

Soils of Pohnpei

Diversity and Fertility

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Outline

- Plant nutrition
- Soil fertility
 - Soil composition
 - Texture and clay minerals
 - Soil organic matter
- Soil diversity and formation
- Soil distribution on Pohnpei



Plant Nutrition

Soil is the source of essential plant elements:

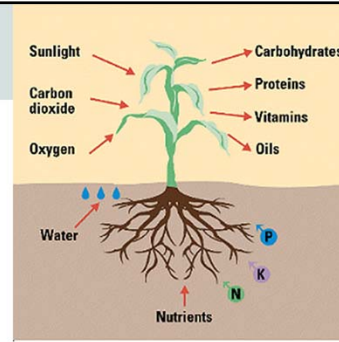
Macronutrients

Nitrogen (N) – proteins and photosynthesis
Phosphorus (P) – energy compounds, fruiting flowering
Potassium (K) – fruit quality and water balance

Calcium (Ca) – cell walls, root and leaf development
Magnesium (Mg) – chlorophyll
Sulfur (S) – proteins, chlorophyll, seed production

Micronutrients

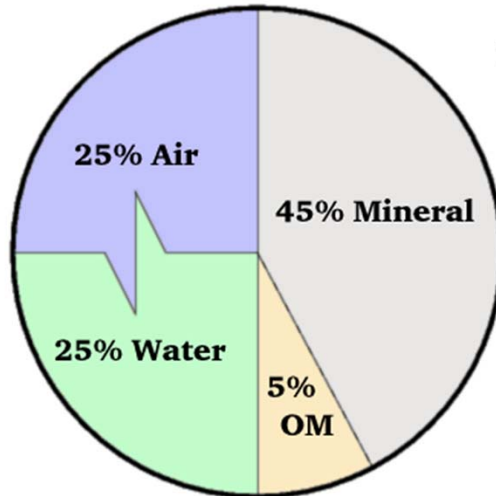
Boron (B)
Copper (Cu)
Iron (Fe)
Manganese (Mn)
Zinc (Zn)



N deficiency in corn

There are 12 elements which plants obtain from the soil that are essential for plant to grow and reproduce successfully. In addition, plants require carbon (from the air), hydrogen, and oxygen (from water) to grow. What makes an element *essential* to plant growth? An element is essential if the plant cannot complete its life cycle without the element. It is essential if the element is directly or indirectly involved in the metabolic processes of the plant (i.e. photosynthesis or respiration). A deficiency in an essential nutrient will result in the development of a characteristic, visual symptom. The essential plant nutrients are: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), molybdenum (Mo), boron (B), copper (Cu).

Soil Composition



1. Mineral: sand, silt and clay
2. OM: organic matter

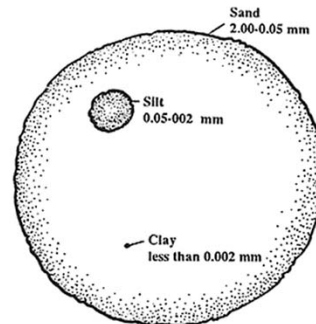


Soil composition is an important aspect of nutrient management. While soil minerals and organic matter hold and store nutrients, soil water is what readily provides nutrients for plant uptake. Soil air, too, plays an integral role since many of the microorganisms that live in the soil need air to undergo the biological processes that release additional nutrients into the soil.

The basic components of soil are minerals, organic matter, water and air. The typical soil consists of approximately 45% mineral, 5% organic matter, 20-30% water, and 20-30% air. These percentages are only generalizations at best. In reality, the soil is very complex and dynamic. The composition of the soil can fluctuate on a daily basis, depending on numerous factors such as water supply, cultivation practices, and/or soil type.

Clay Properties

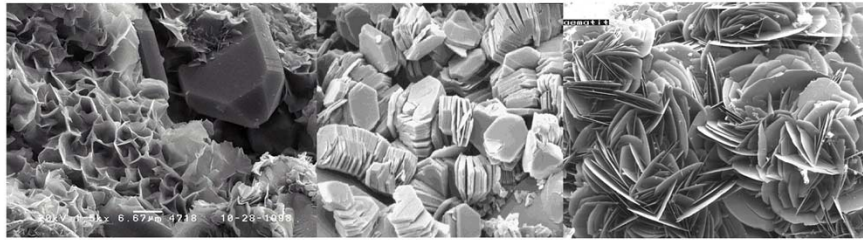
- Extremely high surface area
 - water retention
 - chemical reactions
 - biological activity
- Clay surfaces carry charge (-/+)
- Negative surface charge holds essential plant nutrients



