Understanding and Managing the Soils of Puna for Sustainable Food Production

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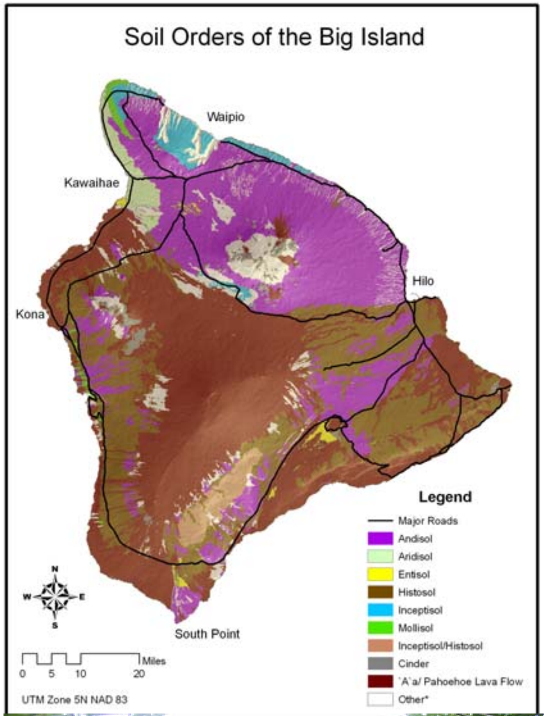
Outline

- Soil Diversity
- Soils of Puna
- Soil Properties
- Soil Quality/Health
- Management Strategies for Healthy Productive Soils



