Soils of Guam

Properties and Diversity

Jonathan Deenik, PhD
Department of Tropical Plant and Soil Sciences
University of Hawaii

Guam Grazing and Livestock Management Workshop

January 27-30, 2010

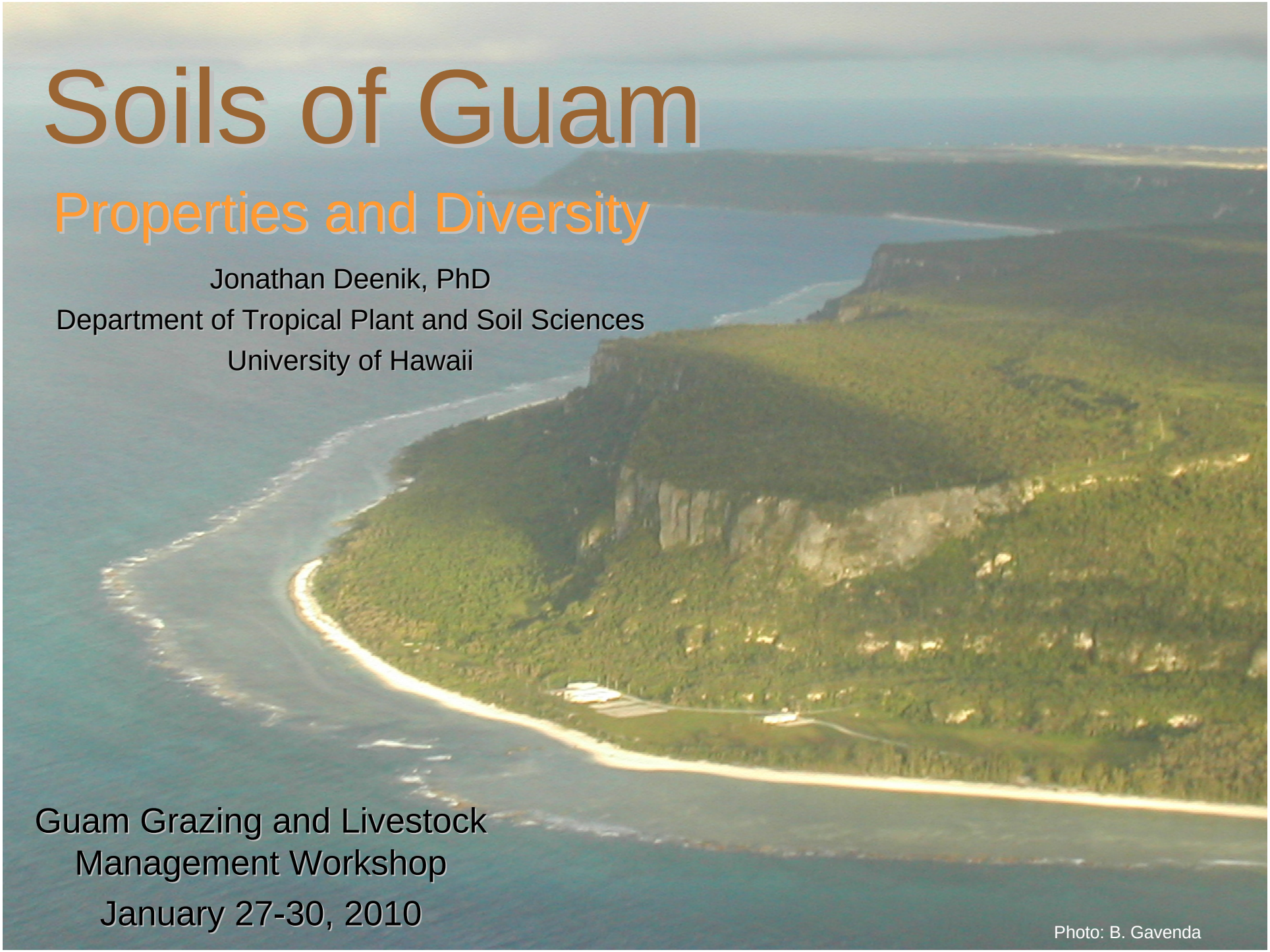


Photo: B. Gavenda

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 Formation

Soil = *f*(PM, Cl, O, R, T)

<u>Factors</u>:

PM = parent material (rocks)

Cl = climate (precipitation and temperature)

O = organisms (plants and animals)

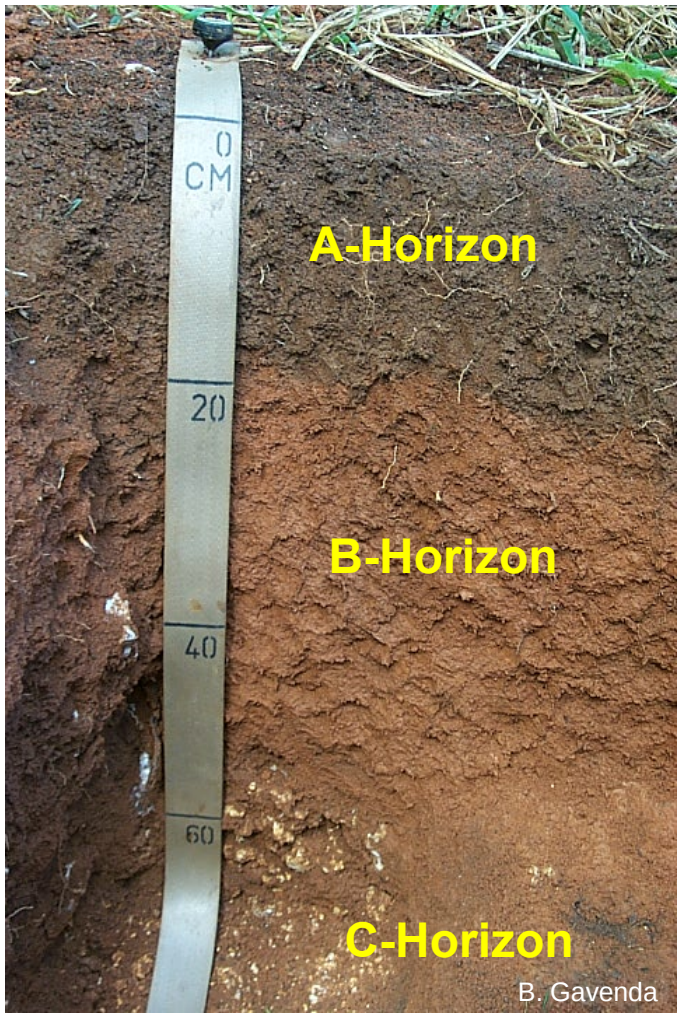
R = relief (topography, drainage)

T = time

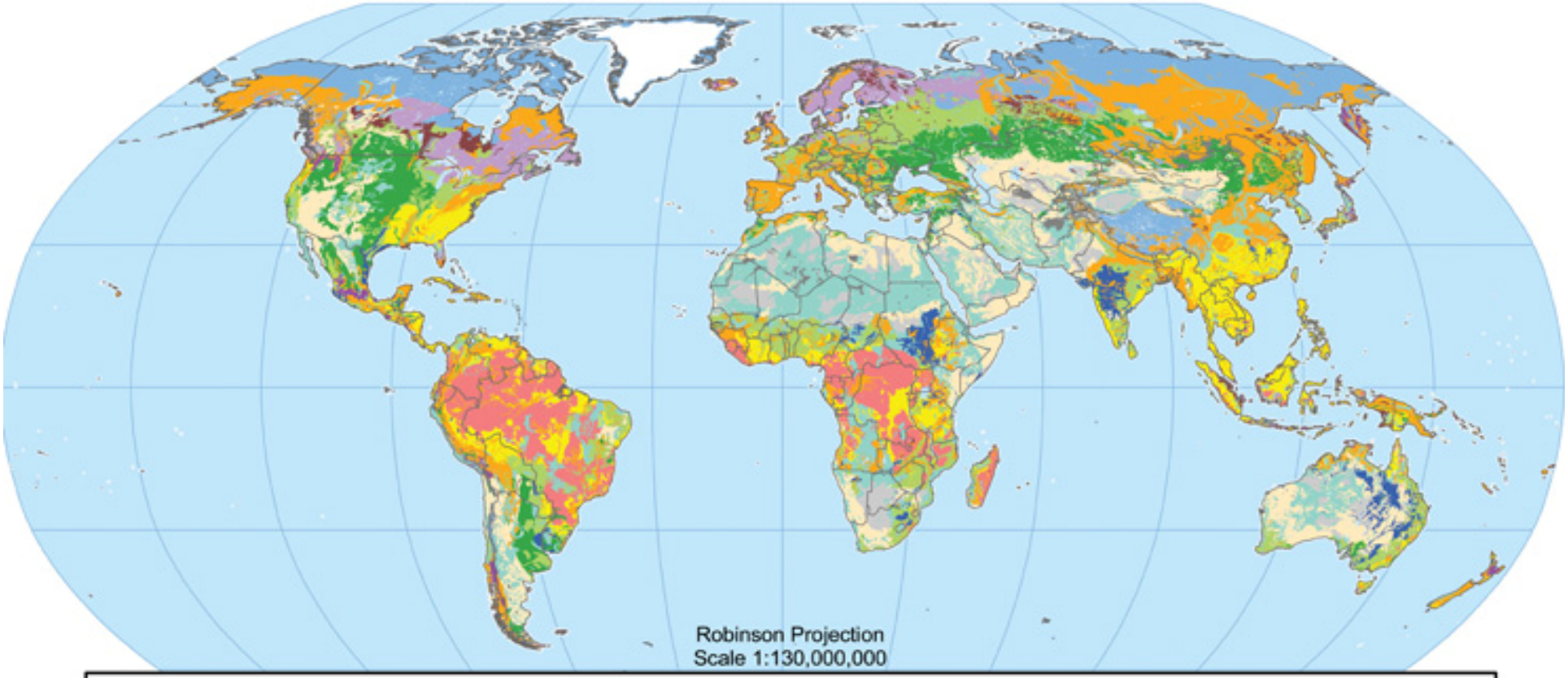
Soil Formation

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



Global Soil Regions



Soil Orders

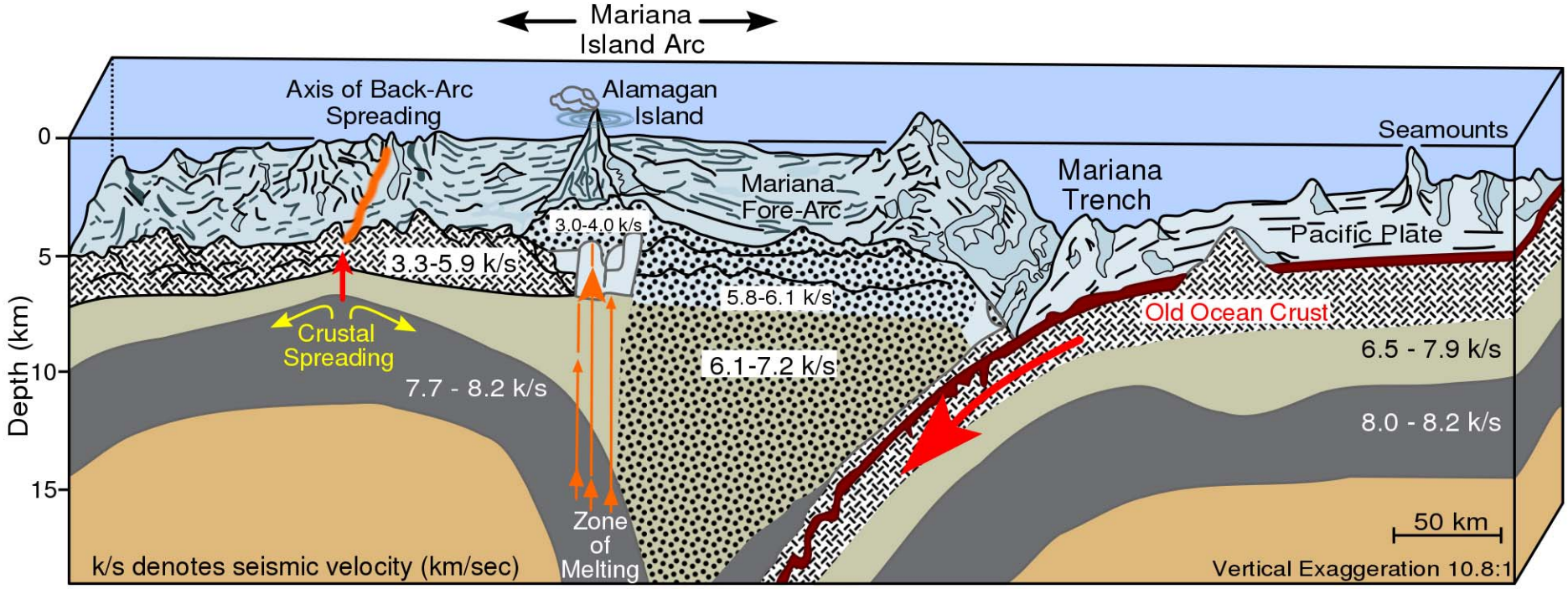
Alfisols	Entisols	Inceptisols	Spodosols	Rocky Land
Andisols	Gelisols	Mollisols	Ultisols	Shifting Sand
Aridisols	Histosols	Oxisols	Vertisols	Ice/Glacier

