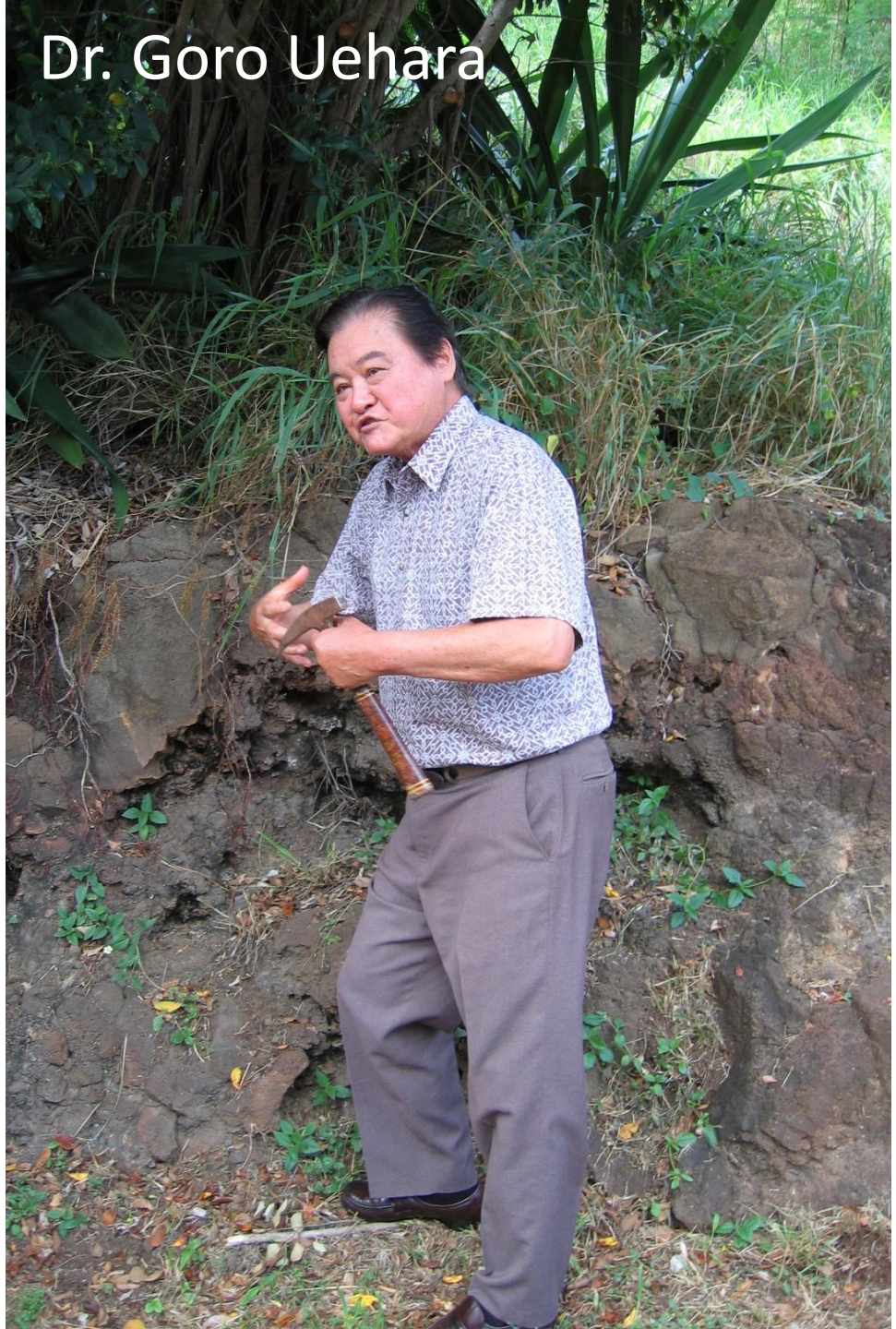
Soil Health Management for Soils of the North Shore