Soil Diversity

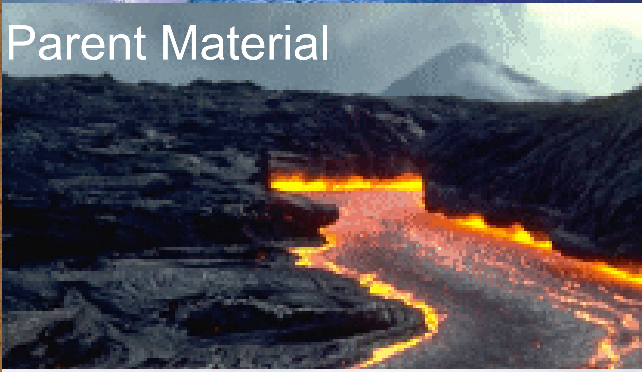
Origin of Soil Diversity

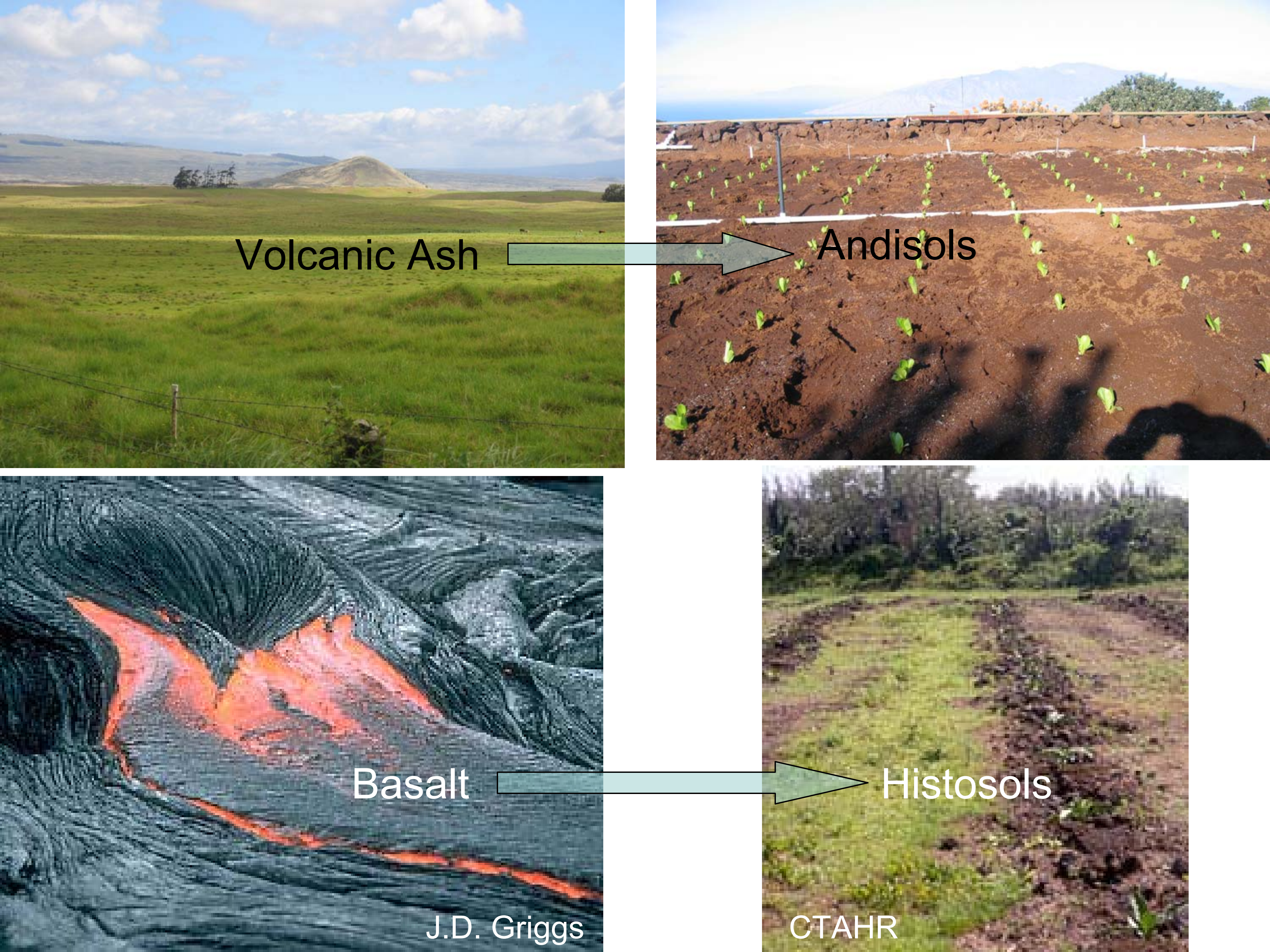
Factors

- Time
- Parent Material
- Climate
- Biota
- Topography

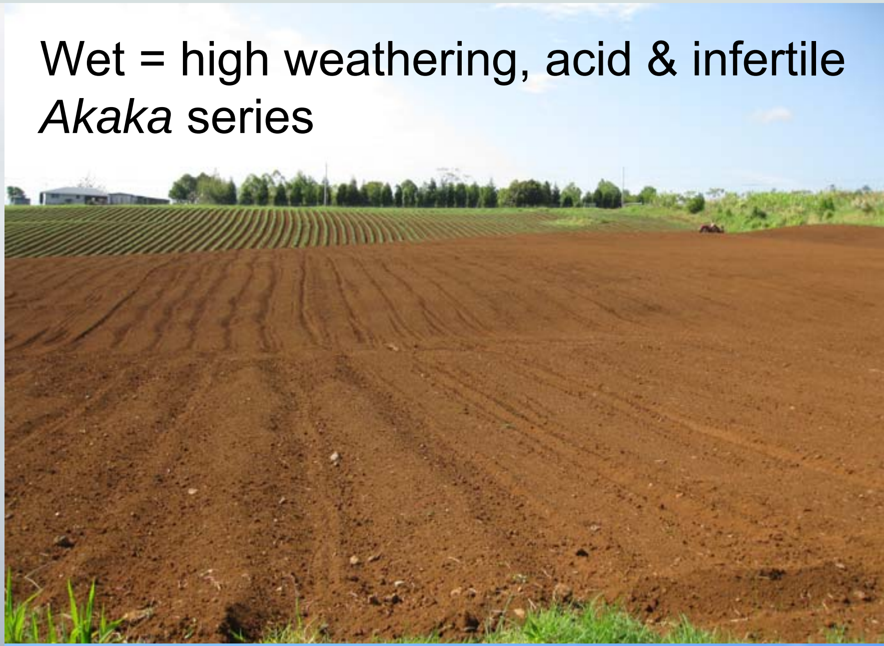
Processes

- Physical weathering
- Chemical weathering

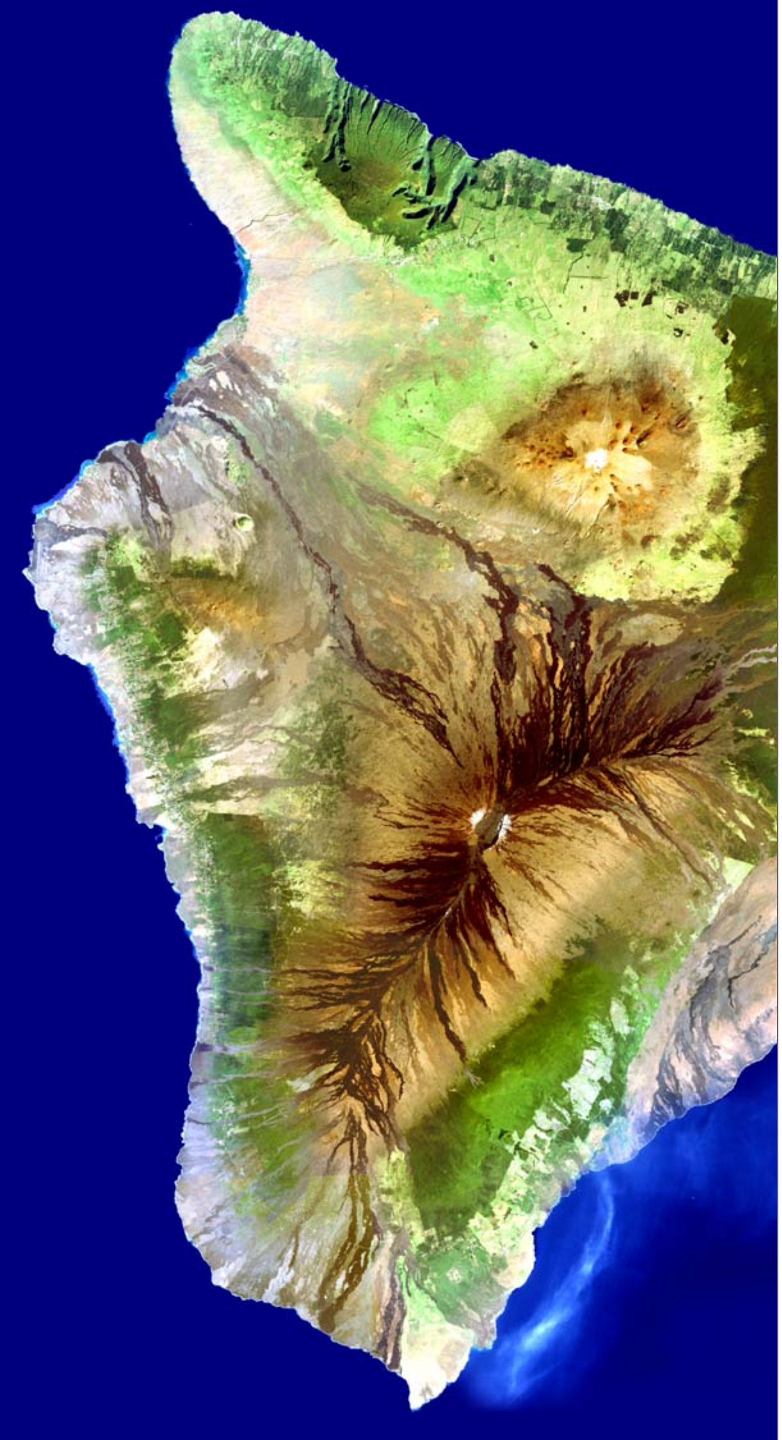


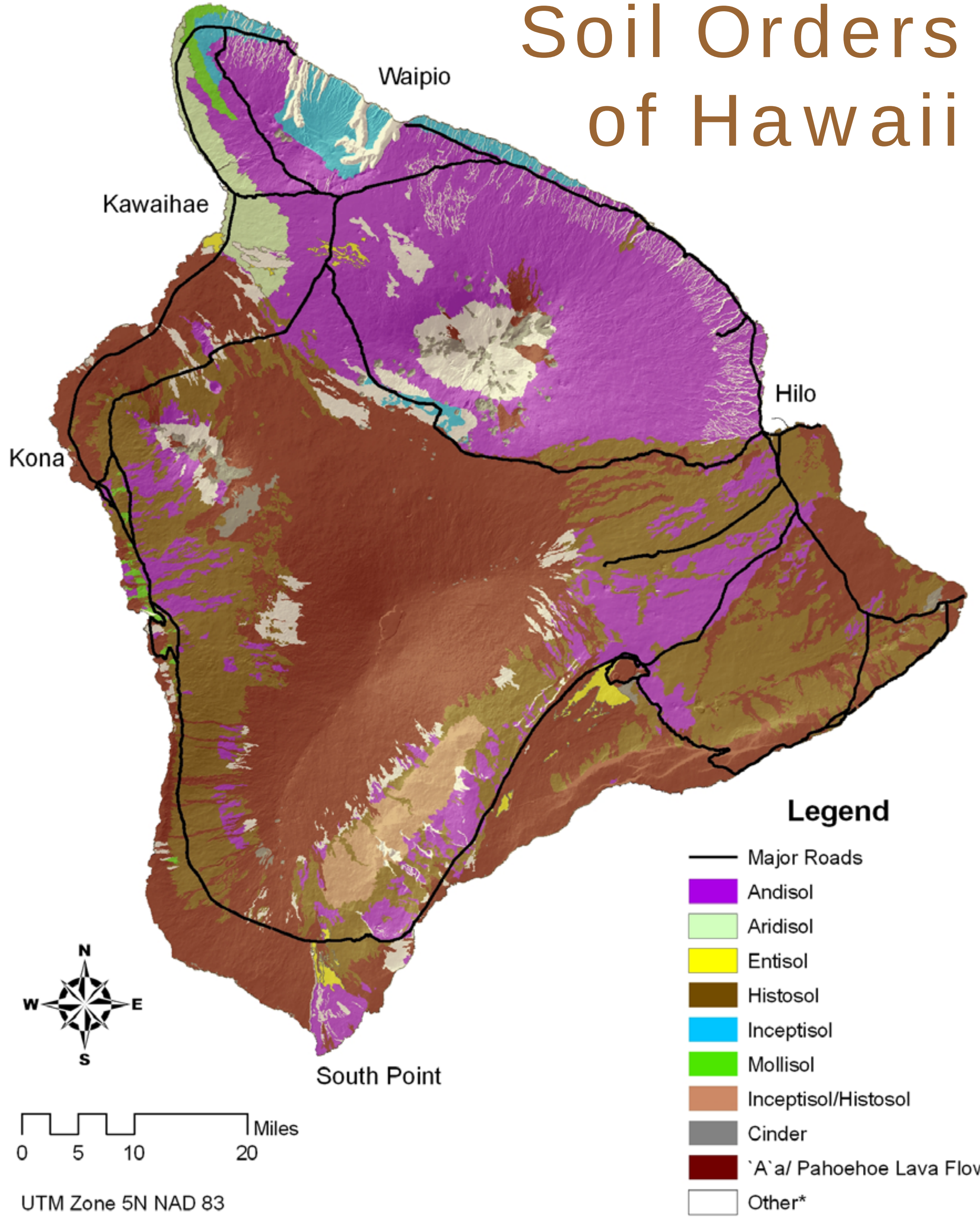

Volcanic Ash
Andisols
Basalt
Histosols
J.D. Griggs
CTAHR

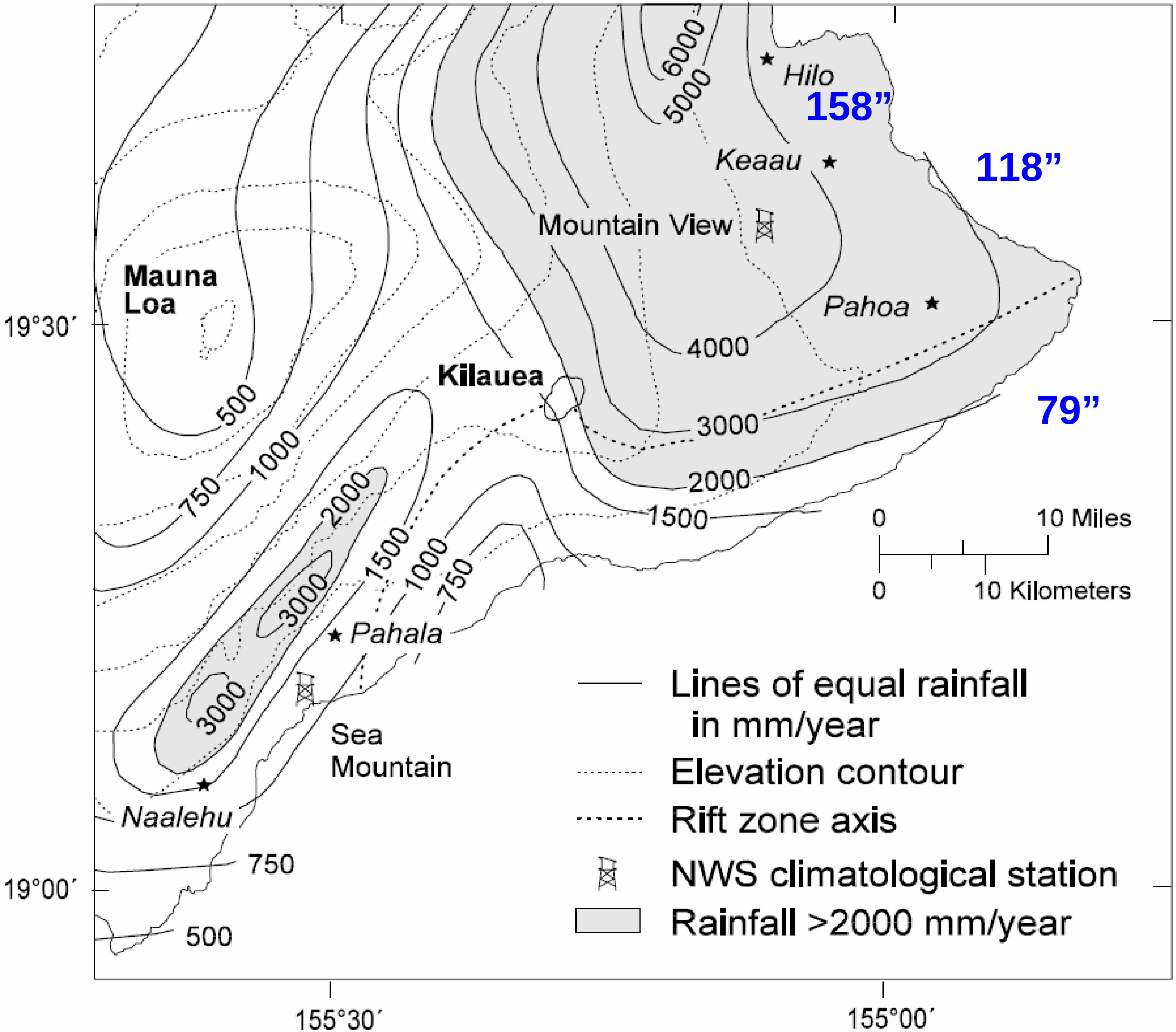
Origin of Soil Diversity



Soil Orders of Hawaii

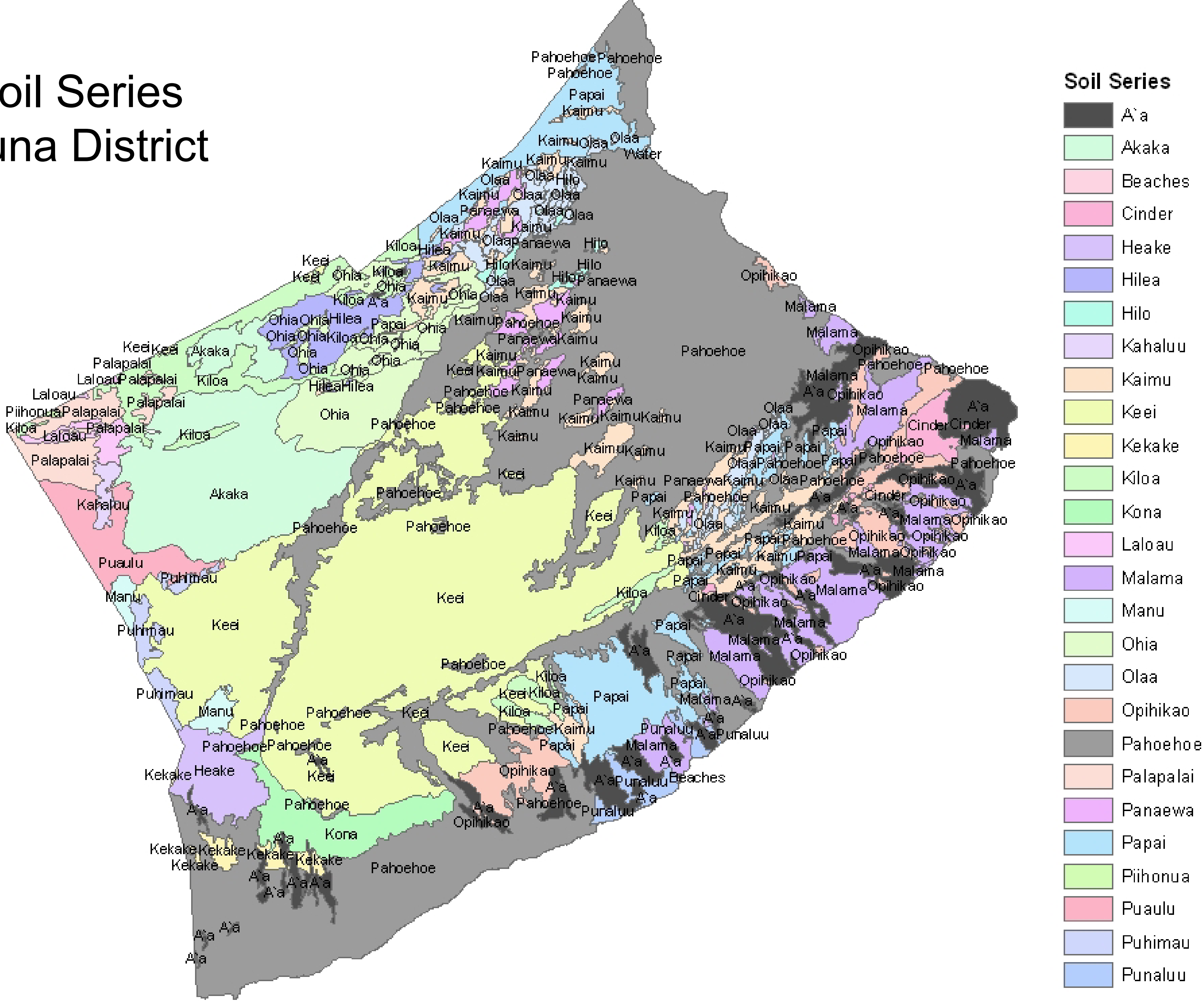






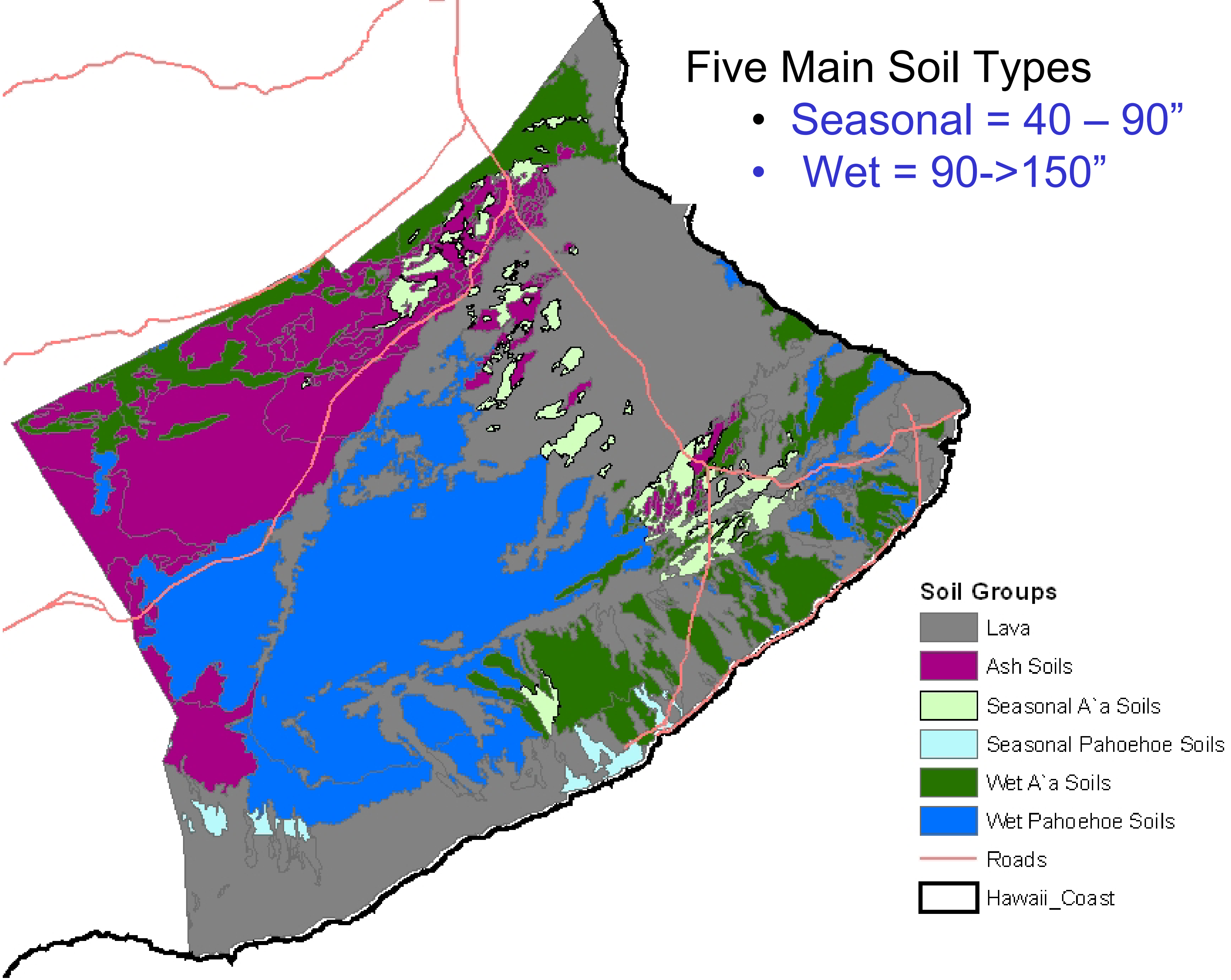
Source: USGS, Water-Resources Investigations Report, 1995

