Soils of Oahu

Jonathan Deenik
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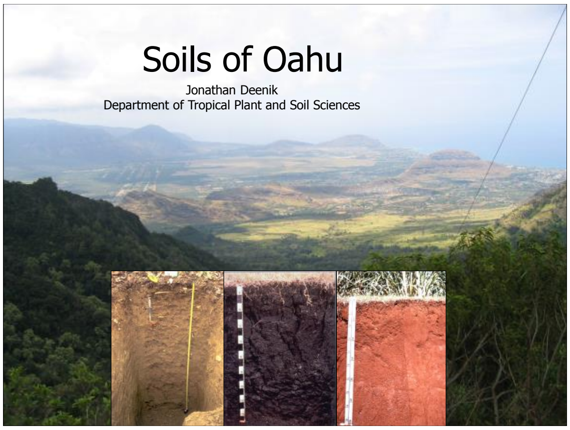
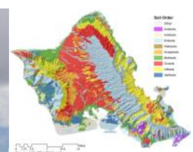
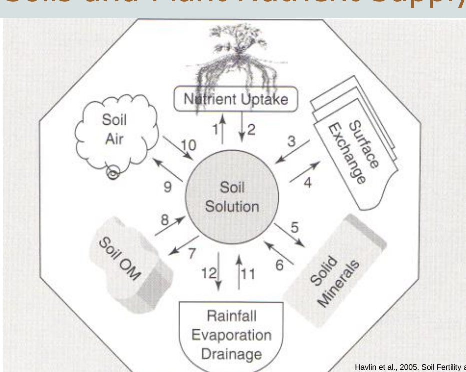


Outline

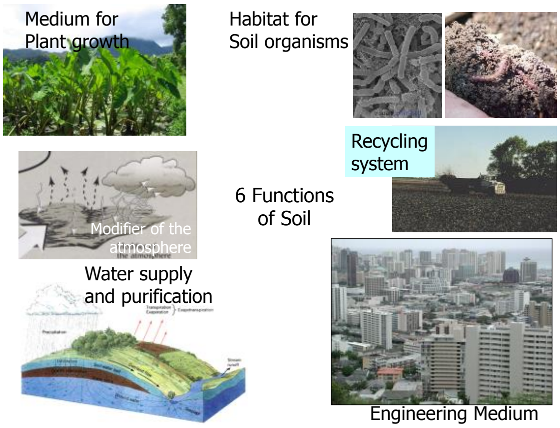
- Importance of Soils
- Soil Diversity on Oahu
- Soil Properties
- Diagnosis and soil testing
- Management for Health

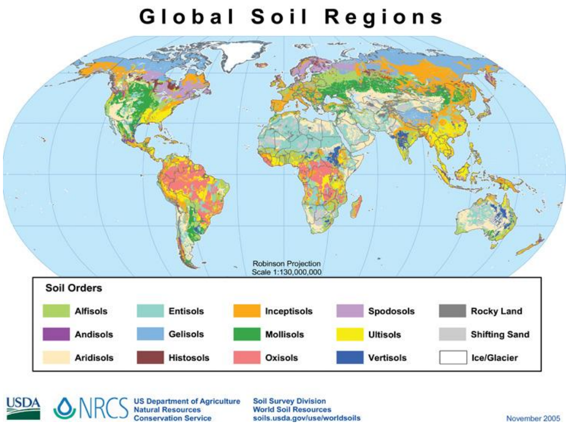


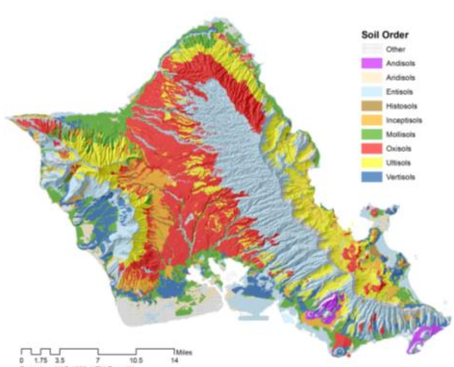
Soils and Plant Nutrient Supply



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
Robinson Projection
Scale 1:130,000,000
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