montmorillonite

kaolinite

hematite



Soil Texture

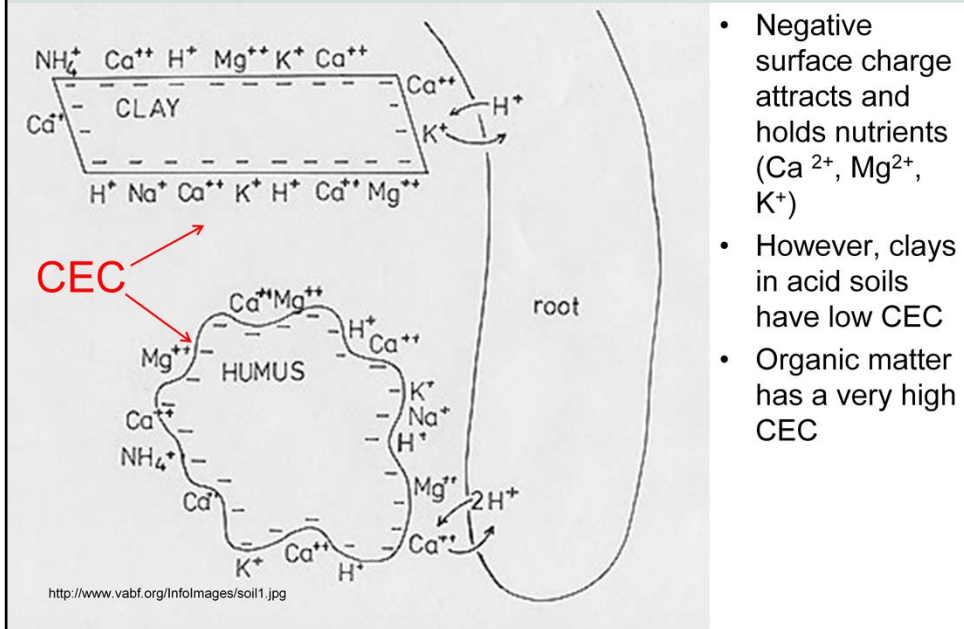
Sand: 2.0 mm - 0.05 mm, gritty feel. Sand is visible to the naked eye, consists of particles with low surface area, low nutrient holding capacity, and permits excessive drainage.

Silt: 0.05 mm - 0.002 mm, buttery feel. Silt is not visible to the naked eye and increases the water holding capacity of soil.

Clay < 0.002 mm, sticky feel. Clay has a high surface area, high water holding capacity, many small pores, and possesses charged surfaces to attract and hold nutrients.

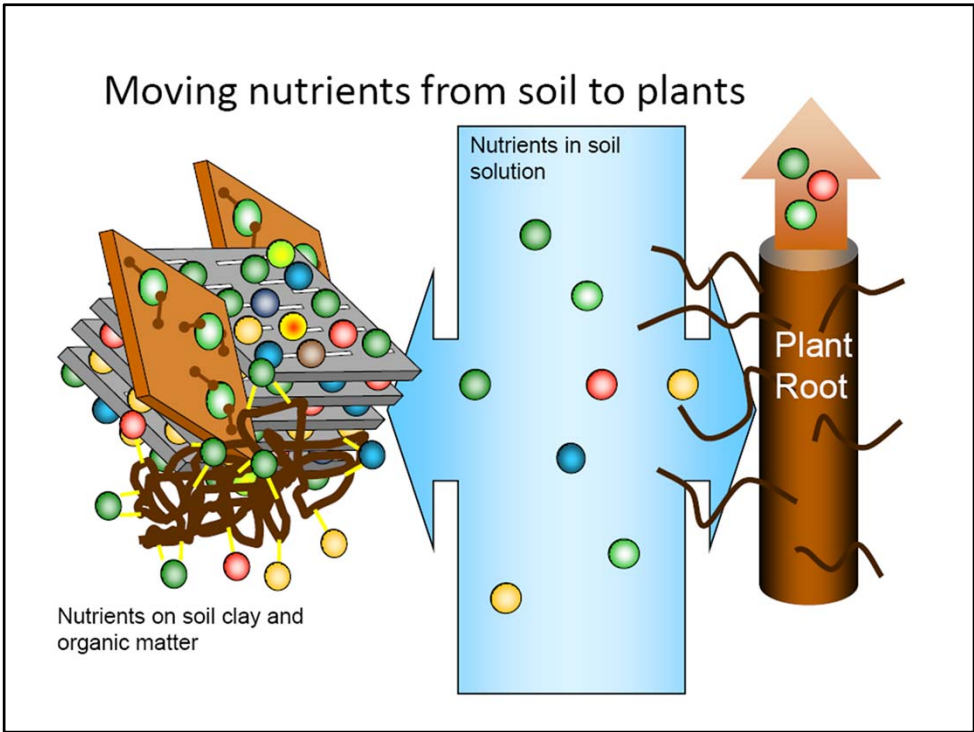
The reddish brown soils of the Babeldoap uplands are dominated by kaolinite, gibbsite (Al oxide) and several iron oxide clay minerals. These are clay minerals with good physical properties, meaning that they form strong granules that resist compaction. These soils are typically well-drained and easily tilled. The soils of the bottomlands, on the other hand, are composed of clay minerals more like montmorillonite, which are sticky and less granulated. These soils tend to have poor drainage. The sticky clays tend to contain more plant nutrients – especially calcium.