23 Soil Series in Puna District

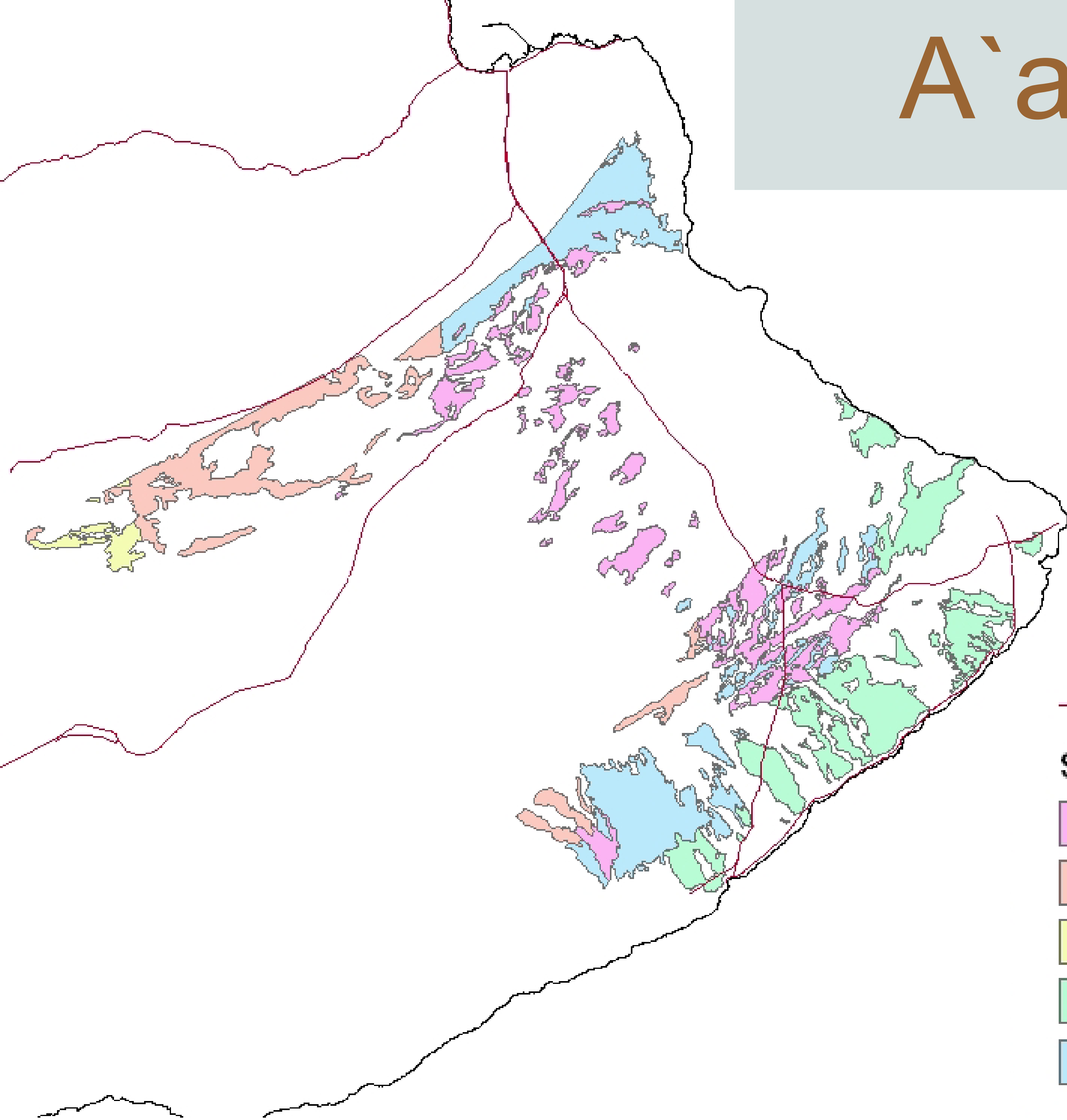


Five Main Soil Types

- Seasonal = 40 – 90”
- Wet = 90->150”



A`a 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

Management	OC	TN	pH	Ca	Mg	K	Na	CEC
	%				cmol$_c$ kg^{-1}			
Forest	24.0	1.48	6.9	46.4	3.62	0.42	2.08	80.3
Cultivated	22.8	1.41	6.9	48.7	7.10	1.29	3.83	69.5

Source: Periswamy, 1973

- Organic matter is the primary source of nutrient supply and retention
- pH is relatively high due to high Ca
- K tends to be low under natural conditions

Physical Properties of Pahoehoe Soils

- Even coarser than A`a soils
- Organic matter accumulation above solid pahoehoe lava

