Soils of Hamakua

Concepts in Soil Fertility

Jonathan Deenik

Assistant Specialist, Soil Fertility

Department of Tropical Plant and Soil Sciences

College of Tropical Agriculture and Human Resources

University of Hawaiʻi at Mānoa

Outline

- Importance of Soils
- Concepts in Soil Fertiltiy
  - Clays
  - CEC
  - Organic matter
  - pH
  - N and P
- Soils of Hamakua

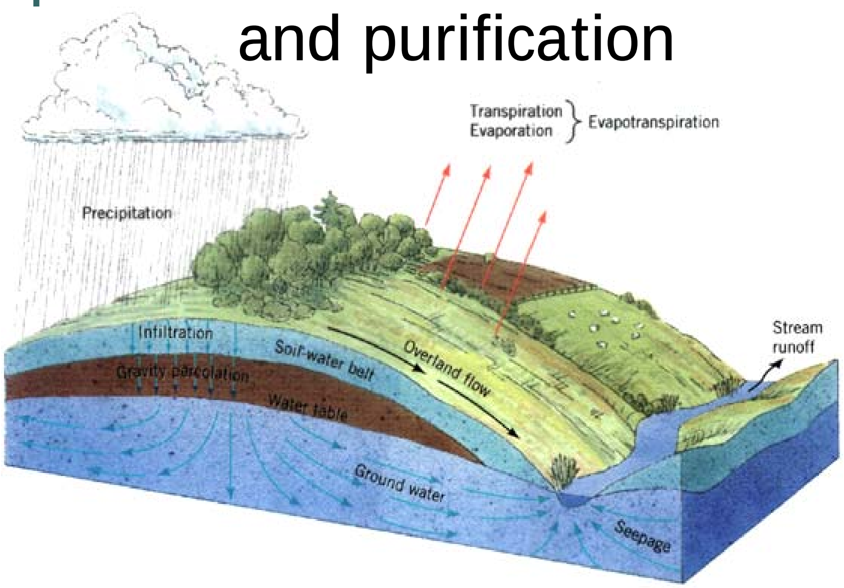
Medium for
Plant growth

Recycling
system

Habitat for
Soil organisms

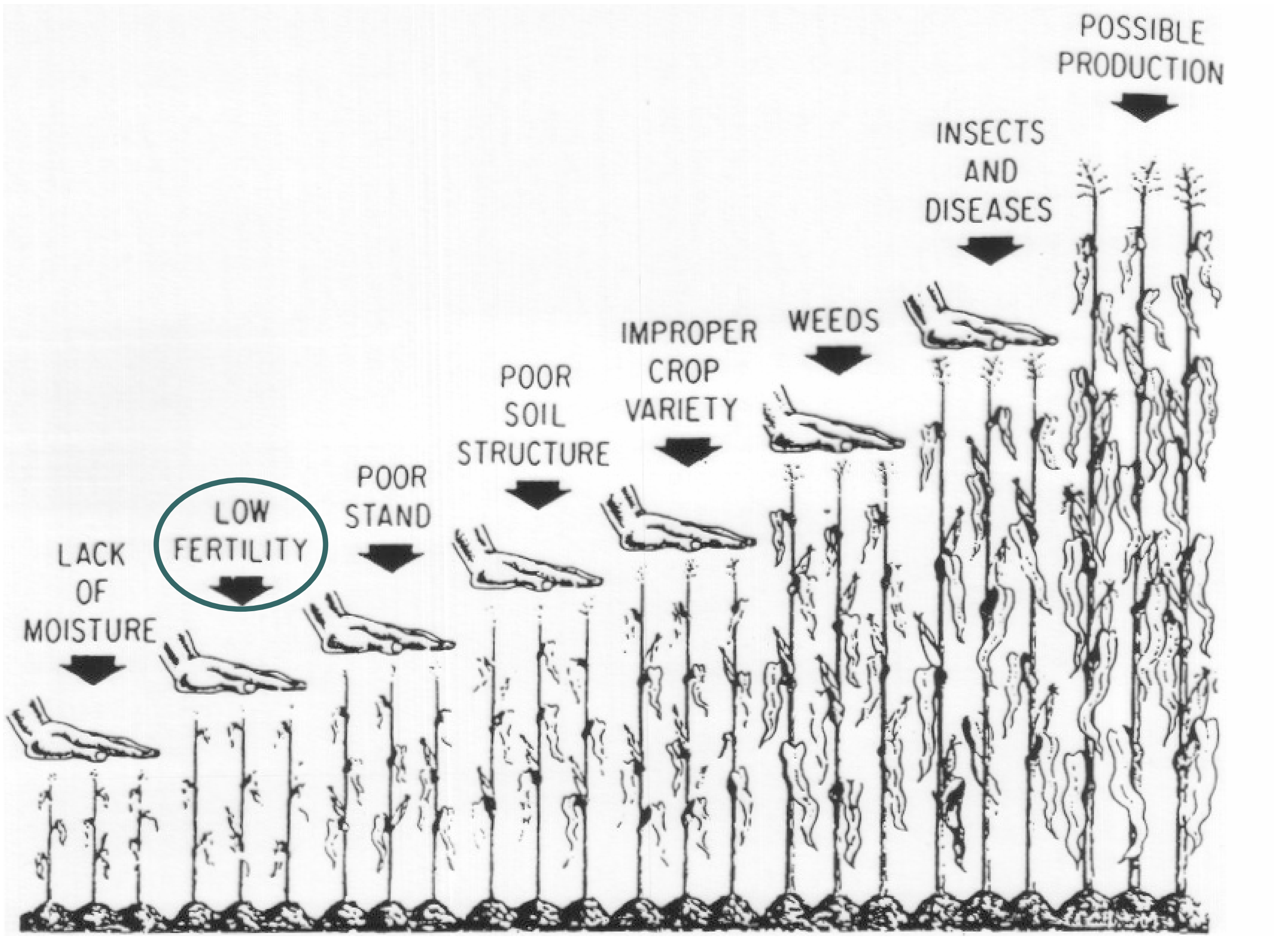
5 Functions
of Soil

Water supply
and purification



Engineering Medium

Plant Growth Factors



Essential Plant Nutrients

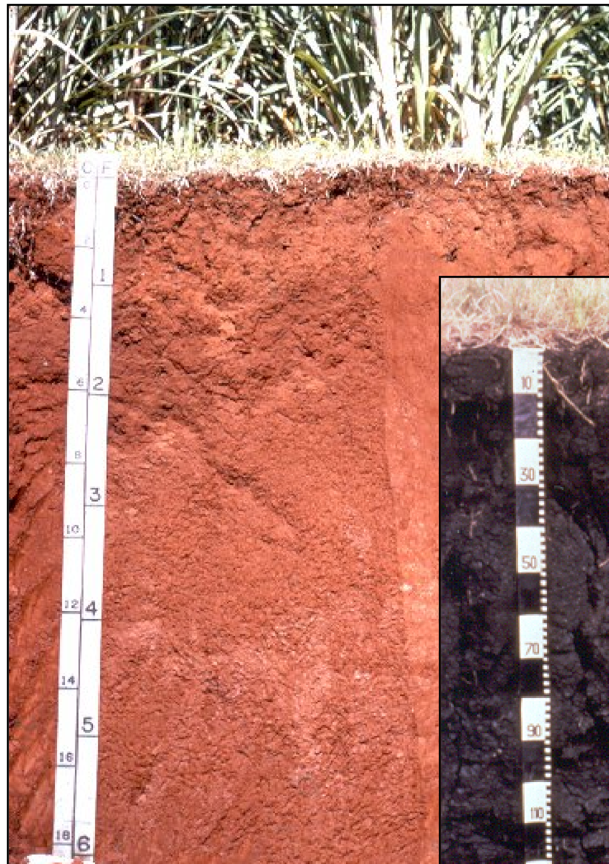
Air and water: C, H, O

Macronutrients: N, P, K, Ca, Mg, S

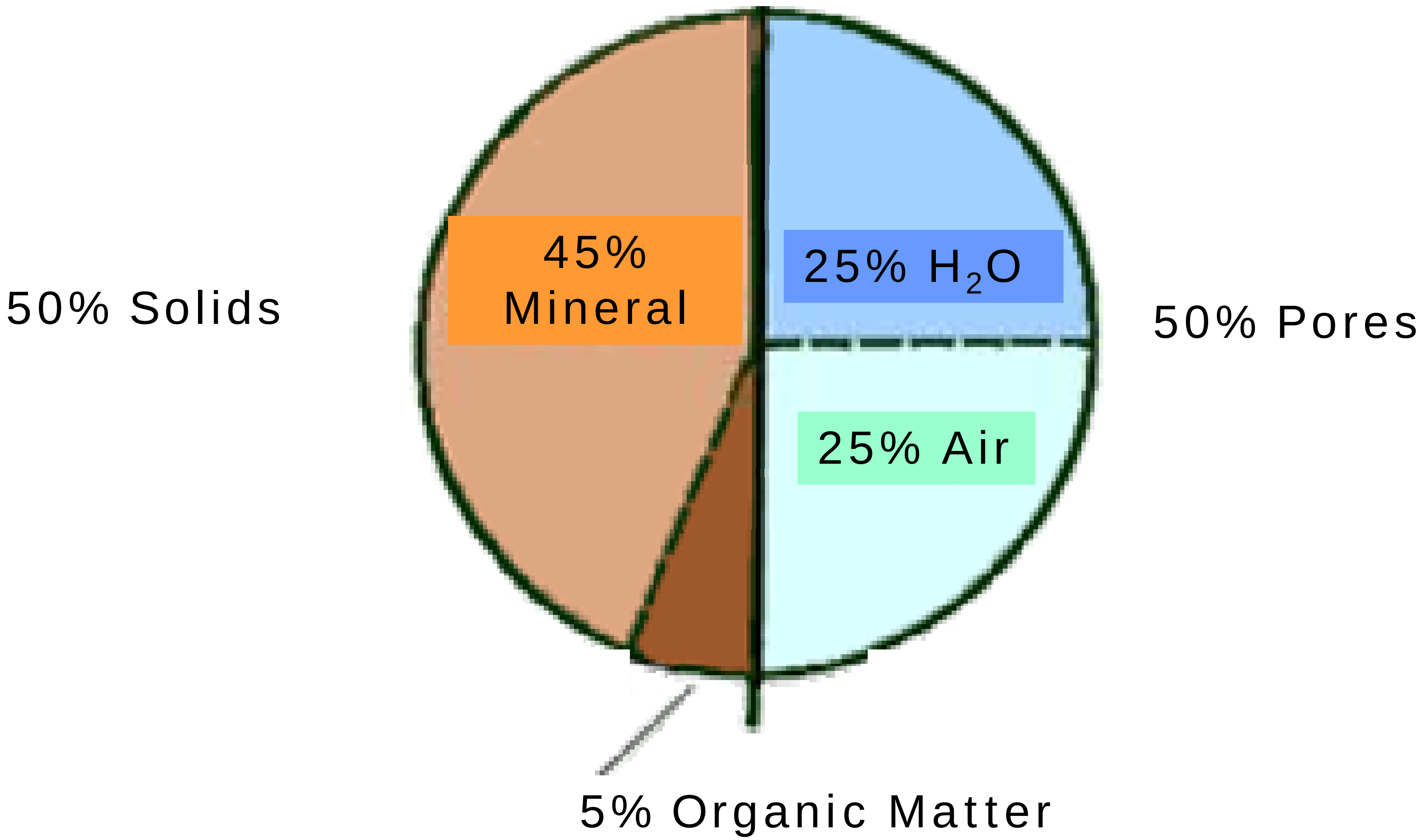
Micronutrients: B, Cu, Fe, Mn, Zn, Mo, Ni, Co, Cl

Soil Factors Affecting Plant Nutrients

- Type and amount of clay
- pH
- Organic matter
- Water



Idealized Soil Composition



Composition of Hamakua Soils

- Defy conventional rules of soil science
- Why?
  - Made from weathered volcanic ash with exceptionally high surface area
  - High organic matter content (20%)
  - Very low bulk density (0.4)

Clay is Where the Action is!