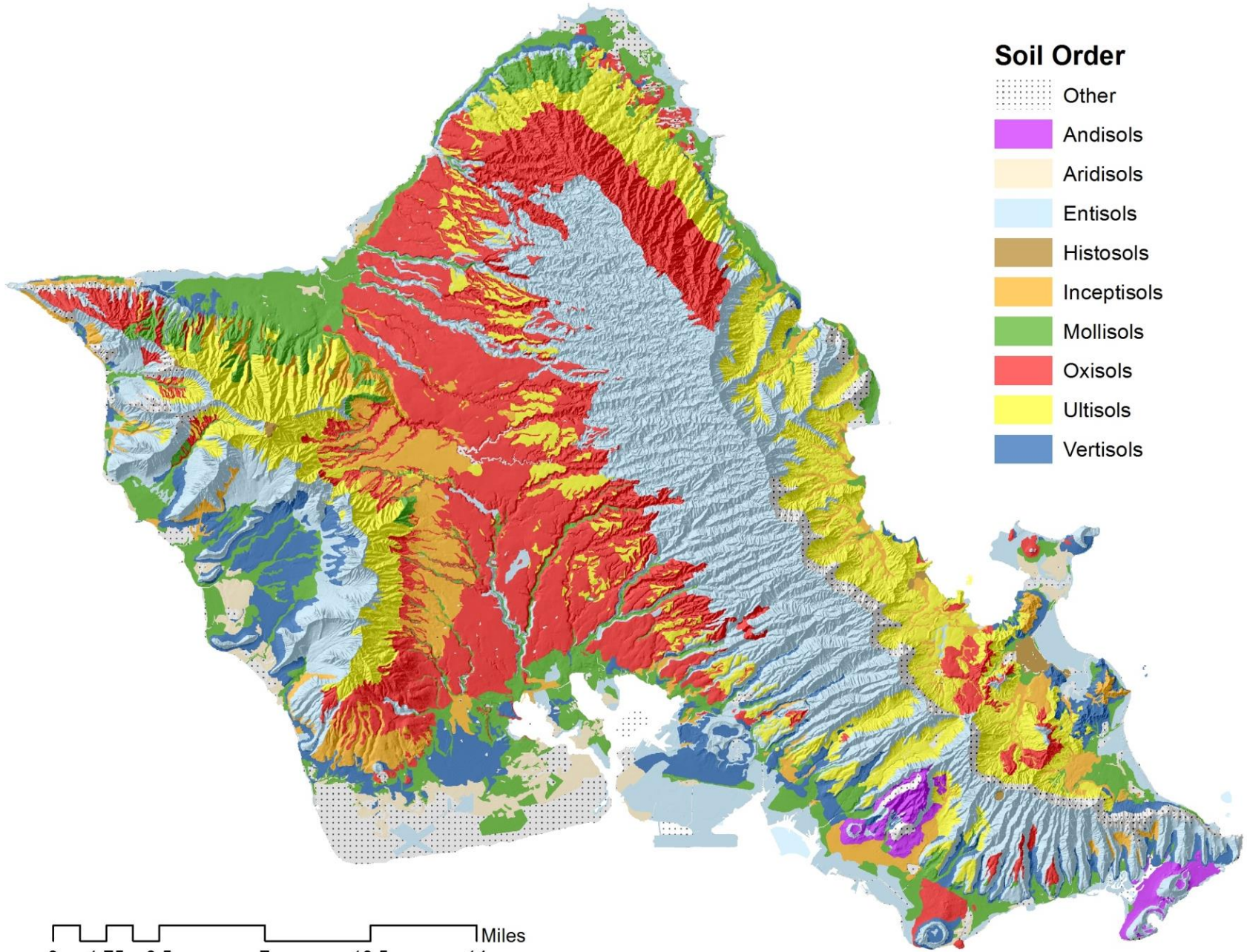
Soil Health Training ORCD

March 29, 2022

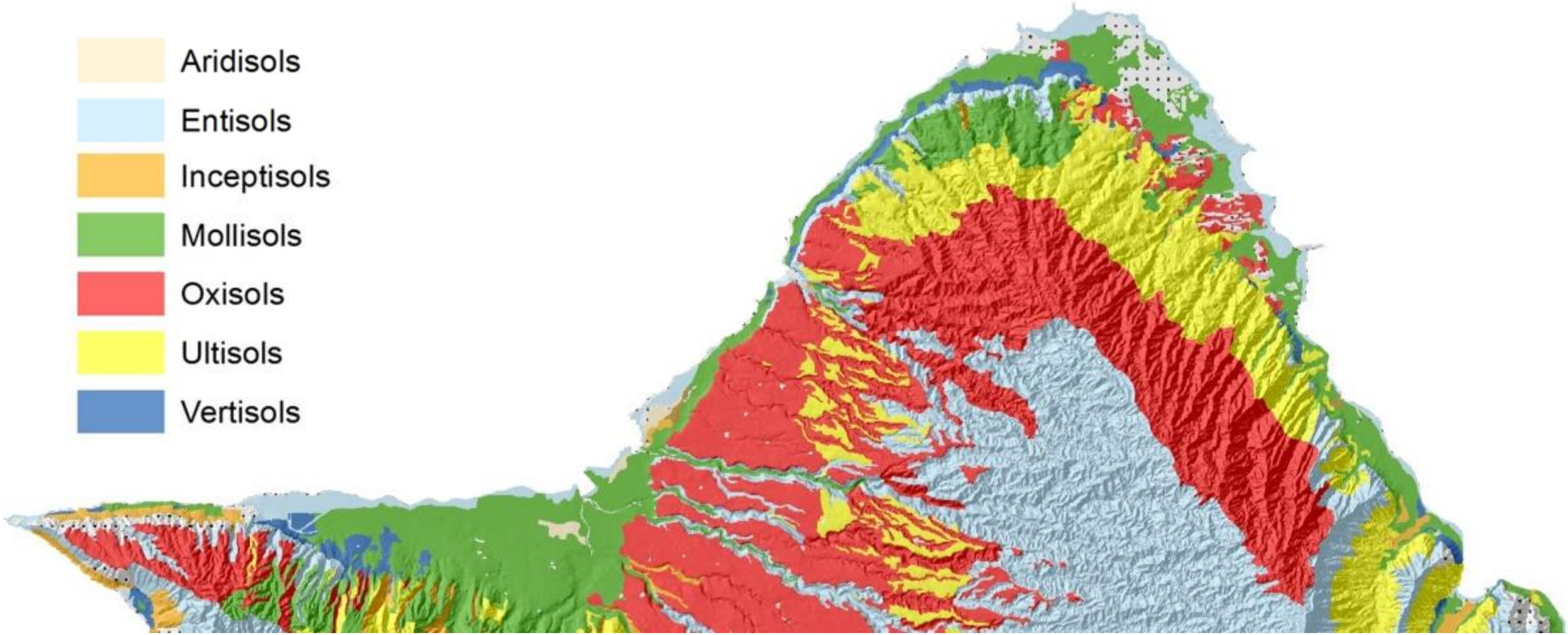
Haleiwa Oahu


Kupuna
Eddy Ka`anana


Dr. Goro Uehara


Soil Order
Other
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols
0
1.75
3.5
7
10.5
14
Miles
Projection: NAD 1983, UTM Zone 4N
Source: Natural Resource Conservation Service

Soil Order


Aridisols
Entisols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

Vertisol

(Keaau series)

- Clay: 60% (very sticky)
- Drainage: 0.5 mm/hr
- Erodibility: 0.3

- pH: 7.5 – 8.0
- CEC: 35 $cmol_c\ kg^{-1}$
- Organic matter: 1.4%
- P availability: high

- Al toxicity: none
- Mn toxicity: none

Mollisol

(Waialua series)

- Clay: 60% (sticky)
- Drainage: 25 mm/hr
- Erodibility: 0.3

- pH: 6.5 – 7.0
- CEC: 20-25 $cmol_c\ kg^{-1}$
- Organic carbon: 3.5%
- P availability: high

- Al toxicity: none
- Mn toxicity: low potential

Oxisol

(Lahaina series)

- Clay: 60-80% (non-sticky)
- Drainage: 80 mm/hr
- Erodibility: 0.18

- pH: 5.5 – 6.0
- CEC: 10-13 $cmol_c\ kg^{-1}$
- Organic carbon: 1.4%
- P availability: low

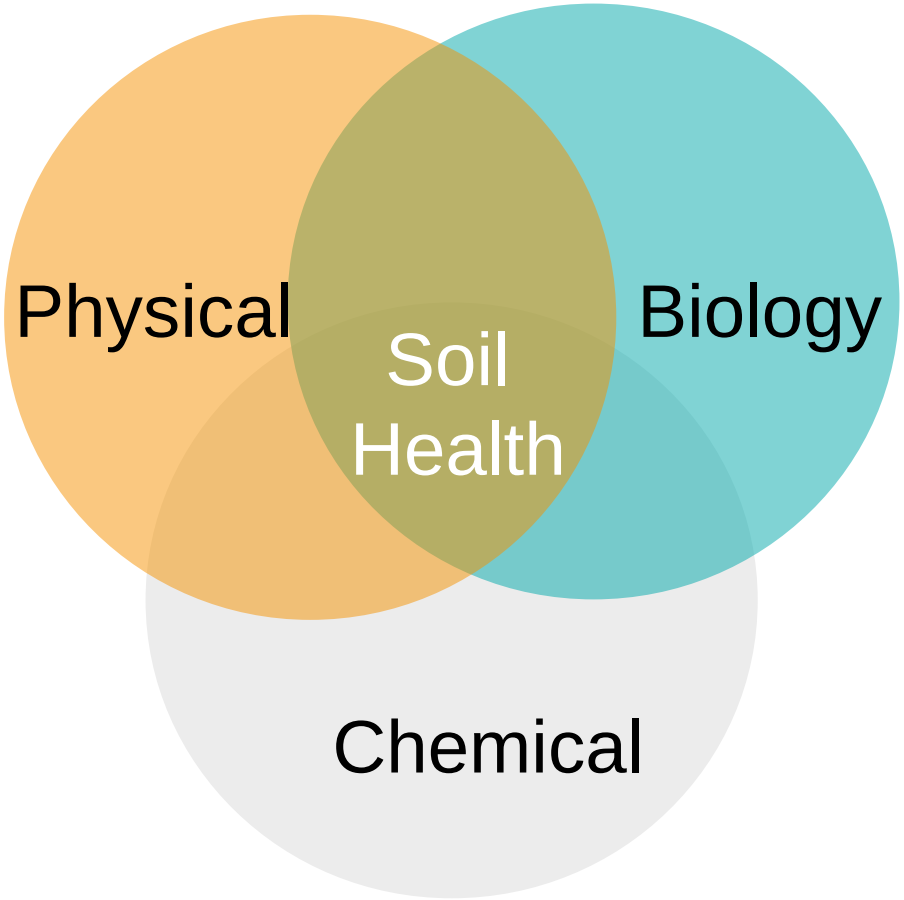
- Al toxicity: low potential
- Mn toxicity: high potential

