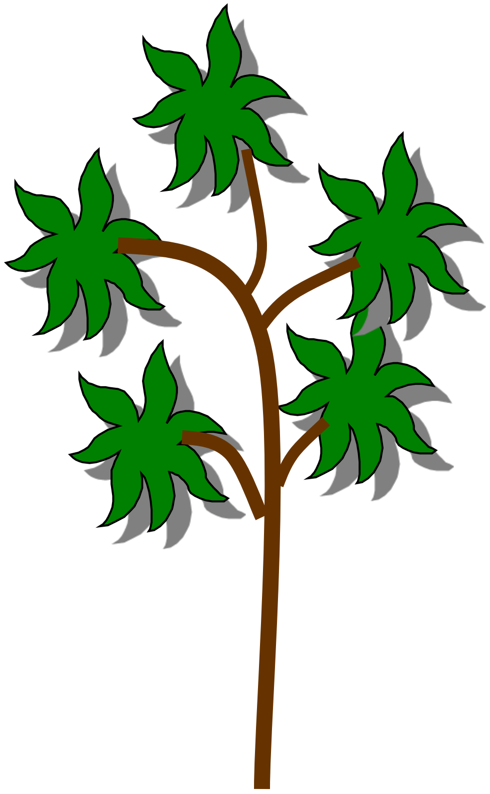
Micronutrients: B, Cu, Fe, Mn, Zn, Mo, Ni, Co, Cl

Nutrient Mobility in Plants

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

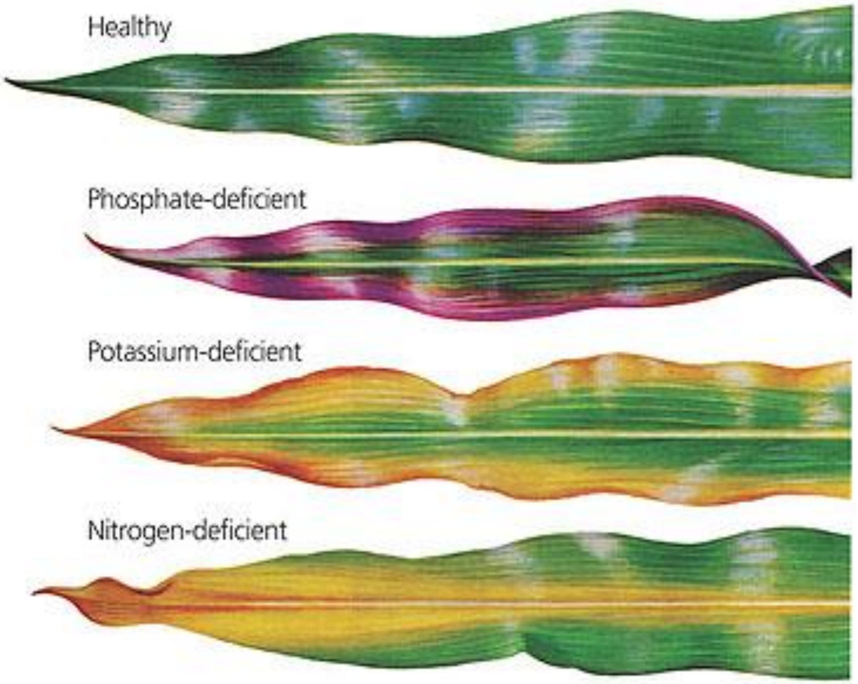
Manganese – mottled interveinal chlorosis on new leaves