Clay Properties:

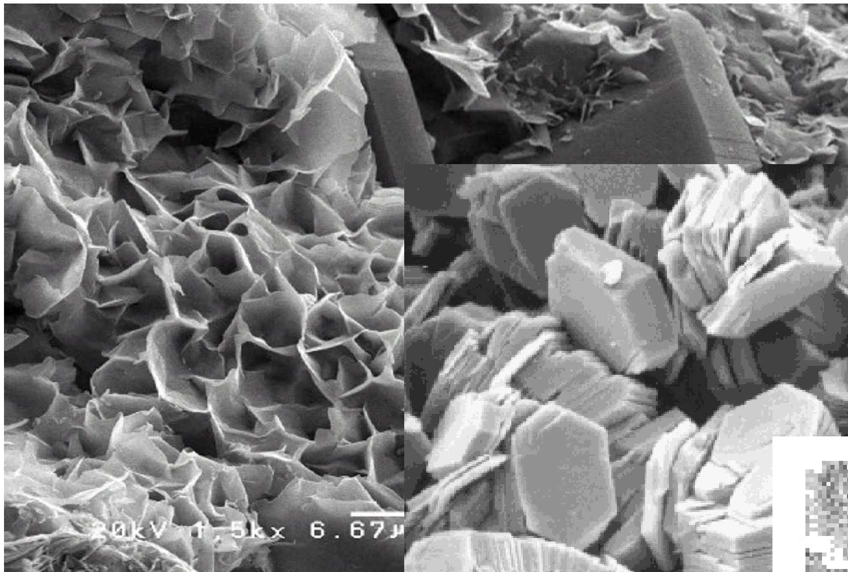
Microscopic size (<0.002 mm)

Extremely high surface area

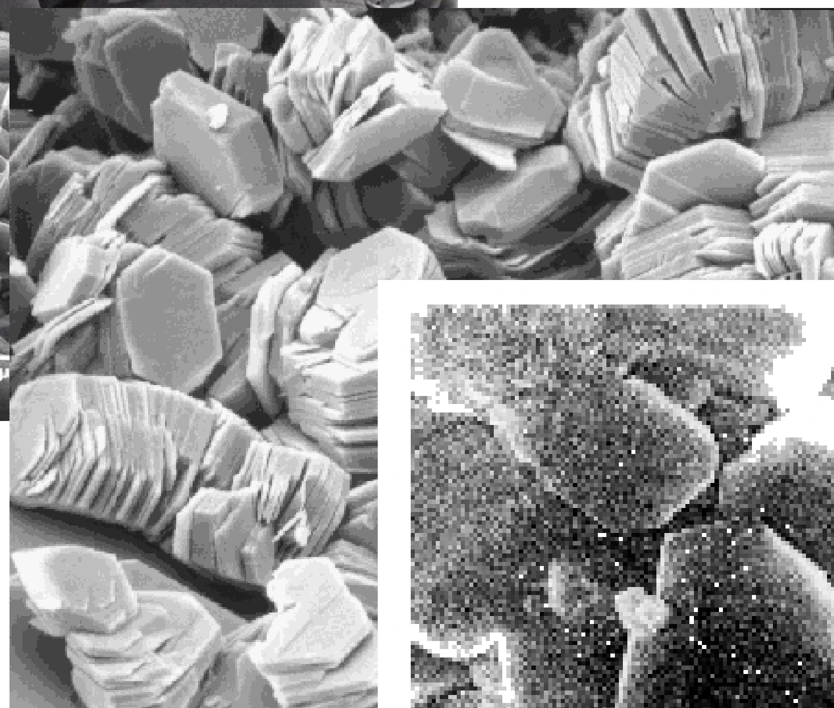
- water retention
- chemical reactions
- biological activity

Clay surfaces carry charge (-/+)