USDA NRCS US Department of Agriculture
Natural Resources
Conservation Service

Soil Survey Division
World Soil Resources
soils.usda.gov/use/worldsoils

November 2005

Island Formation

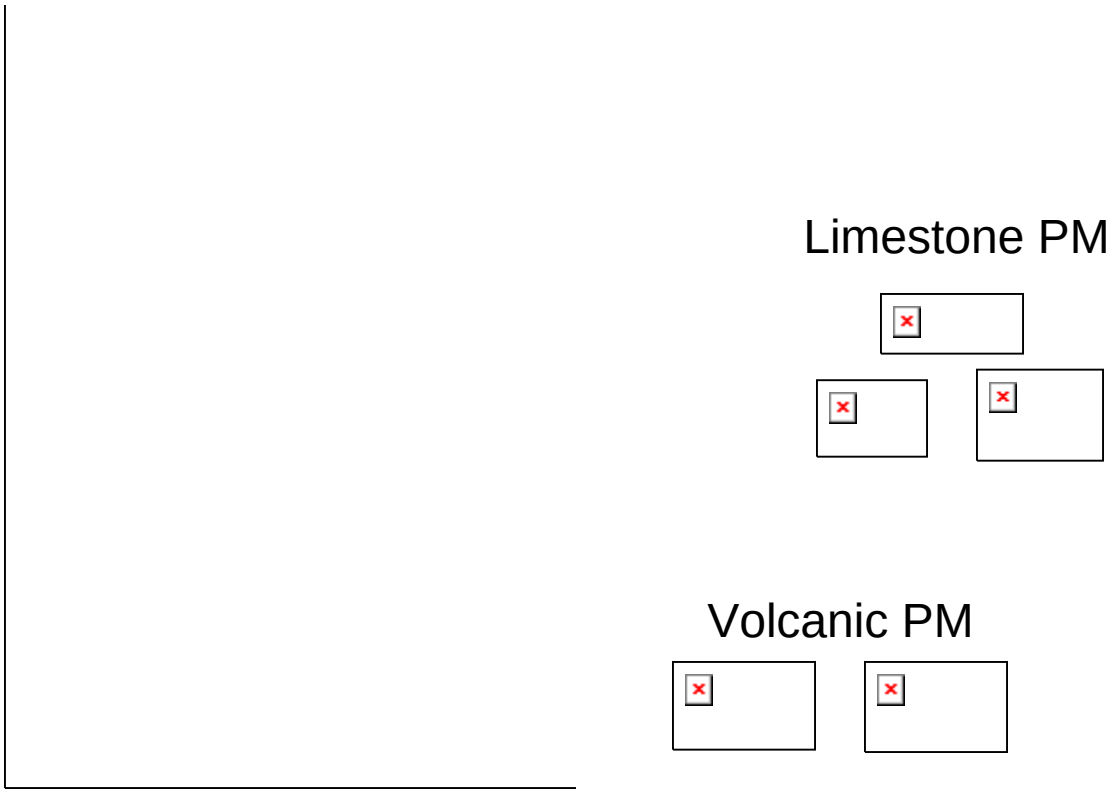


Cross-Section Sketch of Mariana Arc

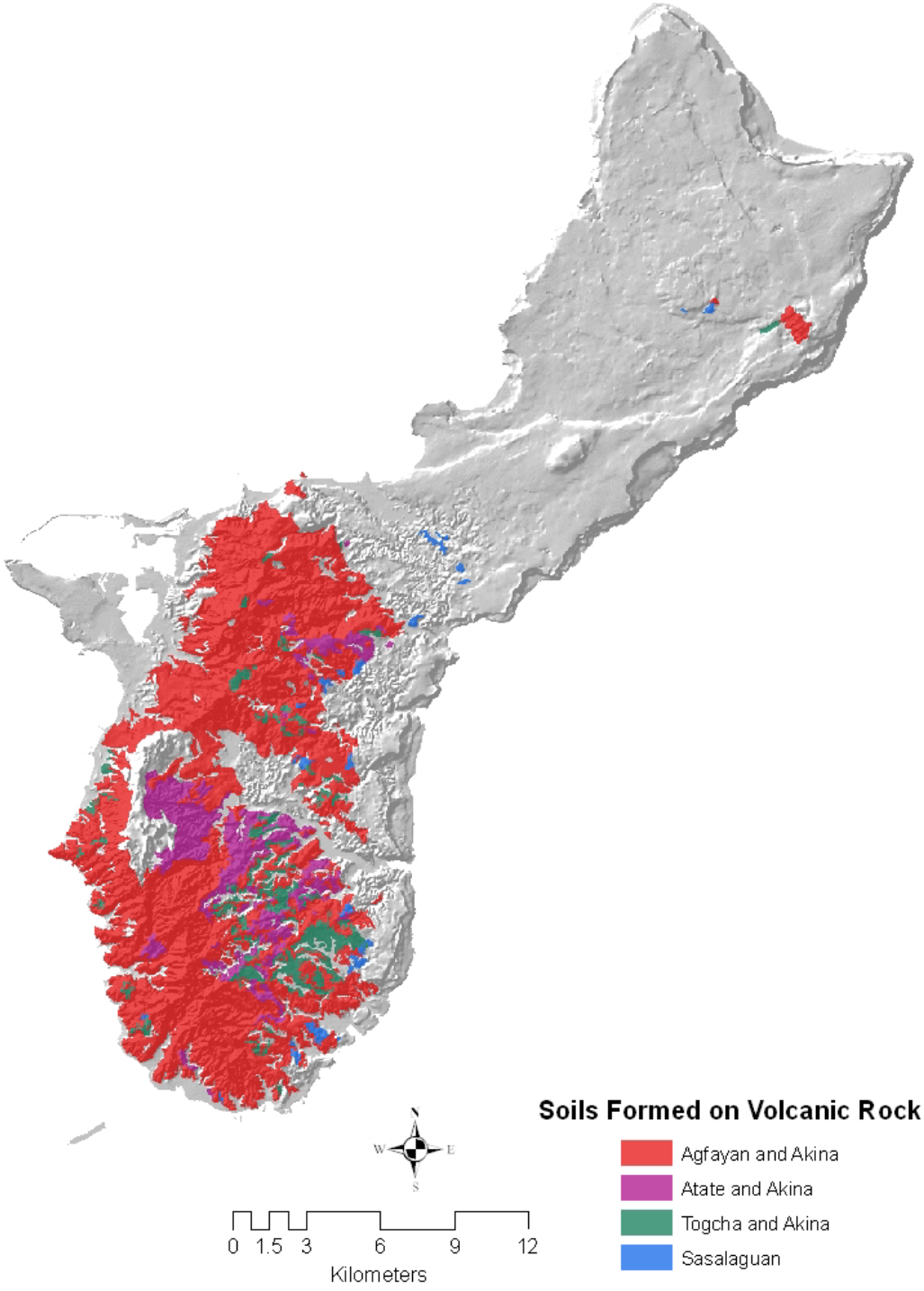
(After Hussong and Fryer, 1981)

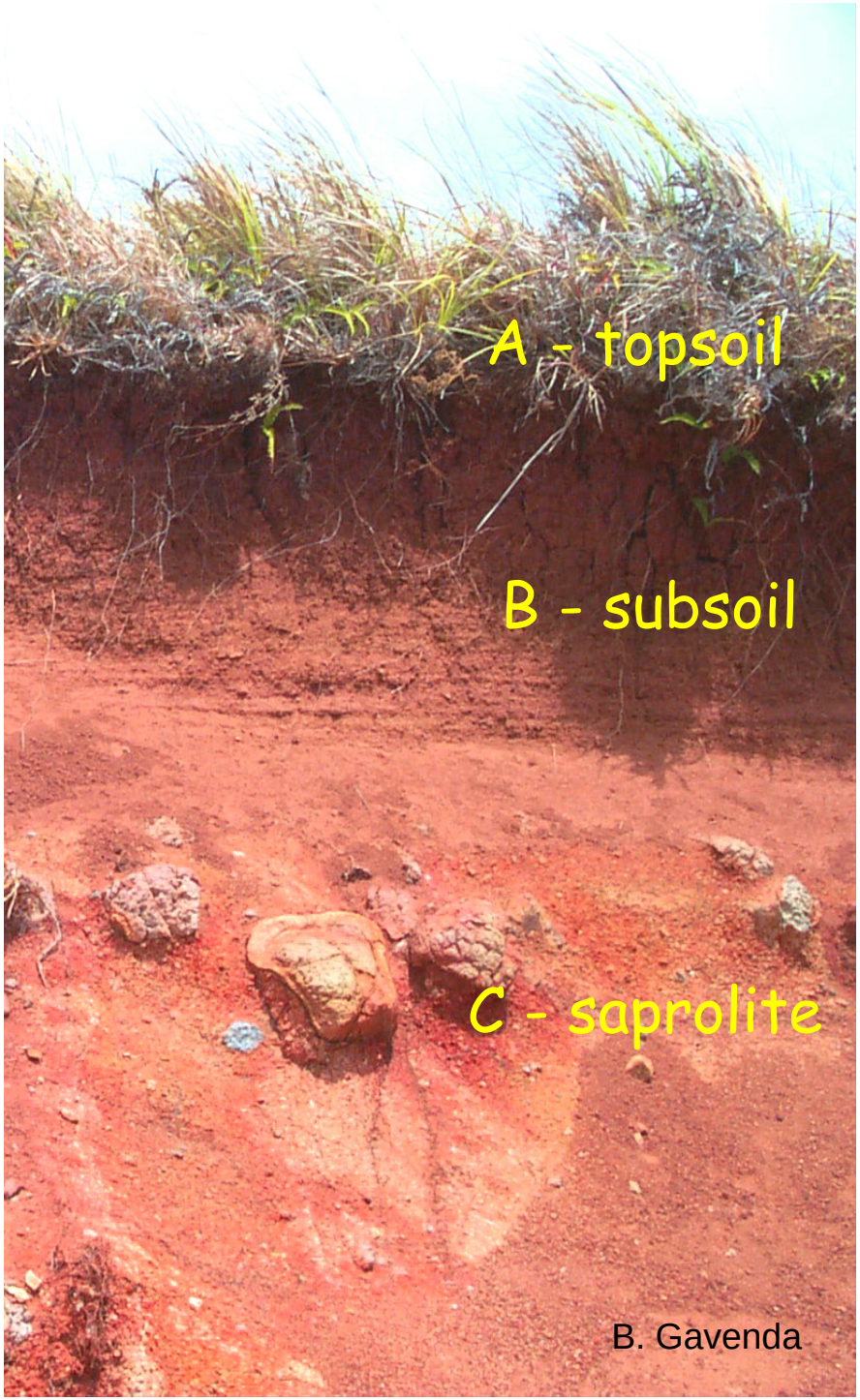
Parent Material on Guam

- 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


Soils Formed on Volcanic Rock
Agfayan and Akina
Atate and Akina
Togcha and Akina
Sasalaguan
0 1.5 3 6 9 12
Kilometers