Zinc – interveinal chlorosis in bands on new leaves

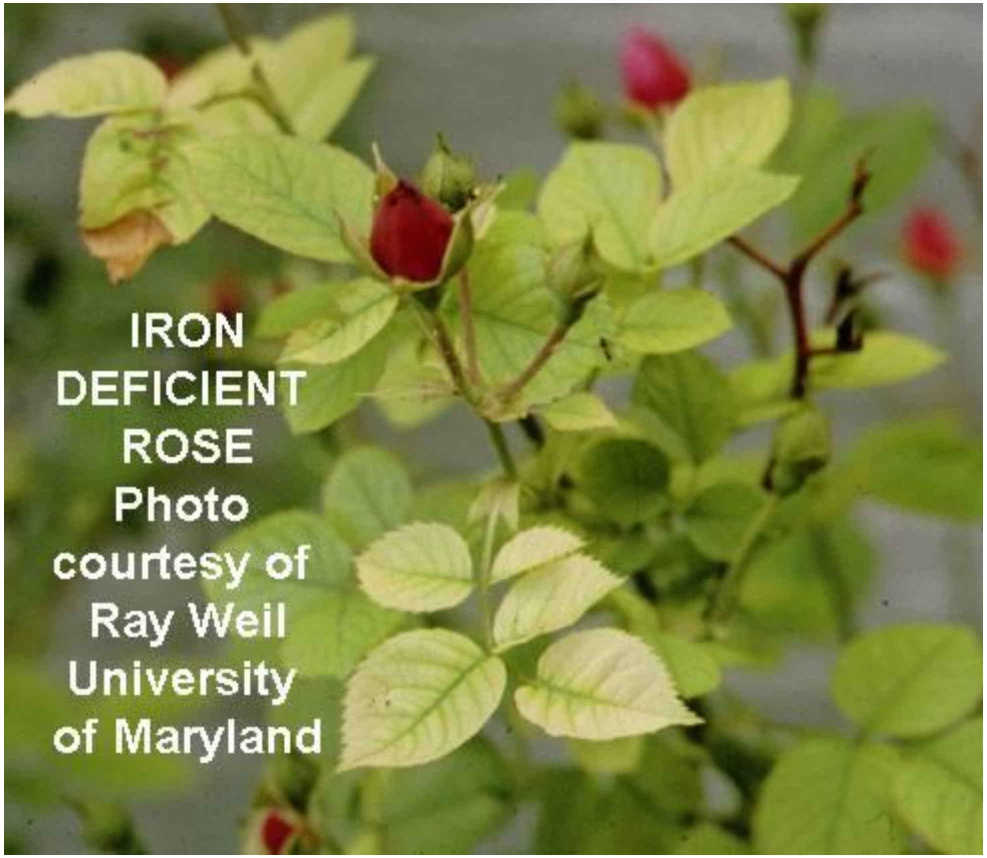
Diagnosis

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

Deficiency Symptoms



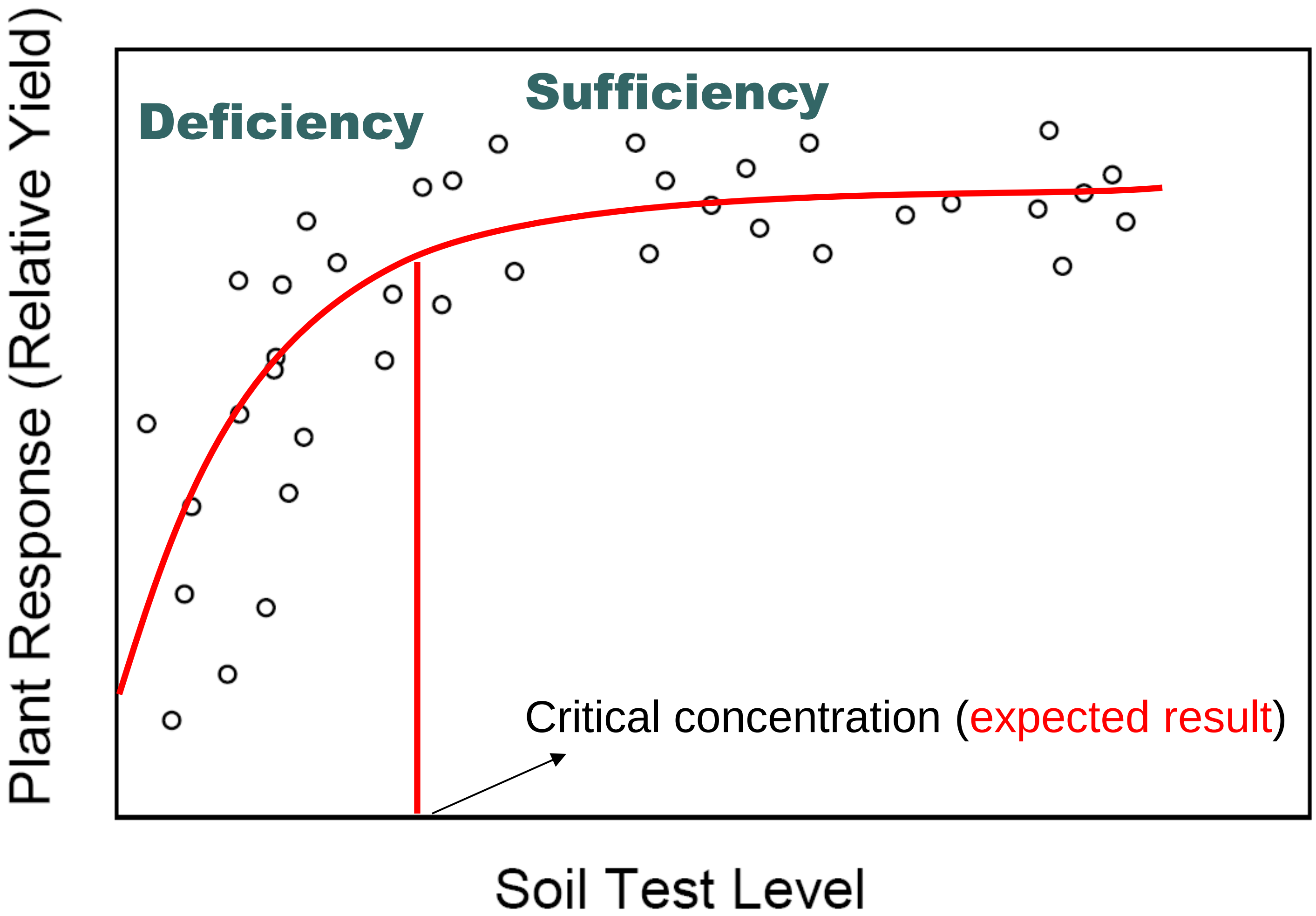
Old Leaves



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 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	Agent:	SATO, DWIGHT, Office: HILO
	P.O. Box 959 Attn: Eric Schott		875 KOMOHANA STREET
	Honokaa, Hawaii 96727		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