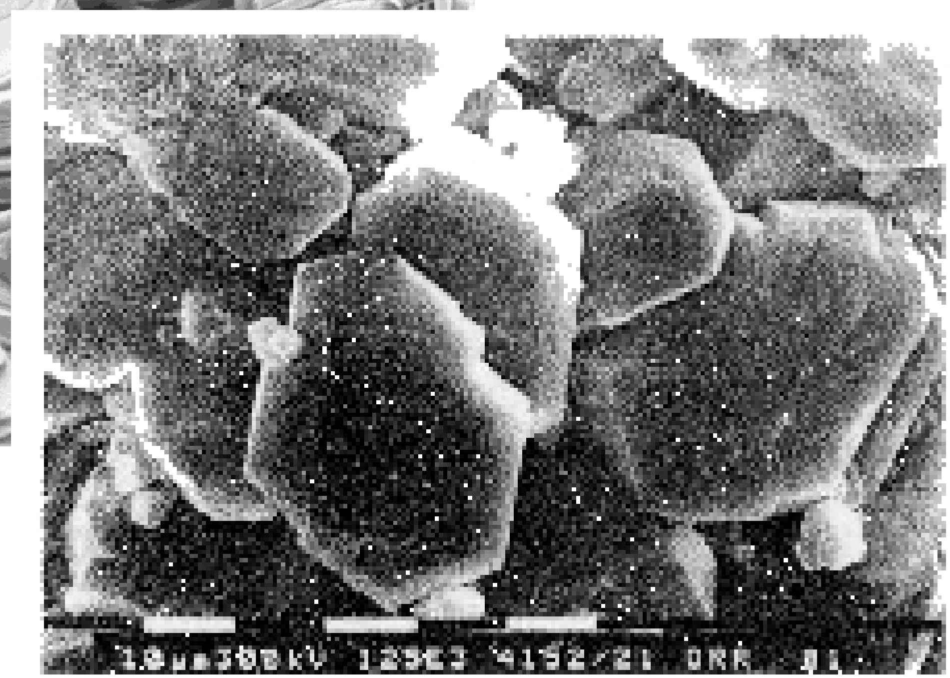
In Hawaii Type of Clay is Critical



2:1 layer silicates



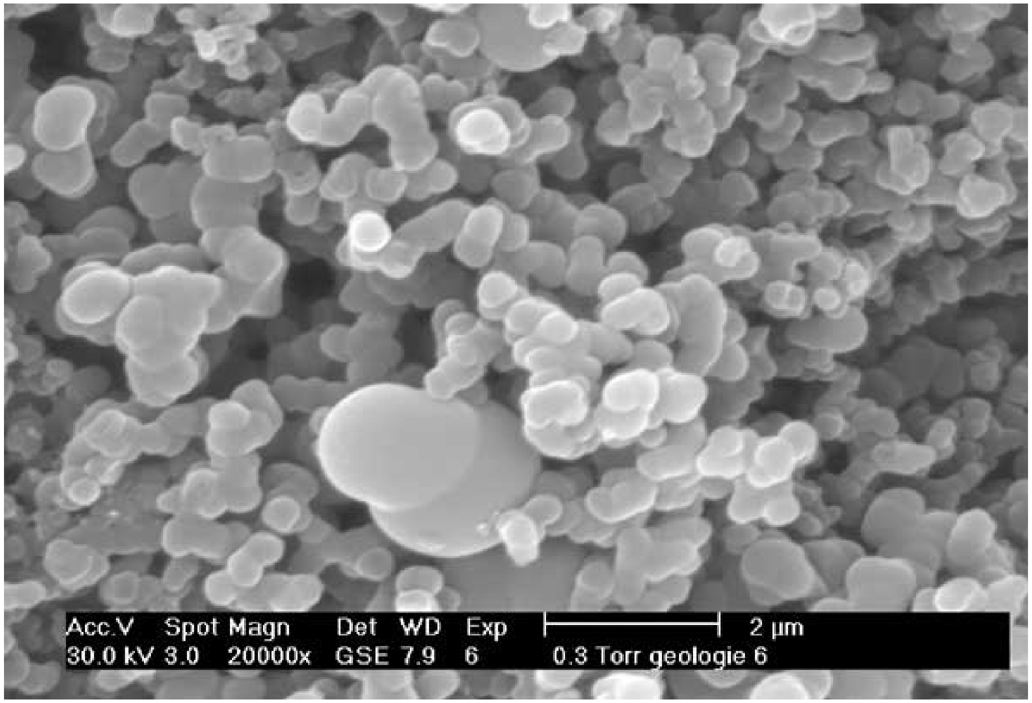
1:1 layer silicates



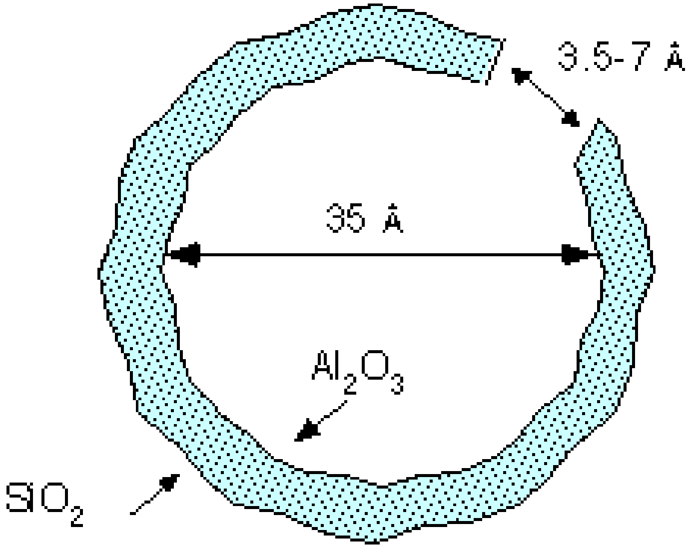
oxides

Volcanic Ash Soils Contain Allophane

Allophane



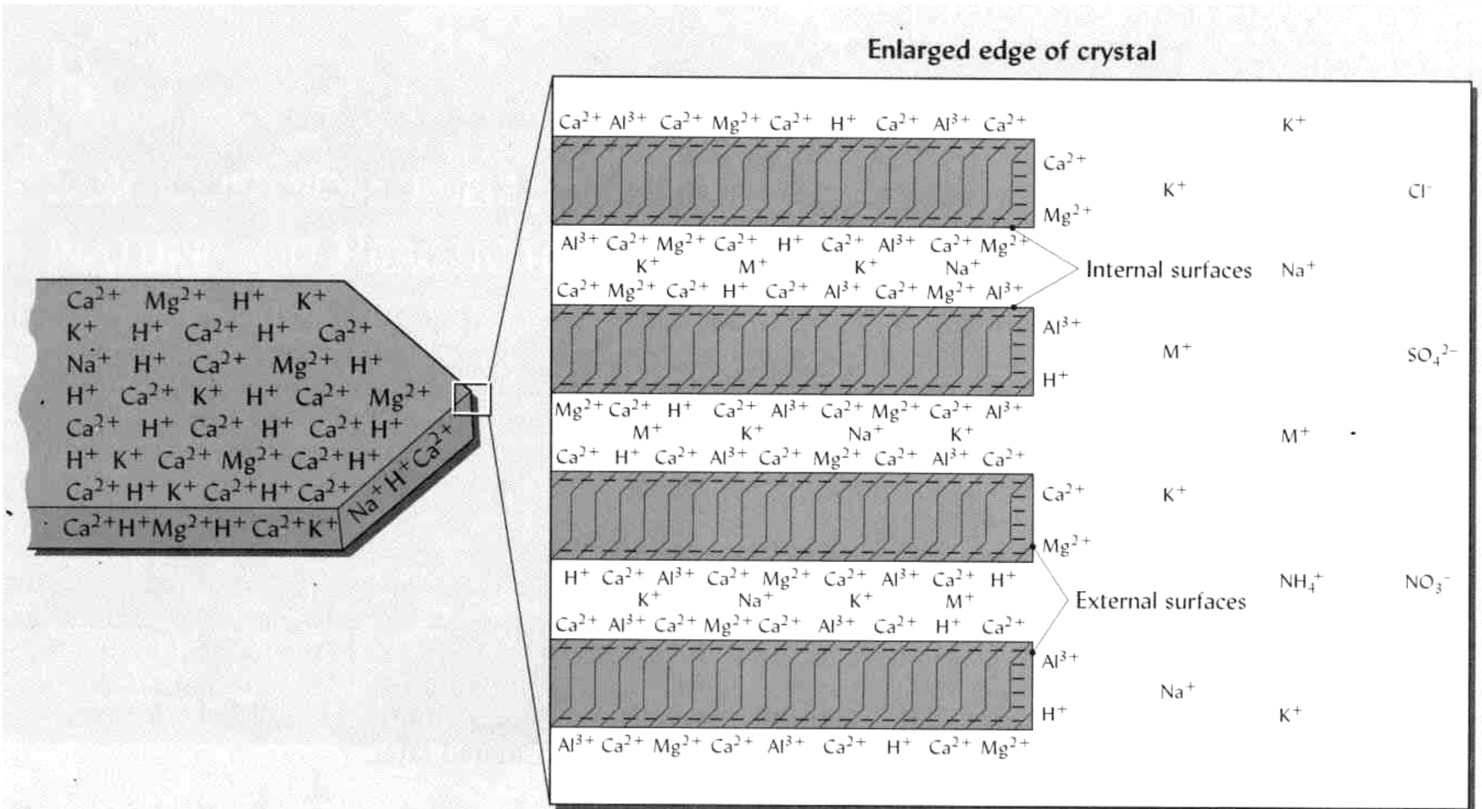
http://www.naturalsciences.be/institute/structure/geology/gsb_website/products/geolbelgica/publication/vol7a/goe



Properties:

- Exceptionally high surface area
- Variable charge (-/+)
- Low CEC

Cation Exchange Capacity
CEC



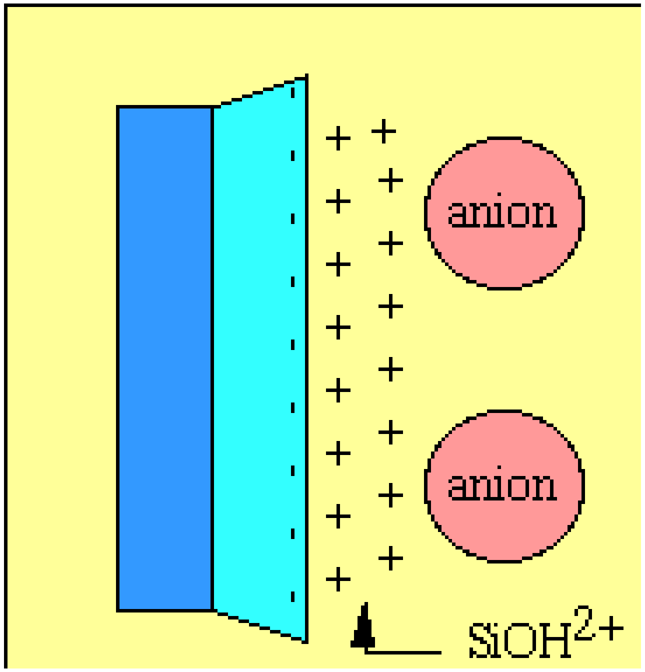
Brady & Weil, 2004. Elements of the Nature and Properties of Soils

Negatively charged sites that adsorb cations:

Ca^{2+}, Mg^{2+}, K^{+}, NH^{4+}

Allophane and CEC

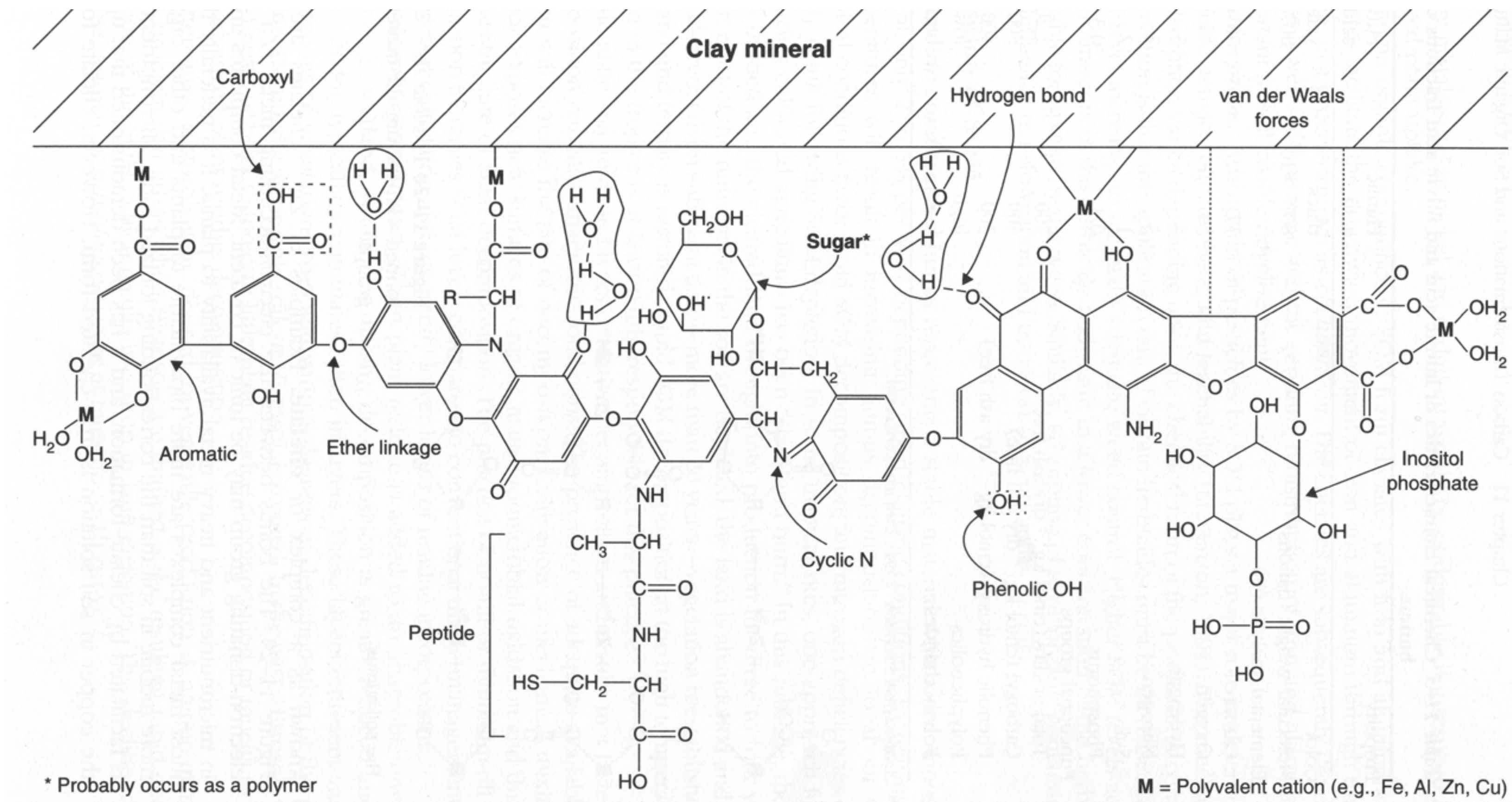
- When allophane is present surface charge can be - (CEC) or + (AEC)
  - Under acid conditions + charges increase
  - This results in a less fertile soil



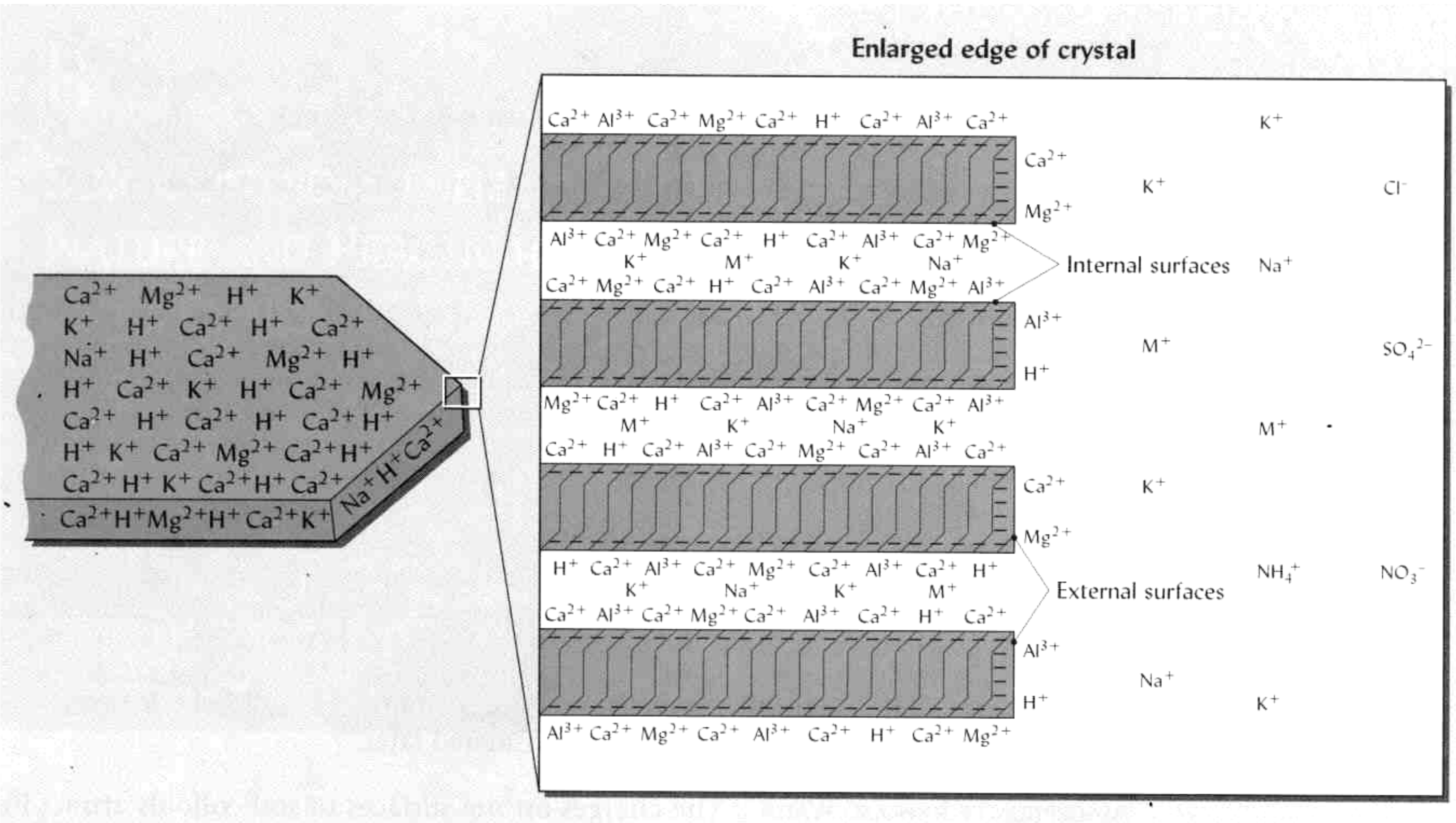
Organic Matter and CEC

- Organic matter has a high CEC
  - OM high in surface horizon
  - CEC always higher in surface soil

