Outline

• Soil formation
• Importance of Soil
• Soil Basics
  – Soil composition
  – Texture and clay minerals
  – Soil pH and nutrient availability
  – Soil organic matter
• Soil distribution on Guam
Soil = $f(\text{PM, CI, O, R, T})$

Factors:
- PM = parent material (rocks)
- CI = climate (precipitation and temperature)
- O = organisms (plants and animals)
- R = relief (topography, drainage)
- T = time
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
Island Formation

Cross-Section Sketch of Mariana Arc
(After Hussong and Fryer, 1981)
• Volcanic rock is the foundation of the island
• Southern portion is primarily volcanic rock
• Northern portion is limestone overlying volcanic rock

Source: Gingrich (2003) USGS Report 03-4126
A - topsoil
B - subsoil
C - saprolite
Soil Formation on Limestone

1. Dissolution of \( \text{CaCO}_3 \) limestone, and soil forms from impurities
   - 30-100 ft of limestone to produce 1 ft of soil

2. Deposition of dust blown from Asian deserts, and soils form from weathering of the dust
5 Functions of Soil

- Medium for Plant growth
- Habitat for Soil organisms
- Recycling system
- Water supply and purification
- Engineering Medium
• Animal health begins with good nutrition
• Grasses and other plants are the source of nutrients
• Soils supply nutrients and store water for plant growth
Soil Composition

Inarajan soil

Photos: B. Gavenda

Akina soil
<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Textural Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agfayan</td>
<td>Clay</td>
</tr>
<tr>
<td>Akina</td>
<td>Silty Clay</td>
</tr>
<tr>
<td>Atate</td>
<td>Clay</td>
</tr>
<tr>
<td>Chacha</td>
<td>Clay</td>
</tr>
<tr>
<td>Guam</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Inarajan</td>
<td>Clay</td>
</tr>
<tr>
<td>Kagman</td>
<td>Clay</td>
</tr>
<tr>
<td>Pulantat</td>
<td>Clay</td>
</tr>
<tr>
<td>Ritidian</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Sasalaguan</td>
<td>Clay</td>
</tr>
<tr>
<td>Shioya</td>
<td>Loamy Sand</td>
</tr>
<tr>
<td>Togcha</td>
<td>Silty Clay</td>
</tr>
<tr>
<td>Yigo</td>
<td>Silty Clay</td>
</tr>
<tr>
<td>Ylig</td>
<td>Clay</td>
</tr>
</tbody>
</table>
Properties and Importance of Clay

• Properties
  – High surface area
    • 1 gram = 10 to 800 m²
  – Charged surfaces
    • Usually negatively charged, but highly weathered oxide clays have + charge

• Importance
  – High water holding capacity
  – High nutrient retention capacity (cation exchange capacity, CEC)
Clay Type is Important

- Montmorillonite *(high activity clay)*
  - Shrink-swell clay (unstable)
  - High fertility clay (high cation exchange capacity)
- Kaolinite *(low activity clay)*
  - Non-expanding clay (stable)
  - Low fertility clay (low cation exchange capacity)
- Fe & Al oxides *(low activity clay)*
  - Goethite, gibbsite
  - Non-expanding clay (stable)
  - Very low fertility (no cation exchange capacity)
Negatively charged sites that adsorb cations:

- Ca$^{2+}$
- Mg$^{2+}$
- K$^+$
- NH$_4^+$

Cation Exchange Capacity (CEC)
• Guam Clay Loam contains high Al-oxides (low activity clay) with good physical properties

• But has high CEC, a property associated with high activity clay
The pH Scale
Soil Acidity and Nutrient Availability

Optimum pH
• Soils typically acid to strongly acid
• Aluminum toxicity especially severe in Akina subsoil
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>OM</th>
<th>pH</th>
<th>CEC</th>
<th>Base$_{sat}$</th>
<th>Al$_{sat}$</th>
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<tbody>
<tr>
<td>0-10</td>
<td>5</td>
<td>5.0</td>
<td>12.4</td>
<td>85</td>
<td>15</td>
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<tr>
<td>20-10</td>
<td>2.8</td>
<td>4.9</td>
<td>8.4</td>
<td>49</td>
<td>51</td>
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</tbody>
</table>

The diagram shows the geographic distribution of various soil types, including Akina Silty Clay and Togcha and Akina. The photograph on the left depicts a soil sample with visible organic matter and roots.
Role of Organic Matter in Soil

**Physical**
- Improves soil structure
- Increases water retention

**Chemical**
- Increases nutrient availability (N & P cycling, solubility)
- Increases nutrient retention (CEC)
- Detoxifies Al

**Biological**
- Increases microbial diversity
- N fixation (rhizobia), P availability (myccorhiza)
- Increases pathogen suppression
- 53 map units on the soil survey
- Map unit name provides no information on soil properties
- Soil Taxonomy is a classification system used to group soils based on measurable properties
### Soil fertility properties

<table>
<thead>
<tr>
<th>Horizon</th>
<th>%Clay</th>
<th>pH</th>
<th>% C</th>
<th>Ca (cmol_c kg⁻¹)</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
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<tbody>
<tr>
<td>A</td>
<td>70.0</td>
<td>6.5</td>
<td>5.09</td>
<td>62.8</td>
<td>10.8</td>
<td>0.4</td>
<td>0.6</td>
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<tr>
<td>A / B</td>
<td>75.7</td>
<td>6.6</td>
<td>2.28</td>
<td>51.2</td>
<td>8.5</td>
<td>0.3</td>
<td>0.4</td>
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<tr>
<td>Bw1</td>
<td>85.1</td>
<td>7.5</td>
<td>1.47</td>
<td>65.3</td>
<td>5.6</td>
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<td>0.4</td>
</tr>
<tr>
<td>Bw2</td>
<td>65.5</td>
<td>8.0</td>
<td>1.05</td>
<td>91.2</td>
<td>3.0</td>
<td>0.3</td>
<td>0.3</td>
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</tbody>
</table>

Source: NRCS soil characterization data
Atate series (Alfisol) covers approximately 60% of the map unit

<table>
<thead>
<tr>
<th>Horizon</th>
<th>%Clay</th>
<th>pH</th>
<th>% C</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
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<tbody>
<tr>
<td>A1</td>
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<td>3.86</td>
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<td>6.2</td>
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<td>Bo1</td>
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Akina series (Oxisol)

<table>
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<th>Mg</th>
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<th>K</th>
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<tbody>
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<td>1.1</td>
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<tr>
<td>Bw</td>
<td>50.5</td>
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Source: NRCS soil characterization data
Guam Series

Guam series (Entisol)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>%Clay</th>
<th>pH</th>
<th>% C</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
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<tbody>
<tr>
<td>Ap1</td>
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<td>71.9</td>
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Source: NRCS soil characterization data
Grazing Management and Soil Quality

compaction
→
reduced infiltration
→
runoff
→
erosion
Grazing Management and Soil Quality
Soils are non-renewable!