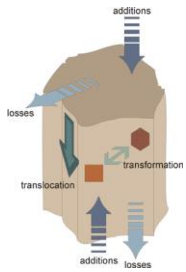

Soil Order
Other
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols
Miles
0 1.75 3.5 7 10.5 14
Projection: NAD 1983, UTM Zone 4N
Source: Natural Resources Conservation Service

Soil Formation



Factors
- Parent material
- Age
- Climate
- Biota
- Topography

Processes
- Additions
- Transformations
- Translocations
- Losses

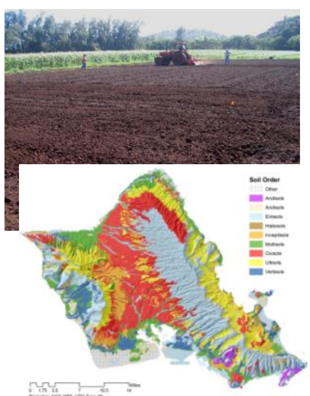


Mollisols

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, high shrink swell potential

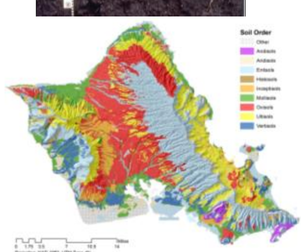


Vertisols

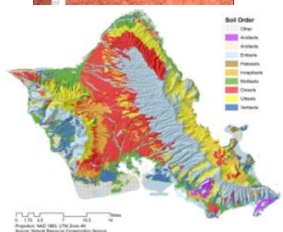
Forming Factors
- Parent material
  - Alluvium, coral
- Climate
  - Low rainfall
- Vegetation
  - Grass and scrub land

Processes
- Transformation
- Moderate weathering

Soil Characteristics
- Very fertile
- Neutral to alkaline
- Poor physical properties

Oxisols

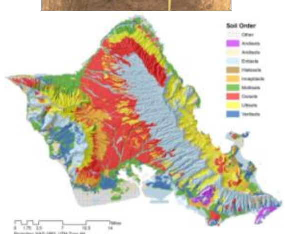


Forming Factors
- Parent material
  - Residuum (basalt lava)
- Climate
  - Moderate to high rainfall
- Vegetation
  - Forest/savanna?

Processes
- High leaching
- Highly weathered

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

Ultisols

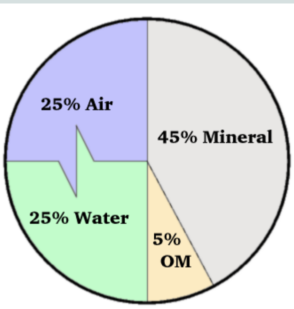


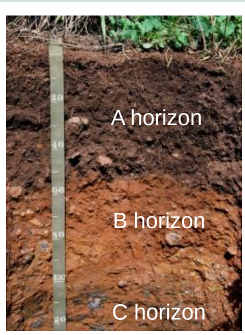
Forming Factors
- Parent material
  - Residuum (basalt lava)
- Climate
  - High rainfall
- Vegetation
  - Forest

Processes
- High leaching
- Highly weathered

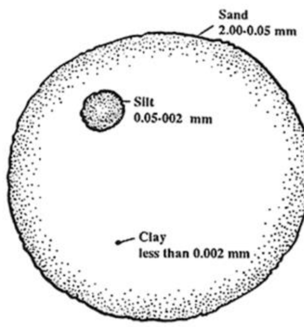
Soil Characteristics
- Infertile soil, nutrient deficient
- Very acidic
- Good physical properties

What is Soil?