Brady & Weil, 2004. Elements of the Nature and Properties of Soils



CEC is a Bank for Nutrients



Brady & Weil, 2004. Elements of the Nature and Properties of Soils

Soil Acidity

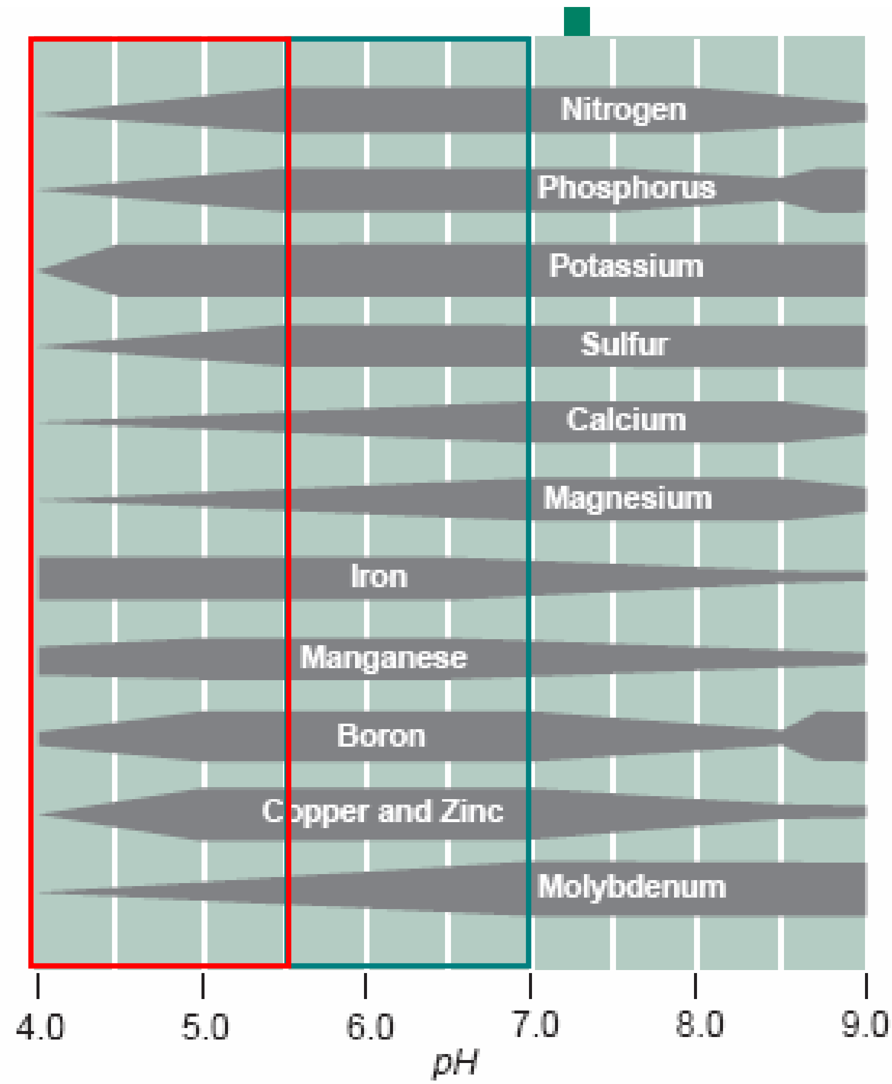
Natural Sources of Acidity:

- Precipitation and cation leaching
- Carbonic acid and organic acids
- Organic matter

Human Induced Acidity:

- Acid rain
- Urea
- Ammonium fertilizers
- Mono and diammonium phosphate
- Elemental S

Soil pH and Nutrient Availability

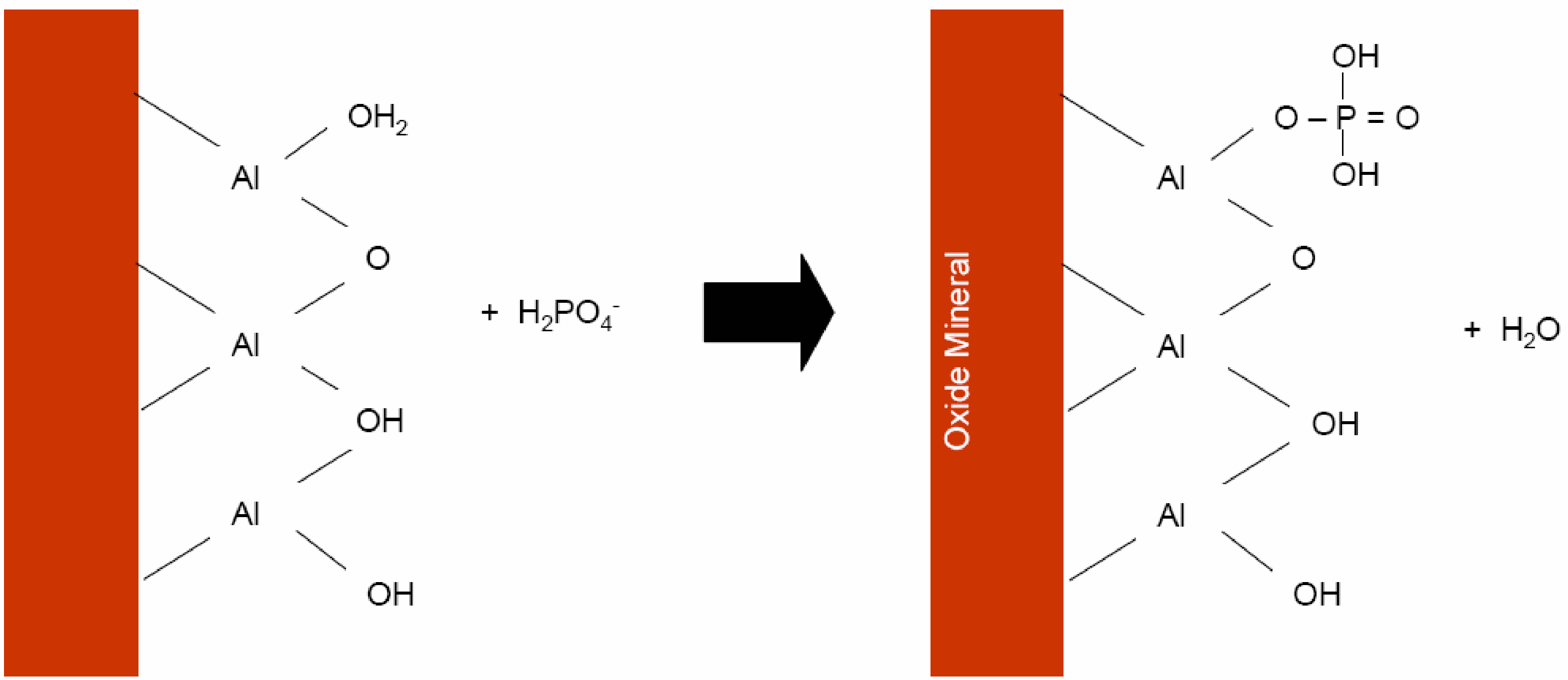


Brady & Weil, 2004. Elements of the Nature and Properties of Soils

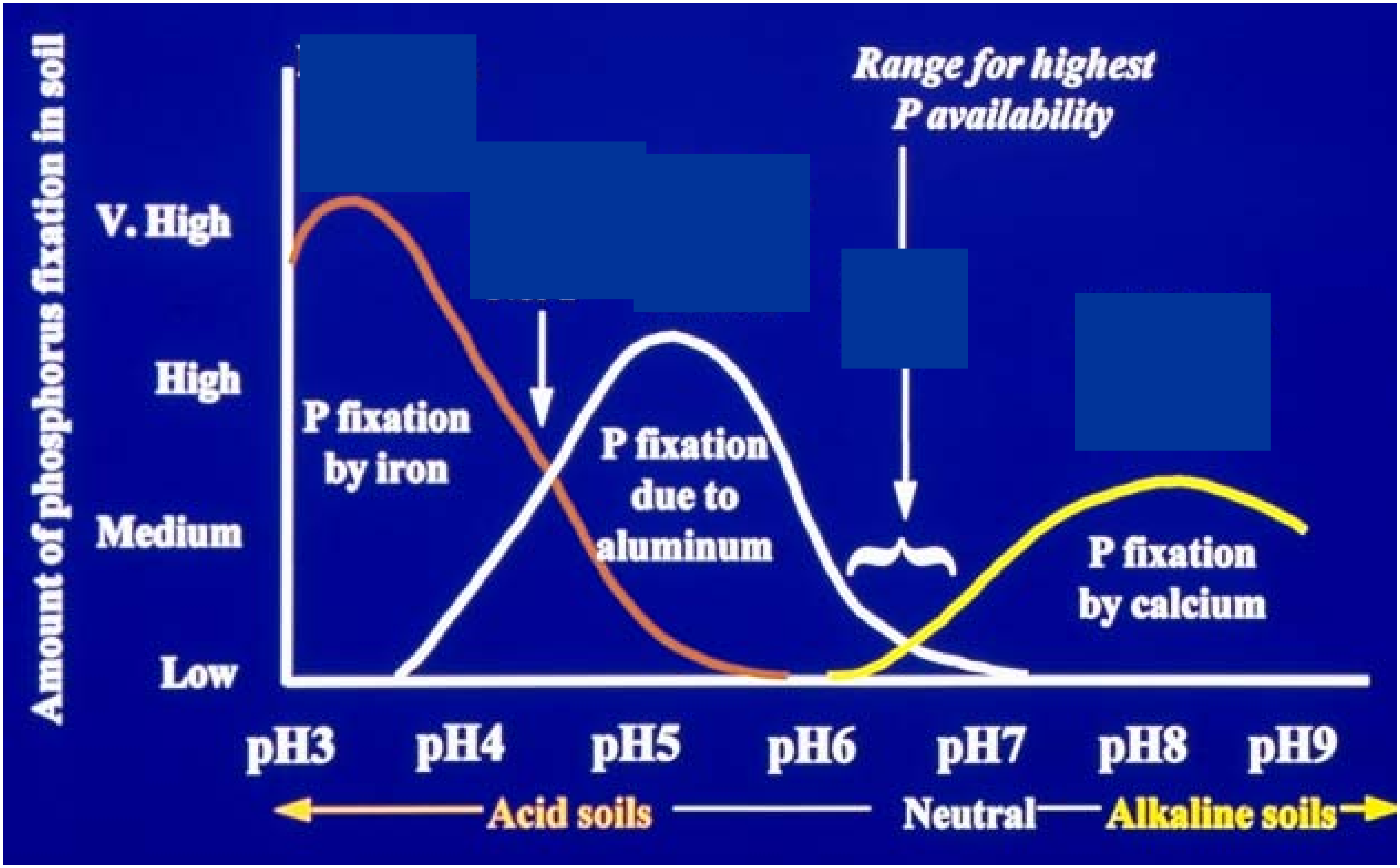
- Soil pH controls nutrient solubility
- Ideal range 6.0-6.5
- CEC decreases at low pH
- P fixation increases at low pH