Clay has Cation Exchange Capacity (CEC)

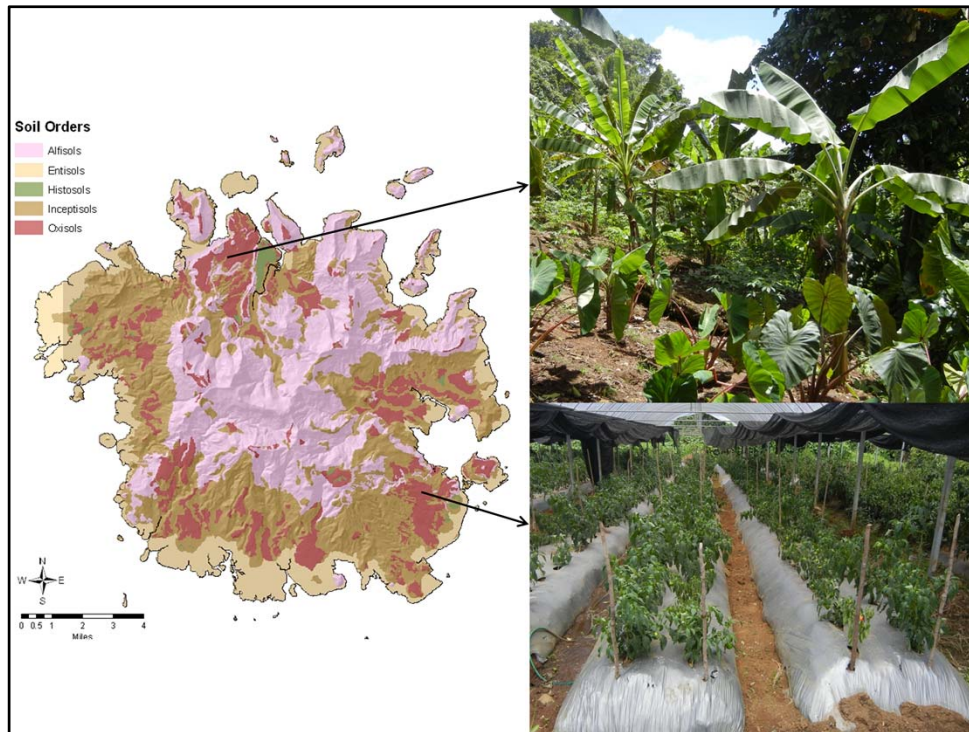


- Negative surface charge attracts and holds nutrients (Ca²⁺, Mg²⁺, K⁺)
- However, clays in acid soils have low CEC
- Organic matter has a very high CEC

Cation exchange capacity is defined as the potential for negatively charged surfaces of clay minerals and organic matter to adsorb important essential elements. It is the primary reservoir of essential plant elements in the soil. The organic matter-rich soils of Palau's bottomlands have high CEC. CEC in the red soils of the uplands is typically low and confined to the organic matter rich surface layers.



Clay and organic matter surfaces attract and hold essential plant nutrients so that they can be used by plant roots.



The top picture is a traditional agroforest system and the bottom picture is vegetable production by Chinese at the Experimental Farm. Both cropping systems are found on the Umpump soil, which is high in hematite clays. This soil has low CEC or a low capacity to hold essential nutrients. In the traditional agroforest system nutrients are supplied through organic matter while in the conventional vegetable production system imported lime and chemical fertilizers are applied to the soil.

Soil pH is an Expression of Acidity/Alkalinity

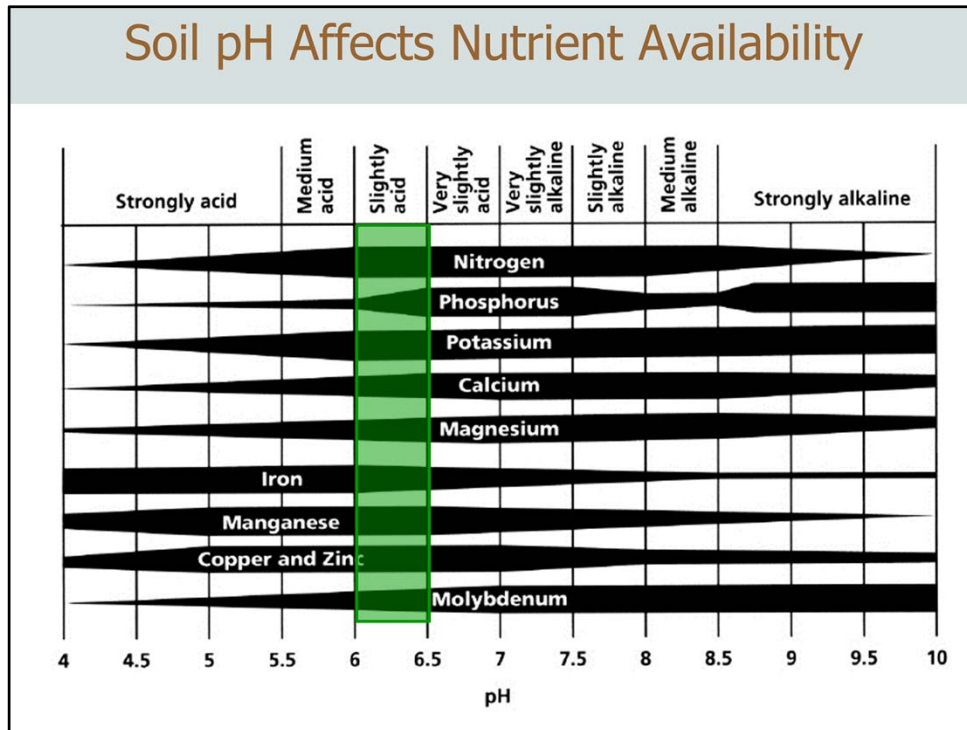
The pH Scale



↑
Typical pH range in soils

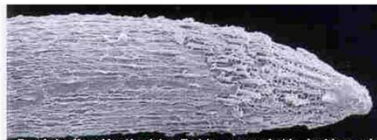
The pH scale is a way determining whether a given substance is acidic (0-6.5), neutral (6.6-7.2) or alkaline (7.3-14). Most soils have a pH that ranges from 3.5 to 9.0. The soils of Pohnpei have pH that ranges from a low of 4 to a high of 8 to 8.5.