A - topsoil
B - subsoil
C - saprolite
B. Gavenda

Soil Formation on Limestone

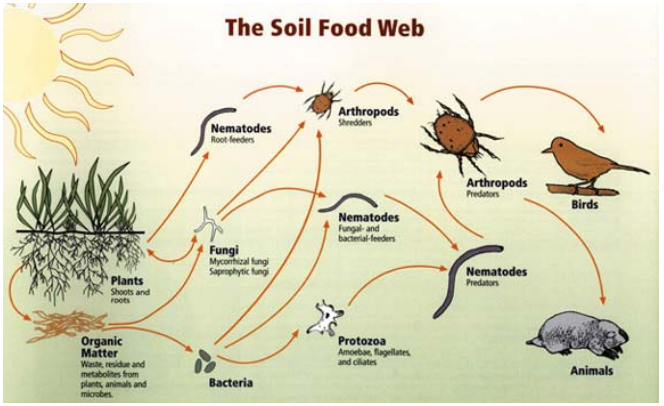
1. Dissolution of $CaCO_3$ limestone, and soil forms from impurities
   - 30-100 ft of limestone to produce 1 ft of soil
2. Deposition of dust blown from Asian deserts, and soils form from weathering of the dust


B. Gavenda

5 Functions of Soil

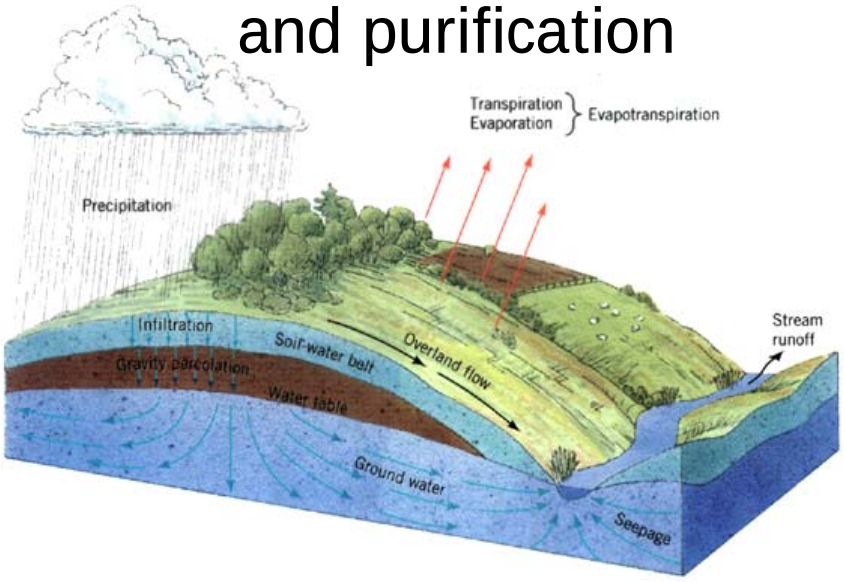
Medium for Plant growth

Habitat for Soil organisms



Recycling system

Water supply and purification

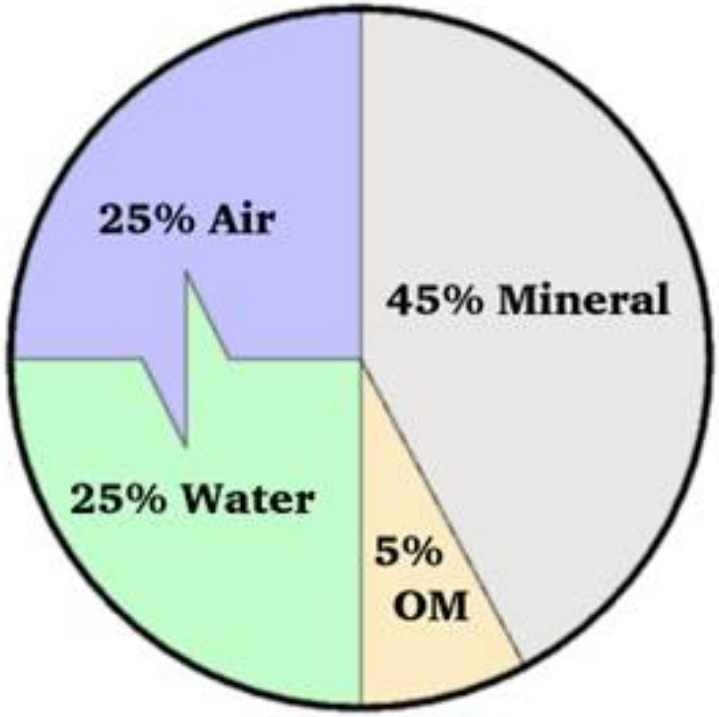


Engineering Medium

- 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

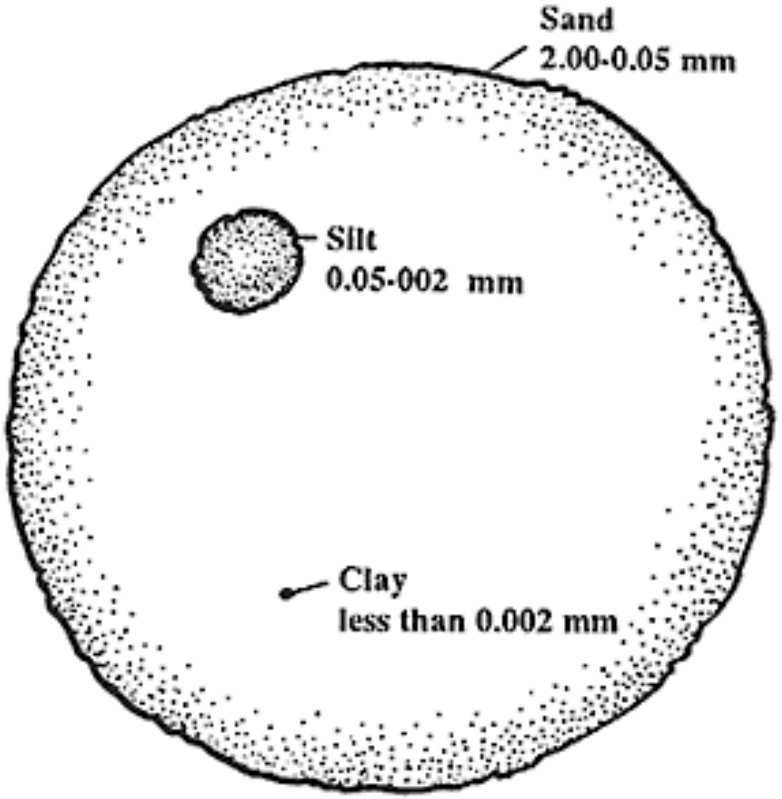

Inarajan soil

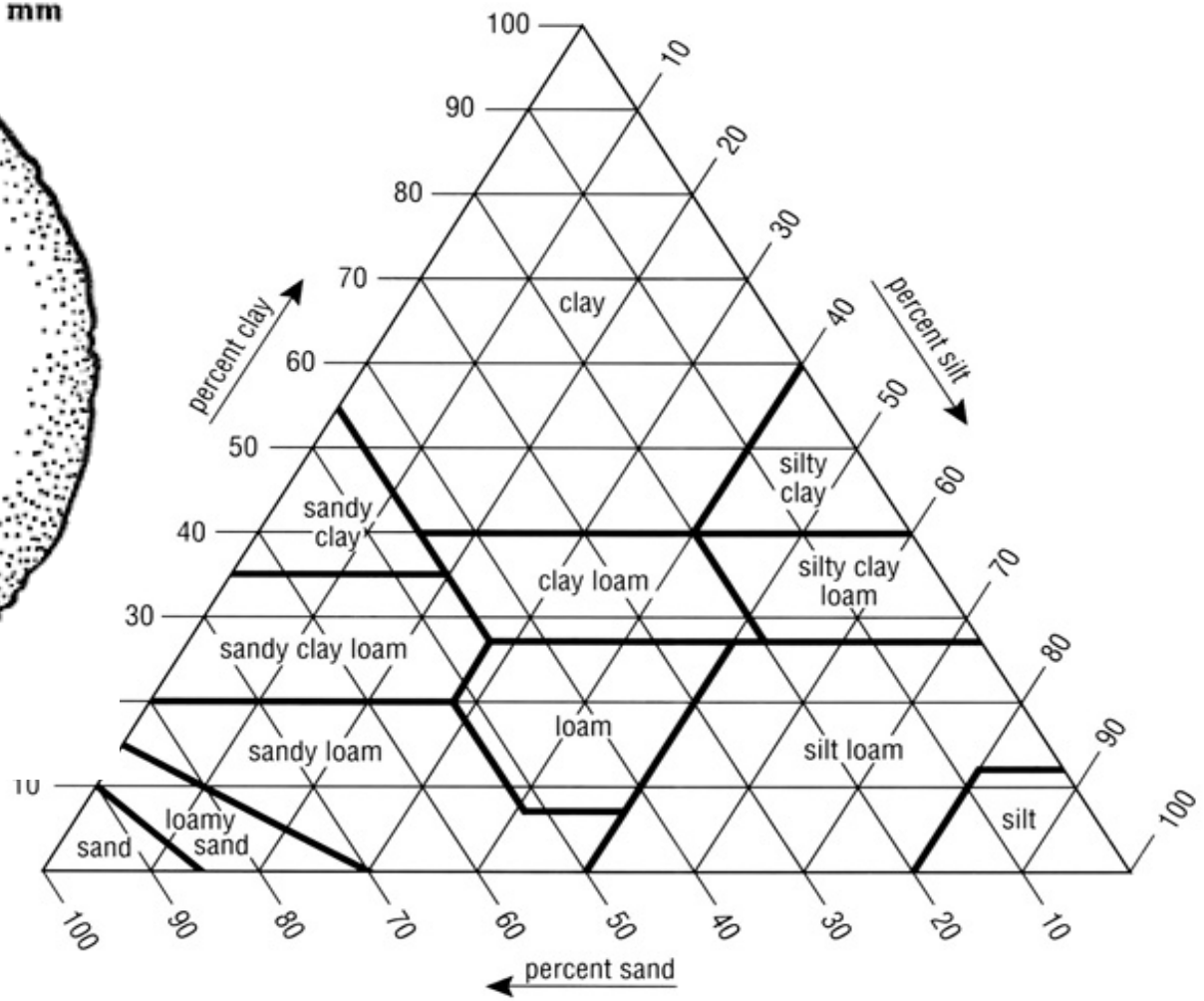



Akina soil

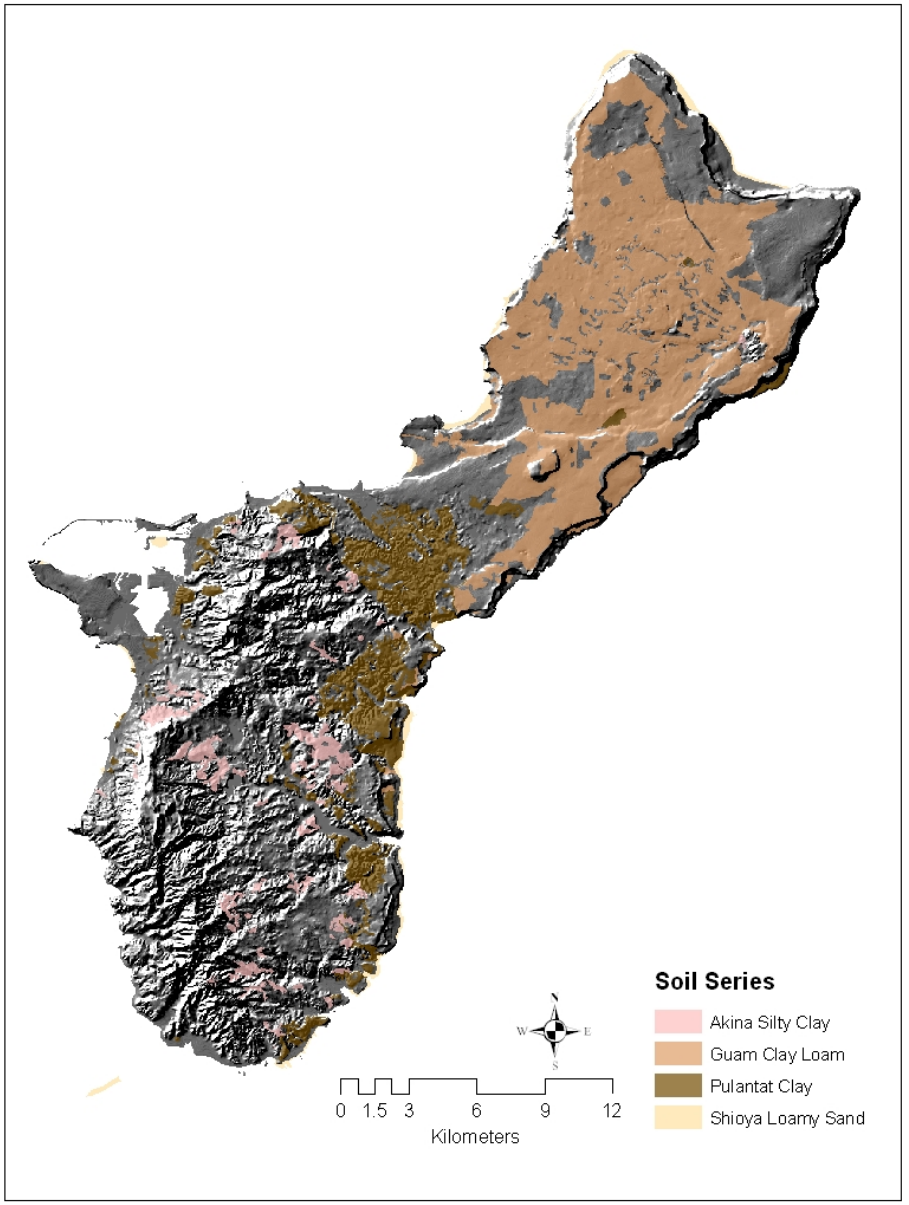
Photos: B. Gavenda

Soil Texture



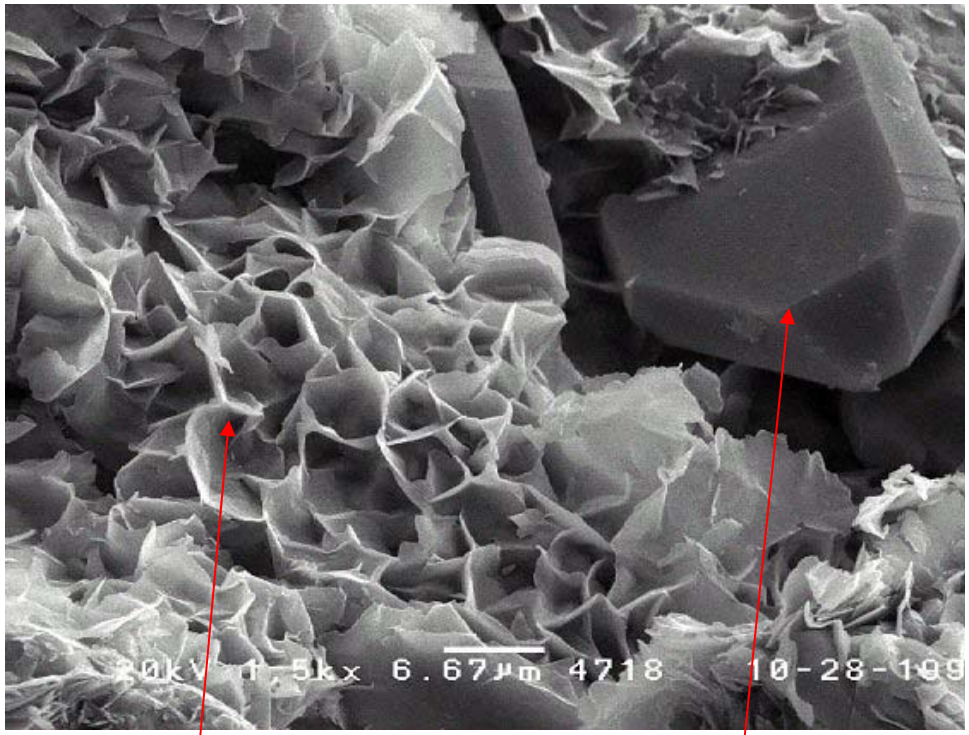


Soil Series	Textural Class
Agfayan	Clay
Akina	Silty Clay
Atate	Clay
Chacha	Clay
Guam	Clay Loam
Inarajan	Clay
Kagman	Clay
Pulantat	Clay
Ritidian	Clay Loam
Sasalaguan	Clay
Shioya	Loamy Sand
Togcha	Silty Clay
Yigo	Silty Clay
Ylig	Clay



Properties and Importance of Clay

- Properties
  - High surface area
    - 1 gram = 10 to 800 m^2
  - 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)