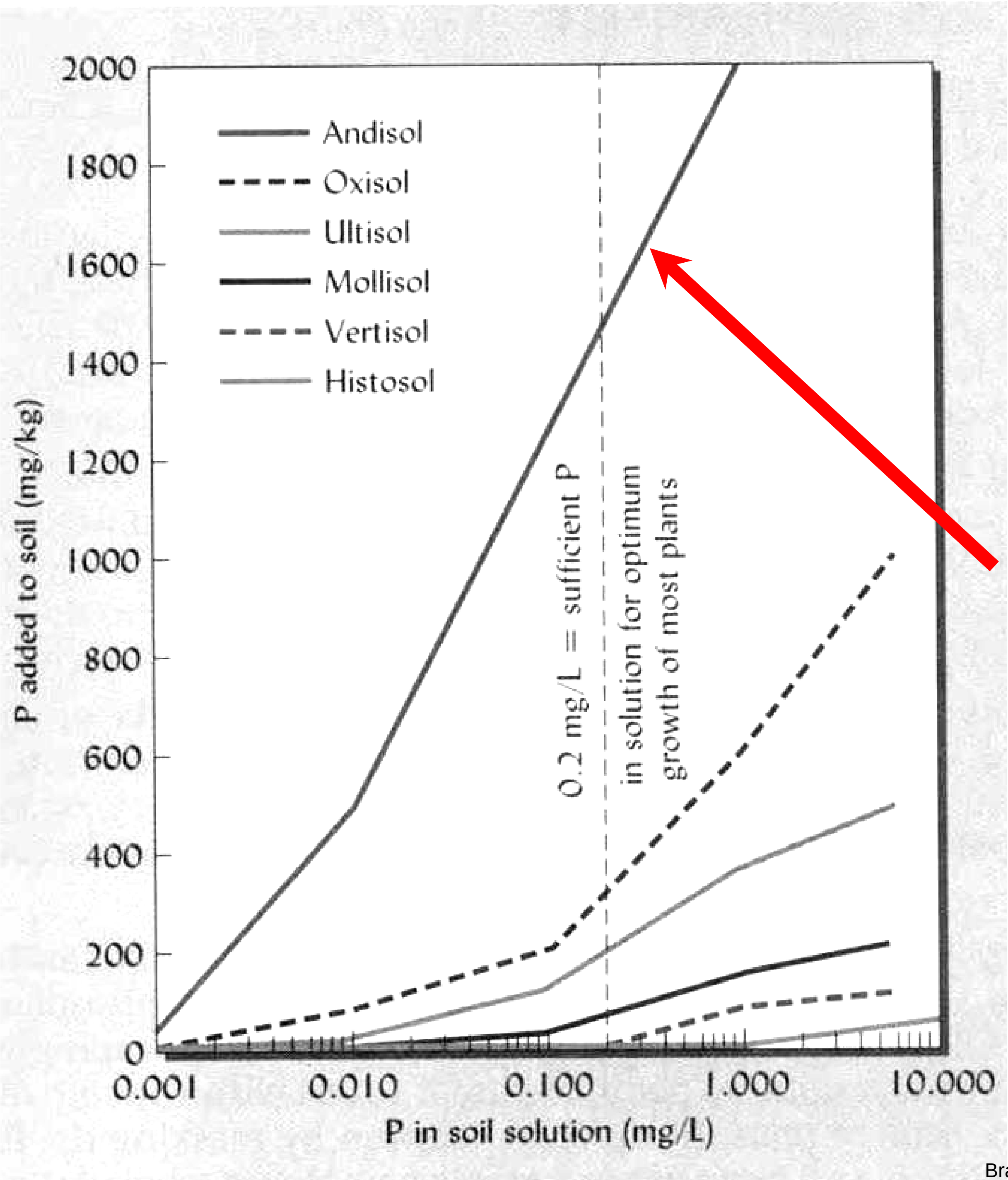
P-Fixation

- Adsorption of P on Oxides



P Fixation Depends on Soil pH





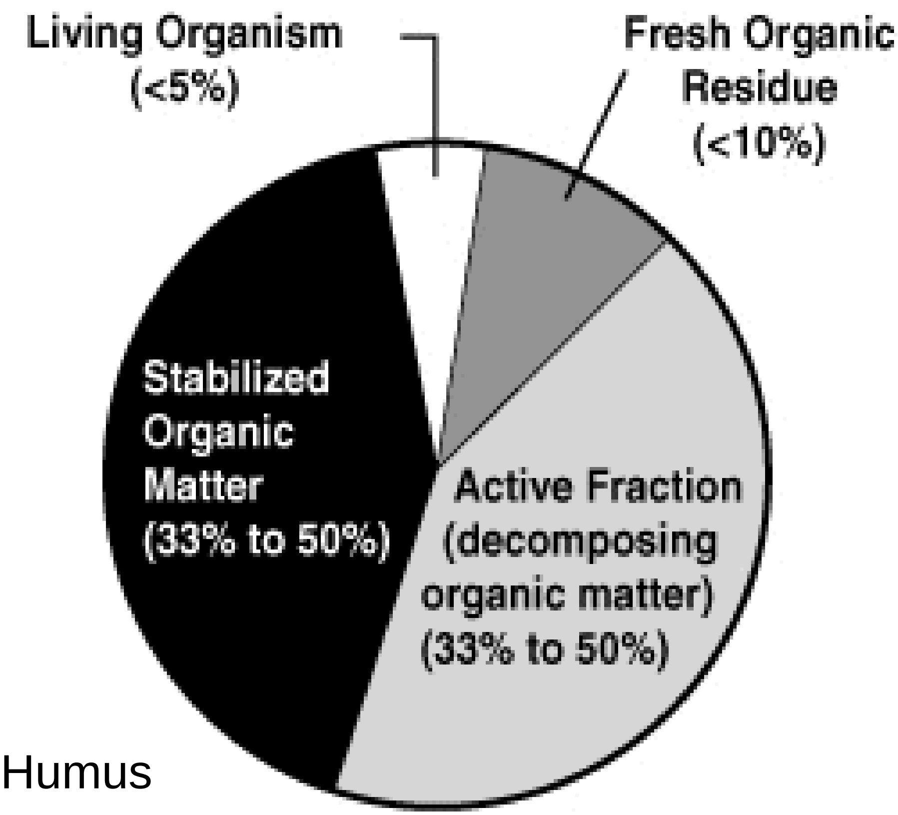
P Fixation is extremely high in ash soils

Brady & Weil, 2004. Elements of the Nature and Properties of Soils

P-Fixation

- Chemical bonding of phosphate with Aluminum/iron on clay surfaces
- Extremely high in wet volcanic ash soils (Hamakua)
- P-fixation increases as soils become more acid
- High P-fixing soils require high P inputs

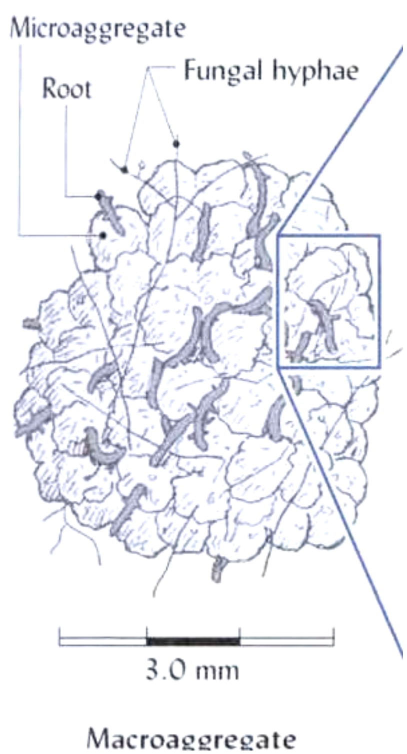
Organic Matter

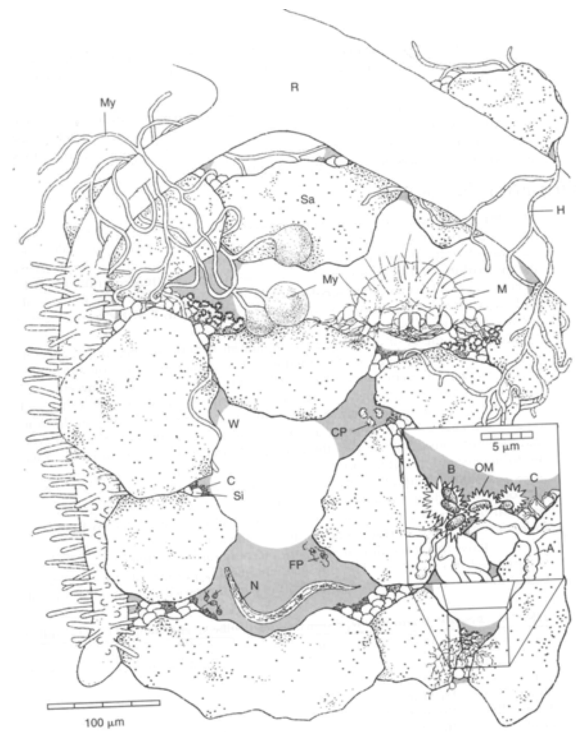


Humus

Importance of Organic Matter in Soils

- Physical Properties
  - Improves aggregation (glue)
  - Improves water holding capacity (surface area)





Brady & Weil, 2004. Elements of the Nature and Properties of Soils

Importance of Organic Matter in Soils

- Chemical
  - Increases nutrient availability (N cycling, P and micronutrient solubility)
  - Increases CEC (200 $cmol_c\ kg^{-1}$)
  - Buffers the soil against pH changes