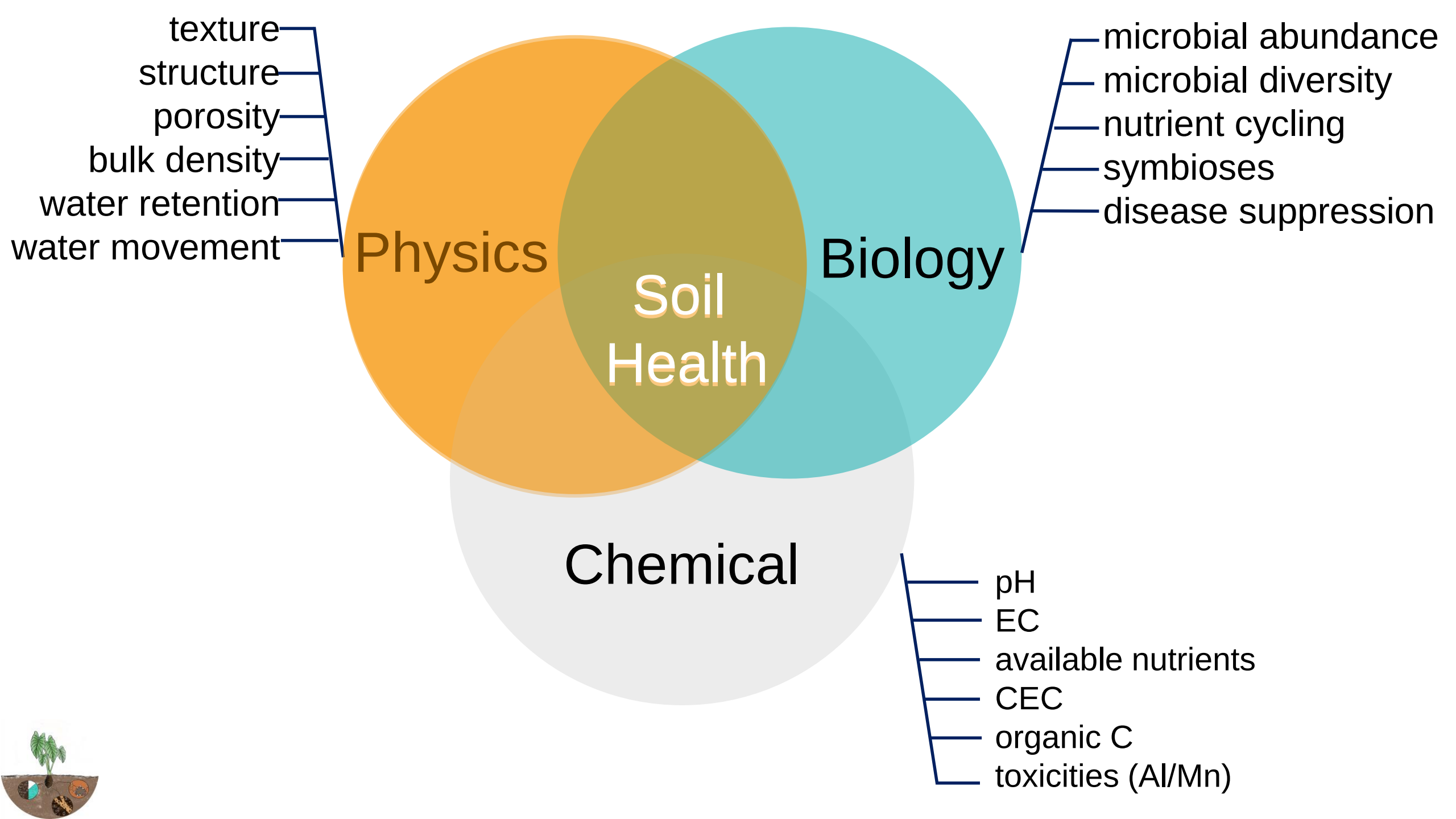
Soil Fertility vs Soil Health

According to FAO, soil fertility is the ability of a soil to supply the essential nutrients and adequate amounts of soil water to plant growth

According to USDA, soil health is the the capacity of soil to function as a vital living system to sustain biological productivity, maintain environment quality, and promote plant, animal, and human health.

- Nutrient supply
  - pH (controls solubility)
  - Cation exchange capacity (controls retention)
    - Texture (clay content and clay type)
    - Soil organic matter
  - Soil organic matter
    - Retention (CEC)
    - Solubility
    - Supply (microbial activity)
- Soil fertility test
  - pH and salinity (EC)
  - Total organic C and N
  - P and exchangeable bases (Ca, Mg, K, Na)
  - Sulfate, nitrate, ammonium
  - Micronutrients (B, Cu, Fe, Mb, Mn, Zn)




texture
structure
porosity
bulk density
water retention
water movement
Physics
Soil Health
Biology
microbial abundance
microbial diversity
nutrient cycling
symbioses
disease suppression
Chemical
pH
EC
available nutrients
CEC
organic C
toxicities (Al/Mn)