Soil pH Affects Nutrient Availability



Soil pH is an important soil property, because it affects the chemical, biological, and physical processes of the soil. Thus, pH is often considered the “master variable” of soil. Its importance in nutrient management cannot be understated. Soil pH controls the availability of essential plant nutrients. As pH drops below 5.5, the availability of nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, and molybdenum is limited and plants often show deficiency symptoms. On the other end of the spectrum, as pH increases above 7.0 the solubility of phosphorus, iron, manganese, copper, zinc, and boron decreases and plants become deficient in these nutrients. Phosphorus shows only a small pH window between 6.5 and 7.5 where it is available for plant uptake. As pH decreases below 5.5 Al toxicity becomes a severe constraint and limits the growth of many food crops. Soil pH for nutrient availability is optimal between 6.0 and 6.5.

High Soil Aluminum Causes Root Damage



Deformed root hair in soil with high Al

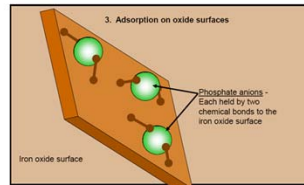


When soils have pH below 5.5 they may contain excessive amounts of soluble aluminum (Al) which is toxic to many plants roots. The picture above shows how under very acidic conditions (<5.5), plant roots stop growing because of damage caused by high concentrations of Al. High Al in acidic soils has a negative effect on many vegetable crops. Some food crops such as sugarcane and pineapple, example, can tolerate high soil Al. Adding high quality organic matter (i.e., compost) or lime corrects Al toxicity by removing soluble Al from solution.

Negative Effects of Soil Acidity



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

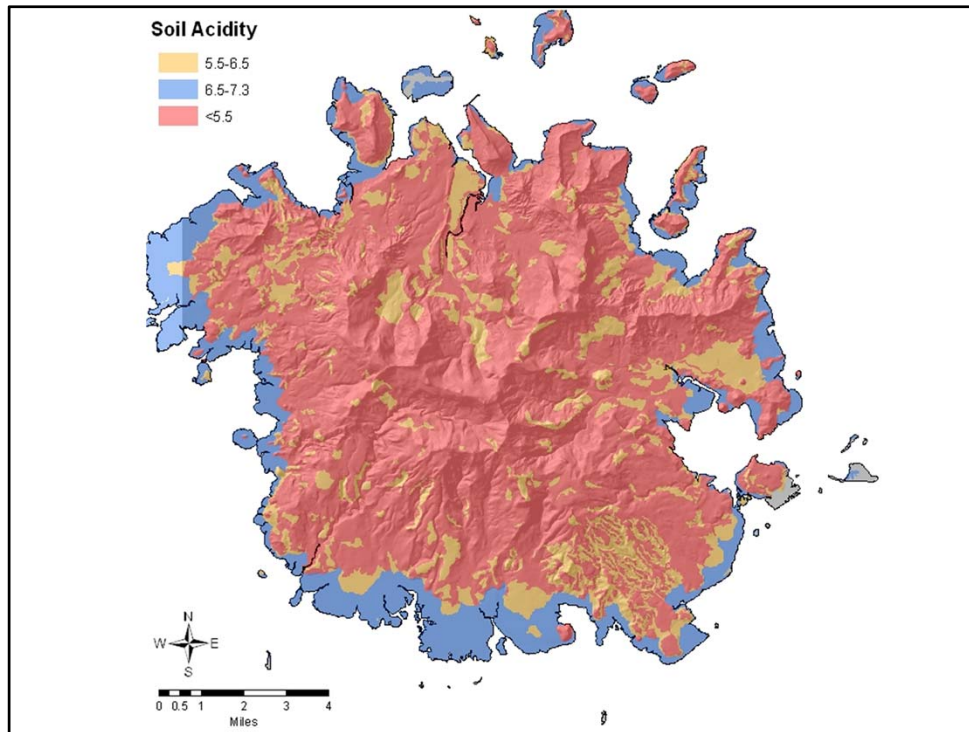


– Ca deficiency



The productivity of acidic soils is often low for the following reasons:

1. Low nutrient retention because CEC is low.
2. Calcium deficiency
3. Phosphorus deficiency because P bonds strongly with Al and Fe oxide clay surfaces and cannot be taken up by plant roots.



The map shows that most of the soils covering the interior of Pohnpei are very acidic (pH<5.5). Plants are able to grow on these soils mainly because they are high in organic matter. The organic matter detoxifies the Al and supplies essential plant nutrients.