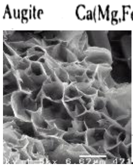
Soil Texture



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

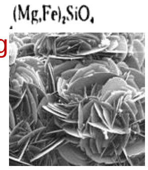
Augite $Ca(Mg,Fe)Si_2O_6 \cdot (Al,Fe)_2O_3$ Olivine $(Mg,Fe)_2SiO_4$



Chemical Weathering

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

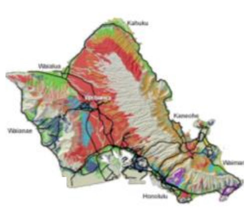
Hematite Fe_2O_3



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



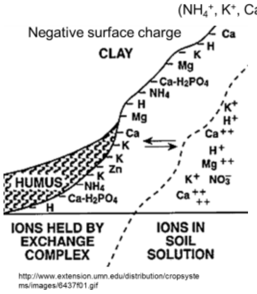
- Non-expanding
- Variable charge
- Low surface area
- Very low CEC
- Non-sticky

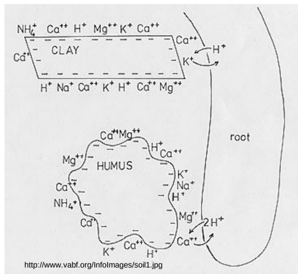
Cation Exchange Capacity

Cation Exchange Capacity

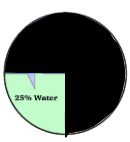
CEC is defined as the degree to which a soil can adsorb and exchange cations

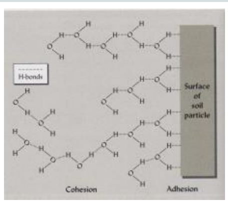
(NH_4^+, K^+, Ca^{++}, Mg^{++}, Fe^{++}….)

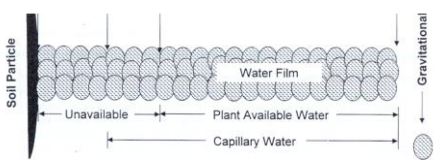




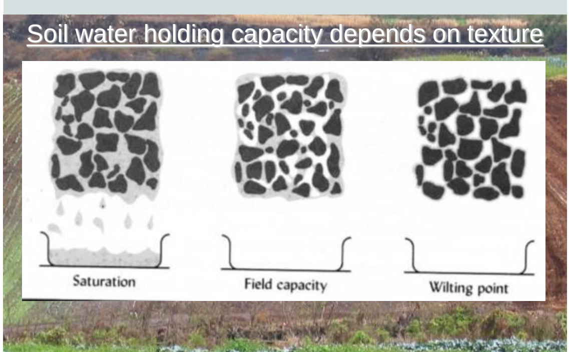
Soil Water



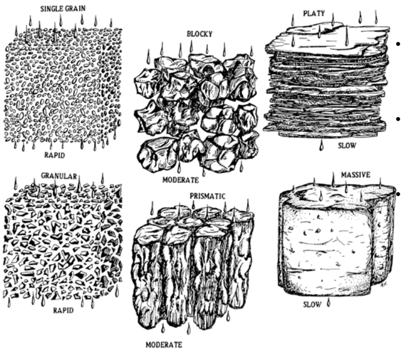




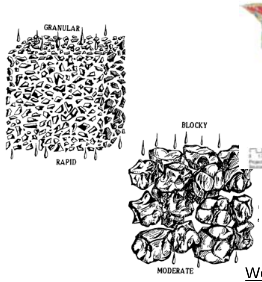
Soil Water Availability

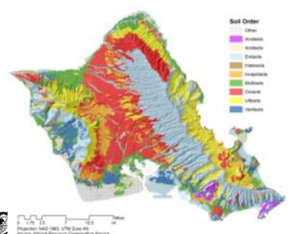


Soil Structure and Water Flow



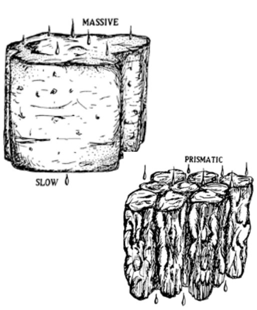
- Soils with strong stable aggregates have good drainage
- Aggregate stability depends on clay mineralogy
- Oxide-rich red soils have strong aggregates with good physical properties