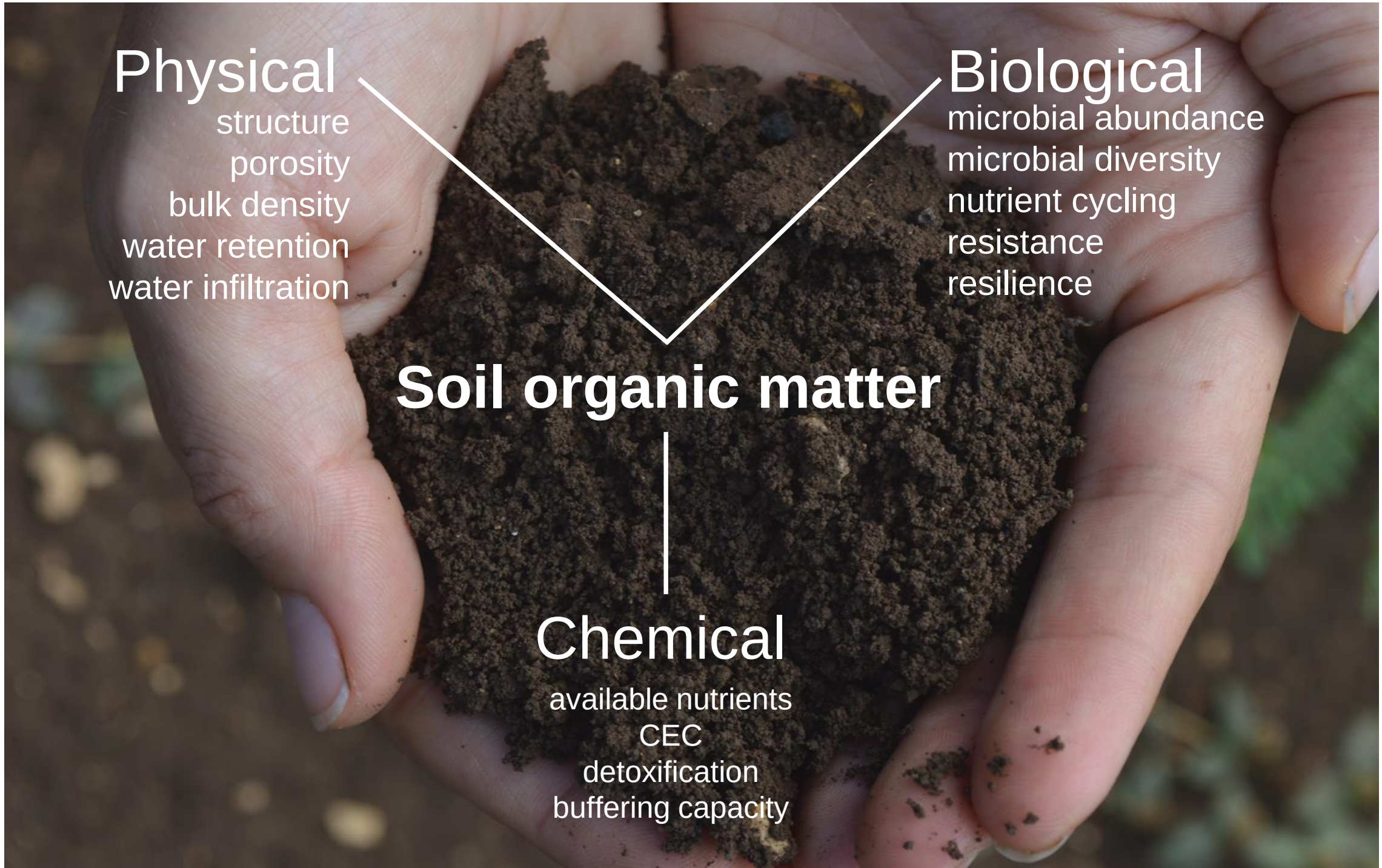
Inherent versus Dynamic Soil Properties

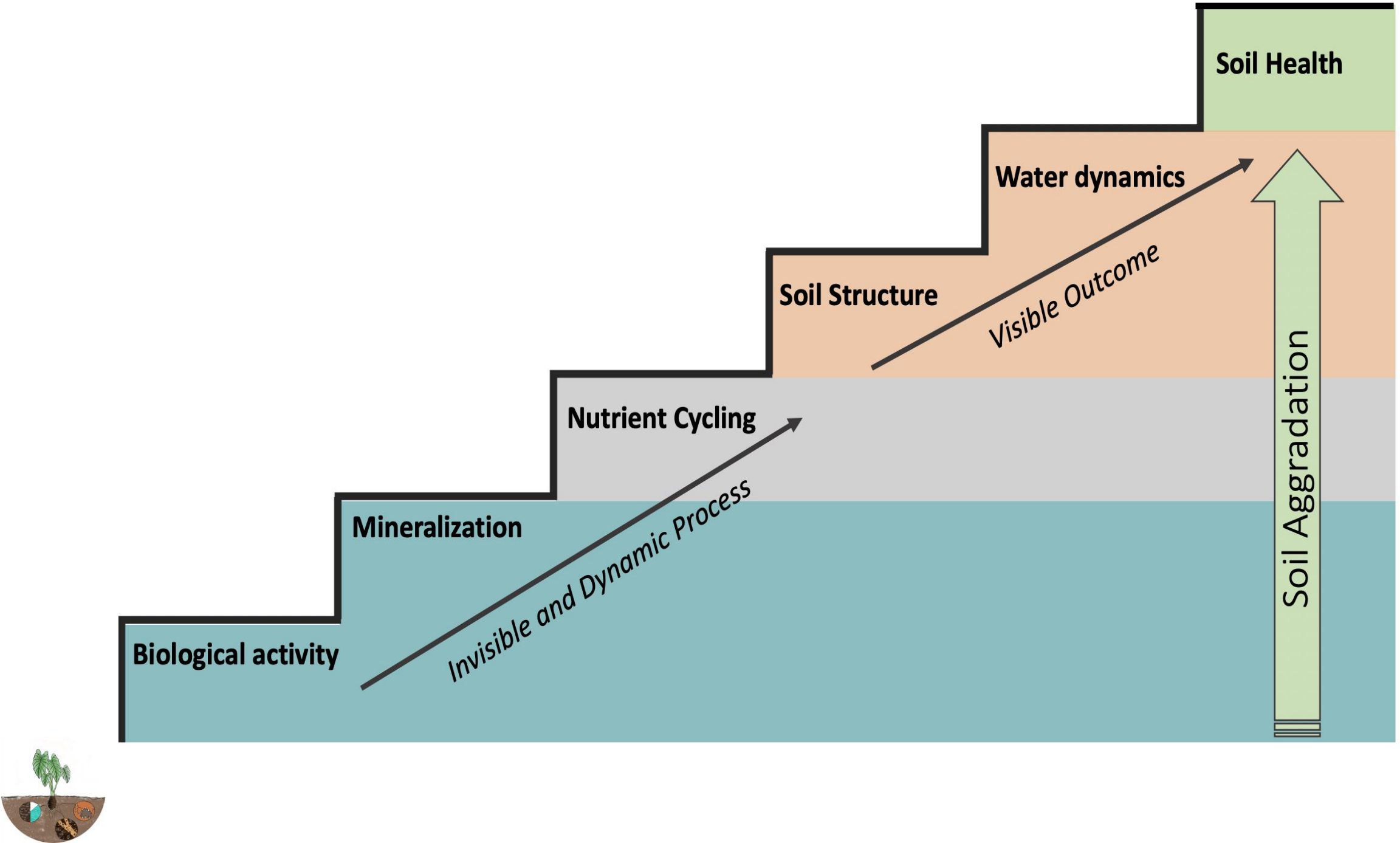
Inherent soil properties are difficult to change

- texture
- clay mineralogy
- drainage
- soil depth

Dynamic soil properties are responsive to disturbances or stressors

- soil organic matter
- soil structure
- bulk density
- microbial diversity


Physical
structure
porosity
bulk density
water retention
water infiltration
Biological
microbial abundance
microbial diversity
nutrient cycling
resistance
resilience
Soil organic matter
Chemical
available nutrients
CEC
detoxification
buffering capacity


Soil Health
Water dynamics
Soil Structure
Visible Outcome
Nutrient Cycling
Mineralization
Invisible and Dynamic Process
Biological activity
Soil Aggradation

Soil Testing

1. Analysis
2. Interpretation
   - Diagnosis
   - Recommendation

Soil Fertility Test

ppm

BROOKSIDE LABORATORIES, INC.