Soil Organic Matter is Responsible for Crop Productivity in Tropical Island Soils



Soil organic matter (SOM) includes: living organisms (soil biomass), the remains of microorganisms that once inhabited the soil, the remains of plants and animals, organic compounds that have been decomposed within the soil over thousands of years and reduced to complex and relatively stable substances commonly called humus. The soils of Pohnpei, especially those under forest, contain high concentrations of SOM, which performs very important functions in the soil including the following: SOM acts as a binding agent for mineral particles, which produces friable (easily crumbled) surface soils, SOM increases the amount of water that a soil can hold for plant use, SOM provides food for organisms that inhabit the soil, SOM is a source essential plant nutrients, and the humus in SOM has cation exchange capacity (CEC), which acts as a nutrient reservoir.

Organic Matter Improves Soil Physical Properties

- OM decreases soil bulk density
- OM increases soil porosity
- OM promotes H₂O infiltration and aeration
- OM increases water retention



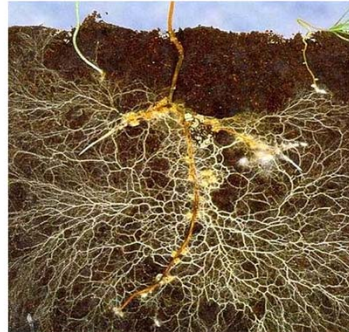
Organic Matter Improves Soil Chemical Properties

- OM increases nutrient availability (N cycling, P and micronutrient solubility)
- OM increases nutrient retention (CEC)
- 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 Organic Matter and Nitrogen

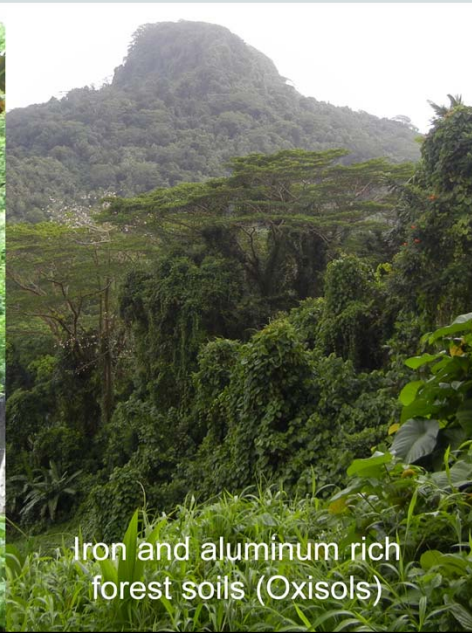
- SOM is one of the most important sources of plant N in natural landscapes.
- Decomposing plant and animal residues provide N for plant growth.
- Traditional agroforest systems rely on natural cycling of N through decomposition



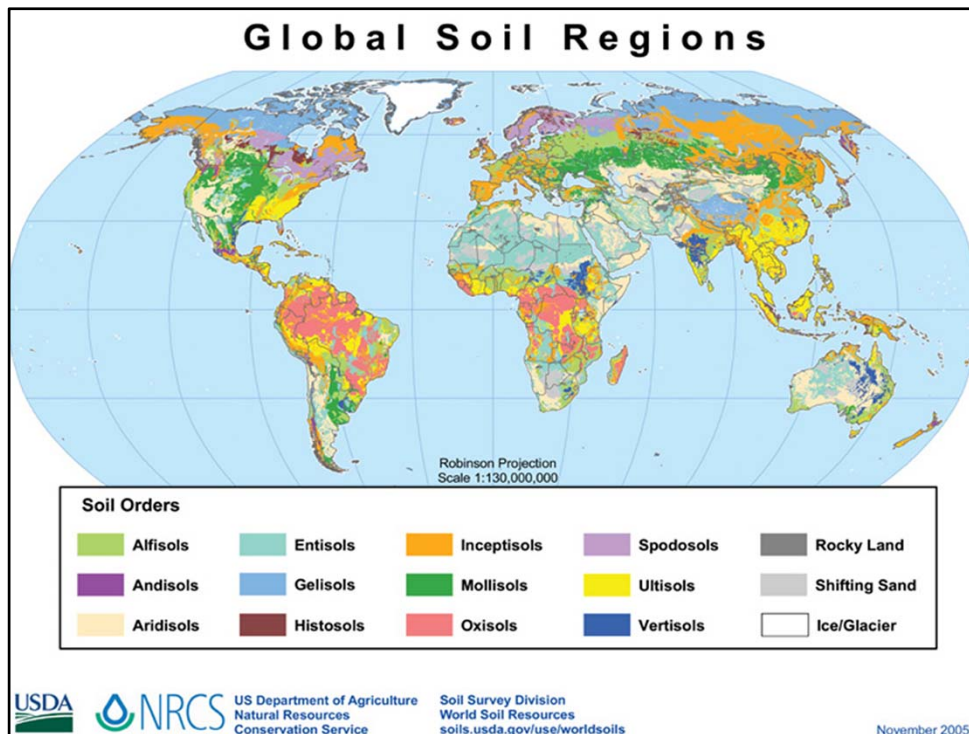
Soil Diversity



Organic matter rich
Mangrove soils
(Histosols)



Iron and aluminum rich
forest soils (Oxisols)



There are twelve soil orders according to the U.S. Soil Taxonomy classification system.