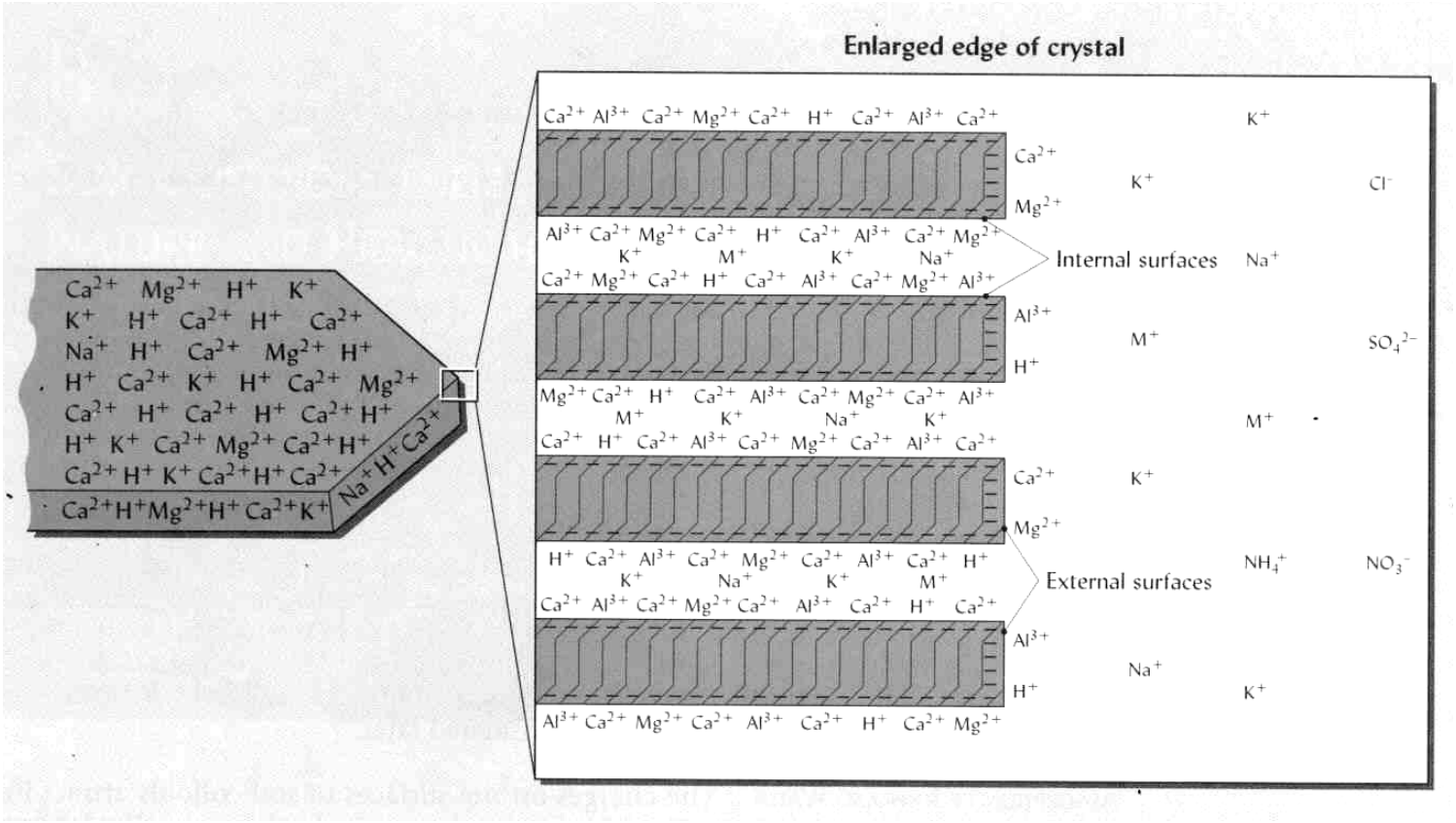
Clay surfaces

Fine quartz sand

Clay Type is Important

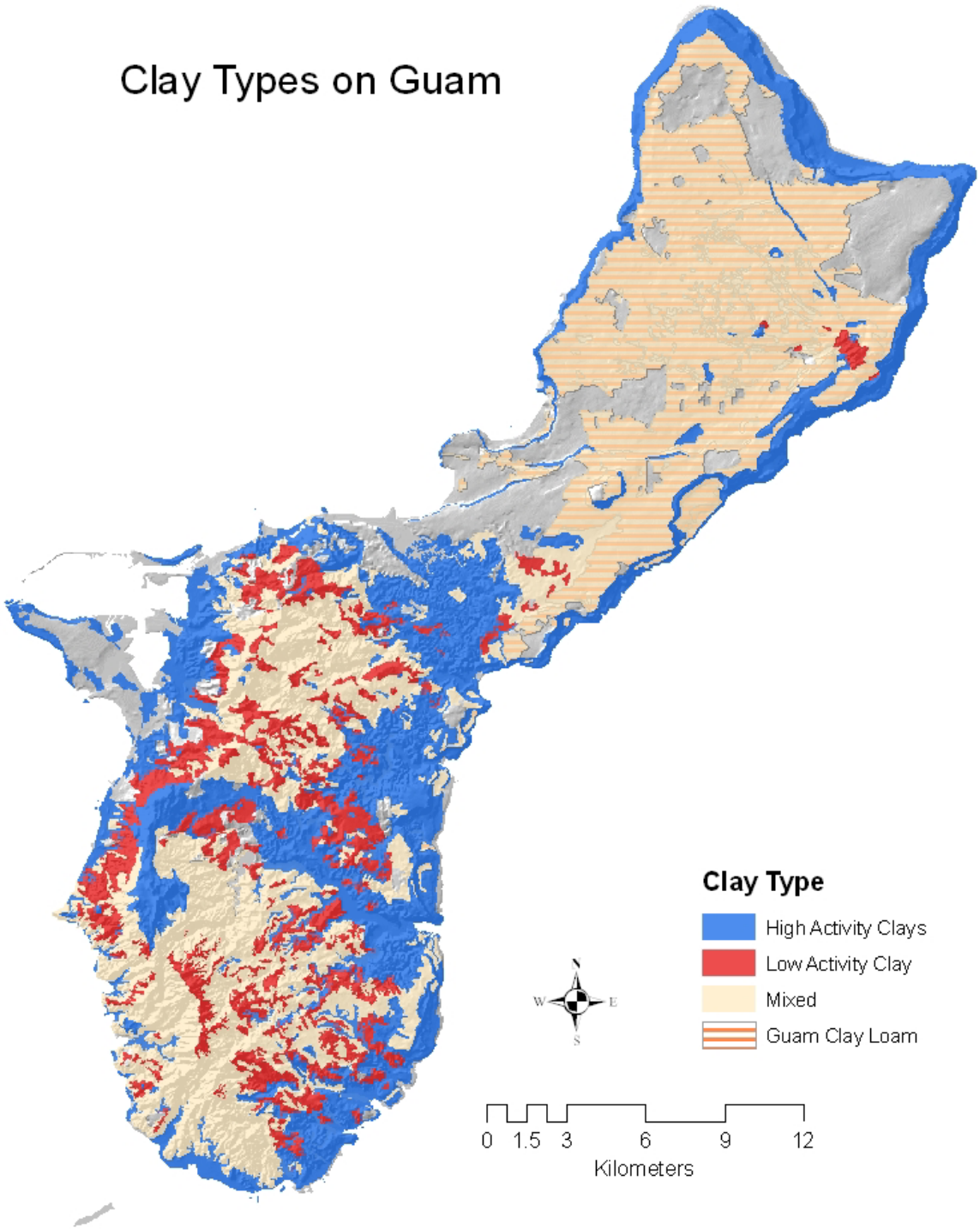
- Montmorillonite (high activity clay)
  - Shrink-swell clay (unstable)
  - High fertility clay (high cation exchange capacity)
- Kaolinite (low activity clay)
  - Non-expanding clay (stable)
  - Low fertility clay (low cation exchange capacity)
- Fe & Al oxides (low activity clay)
  - Goethite, gibbsite
  - Non-expanding clay (stable)
  - Very low fertility (no cation exchange capacity)

Cation Exchange Capacity (CEC)