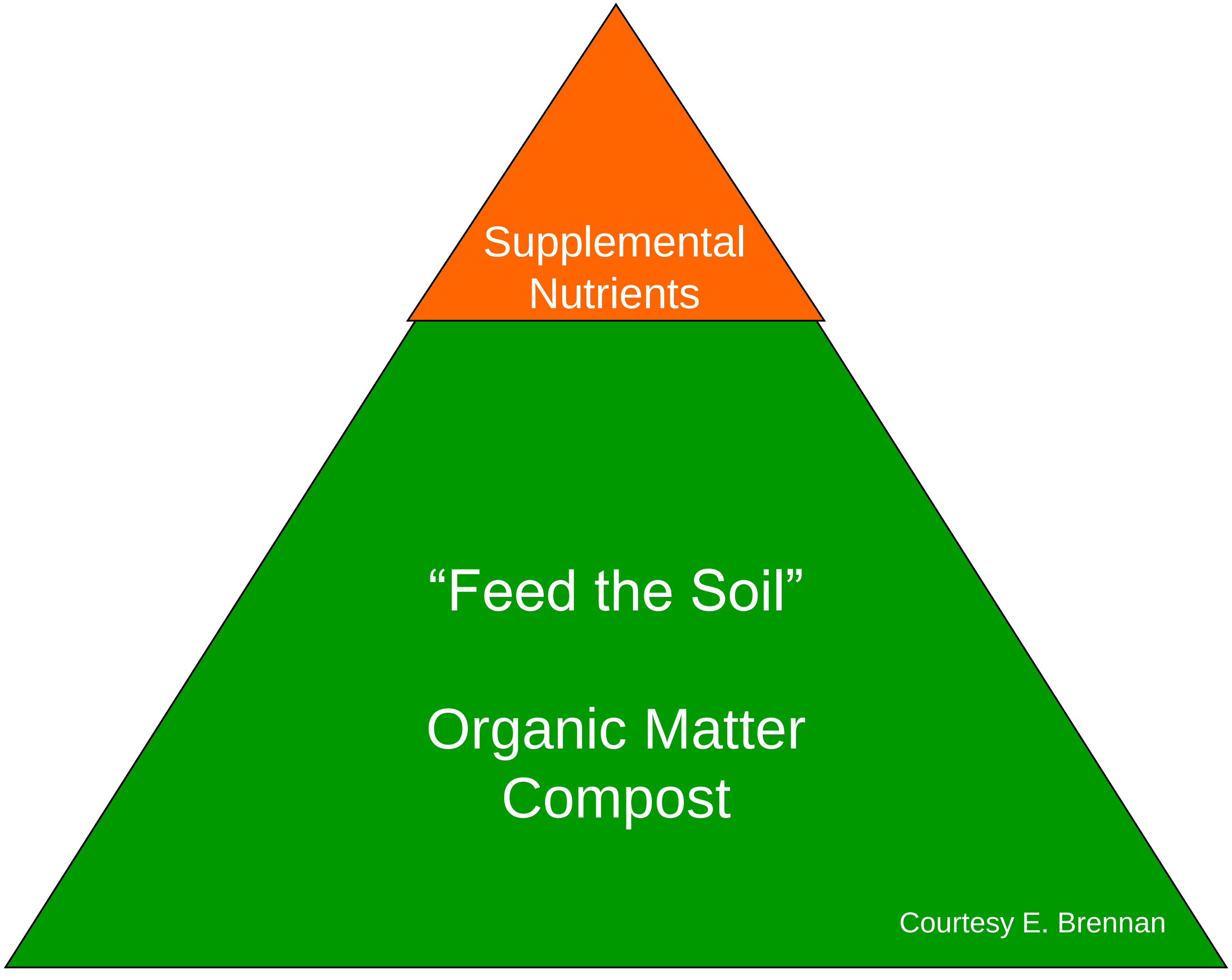
LIGHT SOIL — **INTERPRETATION**

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					

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

- 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 Al
- Buffer pH

Soil Biological Properties

- Increase microbial abundance and diversity
- Create disease suppressive soils

N Fertilizers