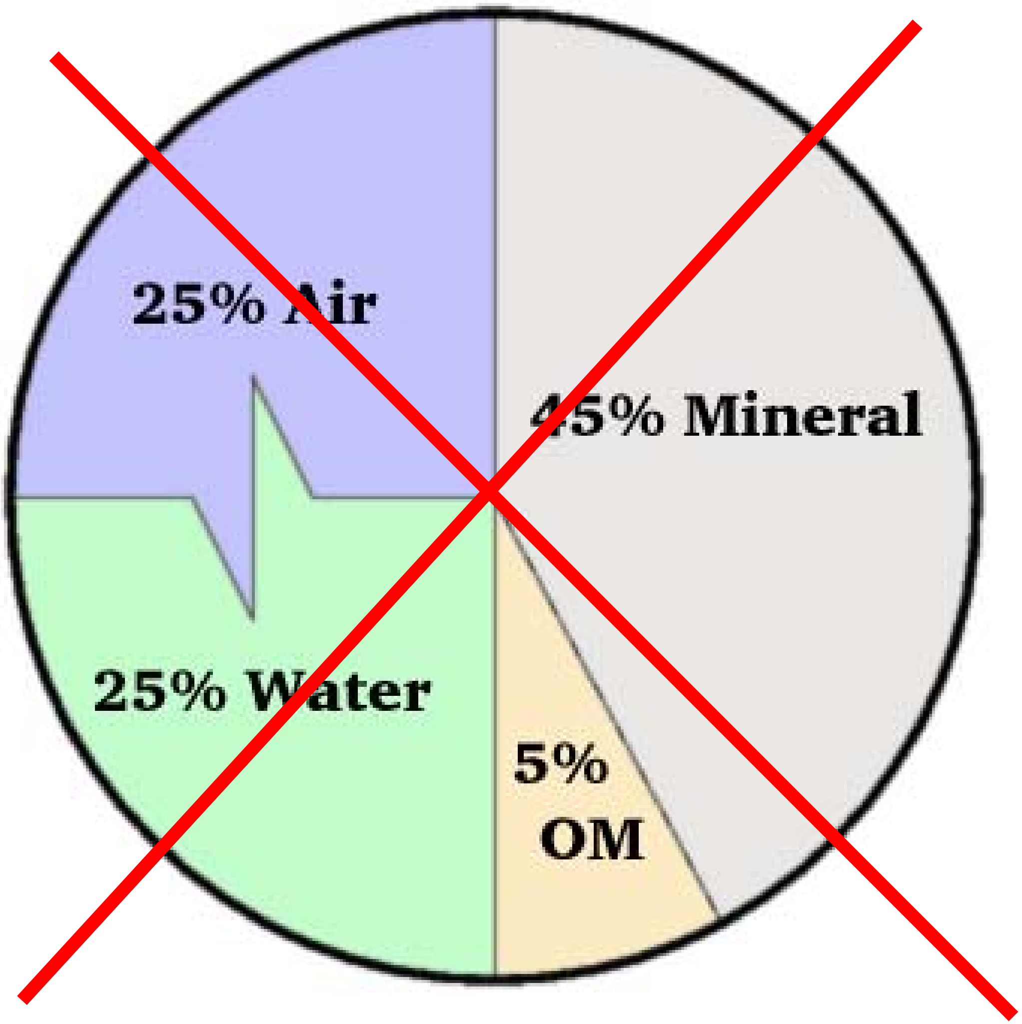
Chemical Properties of Pahoehoe Soils

Management	OC	TN	pH	Ca	Mg	K	Na	CEC
	%				cmol$_c$ kg^{-1}			
A`a	24.0	1.48	6.9	46.4	3.62	0.42	2.08	80.3
Pahoehoe	55.3	1.99	4.6	57.1	10.0	1.6	1.50	152

Source: Periswamy, 1973

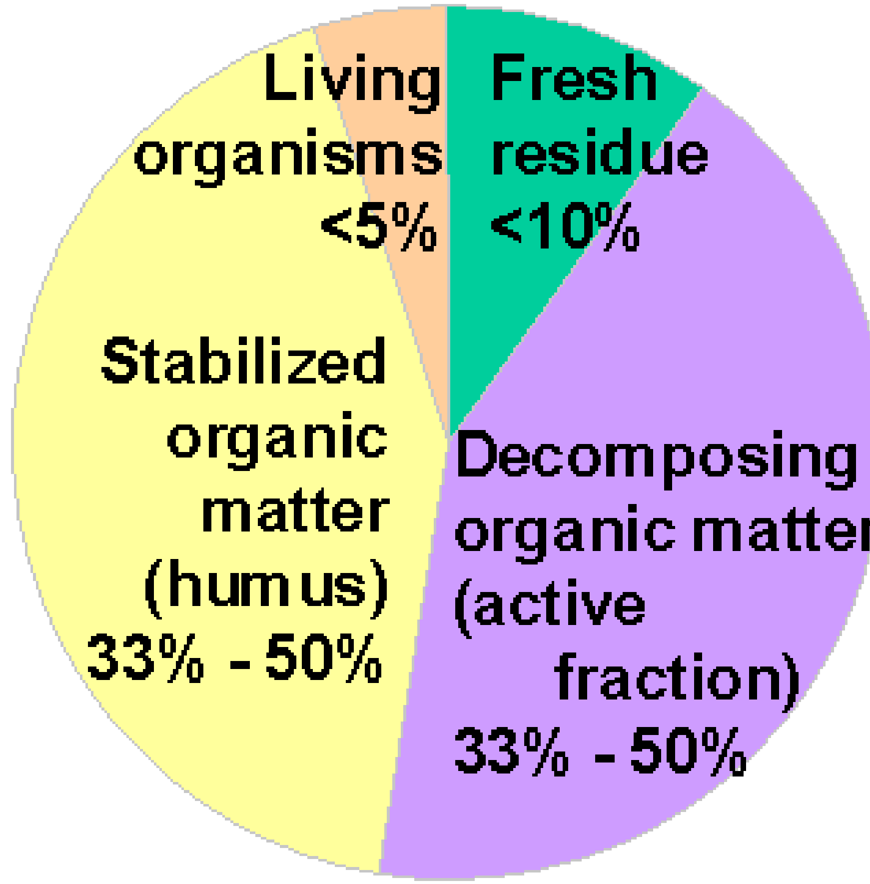
- Organic matter accumulates to high levels in shallow organic layer above pahoehoe bedrock
- pH is typically very acid due to organic matter and no mixing with fine inorganic minerals

Soil Properties



Conventional rules of soil science not always applicable to Puna soils

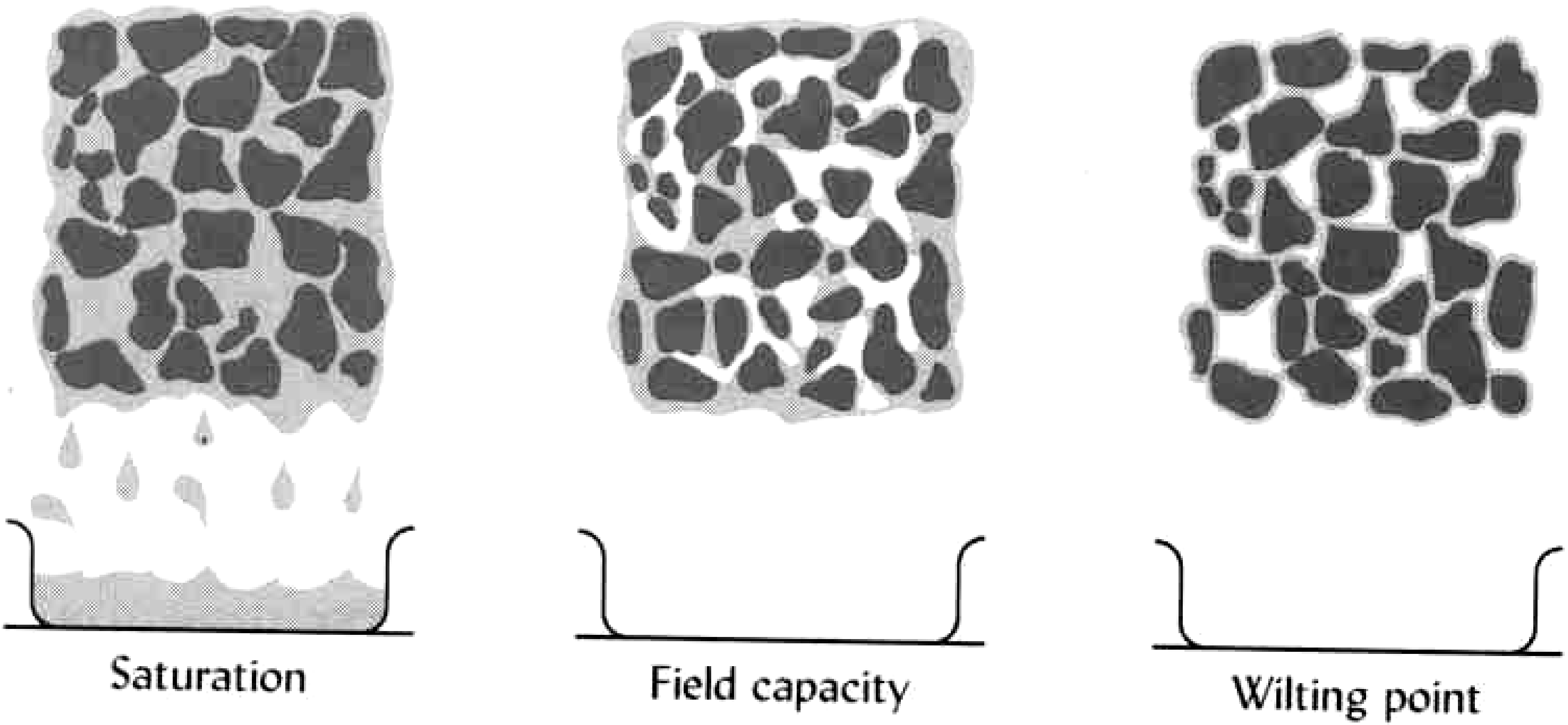
Soil Organic Matter is Queen



Humus

1. End product of decomposition
2. Relatively stable
   - half-life: decades to centuries
   - Humic substances (stable)
   - Non-humic substances (<stable)
3. Properties of Humic substances
   - high surface area
   - high charge density
4. Role
   - Increase water retention
   - Increase CEC