Negatively charged sites that adsorb cations:

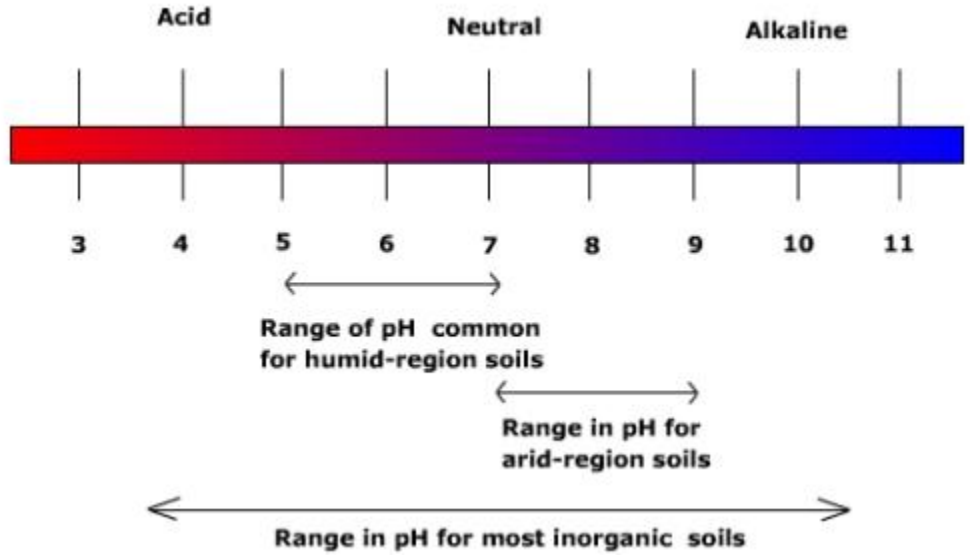
Ca^{2+}, Mg^{2+}, K^{+}, NH^{4+}



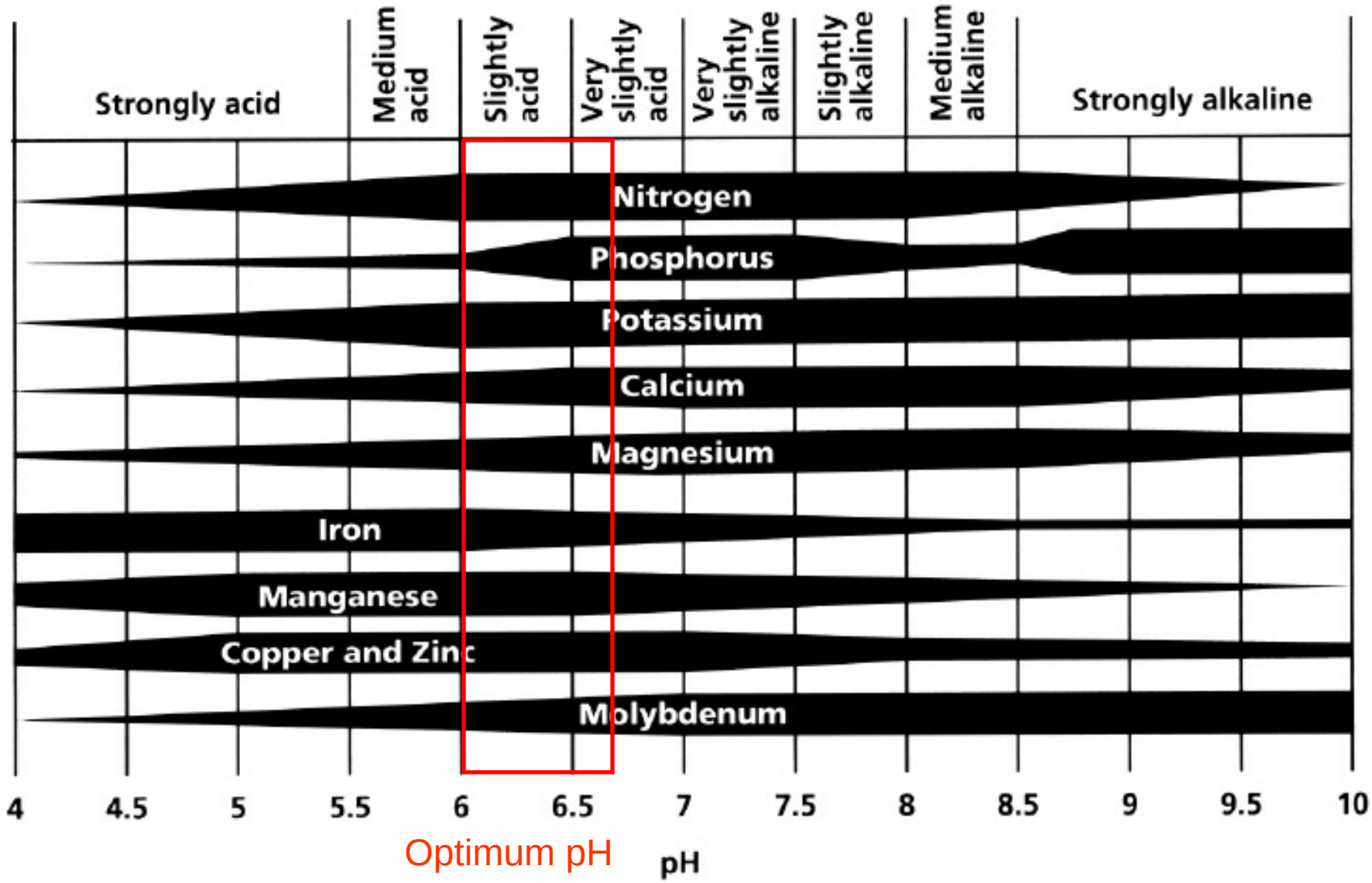
- Guam Clay Loam contains high Al-oxides (low activity clay) with good physical properties
- But has high CEC, a property associated with high activity clay

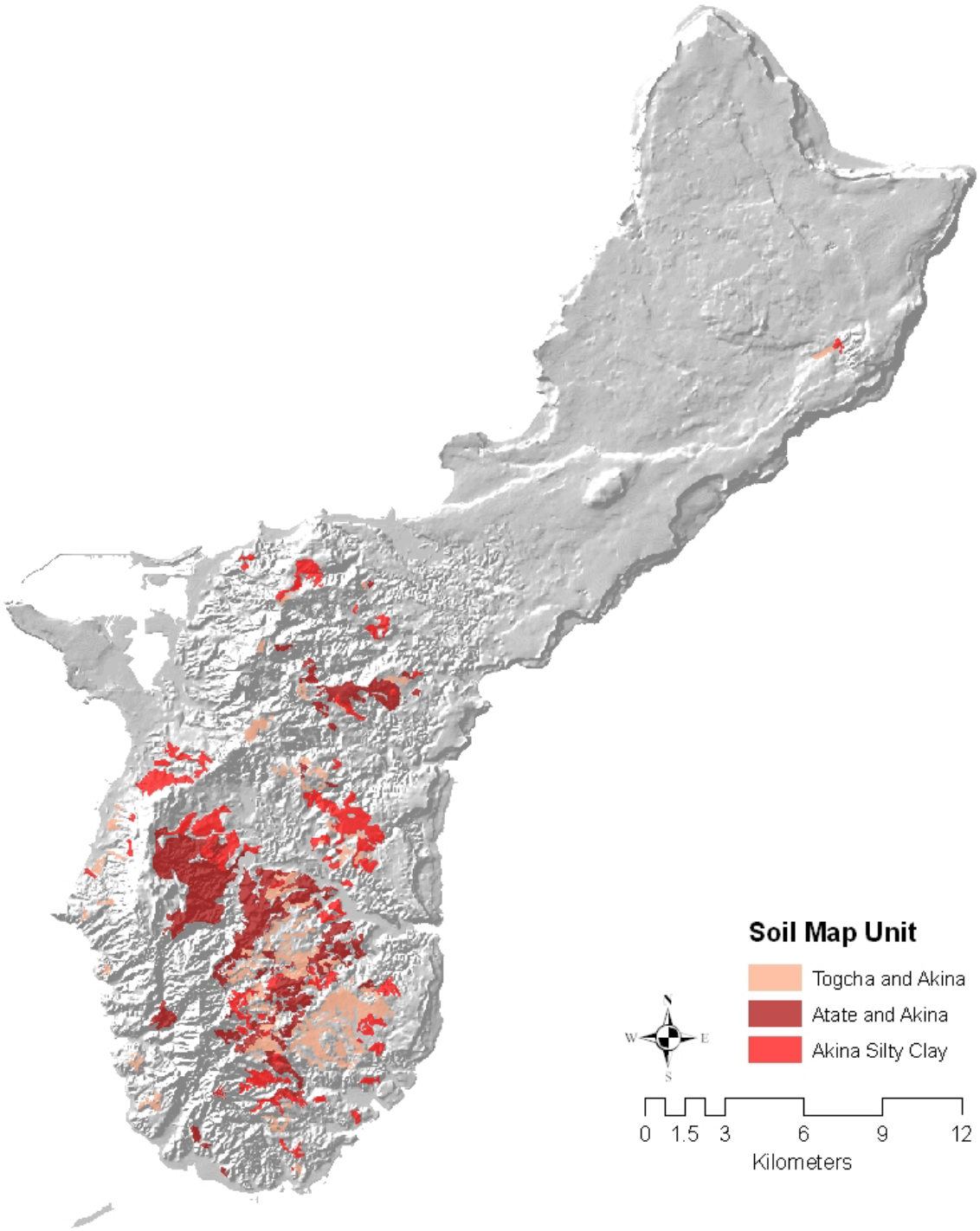
The pH Scale


Hydrochloric acid
Lemon
Apple
Banana
Water
Baking soda
Ammonia
Drain cleaner
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Most acidic
Most basic
Vinegar
Tomato
Milk
Blood
Soap