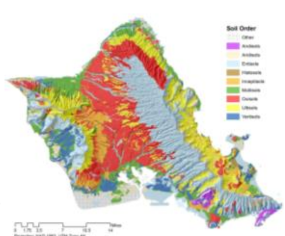




Well-drained soils that resist compaction

Andisols
Ultisols
Oxisols
Entisols



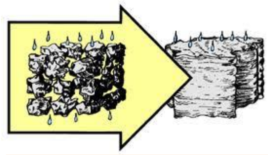


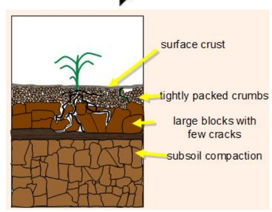
Poorly-drained soils that compact easily

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

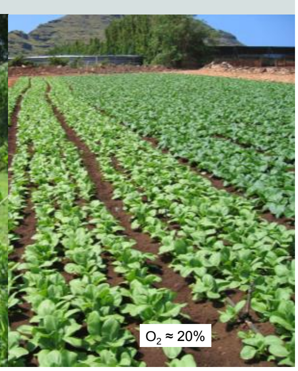




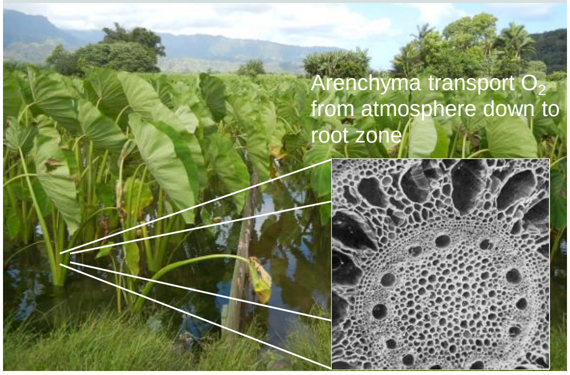
Improving Drainage

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

Soil Air

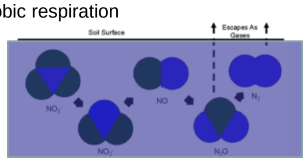


Soil Air



Importance of Soil Air

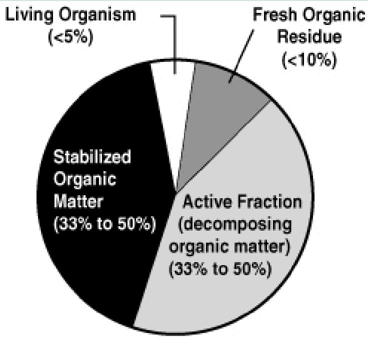
- In compacted and/or waterlogged soil, O_2 is present in very low concentrations creating reducing conditions
  - Gaseous loss of plant available N
  - Increase in toxic levels of Manganese in some soils
  - Fermentation and production of toxic by-products of anaerobic respiration



Loss of plant available N in saturated soils

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

Soil pH

Acid Soils

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

Negative Impacts

- Low CEC
- P deficiency
- Al toxicity (pH < 5.5)
- Mn toxicity (pH < 5.5)