1. Alfisols: moderately fertile soils found under both forest and savannah.
2. Andisols: generally fertile soils formed from volcanic ash
3. Aridisols: soils of the deserts or dry regions of the world
4. Entisols: young soils with minimal development, often sandy or rocky
5. Gelisols: soils of the arctic region
6. Histosols: fertile soils high in organic matter
7. Inceptisols: poorly formed soils often found on steep slopes
8. Mollisols: very fertile soils developed from grasslands
9. Oxisols: infertile, acid soils of the humid tropics
10. Spodosols: acid, infertile soils formed from coniferous forest
11. Vertisols: shrinking and swelling clay-rich soils
12. Ultisols: acid, infertile soils found in wet environments

Soil Formation

$$\text{Soil} = f(\text{PM}, \text{CI}, \text{O}, \text{R}, \text{T})$$

Factors:

PM = parent material (rocks)

CI = climate (rainfall and temperature)

O = organisms (plants and animals)

R = relief (topography, drainage)

T = time



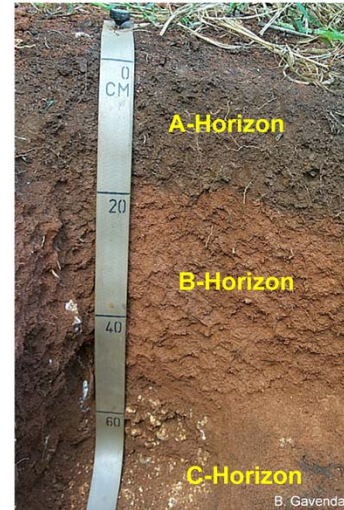
Soils form as a result of the combined effects of climate and biotic activities (microbial, plant, and animal life), modified by landscape relief and position, acting on parent materials over time. Ample rainfall and warm temperatures increase the rate of chemical weathering, which act to transform primary minerals in rocks into secondary minerals such as clays. Plant growth adds organic materials to soils which, in turn, supply carbon and other nutrients fueling microbial growth. Soils on upland landscapes where drainage is rapid tend to lose soluble components more rapidly whereas soils located in bottom lands tend to have poor drainage and soluble compounds accumulate. The nature of the parent also influences the type of soil that is formed. In the top picture we have an example of a forest soil commonly found in central Pohnpei (top) that has formed from volcanic parent material (basalt rock). In the bottom picture is a soil found on the flat coastal plains that has formed from accumulated organic matter under poor drainage conditions.

Soils differ one from the other depending on the relative influence of each of the five soil forming factors.

Soil Formation

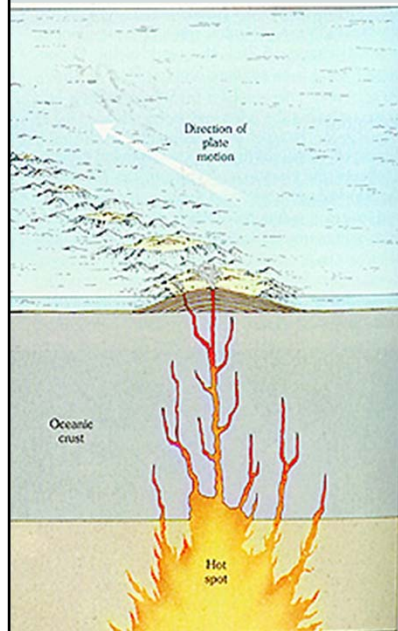
Processes:

1. Additions
 - Water, organic matter, sediment
2. Losses
 - soluble compounds, erosion
3. Transformations
 - Organic matter to humus
 - Primary minerals to clay minerals
4. Translocations
 - Soluble compounds
 - Clays



In addition to the five soil forming factors discussed in the previous slide, four soil forming processes interact to differentiate soil horizons or layers. Additions includes inputs to the developing soil profile from outside sources such as organic matter in the form of falling leaves. Sediments transported by erosion may also be an input. Transformations occur when soil constituents (i.e., organic matter and primary minerals) are chemically altered into new components such as the conversion of plant materials into humus during decomposition or the chemical weathering of primary minerals into clay minerals. Losses include the movement of dissolved elements with percolating water out of the soil profile into the water table, erosion due to surface run-off, and removal of surface soil from wind. Soluble compounds including clay minerals and dissolved organic matter can also be translocated between soil horizons.

Island Formation



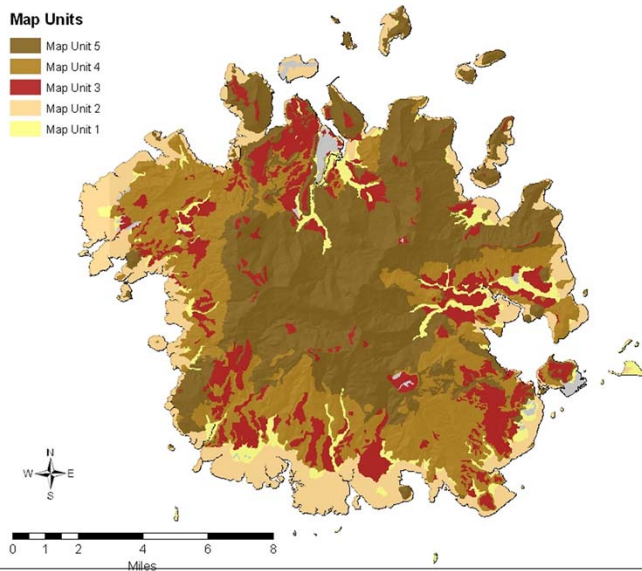
- Pohnpei formed from intermittent volcanic activity over last 8.5 million years
- In the interior, basalt is the parent material.
- Coral reef fringing the island is the parent material for low-lying mangrove swamps