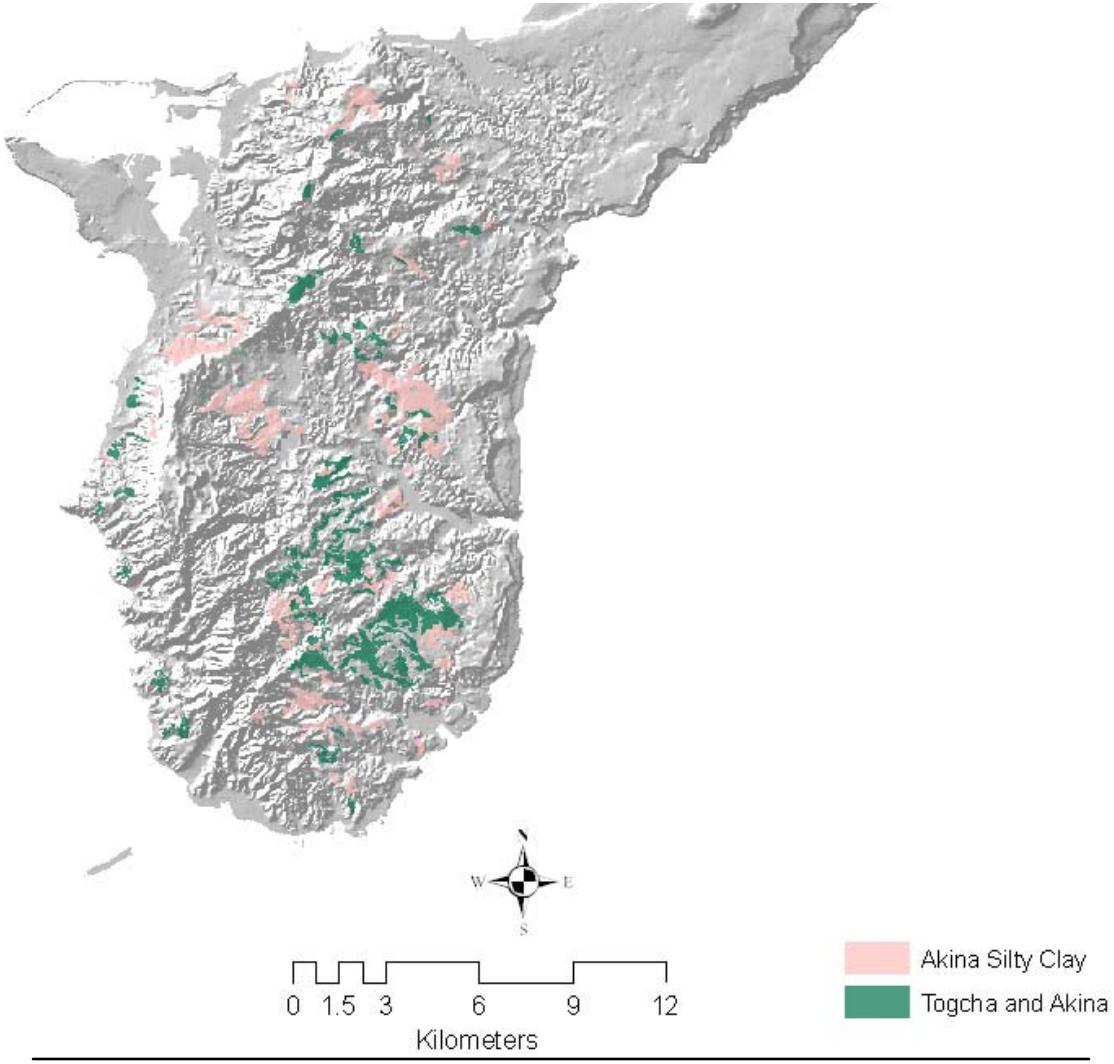

Acid
Neutral
Alkaline
3
4
5
6
7
8
9
10
11
Range of pH common for humid-region soils
Range in pH for arid-region soils
Range in pH for most inorganic soils

Soil Acidity and Nutrient Availability





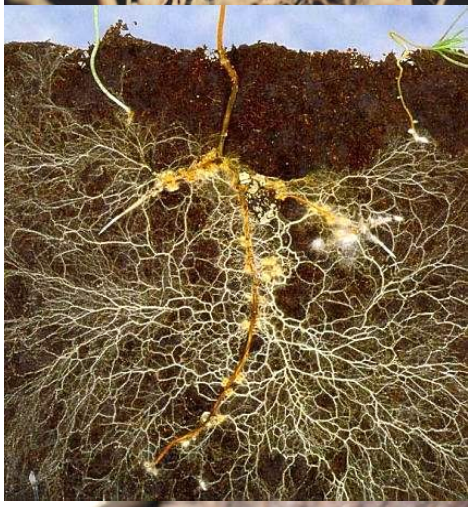
- Soils typically acid to strongly acid
- Aluminum toxicity especially severe in Akina subsoil