40541-1605

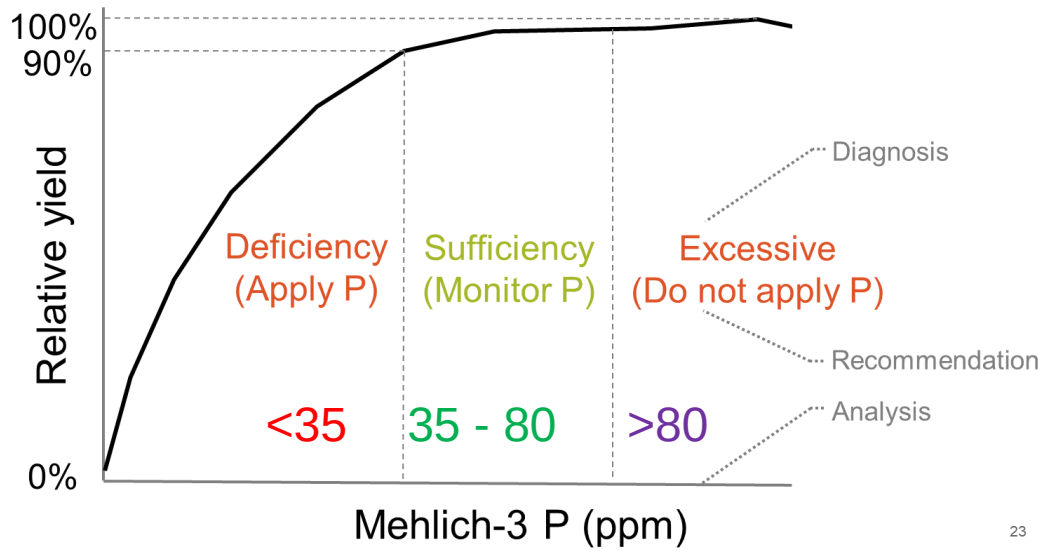
SOIL AUDIT AND INVENTORY REPORT

Name Crop Nutrient Solutions, Inc. City Waimanalo State HI

Independent Consultant Crop Nutrient Solutions, Inc. Date 12/9/2020

			T1-1	T1-2	T1-3	T2-1	T2-2	
Sample Location	TB							
Sample Identification			11/16/20					
Lab Number			0819-1	0820-1	0821-1	0822-1	0823-1	
Total Exchange Capacity (ME/100 g) CEC			16.55	15.55	15.88	14.72	13.86	low
pH (H_2O 1:1)			5.5	6.1	6.1	5.3	5.9	low
Organic Matter (360°C LOI) %								
Estimated Nitrogen Release		ppm						
ANIONS	SOLUBLE SULFUR*	ppm	20	8	8	16	9	
ANIONS / PHOSPHORUS	MEHLICH III	P as P_2O_5 ppm of P	74	85	87	54	68	sufficient
ANIONS / PHOSPHORUS	BRAY II	P as P_2O_5 ppm of P						
ANIONS / PHOSPHORUS	OLSEN	P as P_2O_5 ppm of P	85	90	91	66	82	
EXCHANGEABLE CATIONS	CALCIUM*	ppm	962	1210	1216	786	994	low
EXCHANGEABLE CATIONS	MAGNESIUM*	ppm	441	551	567	333	446	sufficient
EXCHANGEABLE CATIONS	POTASSIUM*	ppm	570	559	585	481	537	
EXCHANGEABLE CATIONS	SODIUM*	ppm	133	131	140	111	121	
BASE SATURATION PERCENT								
Calcium		%	29.06	38.91	38.29	26.70	35.86	
Magnesium		%	22.21	29.53	29.75	18.85	26.82	
Potassium		%	8.83	9.22	9.45	8.38	9.93	
Sodium		%	3.49	3.66	3.83	3.28	3.80	
Other Bases		%	6.40	5.20	5.20	6.80	5.60	
Hydrogen		%	30.00	13.50	13.50	36.00	18.00	
EXTRACTABLE MINORS								
Boron* (ppm)			0.43	0.58	0.54	0.44	0.42	
Iron* (ppm)			185	134	136	172	147	
Manganese* (ppm)			92	153	149	64	117	
Copper* (ppm)			12.95	10.69	9.99	9.67	9.57	
Zinc* (ppm)			11.80	12.29	11.73	9.20	10.85	
Aluminum* (ppm)			643	534	525	566	519	
OTHER TESTS	Soluble Salts (mmhos/cm)		0.51	0.40	0.44	0.51	0.49	
OTHER TESTS	Chlorides (ppm)							
OTHER TESTS	NO_3-N (ppm)		28.4	30.9	34.5	35.8	37.0	
OTHER TESTS	NH_4-N (ppm)		5.1	0.8	0.6	1.3	0.8	
OTHER TESTS	Nitrogen (%)		0.20	0.17	0.18	0.17	0.18	
OTHER TESTS	Organic Carbon (%)		2.21	1.70	1.69	1.89	1.71	

* Mehlich III Extractable

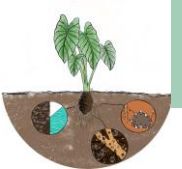


- Soil test result interpreted relative to crop yields
- Goal is to maintain nutrient concentration in the sufficiency range

Development of the Hawai‘i Soil health Test

Tested 44 indicators

Biological	Chemical	Physical
Total PFLA	Organic carbon (%)	Bulk density
Actinobacteria	Nitrogen concentration (%)	Soil hardness measured at surface
Gram + bacteria	OC to N ratio	Soil hardness measured at 15 cm
Gram – bacteria	Hot water extractable carbon	Water holding capacity
Eukaryotes	% of total OC that was HWEC	Mega water-stable aggregates
Arbuscular mycorrhizal fungi	Total water extractable C pool	Macro water-stable aggregates
Anaerobic fungi	C pool respired in 4 months	% sand
Fungi	pH	% silt
Actinomycete to bacteria ratio	Extractable Ca^{2+}, K^{+}, Na^{+}	% clay
Fungi to bacteria ratio	Extractable P	
β-glucosidase	Dissolved organic C, Dissolved organic N	
β-glucosaminidase	Total dissolved N	
Acid phosphatase	Inorganic N (Ammonium, Nitrate)	
Potentially mineralizable N	Dissolved inorganic N	
CO_2 burst	Ratio of DOC to DON	
	Crystalline Fe-oxides	
	Poorly and non-crystalline minerals	
	Ratio of Al_P to Al_H	