Organic

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

Conventional

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

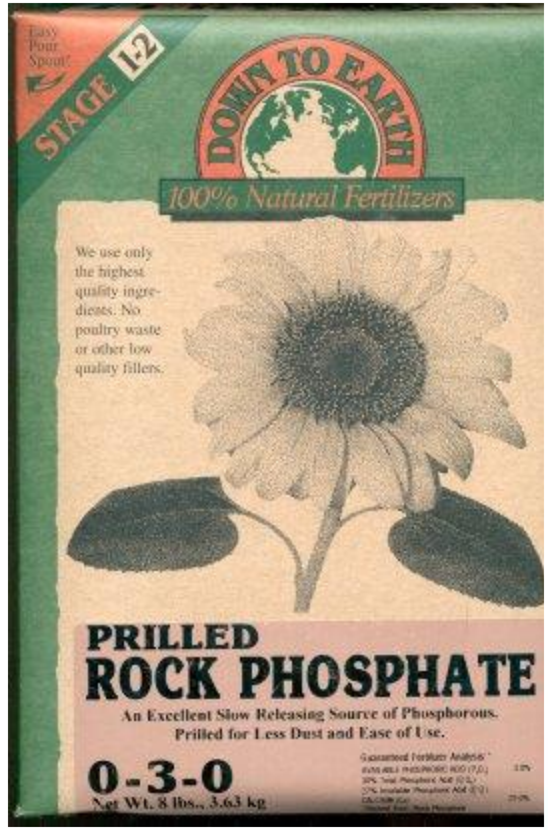
P Fertilizers

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



Potassium Fertilizers

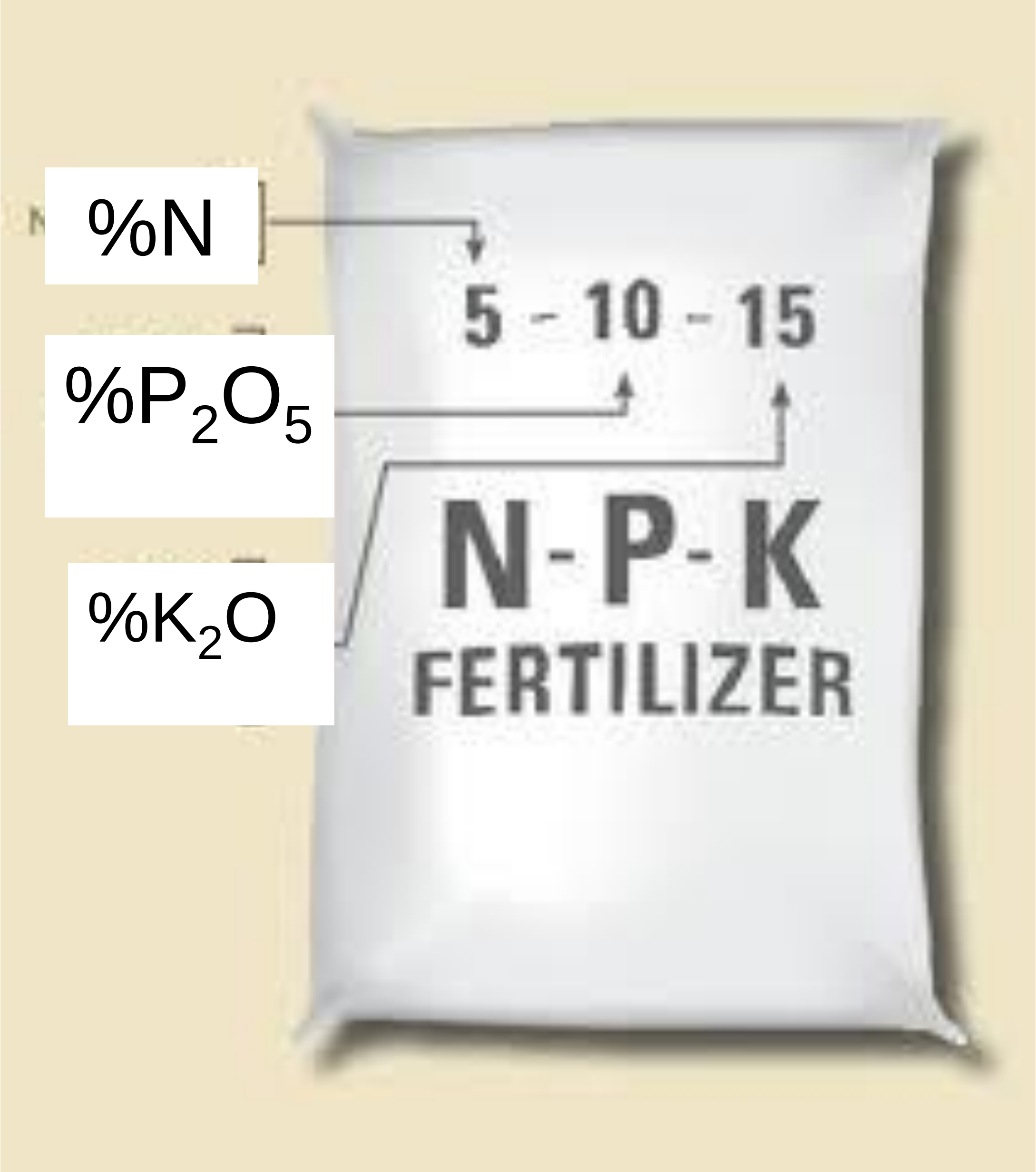
Organic

- 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%)

