SUSTAINABLE FARMING IN TROPICAL ASIAN LANDSCAPES (SFITAL)

Topic 1:
CONCEPTS ON SOIL HEALTH IN CACAO AGROFORESTRY SYSTEMS

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Outline of the session

Divided into 2 sessions:

1. **Basic concepts on soil health and its urgency in cacao agroforestry systems (30 minutes)**
2. **Method on how soil health in cacao agroforestry systems can be monitored? (30 minutes)**

I. Basic concept on soil health in cacao agroforestry systems

Definition and benefits

"Soil health is the capacity of soil **to function as a living system**, with ecosystem and land use boundaries, **to sustain plant and animal productivity**, maintain or enhance water and air quality, and **promote plant and animal health**.

Healthy soils **maintain a diverse community of soil organisms** that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots; **recycle essential plant nutrients**; improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production" (FAO, 2008).

Soil health vs soil fertility:

- Soil health is the continued capacity of the soil to function to sustain productivity.
- Soil fertility is the ability of the soil to provide nutrients to plants in proper amounts and proportions.

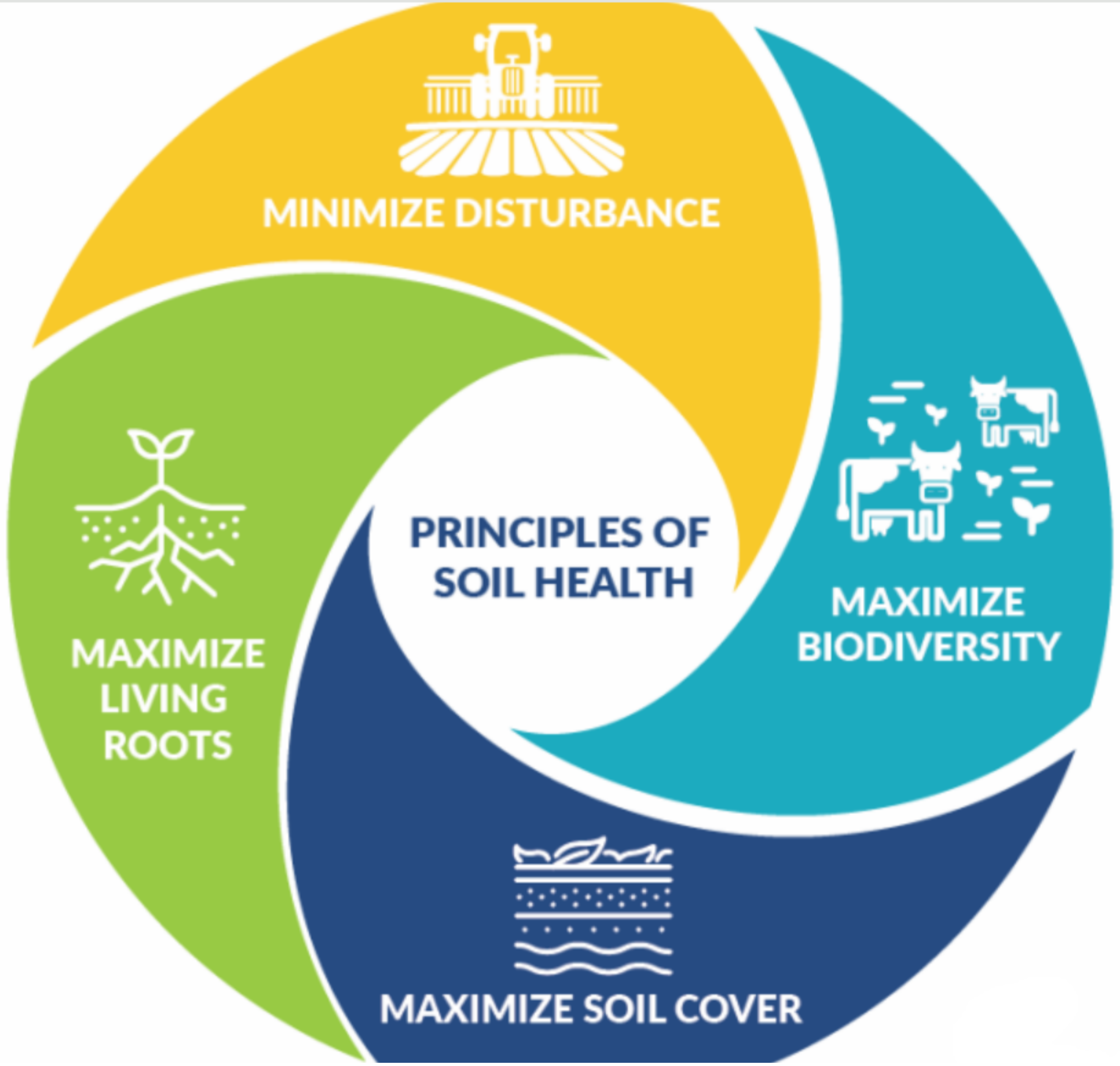
Benefits of soil health in cacao agroforestry systems:

Soil nutrient availability→ soil fertility → Cadmium level in cocoa product

Soil biological characteristics → increase cacao tree resilience to soil-borne pests and diseases

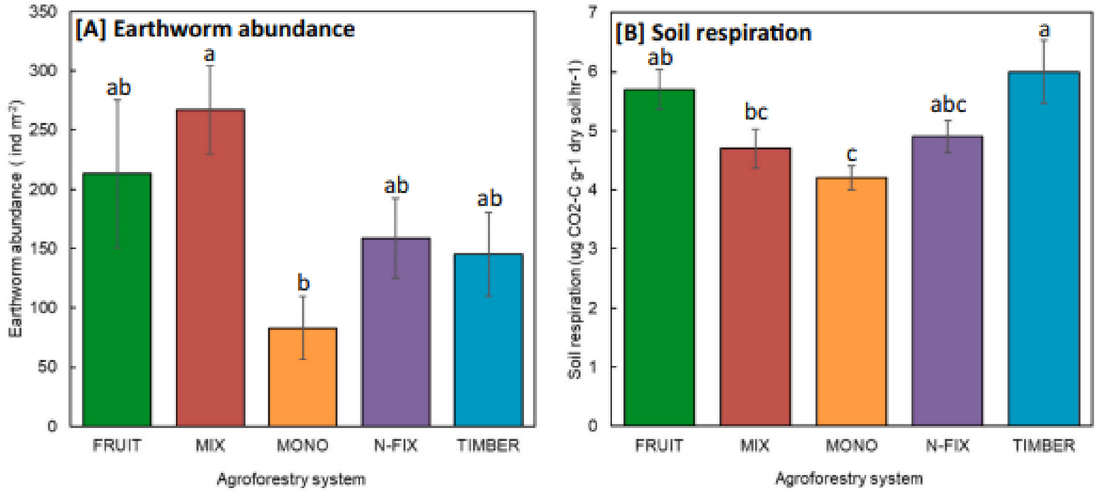
Principles for soil health management

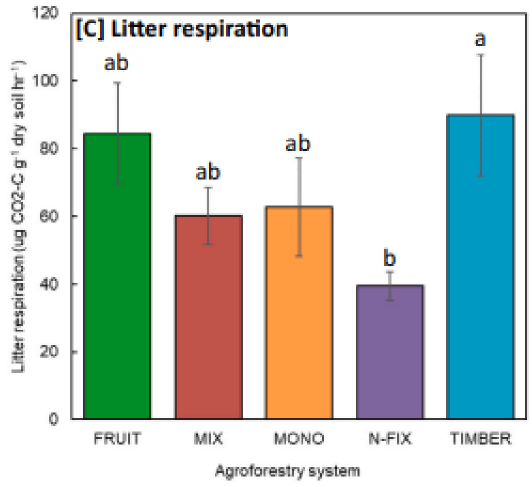
- **Regulating water**
Soil helps control where rain, snowmelt, and irrigation water goes. Water flows over the land or into and through the soil.
- **Sustaining plant and animal life**
The diversity and productivity of living things depends on soil.
- **Filtering and buffering potential pollutants**
The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- **Cycling nutrients**
Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- **Providing physical stability and support**
Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archeological treasures.