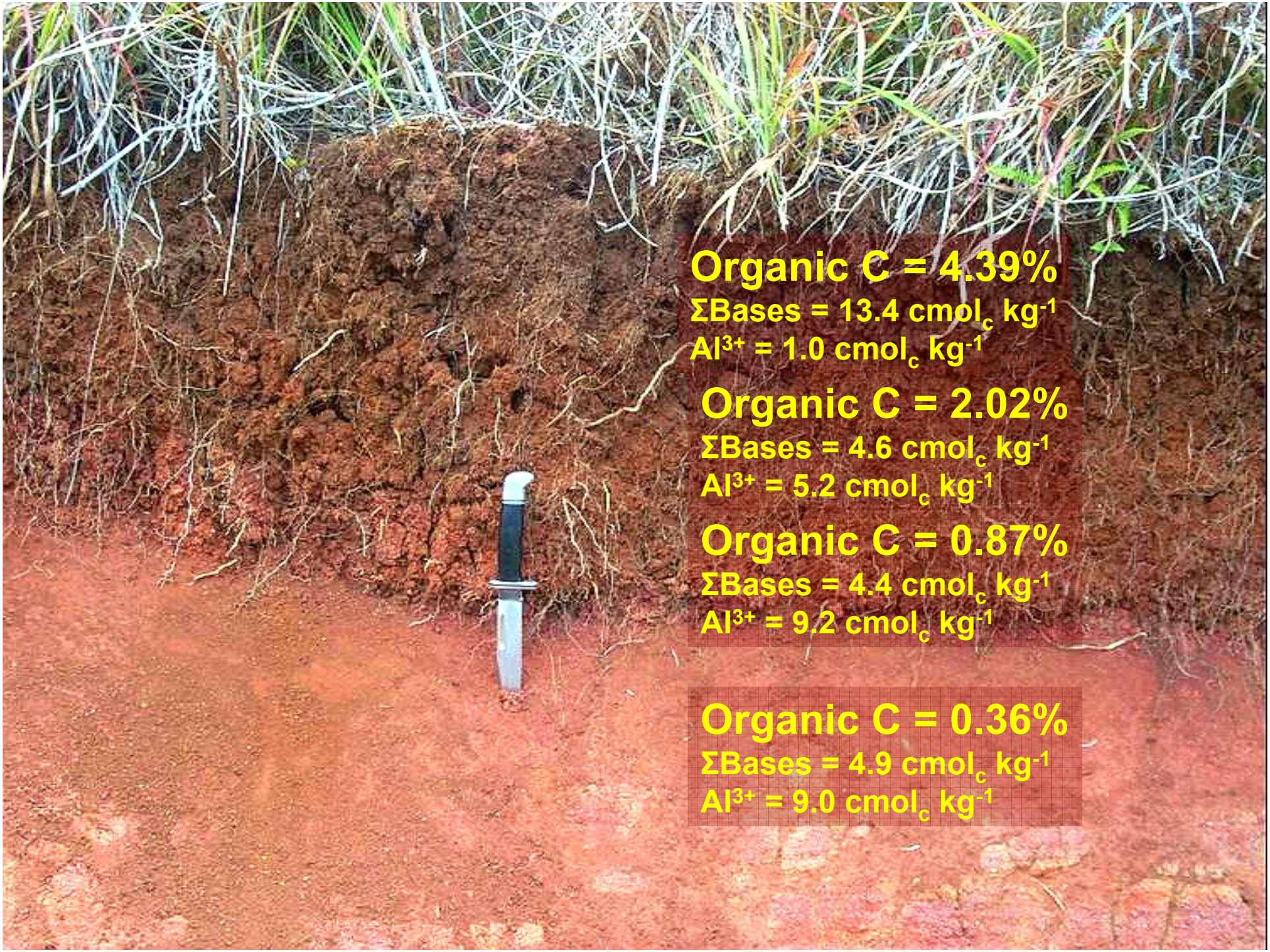


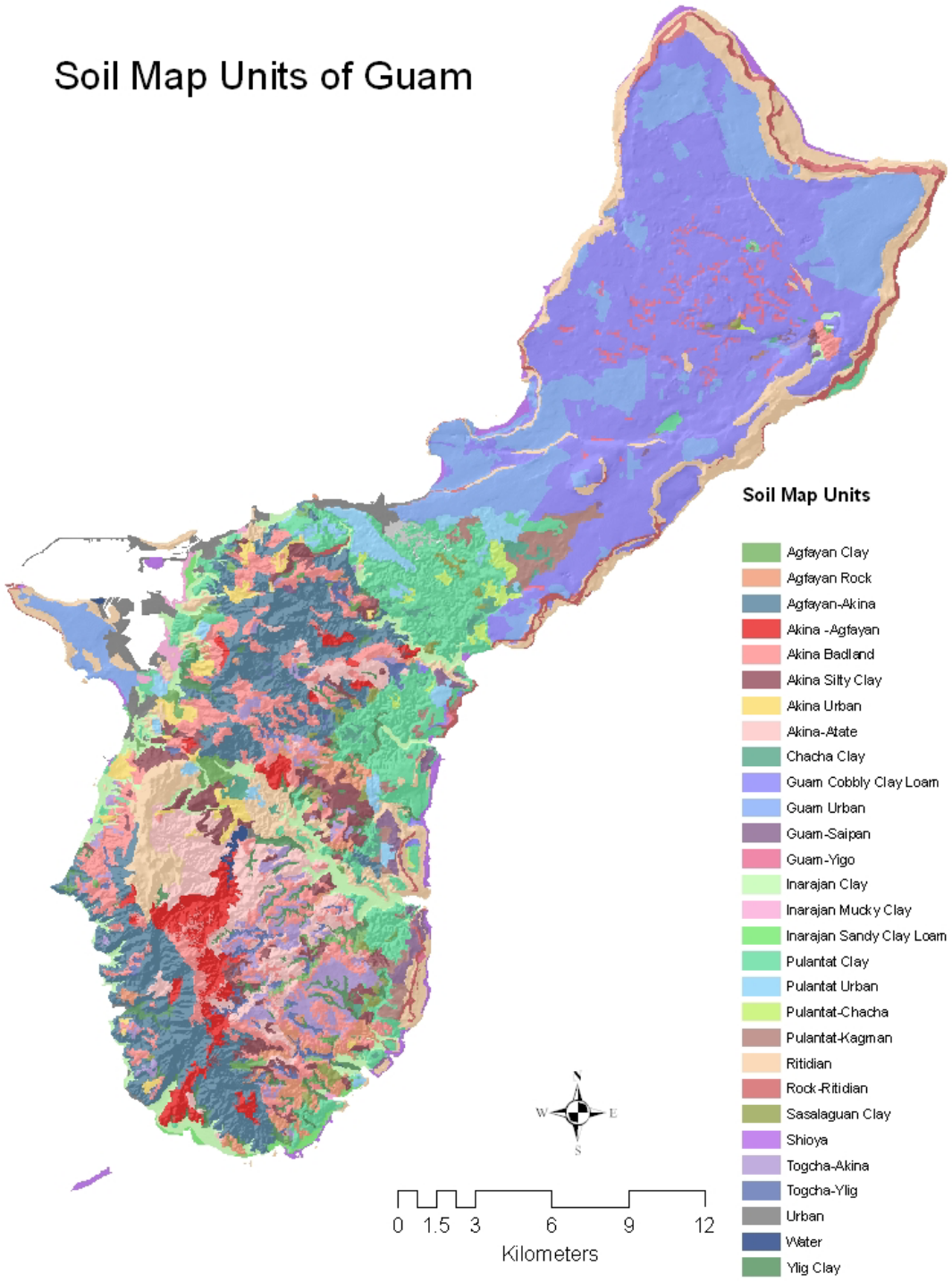
Depth (cm)	OM	pH	CEC	$Base_{sat}$	Al_{sat}
	%		$cmol_c\ kg^{-1}$	%	
0-10	5	5.0	12.4	85	15
20-10	2.8	4.9	8.4	49	51

Role of Organic Matter in Soil

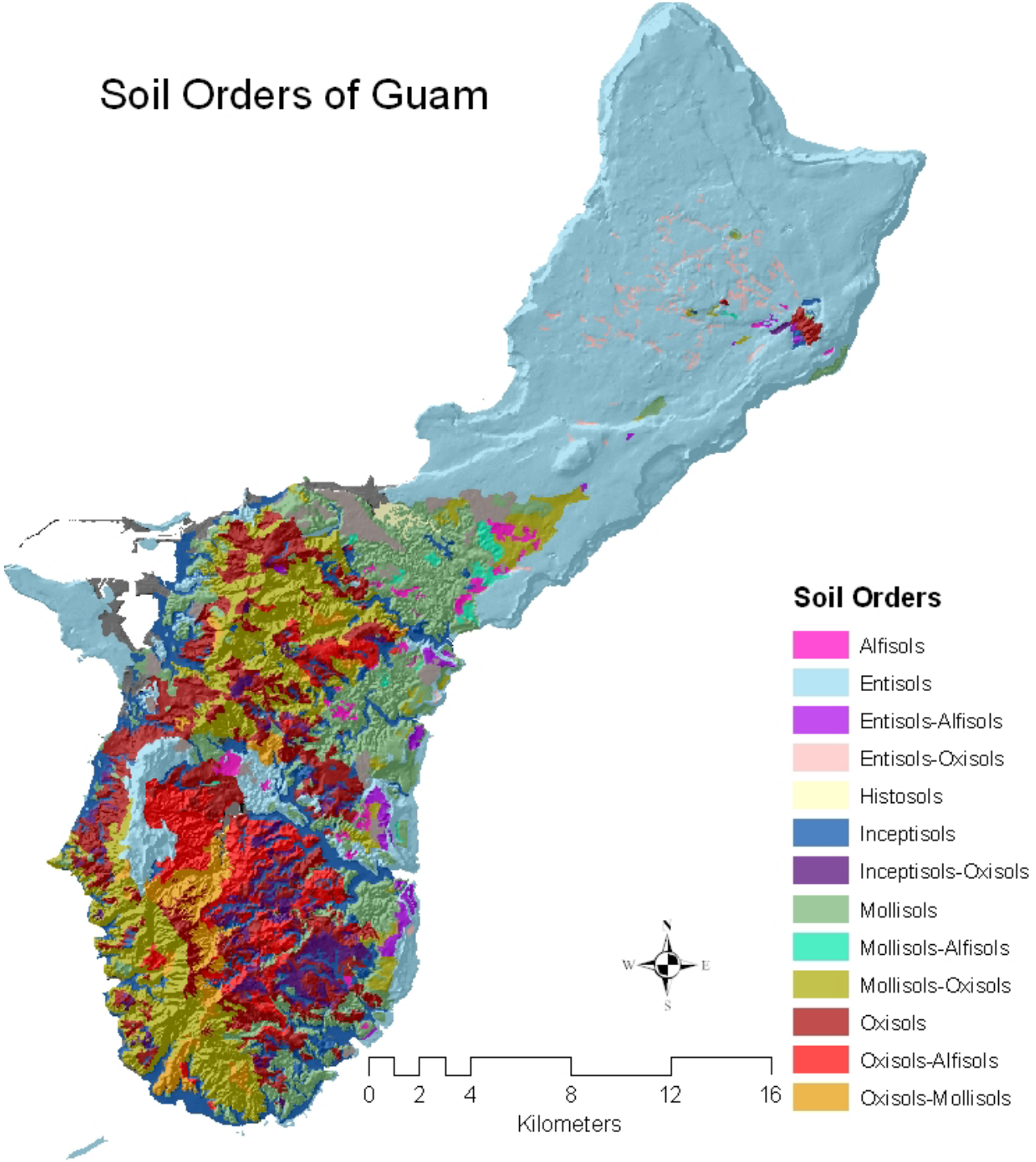
- **Physical**
  - Improves soil structure
  - Increases water retention
- **Chemical**
  - Increases nutrient availability (N & P cycling, solubility)
  - Increases nutrient retention (CEC)
  - Detoxifies Al
- **Biological**
  - Increases microbial diversity
  - N fixation (rhizobia), P availability (myccorhiza)
  - Increases pathogen suppression

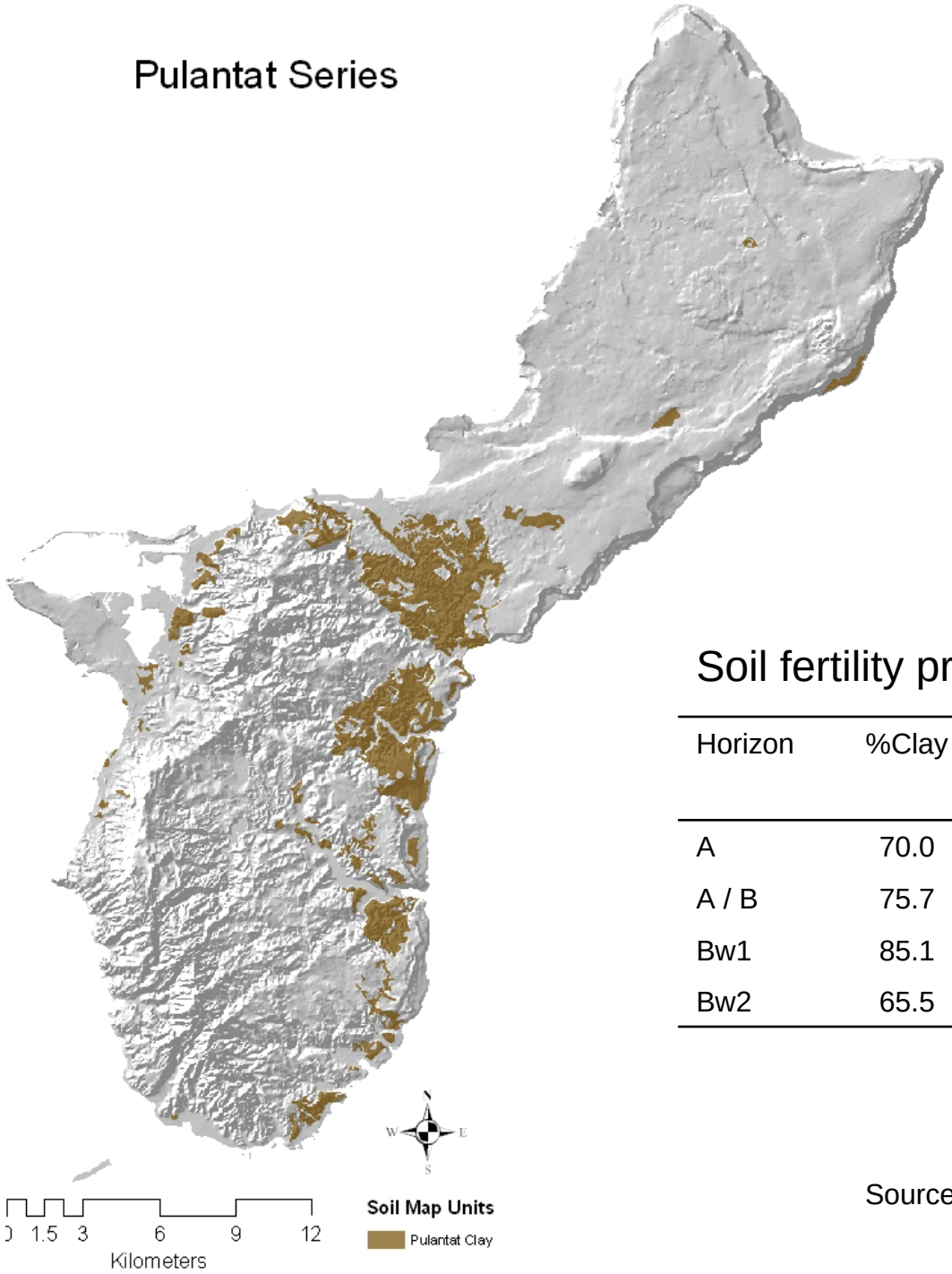



Organic C = 4.39%
ΣBases = 13.4 cmol$_c$ kg^{-1}
Al^{3+} = 1.0 cmol$_c$ kg^{-1}
Organic C = 2.02%
ΣBases = 4.6 cmol$_c$ kg^{-1}
Al^{3+} = 5.2 cmol$_c$ kg^{-1}
Organic C = 0.87%
ΣBases = 4.4 cmol$_c$ kg^{-1}
Al^{3+} = 9.2 cmol$_c$ kg^{-1}
Organic C = 0.36%
ΣBases = 4.9 cmol$_c$ kg^{-1}
Al^{3+} = 9.0 cmol$_c$ kg^{-1}



- 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 Orders of Guam
Soil Orders
Alfisols
Entisols
Entisols-Alfisols
Entisols-Oxisols
Histosols
Inceptisols
Inceptisols-Oxisols
Mollisols
Mollisols-Alfisols
Mollisols-Oxisols
Oxisols
Oxisols-Alfisols
Oxisols-Mollisols
W
E
S
0 2 4 8 12 16
Kilometers