Soil Water



Source: Brady & Weil, 2004

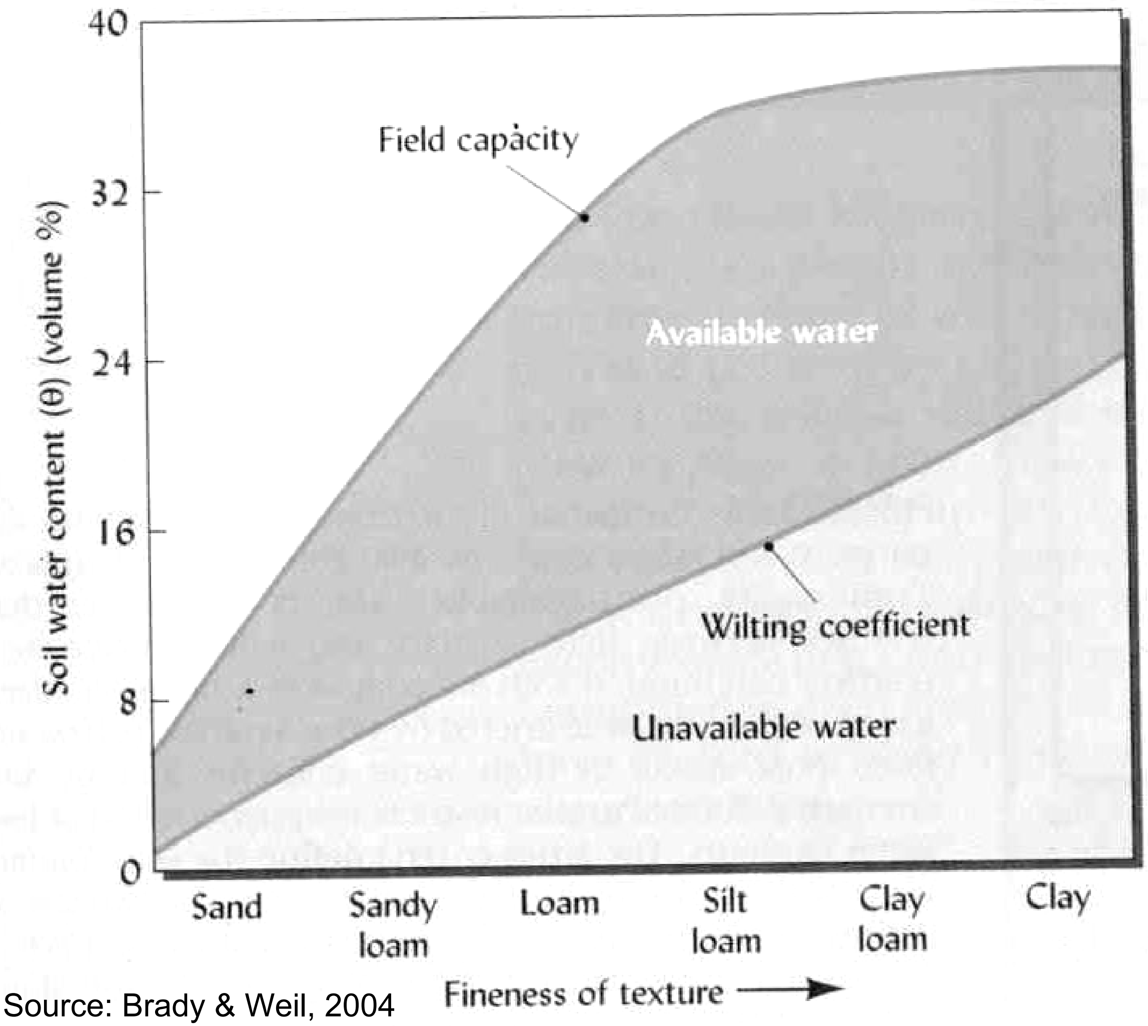
Water Retention

Soil water holding capacity depends on texture

clay = high

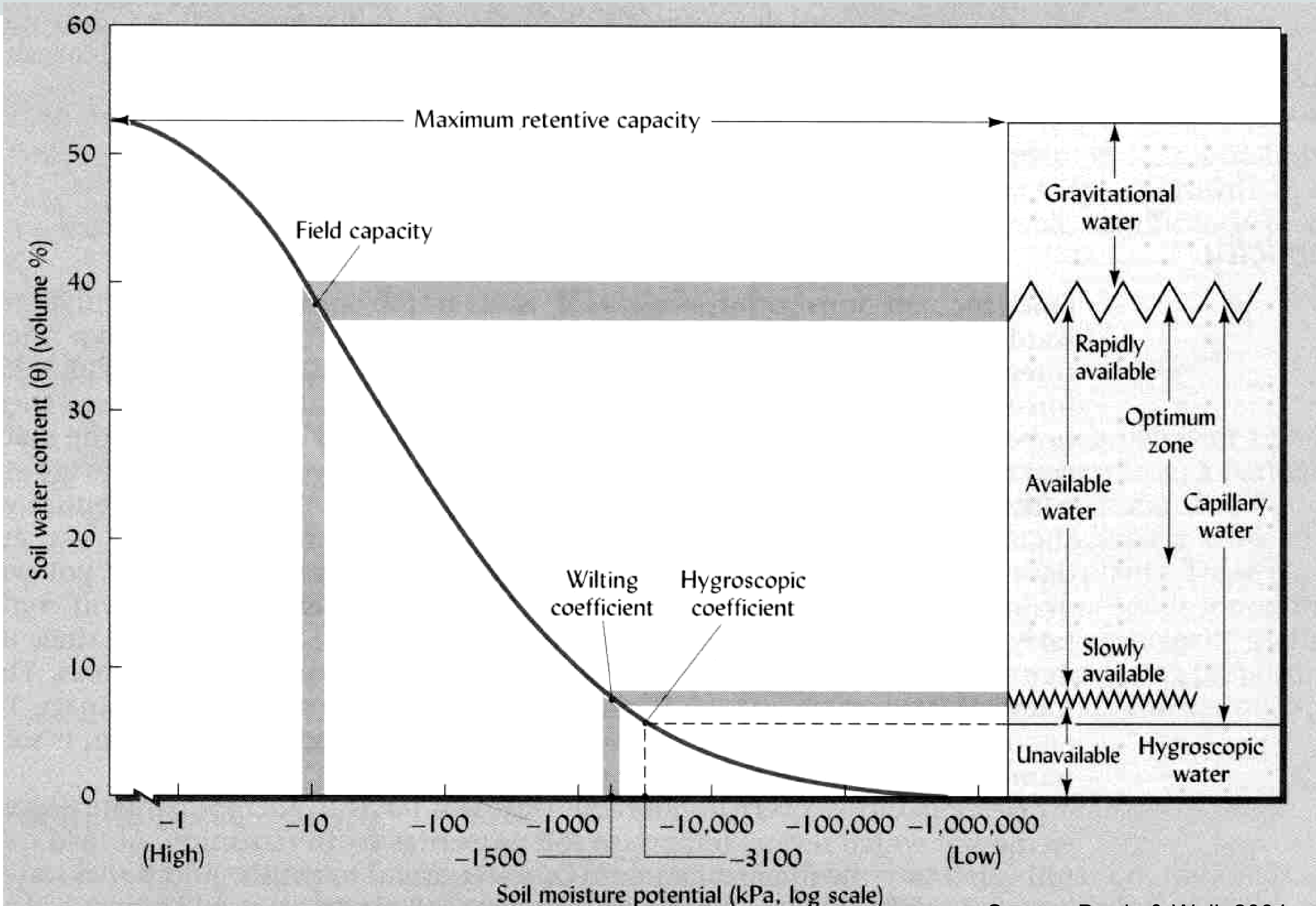
sand = low

OM = high



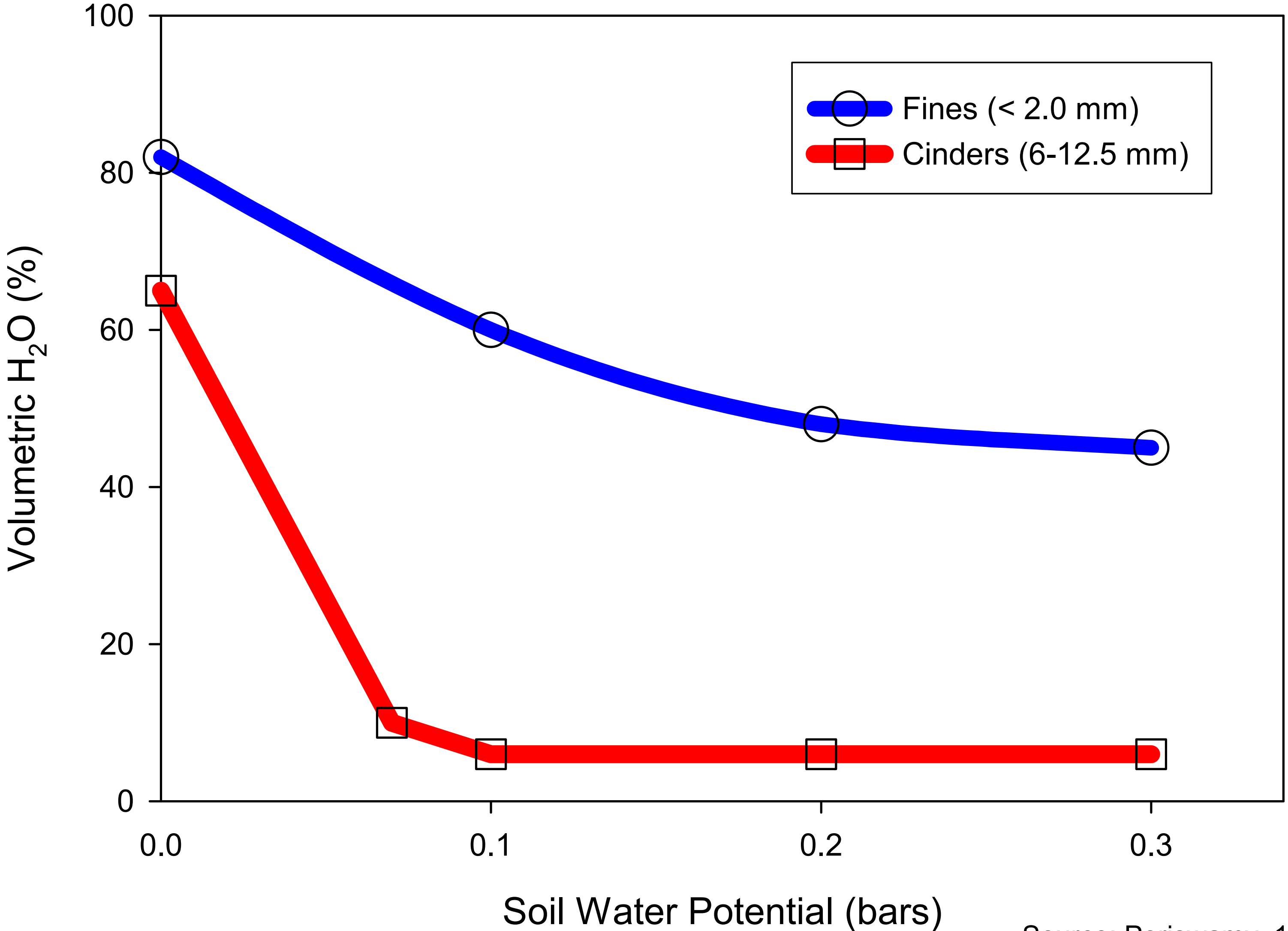
Source: Brady & Weil, 2004

Soil Water



Source: Brady & Weil, 2004

Water Release Curve



Source: Periswamy, 1973

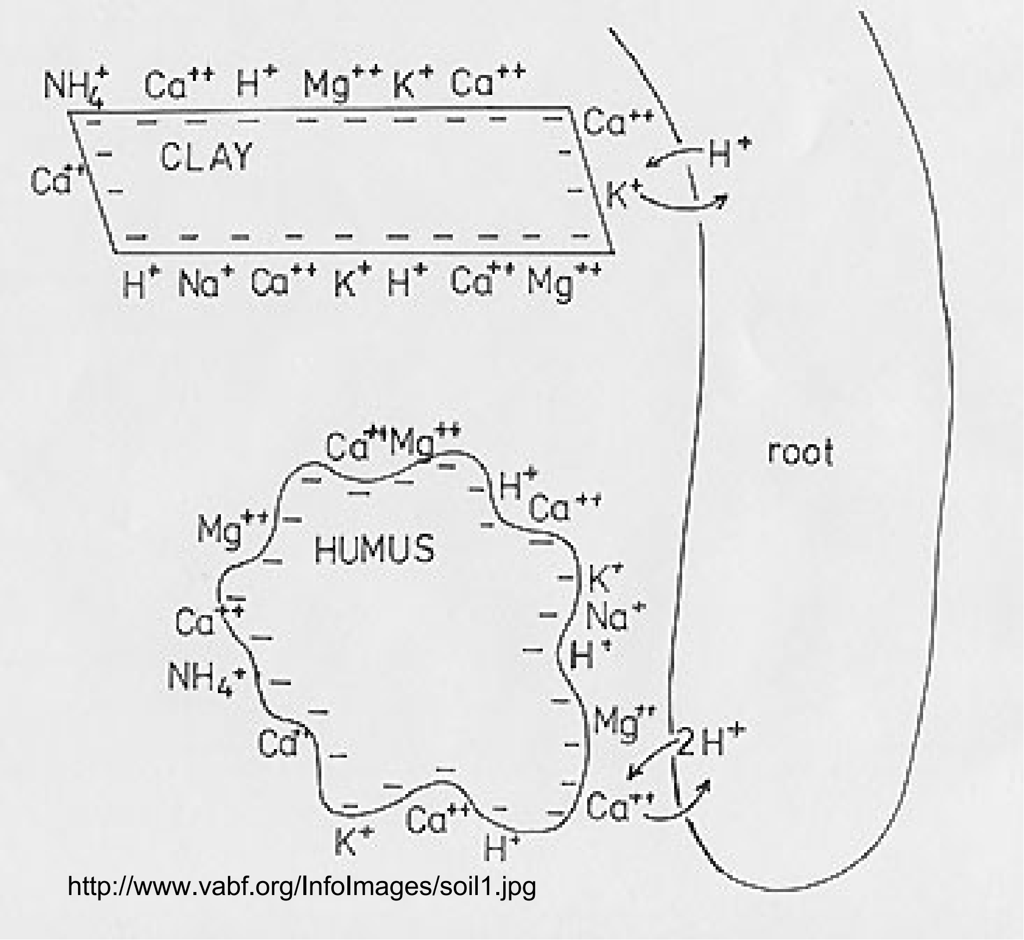
Water Storage

- 1.5 cm available water in 15 cm of soil
- Evapotranspiration = 0.39 cm/day
- 1.5/0.39 = almost 4 days before water consumed
- If roots could access 1 m of soil, then there would be 26 days of available water.
- **So, regular rainfall is necessary for good plant growth!**

Cation Exchange Capacity