Selected indicators based on specific criteria

Sensitivity
Reproducibility
Feasibility
Cost
Time

Soil Health Indicators

% Organic Carbon

DOC:DON

Biological

24-hour CO_2 Burst

ß-glucosidase, ß-glucosaminidase

Potentially Mineralizable Nitrogen

Chemical

pH

Dissolved Organic Carbon:Dissolved Organic Nitrogen ratio

Hot Water Extractable Carbon

Physical

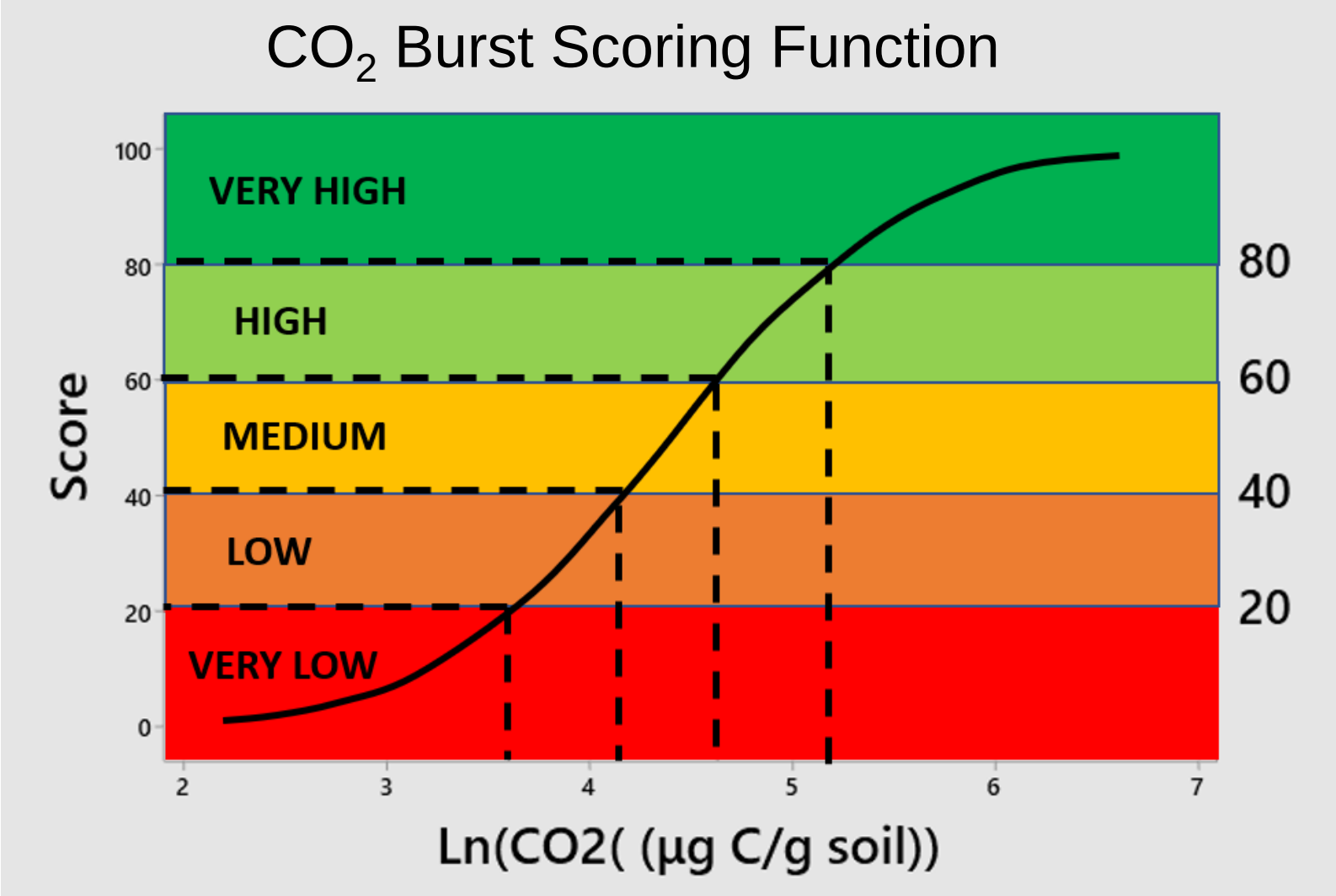
Water Holding Capacity

Water Stable Mega-Aggregates

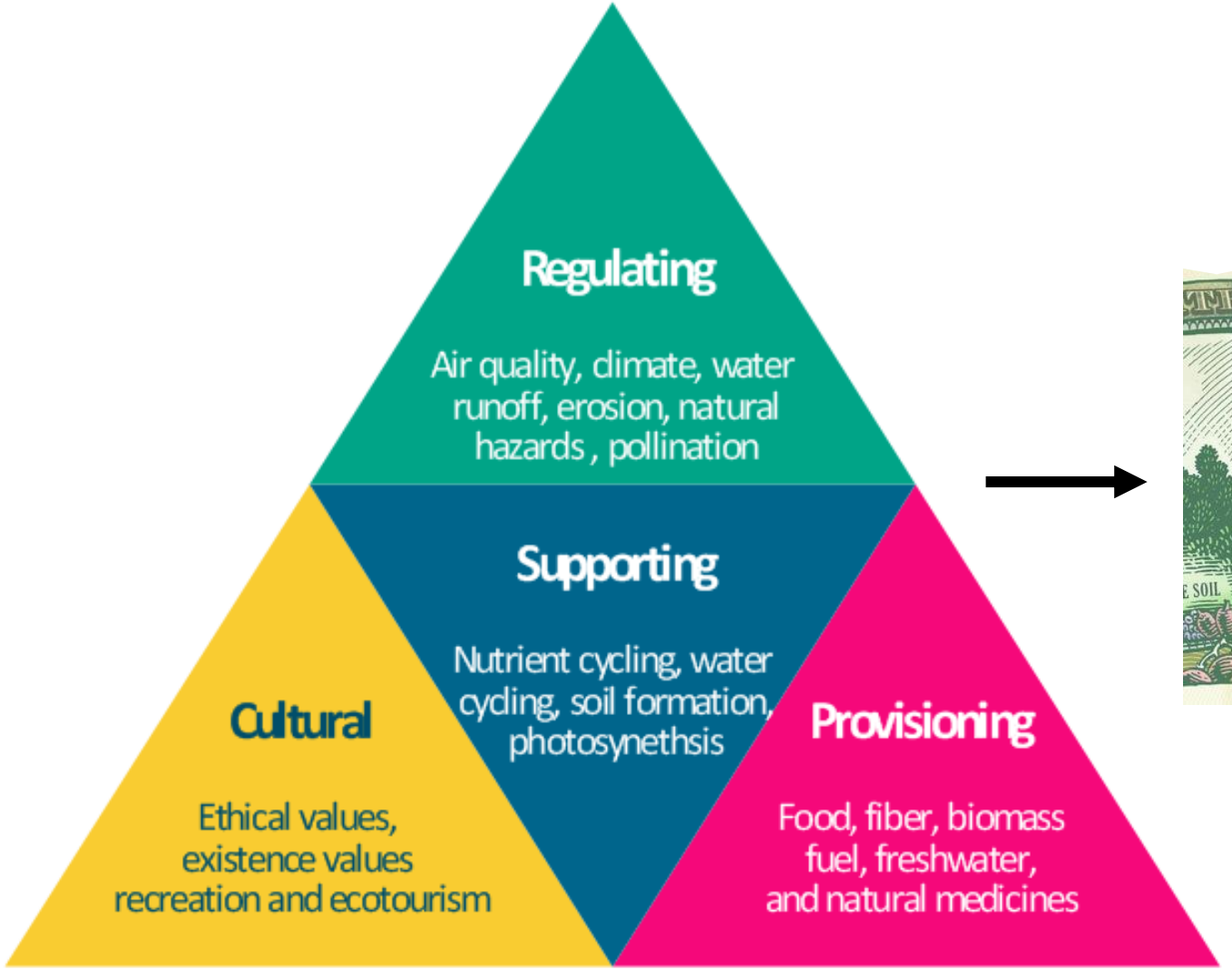
Bulk Density (highly recommended, if possible)

Indicator	Function and interpretation
Total organic carbon (%)	As the backbone of soil organic matter, a proxy measurement of the amount of soil organic matter; higher value typically relates to benefits of multiple biological, chemical, and physical aspects of soil function
Biological Properties	
24 hr CO_2 burst (µg g^{-1})	Soil respiration in response to readily available substrate; higher value indicates high microbial activity and high quality organic matter pools
ß-glucosidase (mg p-nitrophenol kg^{-1} soil h^{-1})	Proximate microbial metabolism of amino-containing substrate; higher value indicates nutrient, predominantly N
ß-glucosaminidase (mg p-nitrophenol kg^{-1} soil h^{-1})	Potential N supply; higher value indicates bioavailable N forms to support soil productivity
Mineralizable nitrogen (µg g^{-1})	Potential N supply; higher value indicates bioavailable N forms to support soil productivity
Chemical Properties	
pH	Biological and nutrient availability; 6.0—7.0 is ideal, this is the pH range where plant essential elements are most available, and toxicities are negligible
DOC:DON	Integrated indicator of the balance of organic carbon and organic nitrogen pools; lower is better; higher value indicates disturbance - high DOC indicates available microbial substrate but also potential runoff, priming, and loss if too high, DON is readily broken down by soil microbes into inorganic forms, but low values are associated with N-deposition or poor nutrient management in disturbed systems
Hot water extractable carbon (µg g^{-1})	Readily available metabolic substrate; higher value indicates soluble organic matter and lysed microbial cells that support microbial activity
Physical Properties	
Water holding capacity (%)	Plant-water relations; higher values indicate improved water storage
Water stable mega-aggregates (%)	Water infiltration, porosity, aeration; higher values improve retention/transport water, promote root growth, provide habitat for microbes, reduce bulk density, and resist erosion
Bulk density (g cm^{-3})	Infiltration, porosity, and rooting environment; lower values indicate soils that are light, aerated, porous, promote root growth, and more workable