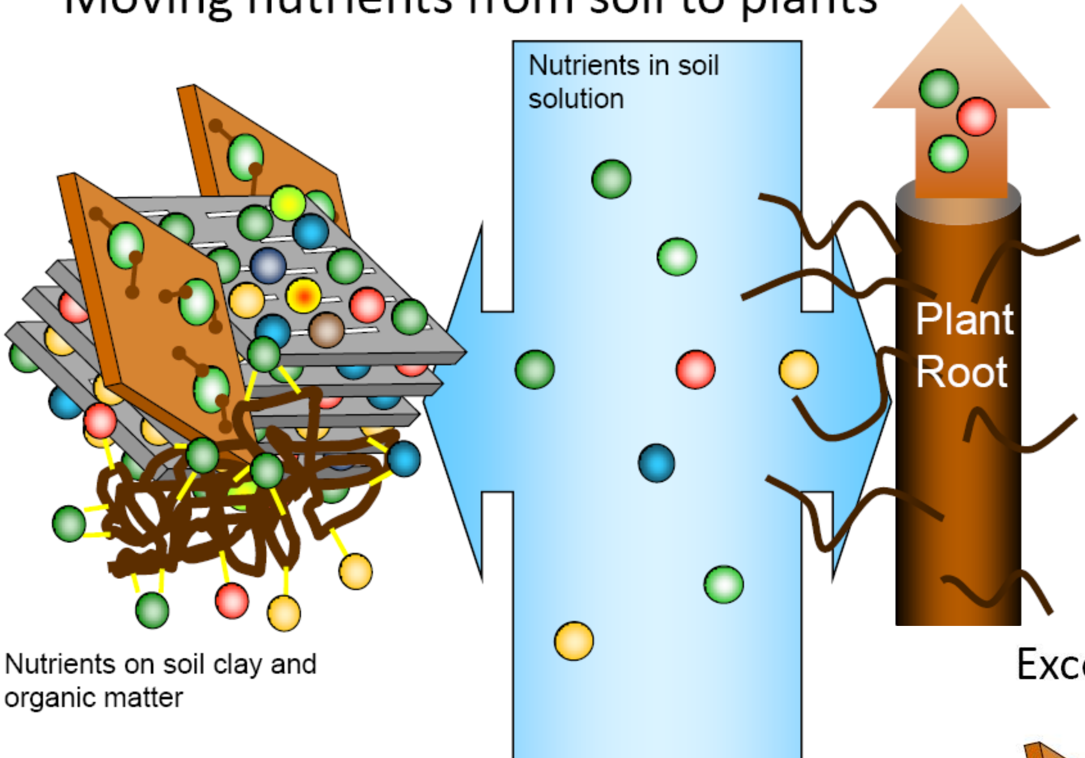
Blended Fertilizers



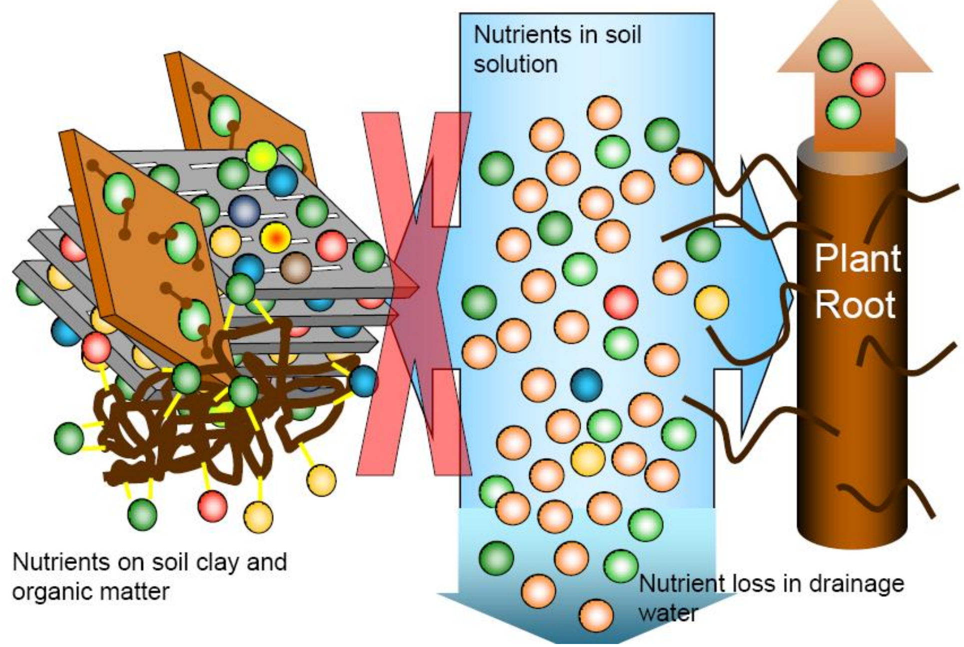
<u>Common Blends</u>

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