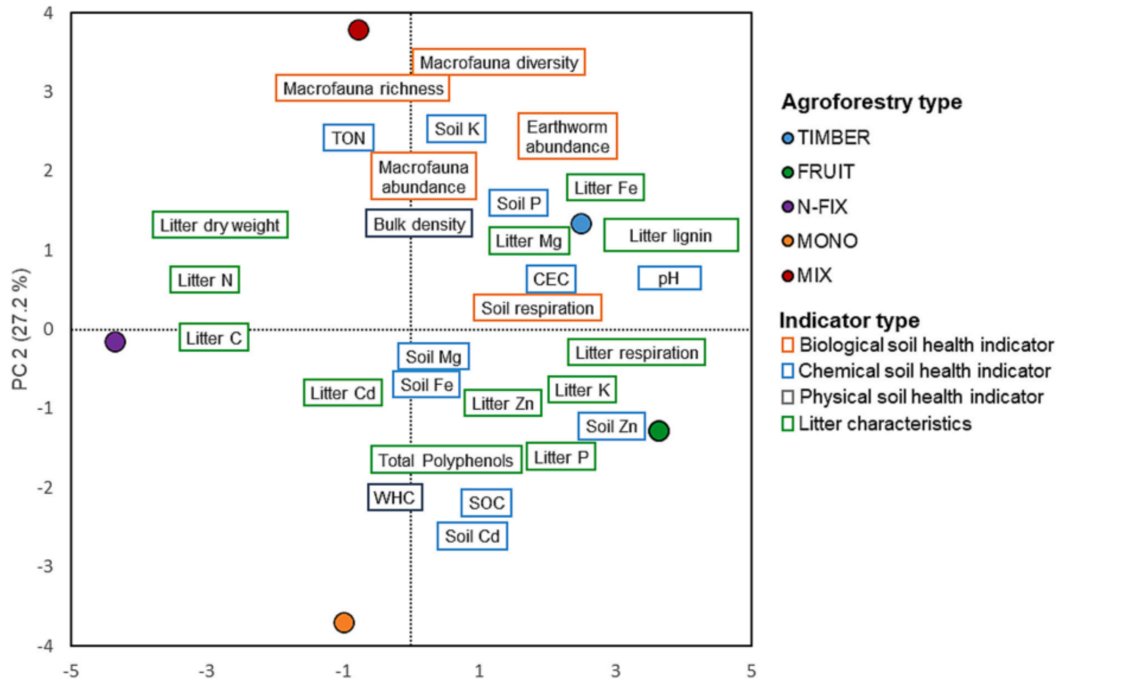


Source: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health

Visscher AM, Chavez E, Caicedo C, Tinoco L, Pulleman M. 2024. Biological soil health indicators are sensitive to shade tree management in a young cacao (Theobroma cacao L.) production system. Geoderma Regional 37 (e00772):1-13.