Interpretation —
scoring functions are used to develop a soil health score

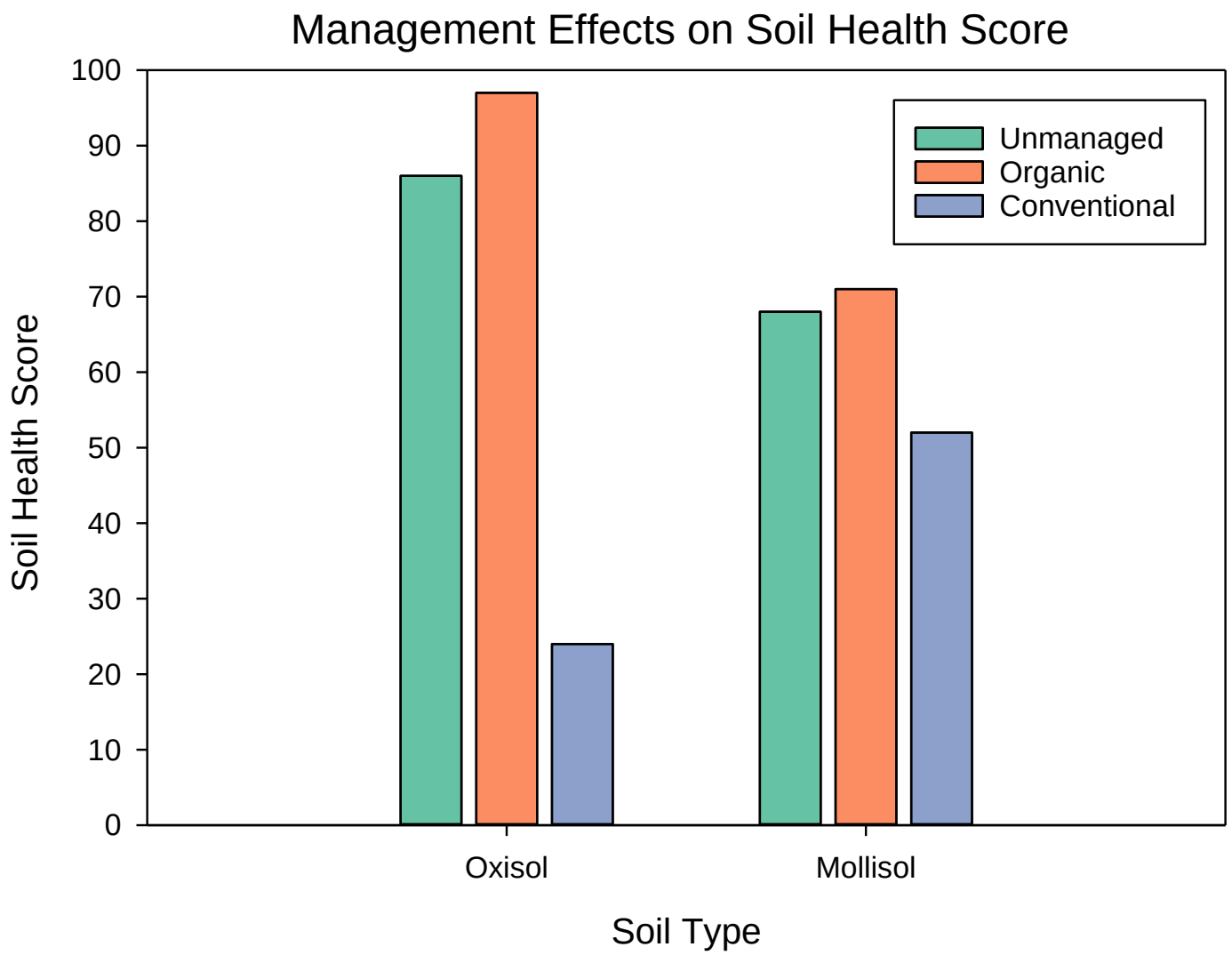


Interpretation — relating to ecosystem services & economics



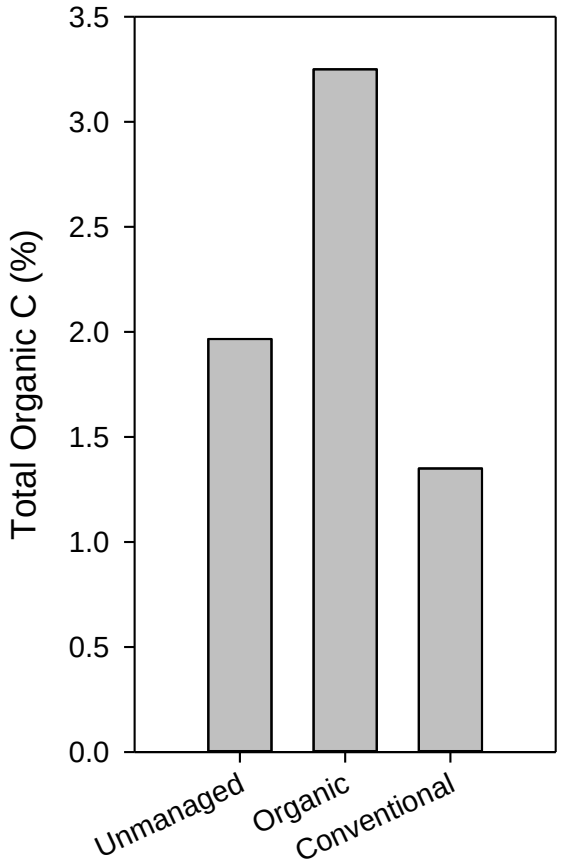
Use soil fertility and soil health testing to ensure crop productivity and environmental stewardship

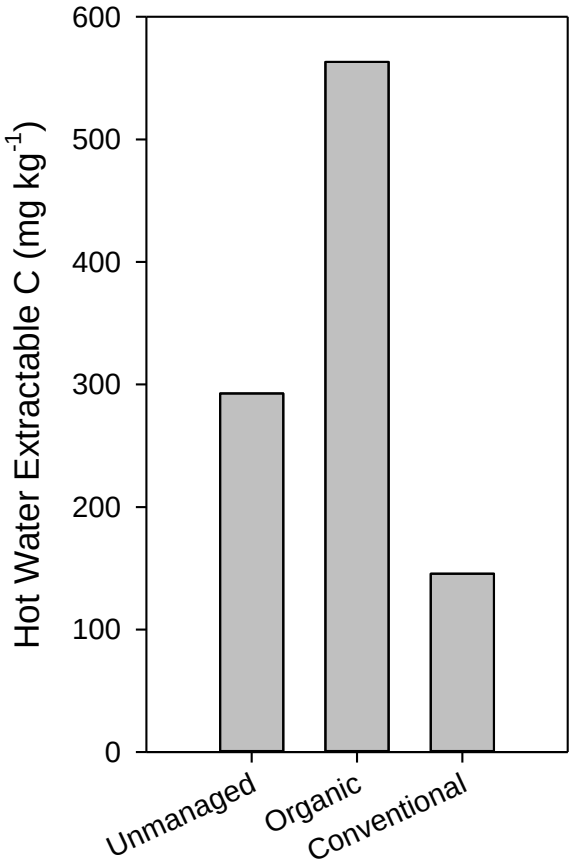
Soil Management and Time in Management Impacts Soil Health

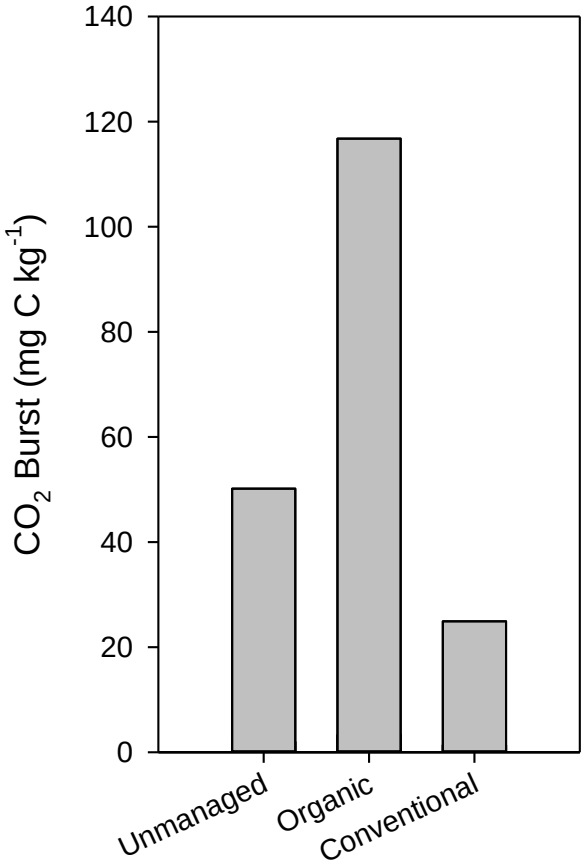


- Soil health in abandoned or unmanaged lands may depend on vegetation cover
  - The Oxisol under unmanaged Leucaena cover has a higher soil health score than the Mollisol under unmanaged guinea grass cover
- Land in long term conventional management shows lowest soil health scores
- Land once in conventional management or abandoned can be improved through organic soil management practices
  - Time in organic management and intensity of organic inputs impact soil health aggradation