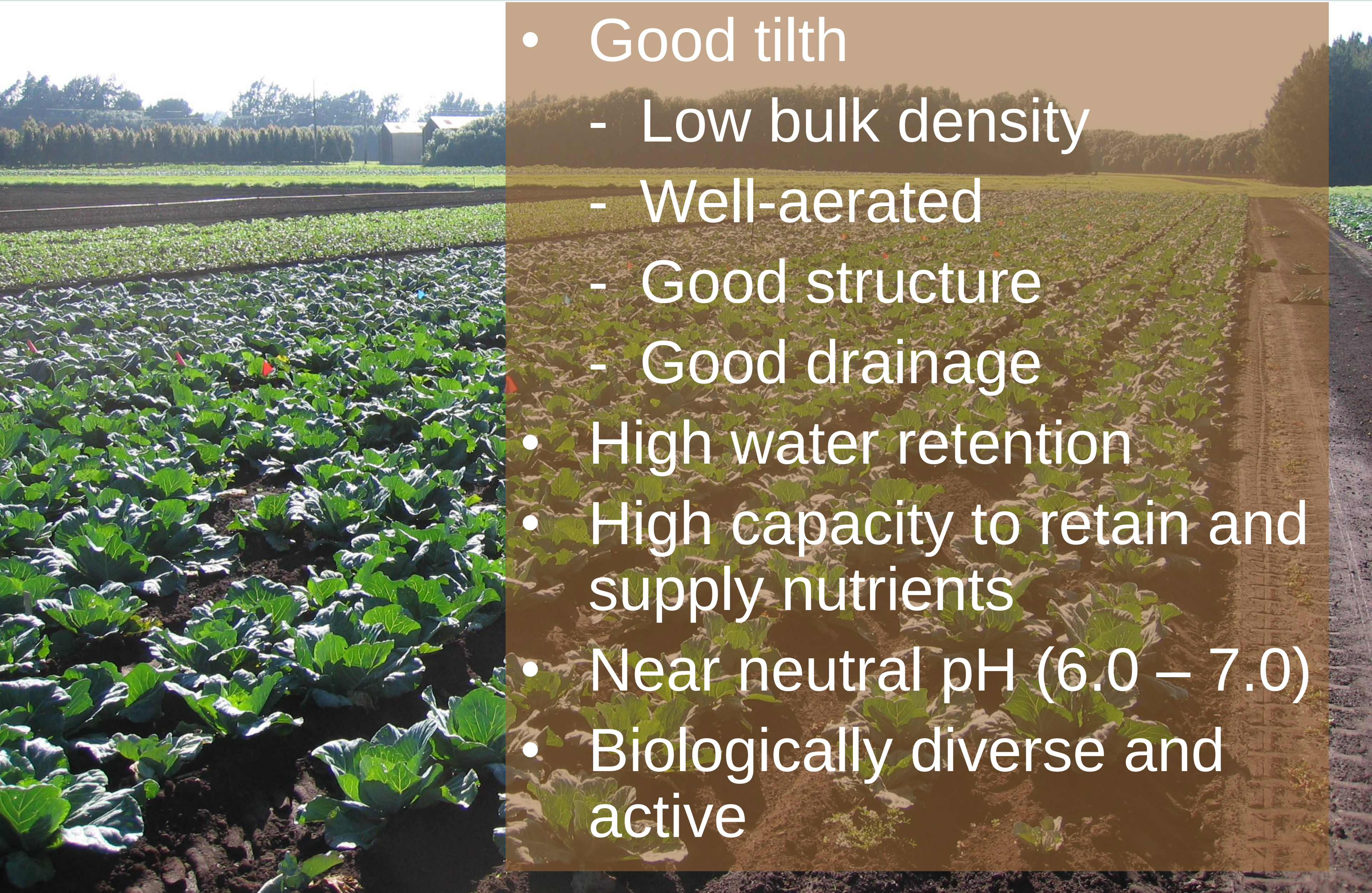
Moving nutrients from soil to plants



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