N mineralization

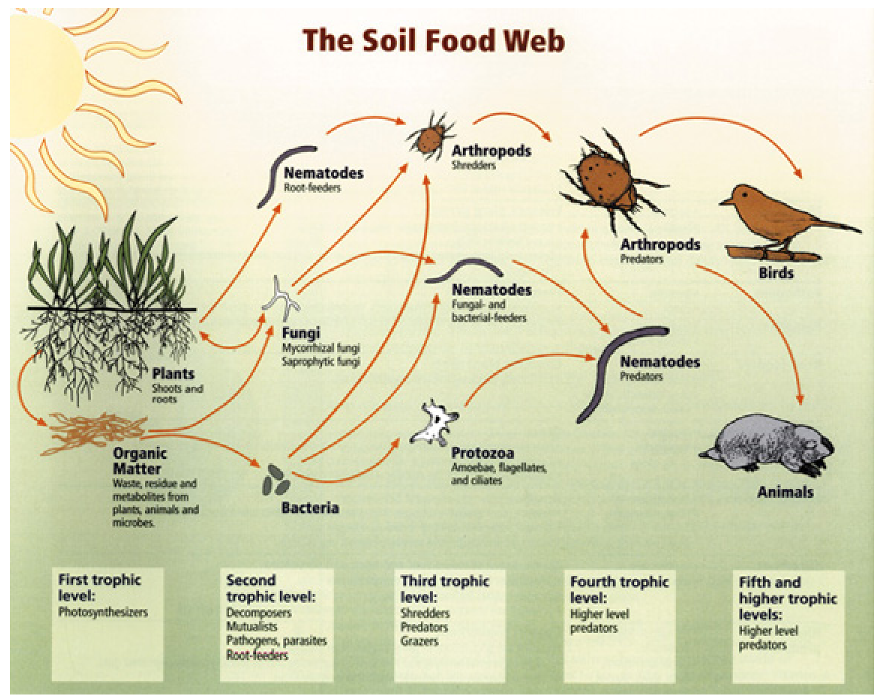
Conversion of organic N to inorganic N

$$R\text{-}NH_2 \rightarrow NH_4 \rightarrow NO_3$$

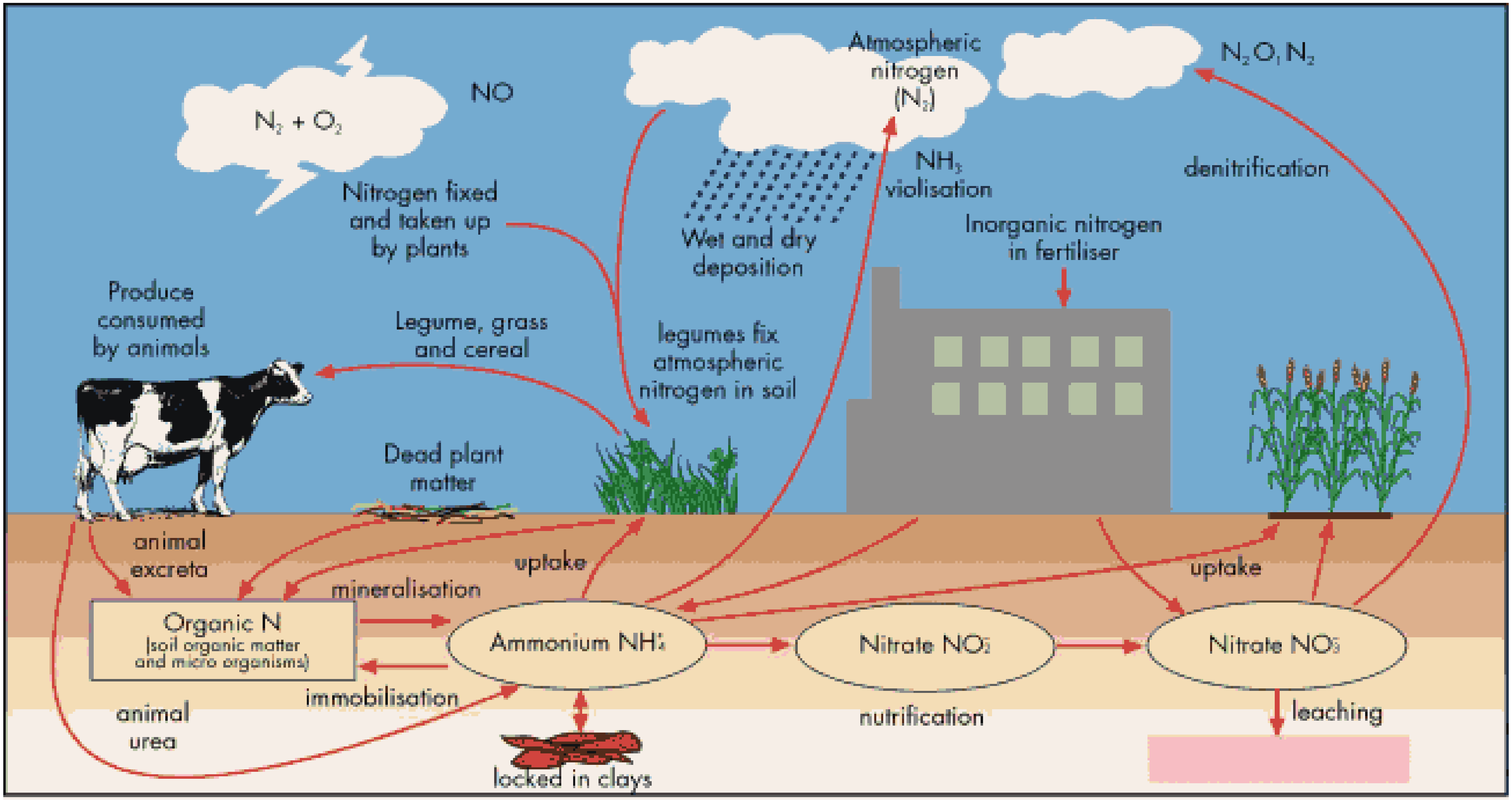
Total N mineralization

Importance of Organic Matter in Soils

- Biological
  - N fixation
  - Increases microbial diversity
  - Assists in pathogen suppression



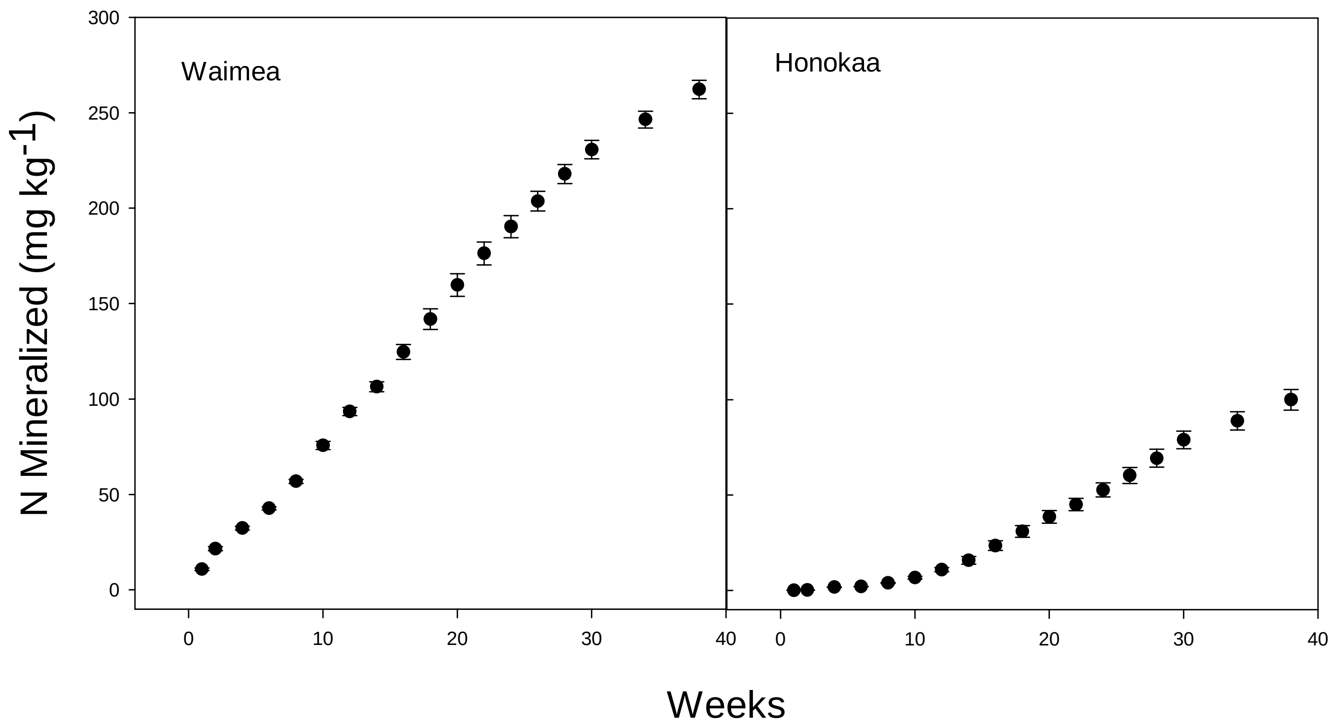
Nitrogen



http://www.bettersoils.com.au/module2/images/27.gif

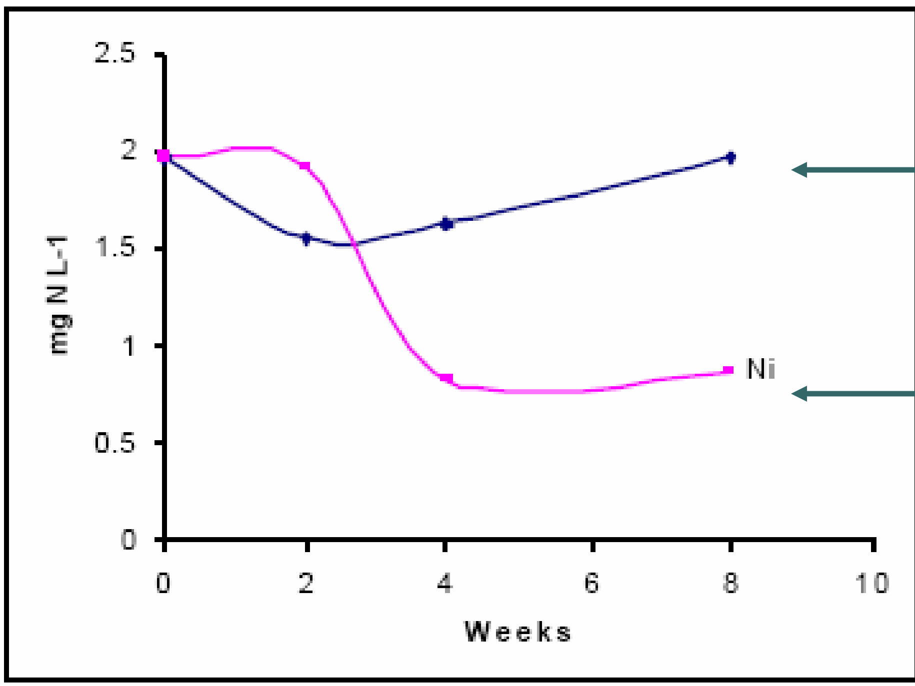
Nitrogen Dynamics

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



Nitrogen Dynamics

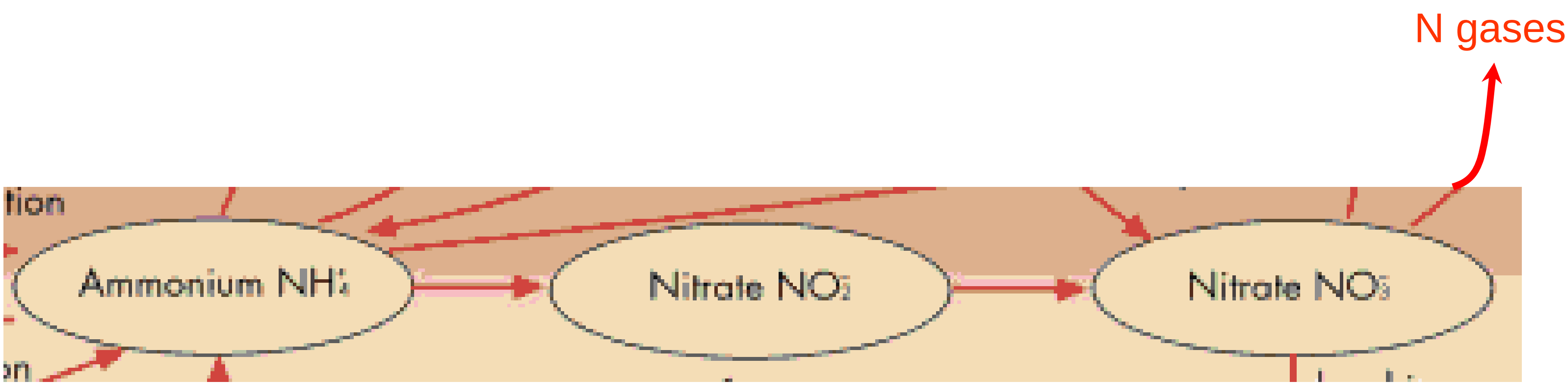
Immobilization: Conversion of inorganic N to organic N by microbes