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

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



CEC of humus = 200 $cmol_c\ kg^{-1}$

CEC of clays = 10 – 80 $cmol_c\ kg^{-1}$

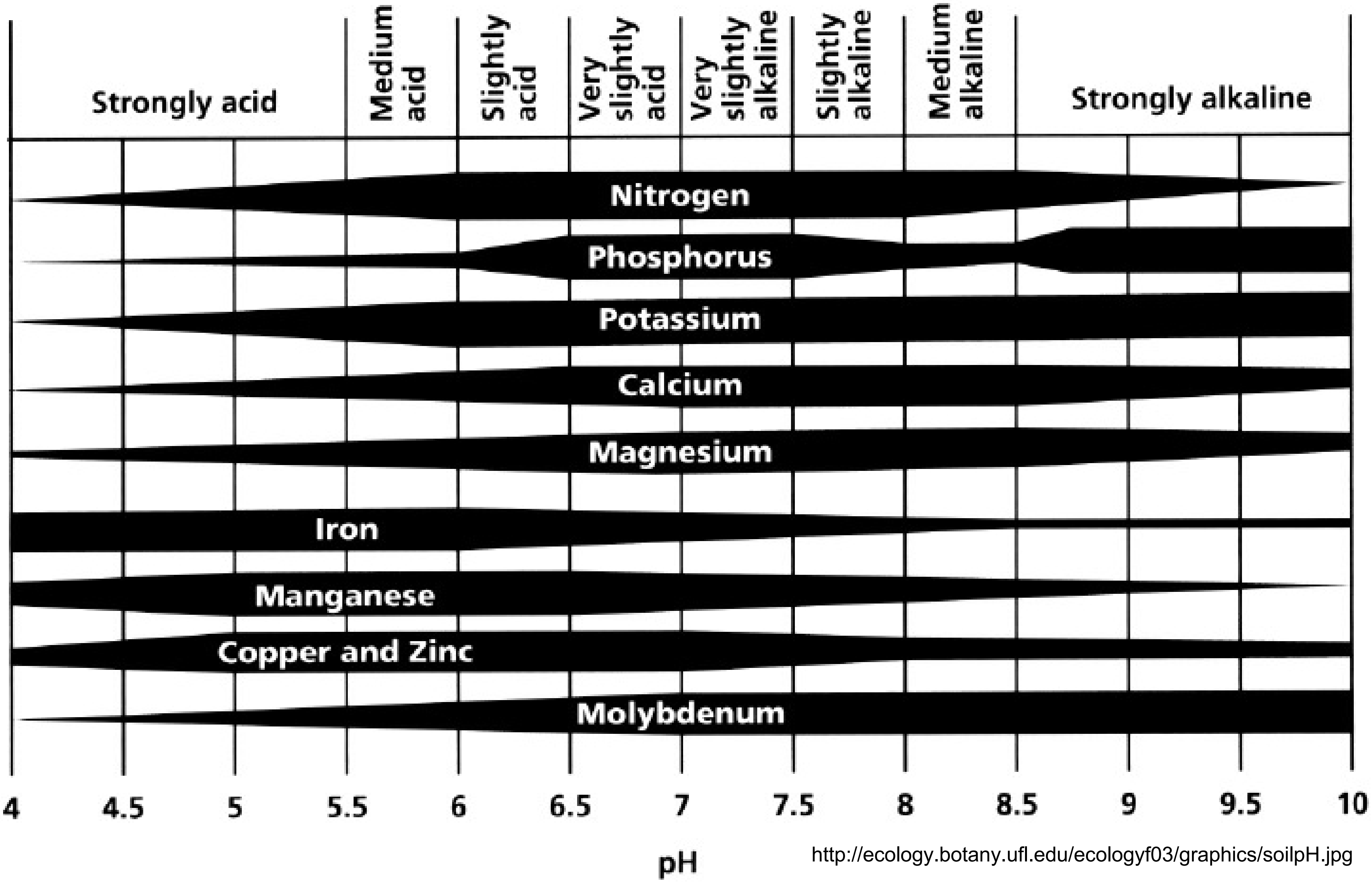
Cation Exchange Capacity

CEC of a`a surface soil = 80.3 $cmol_c\ kg^{-1}$,
but this is for < 2 mm Fraction,
which makes up only 9.8% of the soil volume.

Converted to a volume,
CEC = 7.9 $cmol_c\ L^{-1}$,which is considered low.

A Waimea soil will have a CEC of around
25 $cmol_c\ L^{-1}$ in top 15 cm.

Soil Acidity



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

Effects of Soil Acidity

Typical Acid Soils

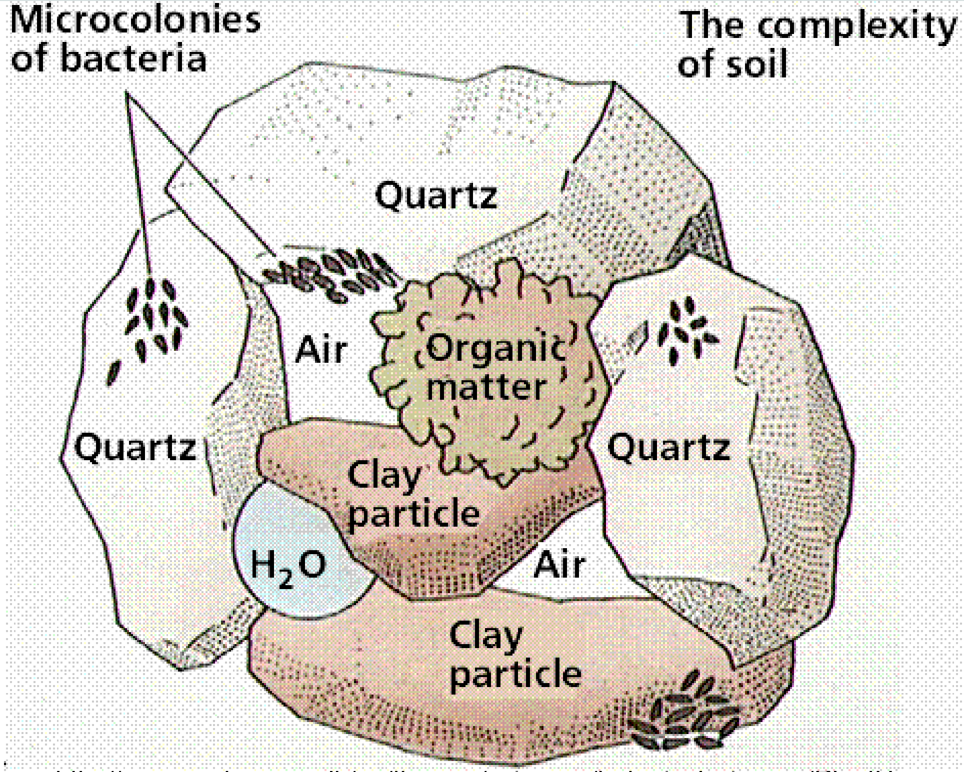
- Al toxicity
- Mn toxicity
- Low base saturation
- P deficiency