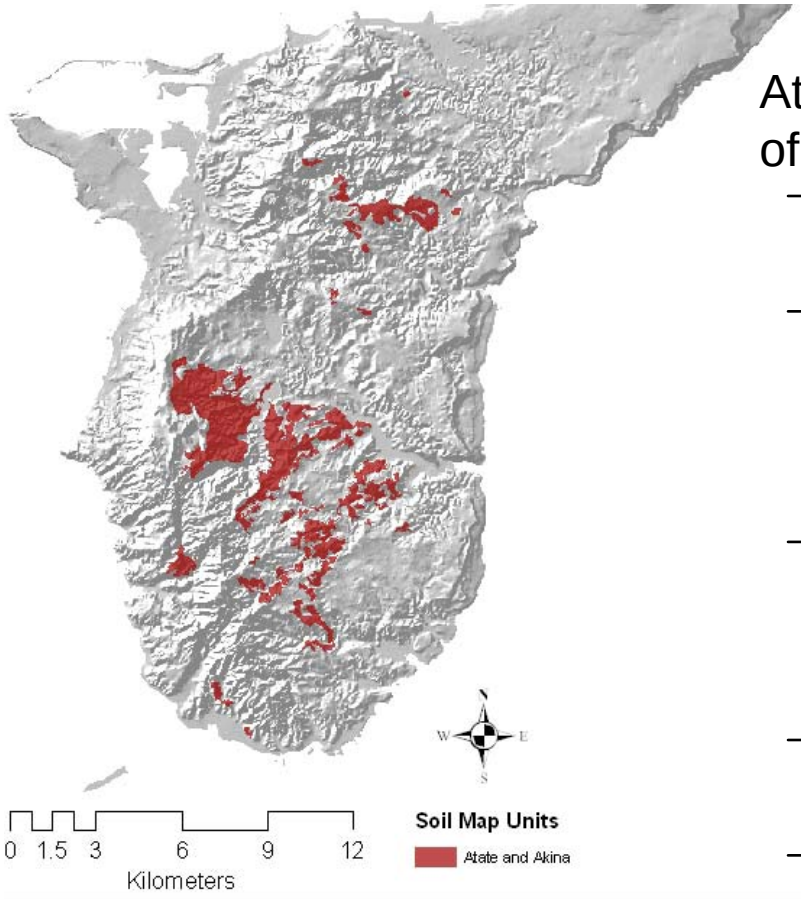


Soil fertility properties

Horizon	%Clay	pH	% C	Ca	Mg	Na	K
					$cmol_c\ kg^{-1}$		
A	70.0	6.5	5.09	62.8	10.8	0.4	0.6
A / B	75.7	6.6	2.28	51.2	8.5	0.3	0.4
Bw1	85.1	7.5	1.47	65.3	5.6	0.2	0.4
Bw2	65.5	8.0	1.05	91.2	3.0	0.3	0.3

Source: NRCS soil characterization data

Atate-Akina Map Unit



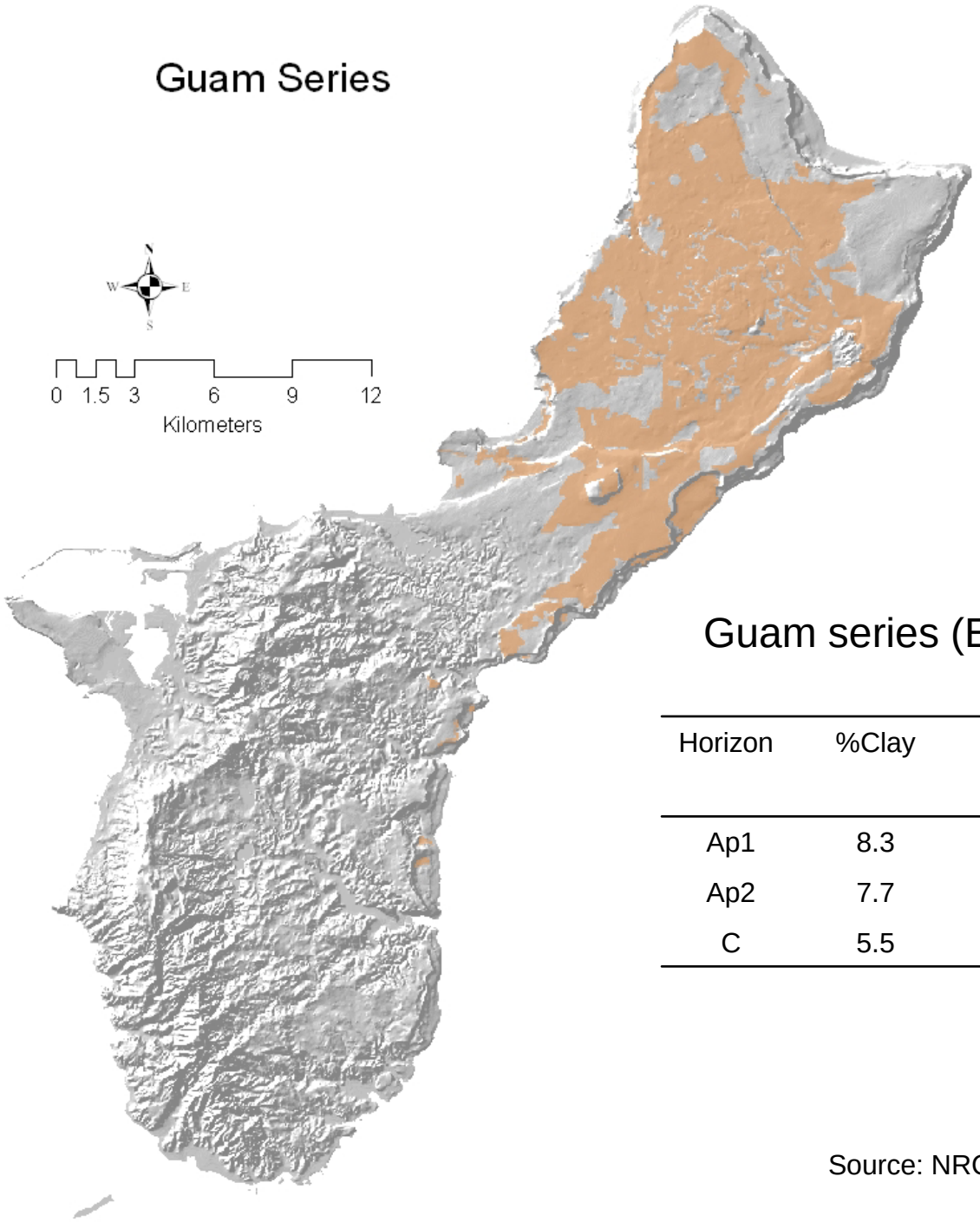
Atate series (Alfisol) covers approximately 60% of the map unit

Horizon	%Clay	pH	% C	Ca	Mg	Na	K
				$cmol_c\ kg^{-1}$			
A1	42.8	5.5	3.86	6.2	4.7	0.2	0.8
A2	53.6	6.2	1.85	2.6	2.7	0.2	0.1
Bo1	74.4	5.8	0.91	2.3	4.3	0.2	0.1
Bo2	56.8	5.9	0.53	3.4	6.9	0.3	0.3

Akina series (Oxisol)

Horizon	%Clay	pH	% C	Ca	Mg	Na	K
				$cmol_c\ kg^{-1}$			
A	65.5	5.0	5.04	3.4	6.6	tr	0.5
Bo1	68.9	4.9	2.81	1.4	2.7	tr	tr
Bo2	62.1	5.0	1.53	1.1	2.6	tr	--
Bw	50.5	5.1	0.63	1.0	2.8	tr	--

Source: NRCS soil characterization data

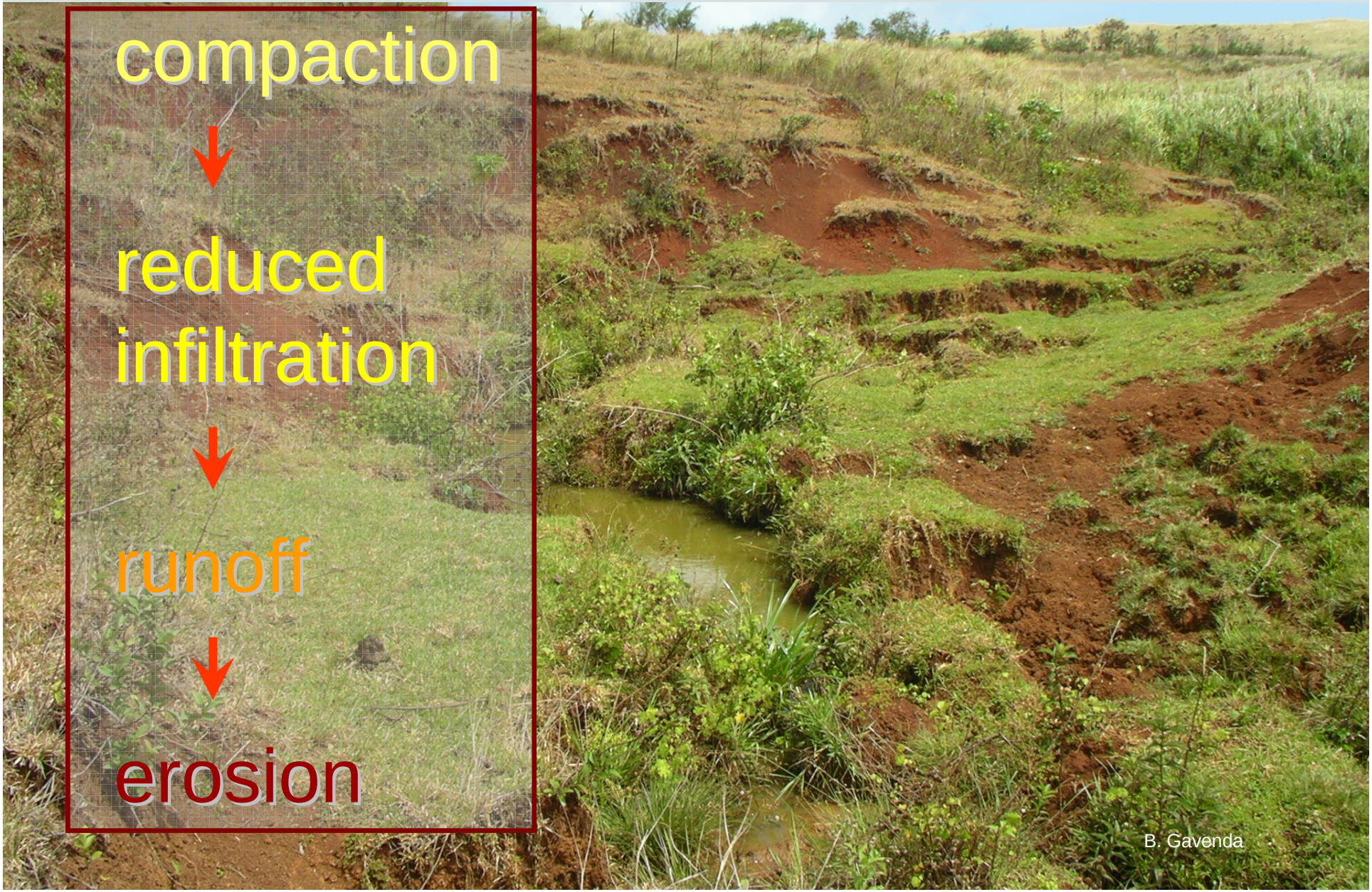


Guam series (Entisol)

Horizon	%Clay	pH	% C	Ca	Mg	Na	K
					$cmol_c\ kg^{-1}$		
Ap1	8.3	7.6	6.8	84.4	4.1	0.1	0.3
Ap2	7.7	7.8	5.9	79.9	2.1	tr	0.1
C	5.5	8	2.8	71.9	0.7	tr	tr

Source: NRCS soil characterization data

Grazing Management and Soil Quality



Grazing Management and Soil Quality


Soils are non-renewable!
B. Gavenda