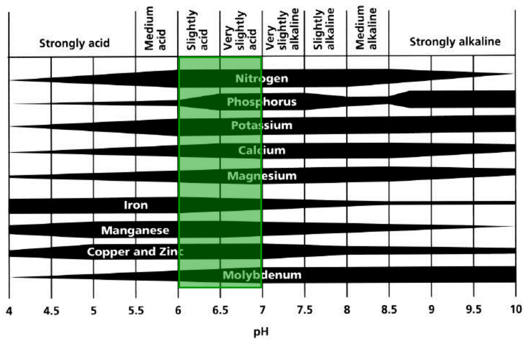
Alkaline Soils

- arid climates, minilmal leaching
- carbonate accumulation
- sodium

Negative Impacts

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

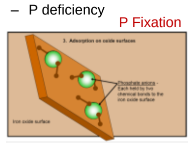
Soil pH Affects Nutrient Availability



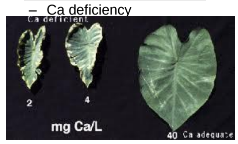
Negative Effects of Soil Acidity

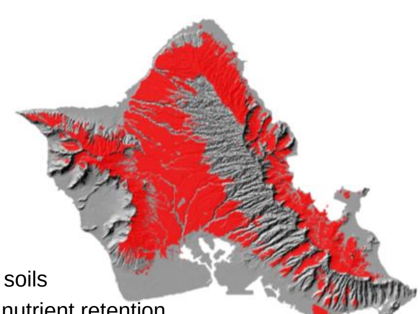
- Low nutrient retention (CEC)
- Nutrient deficiencies
  - P deficiency

P Fixation



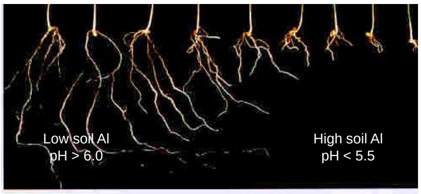
  - Ca deficiency





- Acid soils
- Low nutrient retention and supply
- Manganese and aluminum toxicities
- Require liming and complete fertilizers

High Soil Aluminum Causes Root Damage




Healthy root hair in soil with low Al

Deformed root hair in soil with high Al

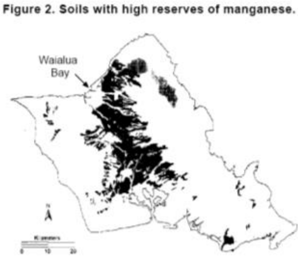
Manganese Toxicity

- A mineral in basalt
- Mn^{2+} is an essential plant nutrient, but at high concentrations it becomes toxic
- Mn^{2+} concentration depends on pH, O_2 availability and organic matter
  - As Soil pH decreases Mn toxicity increases
  - As Oxygen is depleted (saturated soil) Mn toxicity increases
  - Adding organic matter increases Mn toxicity increases

Soils with Potential Mn Toxicity

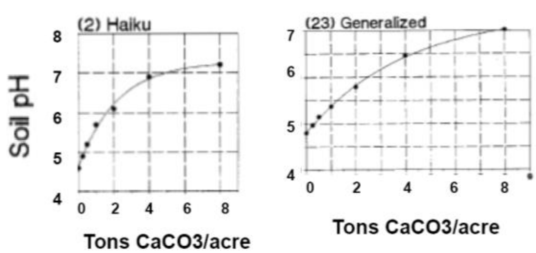
- Oxisols exisiting at low to moderate elevation (200-750 ft) with moderate rainfall (20-60 in/yr)

Figure 2. Soils with high reserves of manganese.



Liming

1. Ideal pH range: 6.0 – 7.0
   - Liming is critical when pH drops below 5.5
2. Raise pH:
   - Increases P availability
   - Corrects Al and Mn toxicity
   - Increases N, S, B, Cu and Mo availability
3. To supply Ca
4. Liming materials
   - calcium carbonate (limestone)
   - calcium/magnesium carbonate (dolomite)



Liming curves for many soil series in Hawaii available online

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

Soil Fertility Depends on:

- Amount of clay
- Type of clay
  - high activity clay
  - low activity clay
- Soil Organic Matter
- Soil Acidity

- Diagnosis of Nutrient Deficiencies
- Soil tests
- Nutrient Management

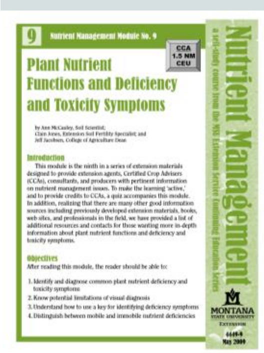
Essential Plant Nutrients

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 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:

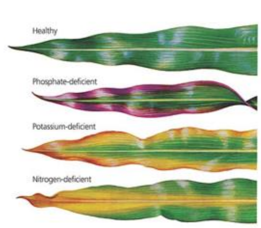
1. Identify and diagnose common plant nutrient deficiency and toxicity symptoms
2. Know potential limitations of visual diagnosis
3. Understand how to use a key for identifying deficiency symptoms
4. Distinguish between mobile and immobile nutrient deficiencies