Management Effects on Organic Matter and Biological Activity

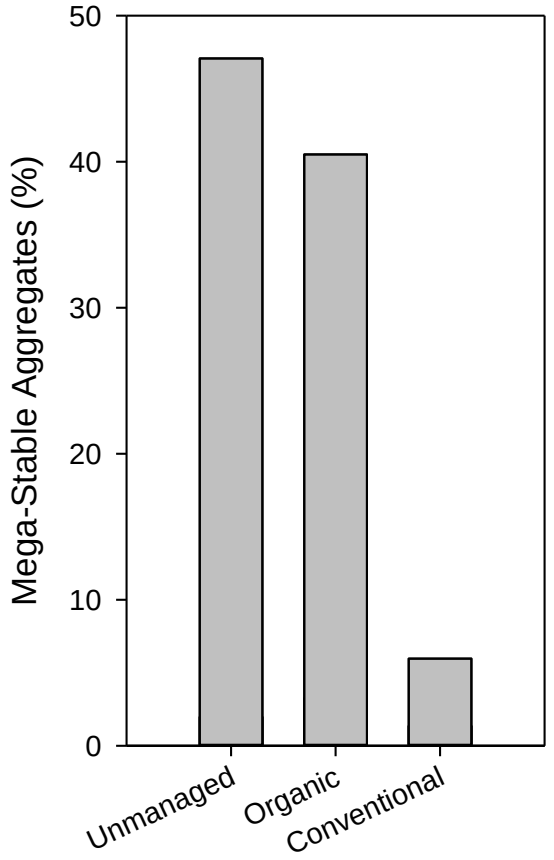


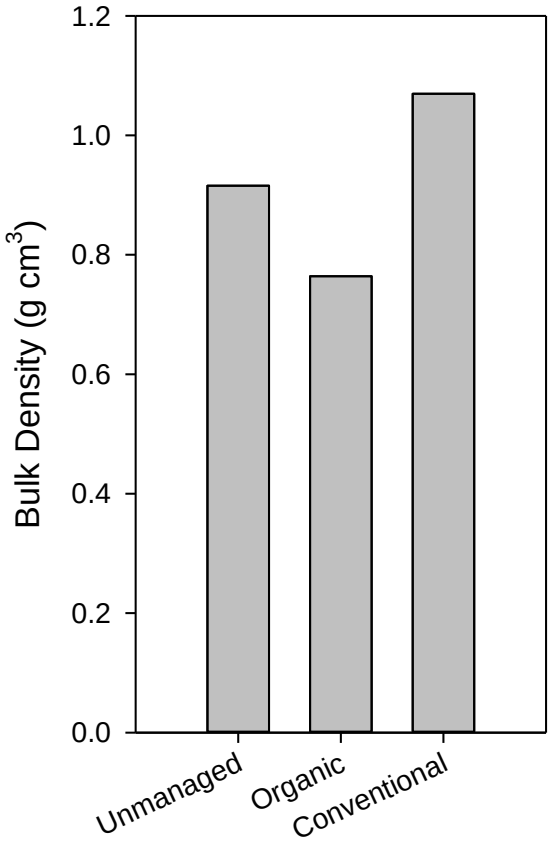


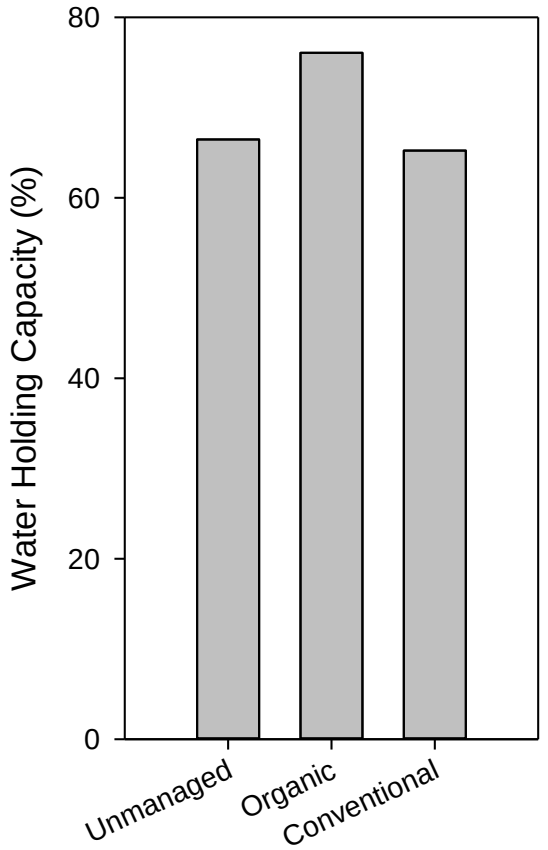


- Management affects quantity of soil organic matter
- Management affects quality of soil organic matter
- Management affects life in the soil

Management Effects on Soil Physical Properties

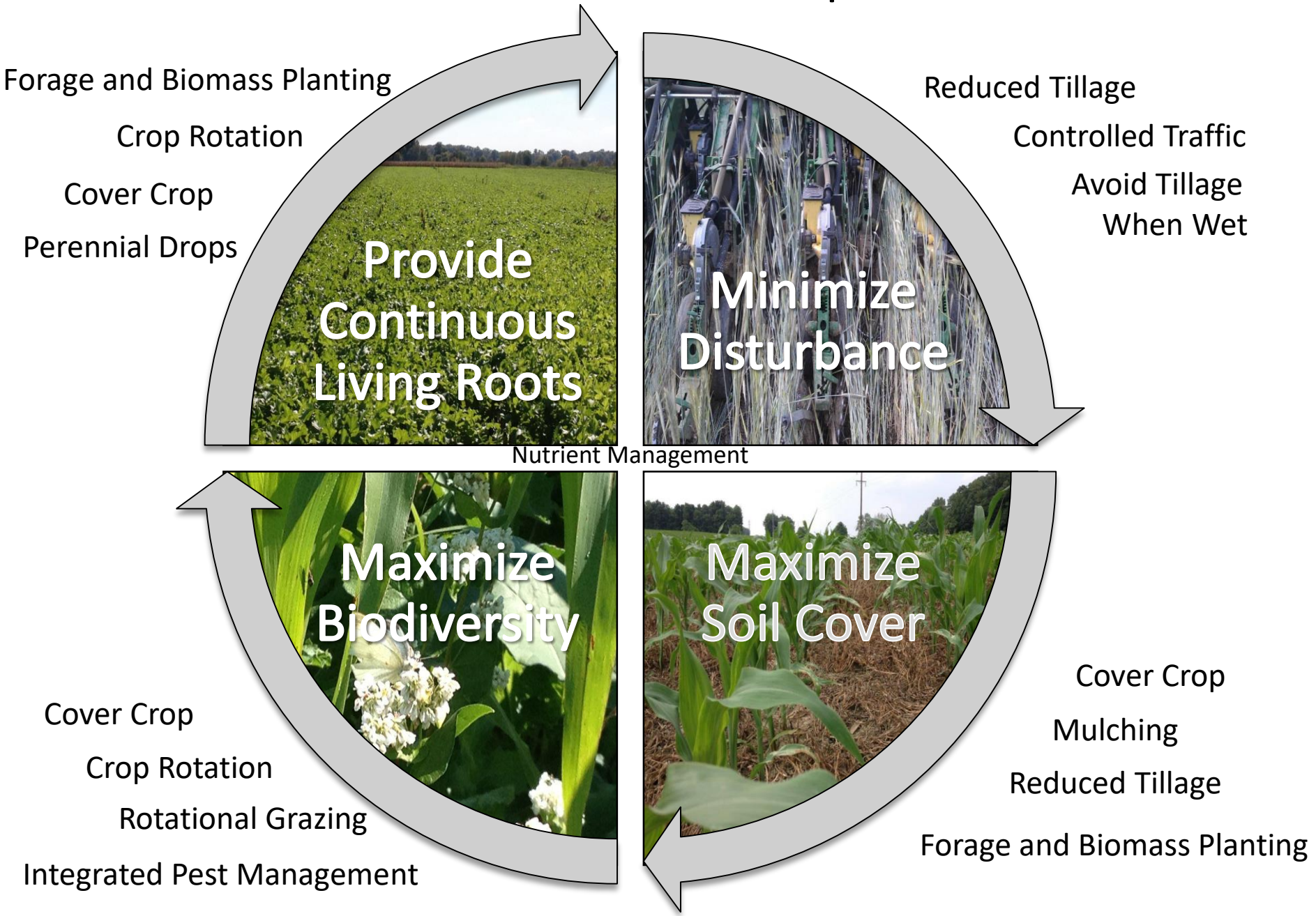






- Loss of aggregates reduces drainage and aeration
- Increases in bulk density reduce aeration and make soil harder to till
- Water holding capacity increases with increasing organic matter

Soil Health Principles



Acknowledgements

- Hannah Hubanks
- Christine Tallamy-Glazer
  - Mitchell Loo and Aleric Krenz
- Dr. Tai Maaz
- Dr. Johanie Zayez
- Dr. Susan Crow
- Many undergraduate students
- Funding
  - USDA HATCH
  - USDA NIFA
  - USDA NRCS


Mahalo