The island of Pohnpei is the eroded remnant of a large shield volcano that was built up from the surrounding sea floor by the repeated eruption of lava episodically over the last 9 million years. The lava cooled to form basalt rock, which has weathered into the soils we find today. The high rainfall has leached many of the nutrients and resulted in acidic soils.

Soil Survey Map

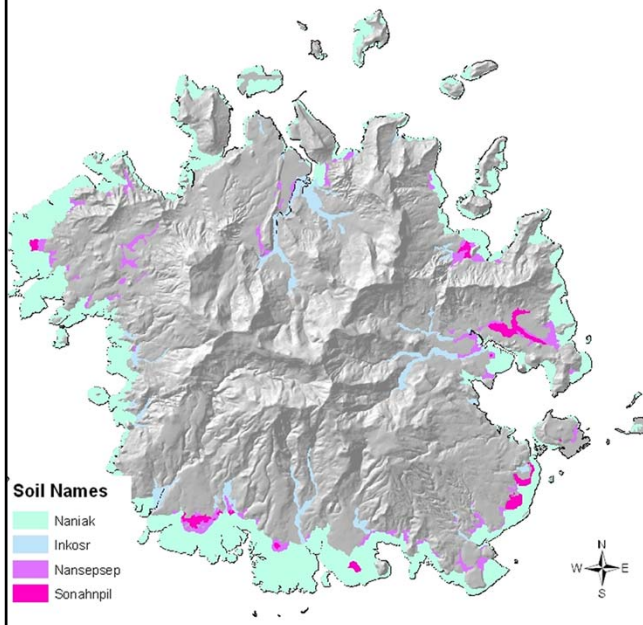
Map Units

- Map Unit 5
- Map Unit 4
- Map Unit 3
- Map Unit 2
- Map Unit 1



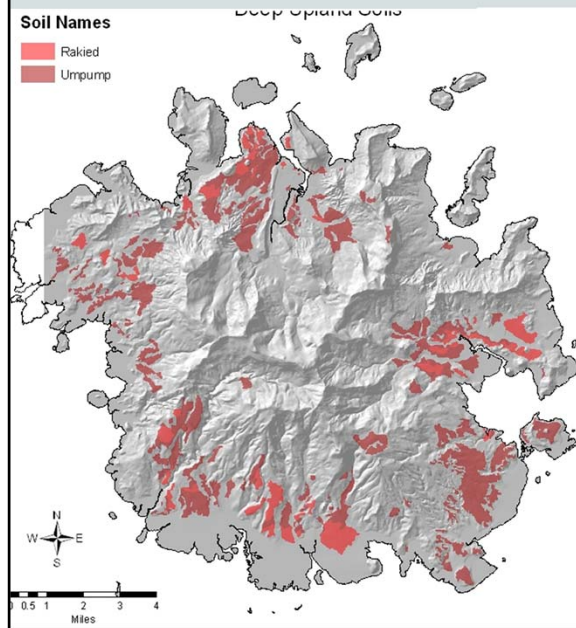
- **Map unit 1:**
Nansepsep,
Sonahnpil,
Inkosro
- **Map unit 2:**
Naniak
- **Map unit 3:**
Umpump-Rakied
- **Map unit 4:**
Dolekai-
Fomseng
- **Map unit 5:**
Tolonier-Dolen

Bottom Land Soils of Pohnpei



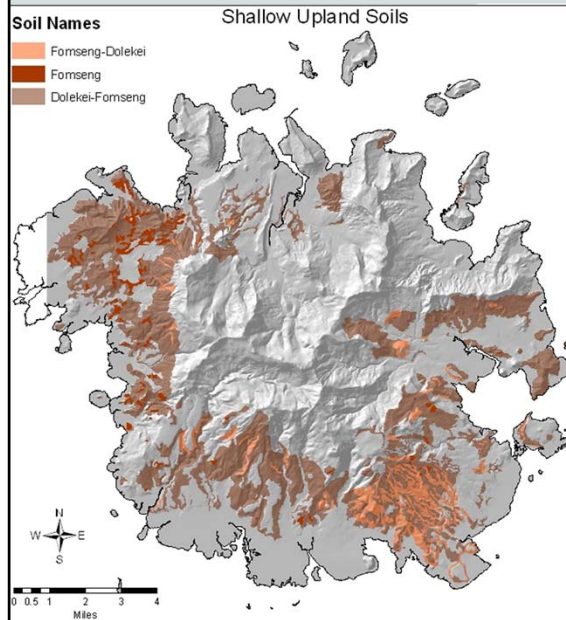
- *Naniak*: deep, neutral, poorly drained coastal marsh soils
- *Inkosr*: poorly drained soils
- *Sonahnpil*: acidic, well-drained soils
- *Nanssepsep*: poorly drained, fertile soils