A`a/Pahoehoe Soils

- Can be very acid
- No Al toxicity because OM forms complexes w/ Al
- High base saturation because primary minerals release bases
- Low P fixation capacity

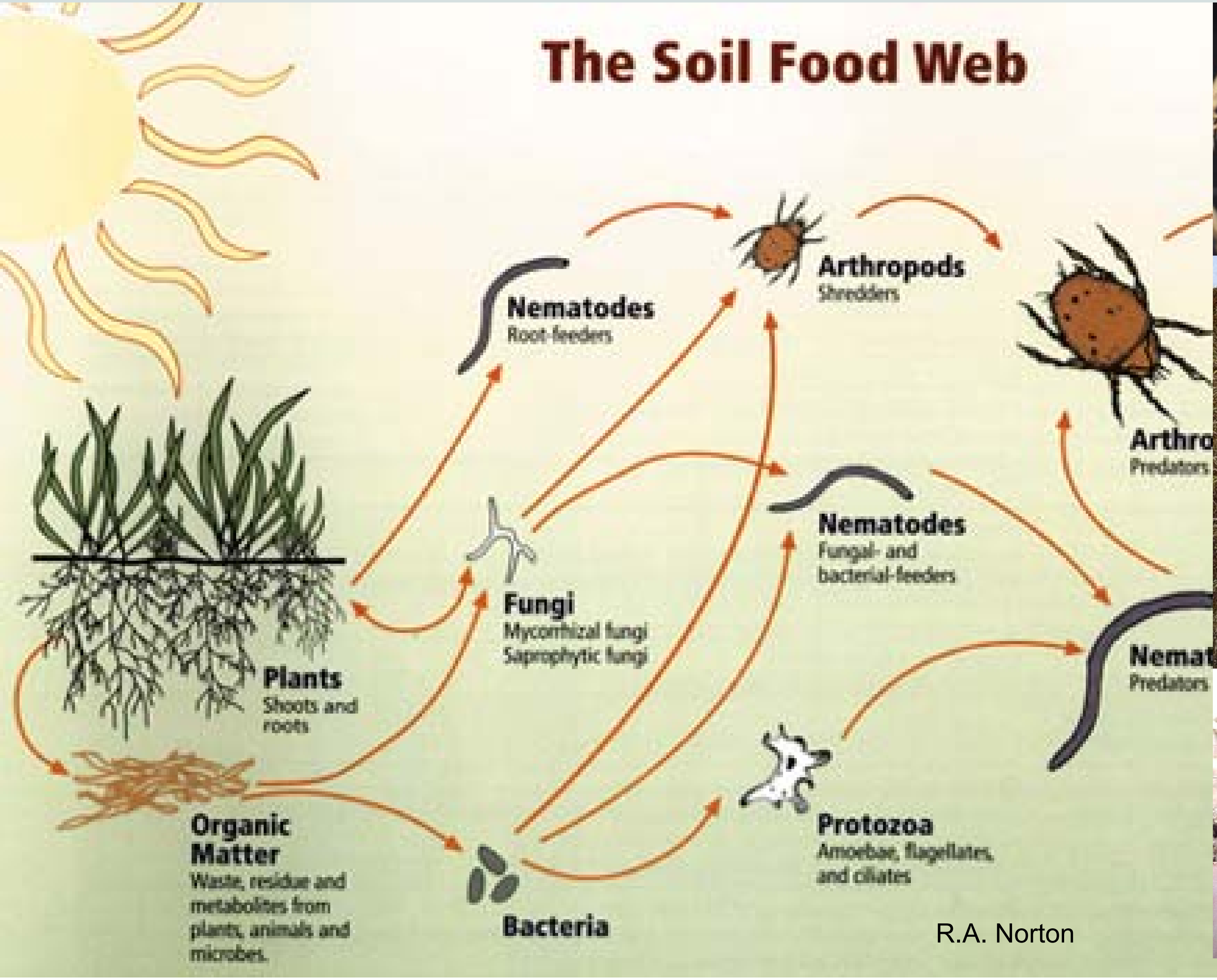
Soil Organic Matter

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



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

Soil Organisms

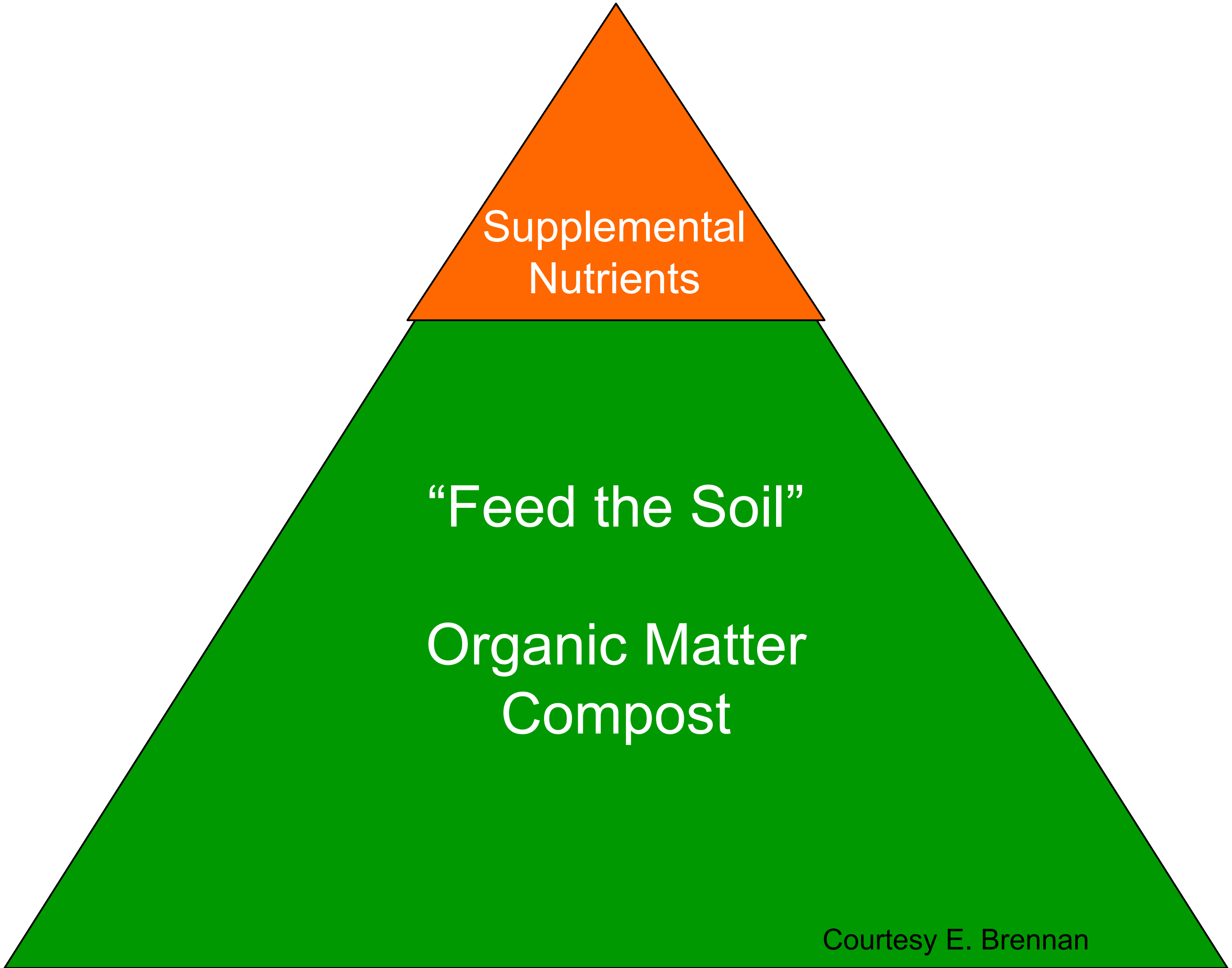


R.A. Norton

Agricultural Potential of Puna Soils

- A`a soils better suited than Pahoehoe
- Rainfall should exceed 90”/yr
- Pahoehoe soils require higher rainfall to maintain good crop growth than a`a soils.
- Nutrient and water retention is low for these soils
  - low CEC leads to rapid leaching losses
  - high proportion of coarse fragments leads to low surface area and low water retention.