soil

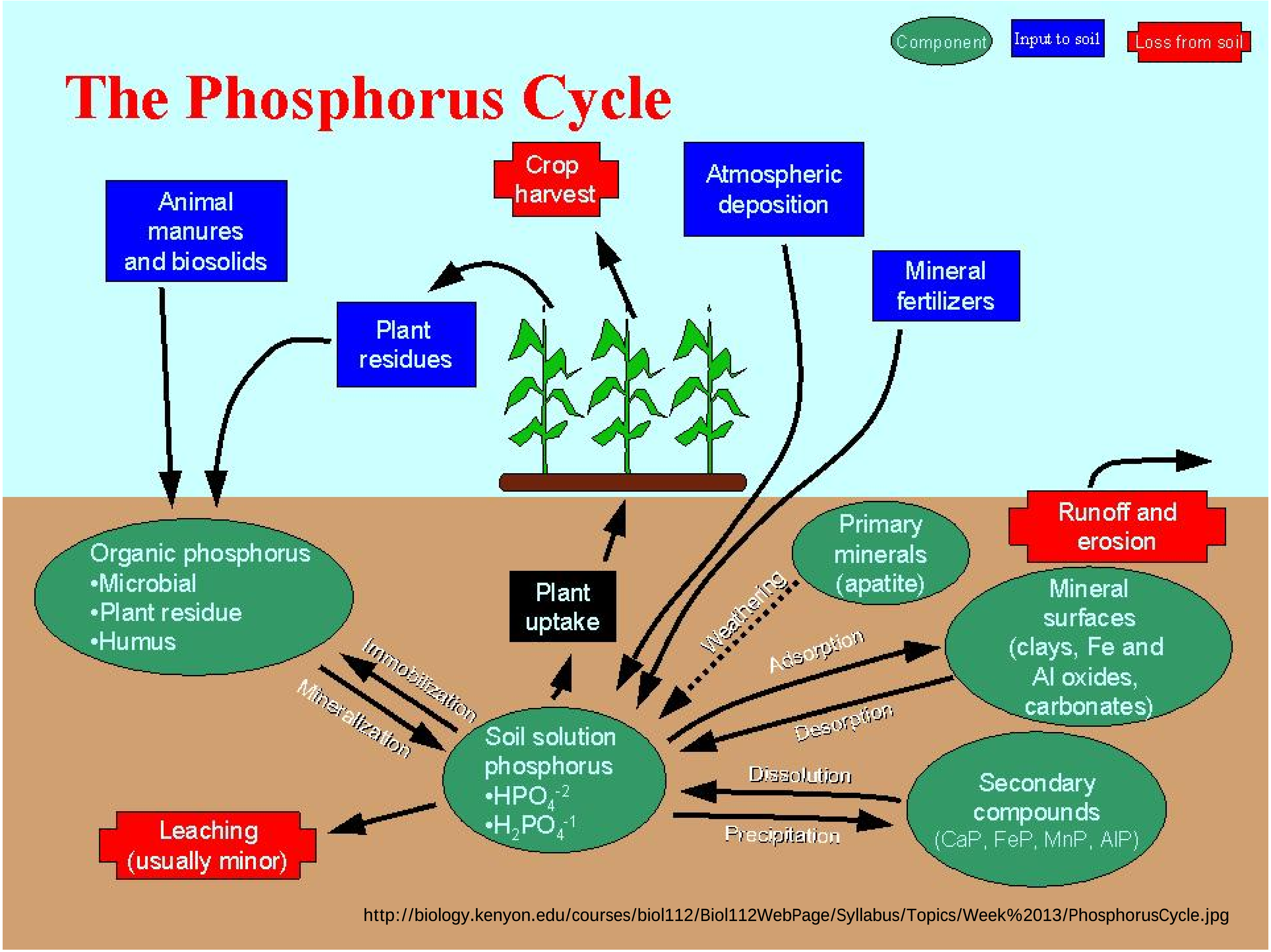
soil + coconut leaves

Denitrification: Conversion of NO_3^- into N_xO gases



Denitrification occurs when:

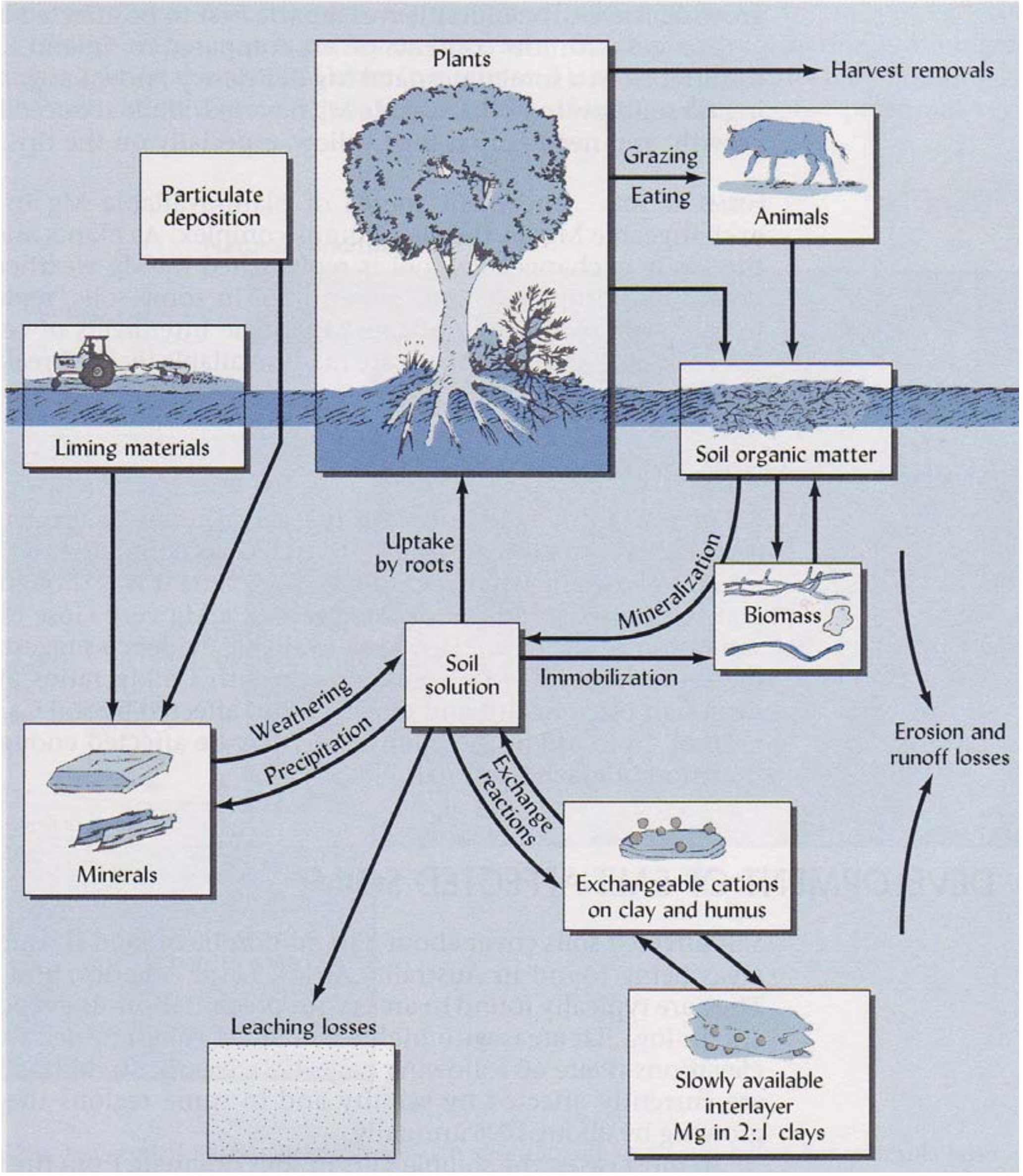
- Soils are saturated and lack oxygen
- Denitrification rate increases with temperature and organic matter content



Component
Input to soil
Loss from soil
The Phosphorus Cycle
Crop harvest
Atmospheric deposition
Animal manures and biosolids
Plant residues
Mineral fertilizers
Runoff and erosion
Primary minerals (apatite)
Organic phosphorus
•Microbial
•Plant residue
•Humus
Plant uptake
Weathering
Mineral surfaces (clays, Fe and Al oxides, carbonates)
Adsorption
Immobilization
Mineralization
Desorption
Soil solution phosphorus
•HPO_4^{-2}
•$H_2PO_4^{-1}$
Dissolution
Secondary compounds (CaP, FeP, MnP, AlP)
Precipitation
Leaching (usually minor)
http://biology.kenyon.edu/courses/biol112/Biol112WebPage/Syllabus/Topics/Week%2013/PhosphorusCycle.jpg

Calcium, Magnesium & Potassium

- Sources:
  - Minerals
  - Organic matter
- Availability:
  - CEC
  - pH
  - Leaching potential



Brady & Weil, 2004. Elements of the Nature and Properties of Soils

Fertile Soils	Infertile Soils
• Slightly acid to neutral pH	• Acid to strongly acid pH
• High CEC	• Low CEC
• High organic matter	• High P fixation
Vertisols - *Lualualei*	
Mollisols - *Waialua*	
Medial Andisols - *Waimea*	

Soil Fertility Depends on:

Fertile Soils

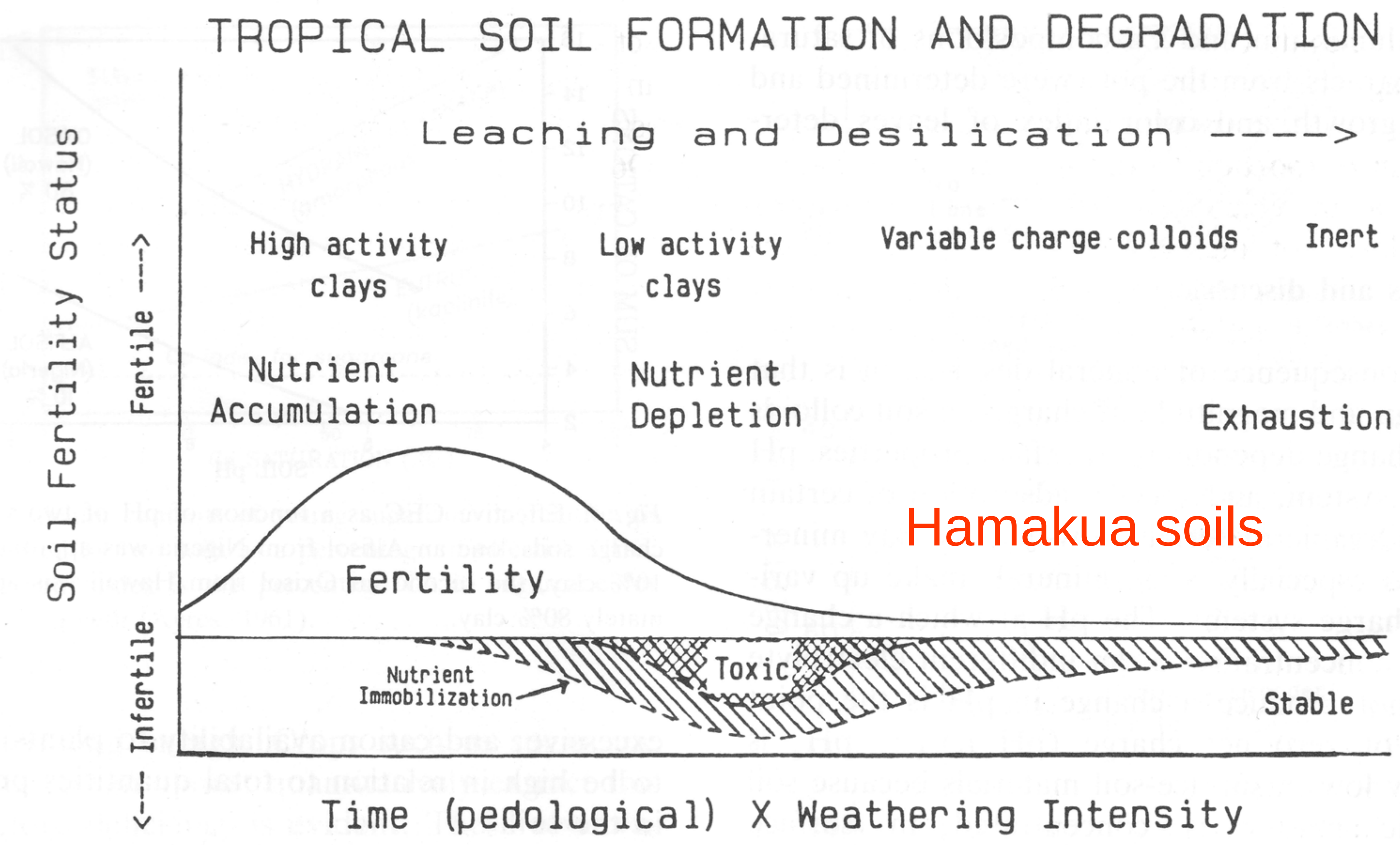
- Slightly acid to neutral pH
- High CEC
- High organic matter

Infertile Soils

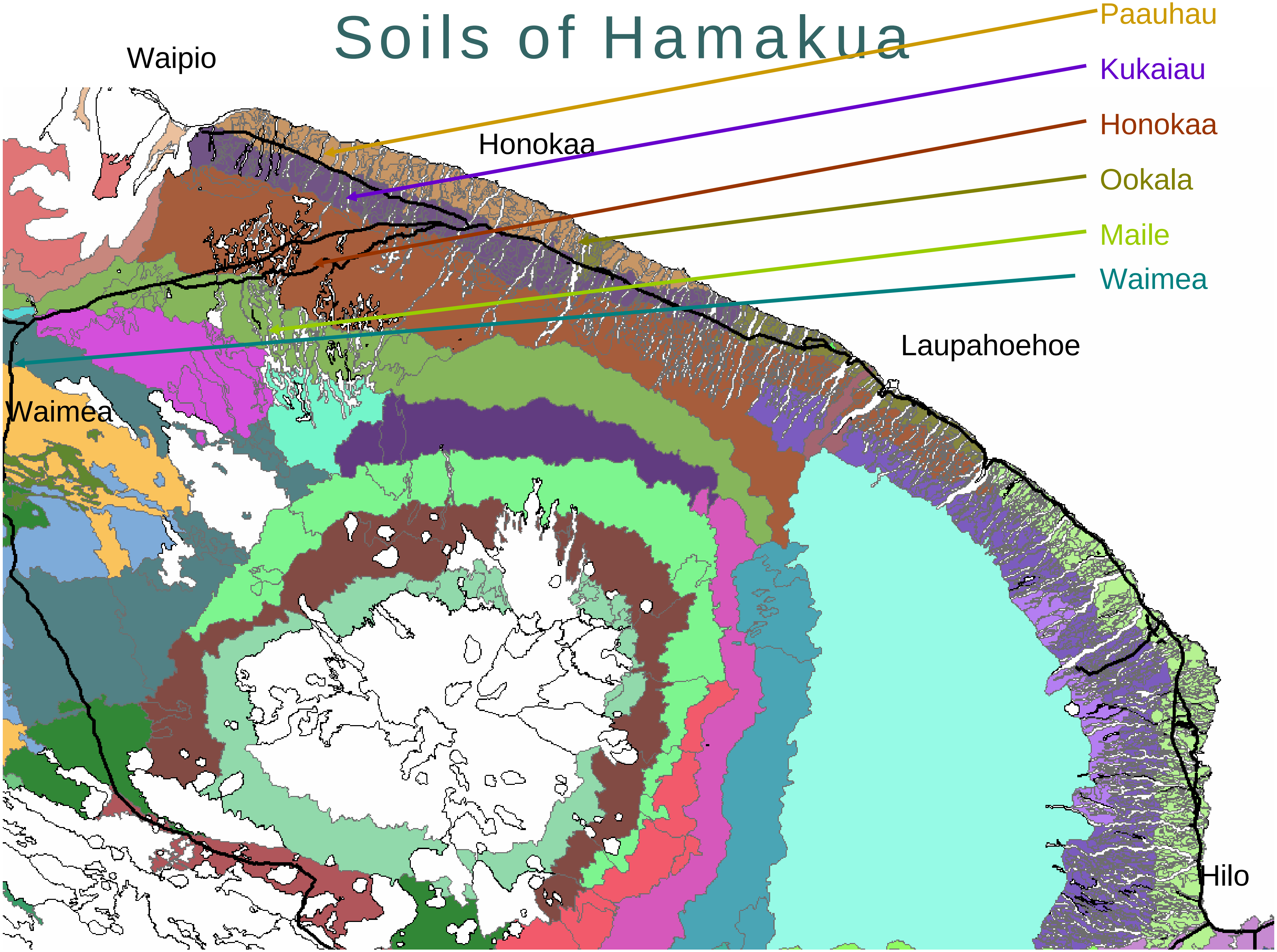
- Acid to strongly acid pH
- Low CEC
- High P fixation

- Amount of clay
- Type of Clay
- Organic Matter

Weathering Intensity and Fertility

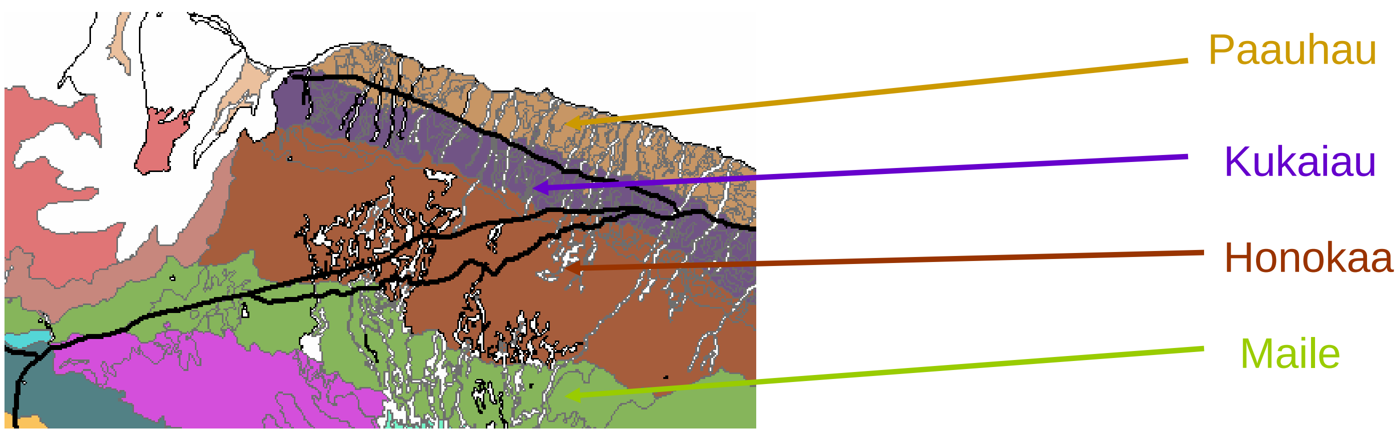


Soils of Hamakua



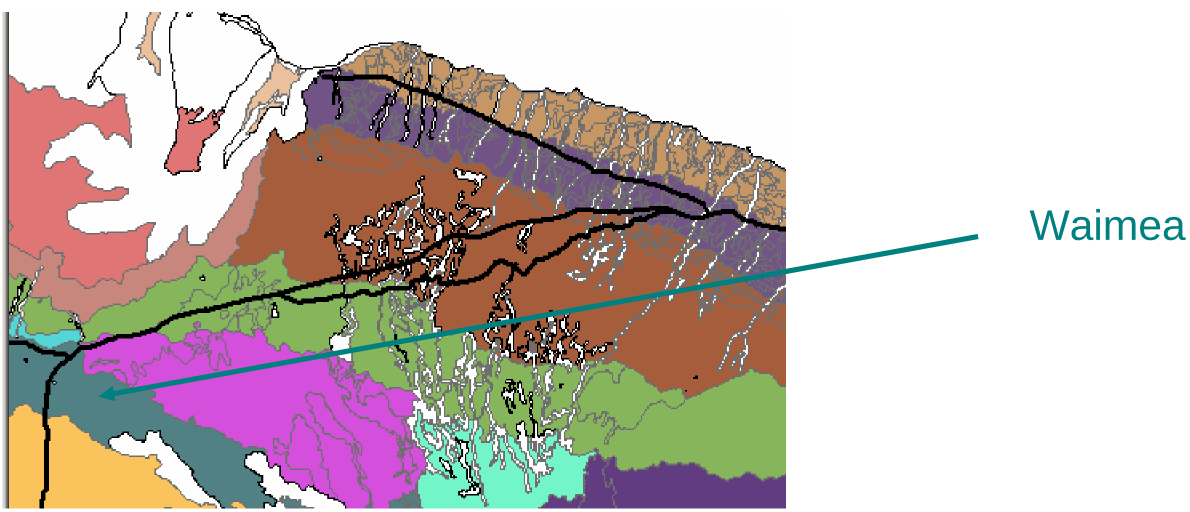
Fertility Status

Soil	Rainfall	pH	Organic C	Total N	Ca
	in		%		ppm
Paauhau	60-80	5.8	5.4	0.6	2,960
Honokaa	120-150	5.4	11.7	0.9	1,880
Maile	60-80	5.7	15.5	1.1	520



Fertility Status

Soil	Rainfall	pH	Organic C	Total N	Ca
	in		%		ppm
Waimea	30	6.4	13.1	1.2	6,000



Summary

- Soils give us life
- Type of clay determines fertility
- Organic matter makes a difference
- Some soils are inherently more fertile than others
- If we know our soils we can manage them well