Nutrient Management

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

MONTANA STATE UNIVERSITY Extension

4449-9 May 2009



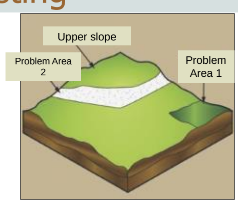
http://landresources.montana.edu/NM/Modules/Module9.pdf

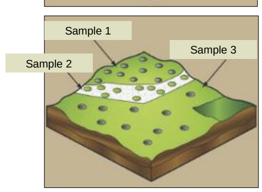
Soil Tests

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

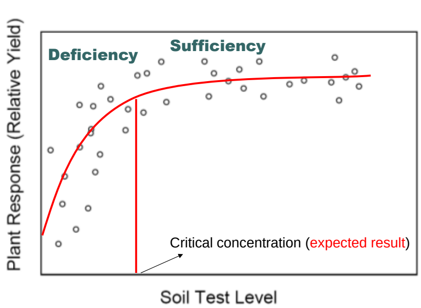
Soil Testing

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

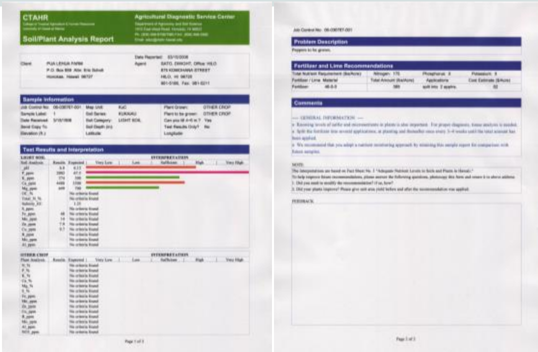




Soil Test Calibration



Soil Test Printout



Soil Test Printout

Test Results and Interpretation

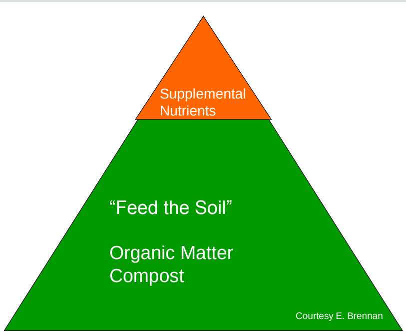
LIGHT SOIL

Soil Analysis	Results	Expected	INTERPRETATION (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



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

Organic

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

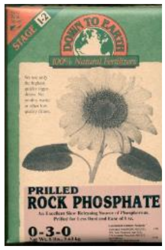
Conventional

- 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



K Fertilizers

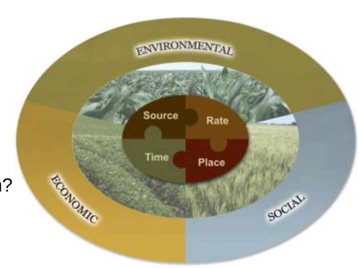
Organic
- Hardwood ashes
- Seaweed
- Sulfate of potash (0-0-50)

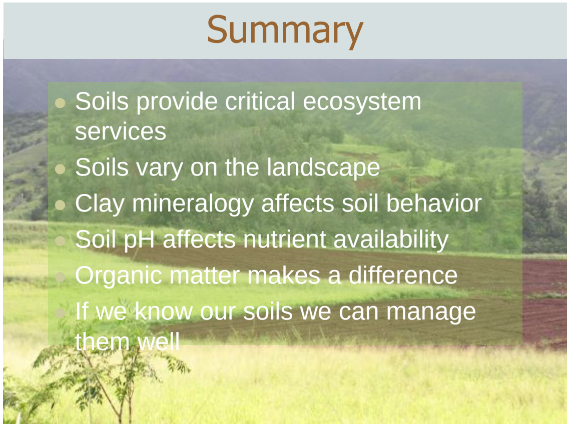
Conventional
- Muriate of potash (0-0-60)


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?




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


Mahalo Nui