Management for Soil Health and Food Security



Compost

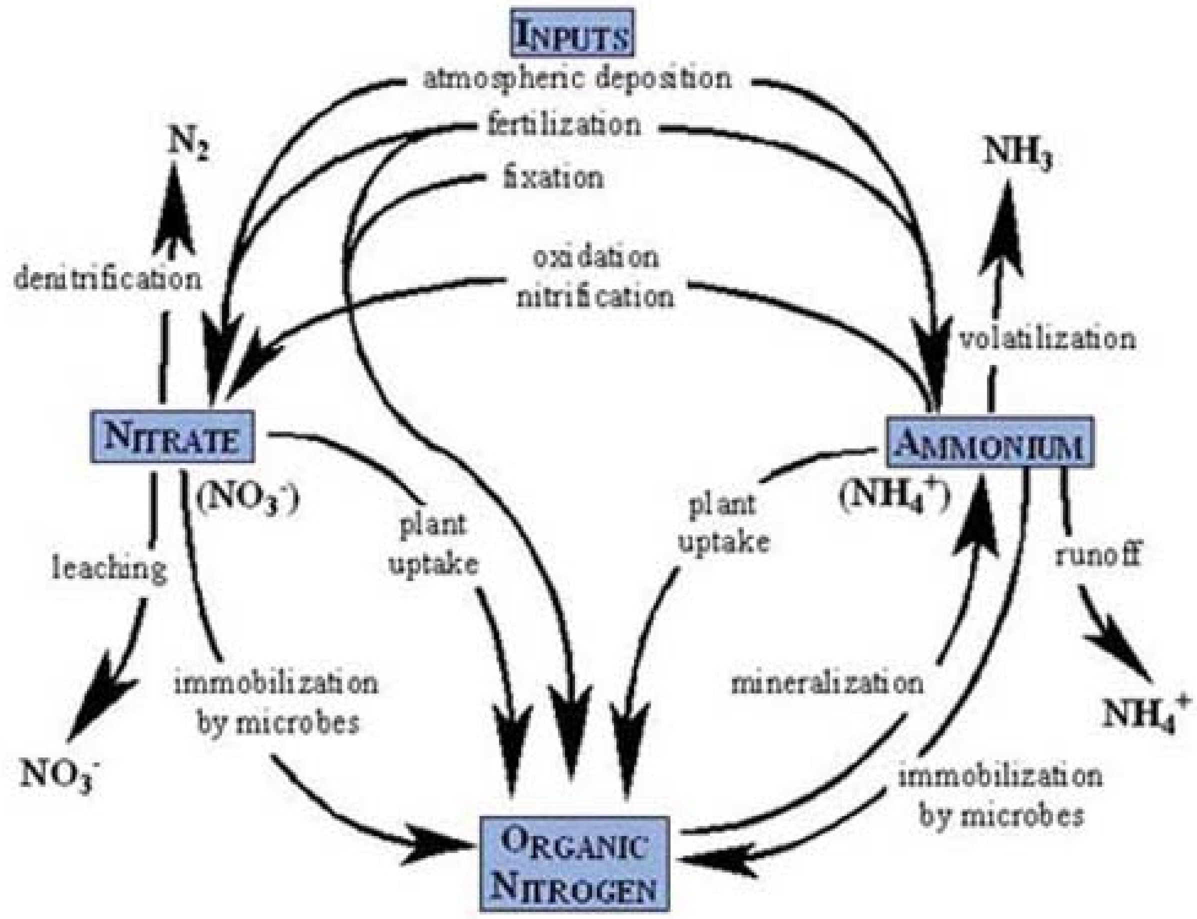
- Improves physical, chemical, and biological properties
- Need to add in large quantities (> 20 T/acre)
- Relatively low N content (< 2.0%)
- Slow-release nutrients

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

N Management

<u>Losses</u>

- Immobilization
- Leaching (NO_3^-)



Source: © U.S. Department of the Interior, National Park Service.

N Management

www.ctahr.hawaii.edu/nelsons/palms/1_pritchar

__N Deficiency__

- Yellowing of older leaves

N Amendments

Amendments

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

Cover Crops

- Sunn hemp
- Perenniel peanut
- legumes

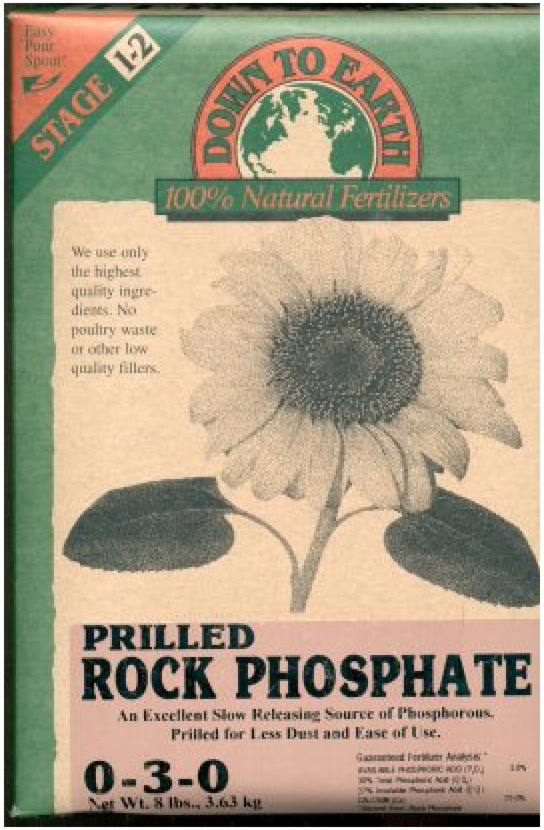
P Amendments

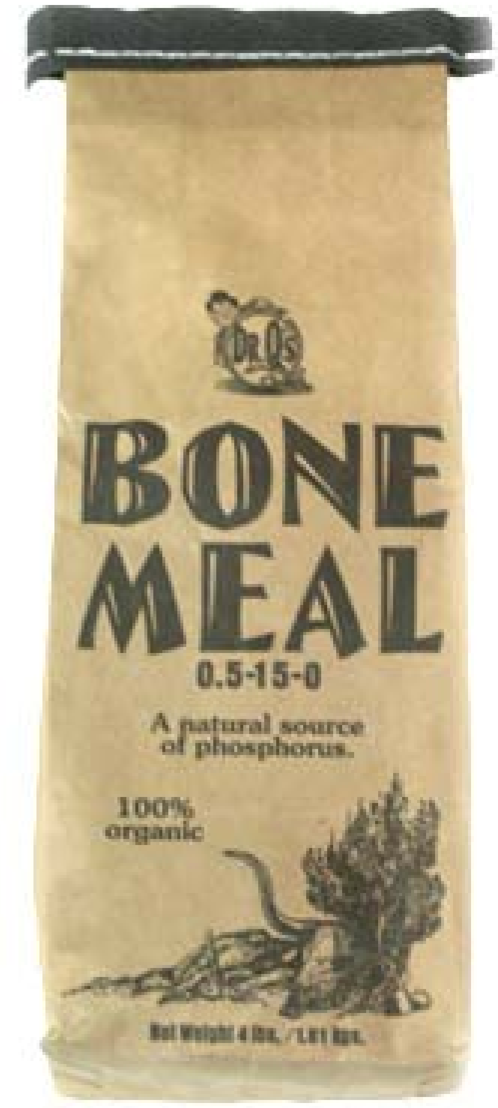
<u>Organic</u>

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

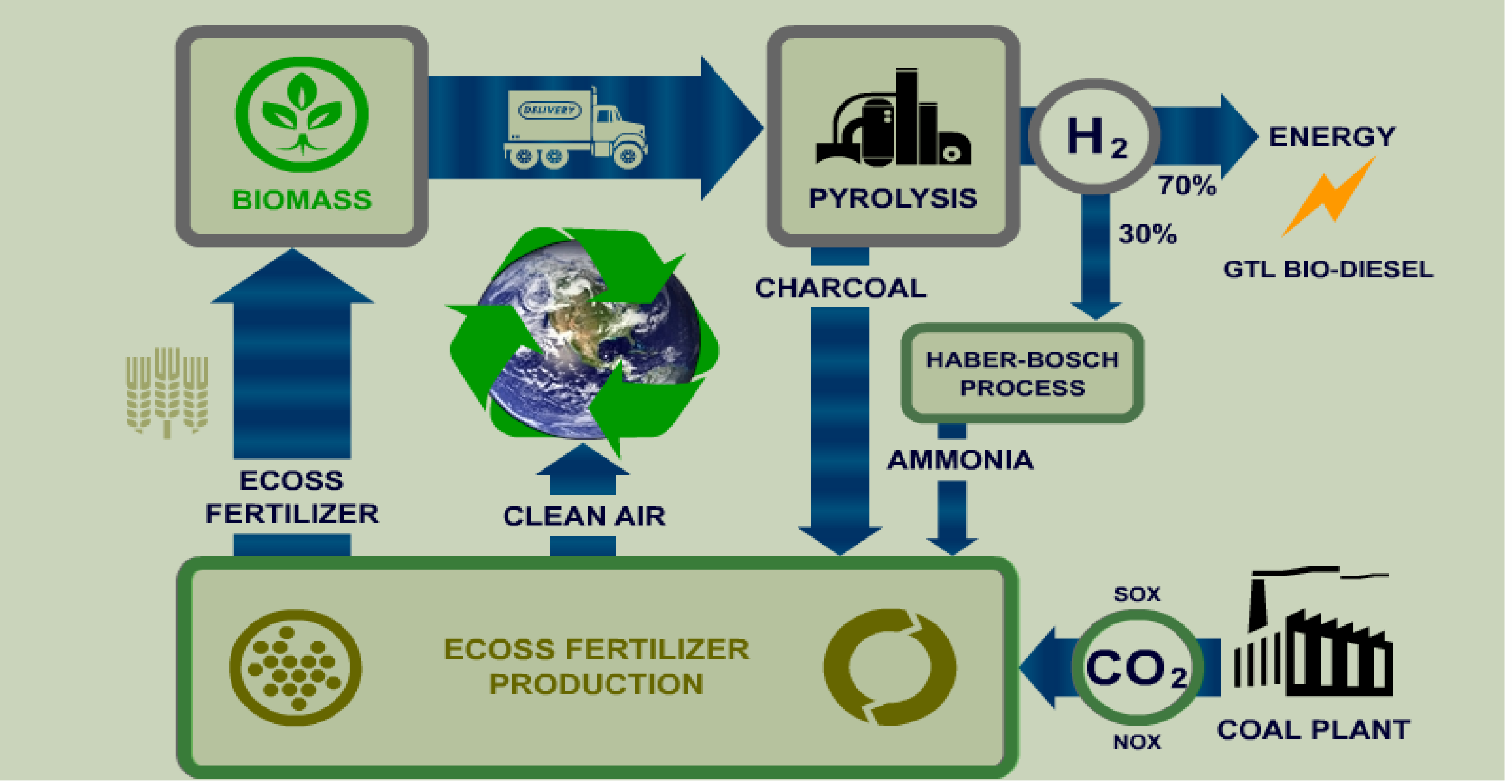
<u>Cover Crops</u>

- Sunn hemp
- Sudex
- Oats





Biochar Soil Amendments



www.eprida.com/eprida_flash

Terra Preta (Amazonian Dark Earths): Highly Fertile Anthropogenic Soils

Picture source: http://www.gerhardbechtold.com/TP/gbtp.php

Photo source: University of Bayreuth

Photo source: University of Bayreuth

Terra Preta Soil

Typical Upland Amazonian Soil

Effect of Charcoal on Plant Growth

Photo source: http://tinselwing.wordpress.com/tag/terra-preta/

Charcoal Additions

No Charcoal Additions

Charcoal as a Soil Amendment

<u>Potential Advantages</u>

- Stable organic matter
- Good way to recycle invasive species/waste
- Increases water retention and CEC
- Promotes microbial diversity

Source: Cornell University

Charcoal as a Soil Amendment

<u>Potential Disadvantages</u>

- Some charcoals have negative effect on plant growth
- Some charcoal inhibits plant N uptake

Summary

Management Strategies

- Maximize organic matter inputs
  - compost
  - green manures
- Keep soil covered
  - cover crops
  - mulches
- Maximize biodiversity
  - multi-story planting


Mahalo!