Acid Soils on Upland Terraces



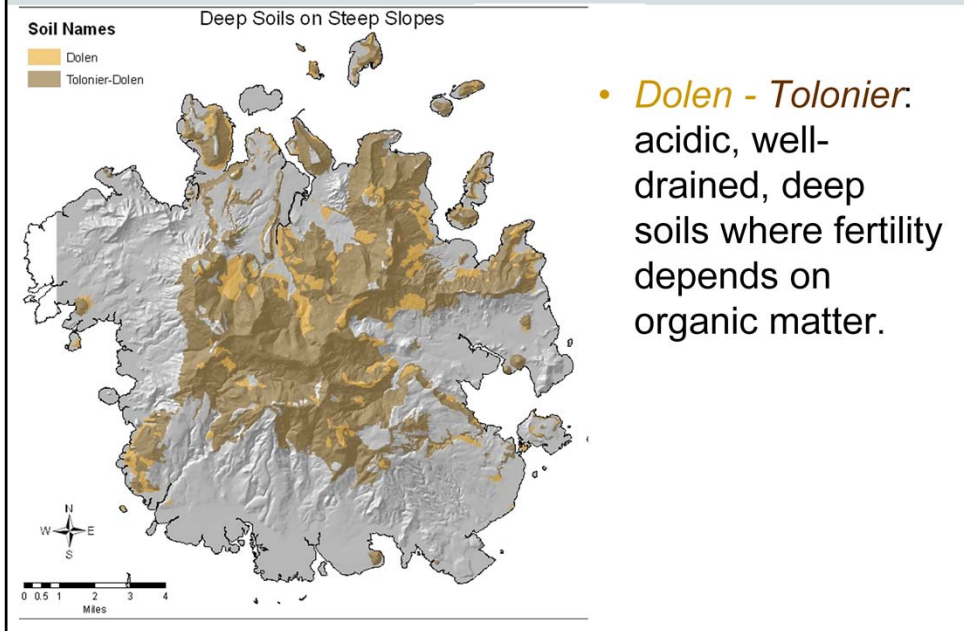
- *Umpump*: acidic, well-drained soils, fertility depends on organic matter, low P and Ca
- *Rakied*: similar to Umpump soils.

Shallow Soils on Steep Land



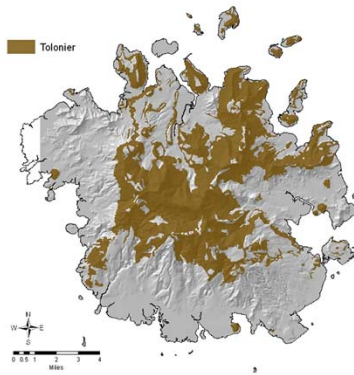
- *Fomseng-Dolekei*: shallow, slightly acid to acid, well-drained, fertility depends on organic matter, low P and Ca

Deep Soils on Steep Slopes



The island of Pohnpei is the eroded remnant of a large shield volcano that was built up from the surrounding sea floor by the repeated eruption of lava episodically over the last 9 million years. The lava cooled to form basalt rock, which has weathered into the soils we find today. The high rainfall has leached many of the nutrients and resulted in acidic soils.

Tolonier Soil (Forests)



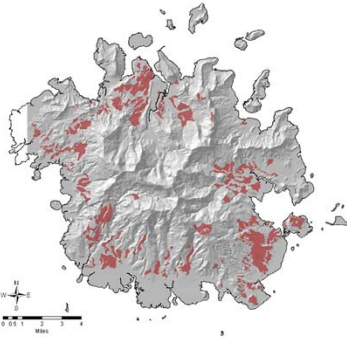
Select chemical properties of the Tolonier soil

Depth	pH	Org C	Ca	Mg	K	Al _{sat}
cm		%		ppm		%
0-10	4.9	3.5	1040	660	117	22
10-20	5.5	0.8	660	444	78	46

- Fertility is in dependent on organic-rich surface horizon

The Tolonier soil is a Inceptisol commonly found on hill slope positions throughout central Pohnpei. These soils are mostly covered by mixed forest. They have a dark surface layer rich in organic matter, which provides most of the plant nutrients supporting vigorous growth. The high levels of organic matter detoxify aluminum. The lower horizons are red, lower in organic matter and high in soluble aluminum. These soils are susceptible to erosion if they are cleared.

Umpump Soil



Select chemical properties of the Palau soil

Depth	pH	Org C	Ca	Mg	K	Al _{sat}
cm		%		ppm		%
0-10	5.2	6.35	600	440	78	29
10-20	5.0	2.16	120	72	39	35

- The Umpump is an important agricultural soil

The Umpump soil is an Oxisol. These soils developed under forests and are rich in organic matter in their natural state. They can have high levels of soluble aluminum and low levels of essential plant nutrients throughout the soil profile. The organic rich surface layer detoxifies aluminum and acts as an important source of plant nutrients.

Summary

- Plants require 15 essential nutrients, which they get primarily from the soil.
- Organic matter is a critical source of nutrients
- Soils vary on the landscape
- Pohnpei has 5 main soil types
- Most of the interior soils are acid.
- Traditional Agroforest systems rely on organic matter inputs