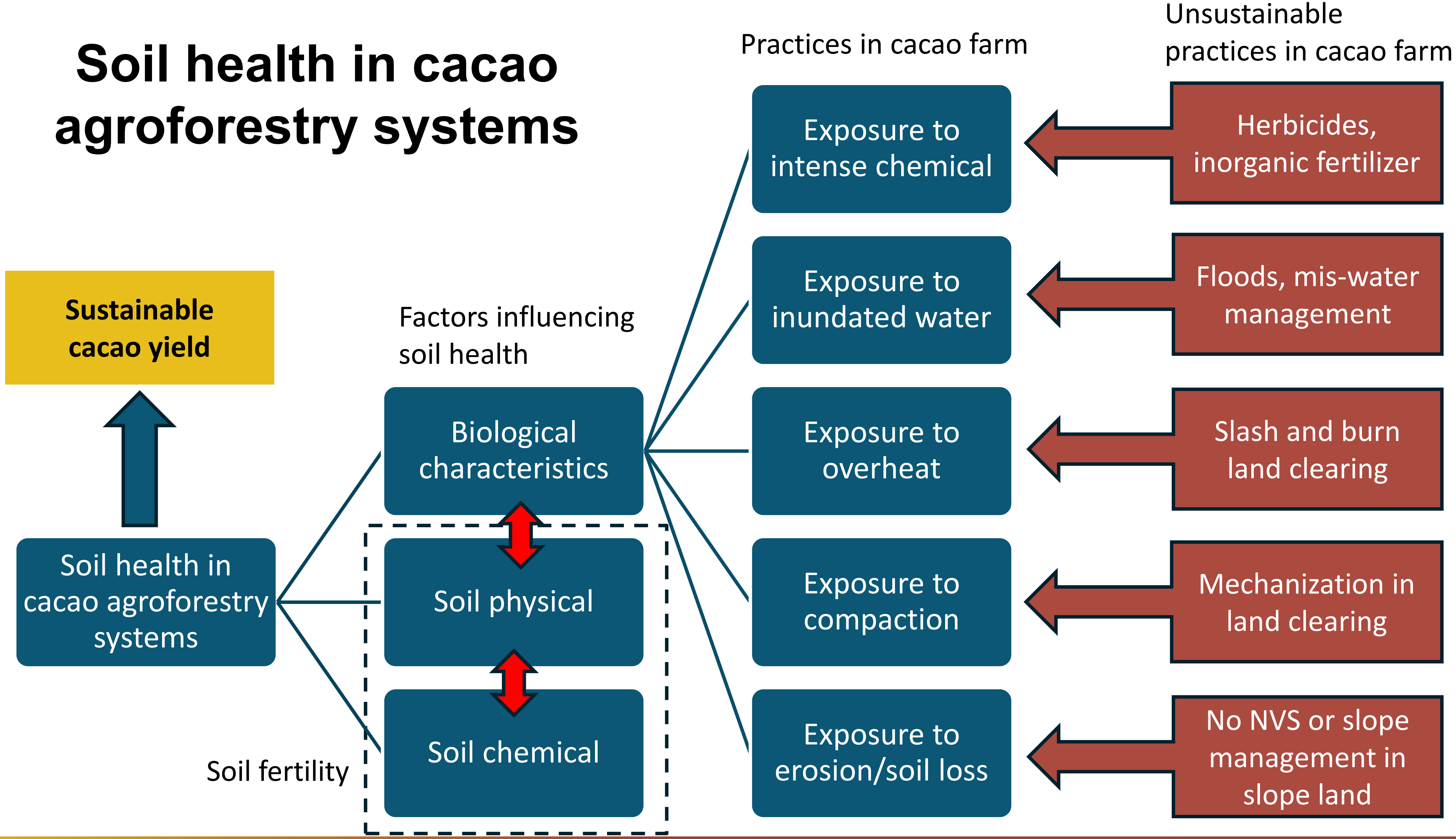






		Cocoa agroforestry systems										p-values		
		FRUIT		MIX		MONO		N-FIX		TIMBER		Treat.	Block	Int.
Indicator	Unit	mean	(s.e)	mean	(s.e)	mean	(s.e)	mean	(s.e)	mean	(s.e)			
Cocoa pod yield														
Yield 2017	$kg\ ha^{-1}$	29.6	(29.62)	48.9	(30.71)	50.6	(30.76)	79.91	(46.97)	29.4	(29.39)	0.667	0.338	0.964
Yield 2018	$kg\ ha^{-1}$	631.7	(116.12)	627.7	(189.67)	545.1	(237.34)	436.6	(74.59)	336.3	(47.06)	0.636	0.501	0.227
Yield 2019	$kg\ ha^{-1}$	79.1	(32.27)	260.2	(111.09)	122.0	(68.37)	116.1	(63.59)	132.5	(58.26)	0.806	0.218	0.508

Soil health in cacao agroforestry systems

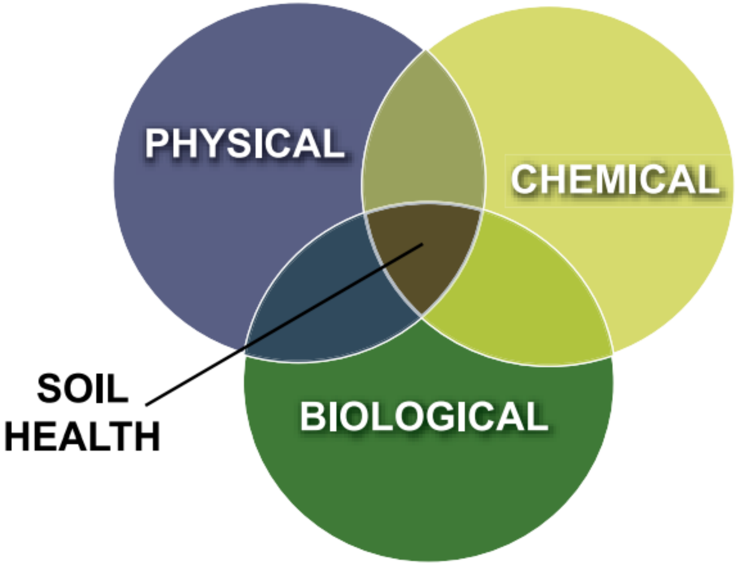


II. Methods for monitoring soil health in cacao agroforestry systems

Indicators of soil health at plot level

https://www.css.cornell.edu/extension/soil-health/2assessment.pdf

Soil health indicators are a composite set of measurable physical, chemical, and biological attributes which relate to functional soil processes and are being used to evaluate soil health status.



The physical, chemical, and biological indicators must be employed to verify soil status use and to undertake remedial management measures within a desired timescale.

Assessment Sheet

Date________________ Crop____________

Farm/Field ID ______________________

Soil Quality	Poor			Medium			Good		
INDICATORS	1	2	3	4	5	6	7	8	9
Earthworms									
Organic Matter Color									
Organic Matter Roots/Residue									
Subsurface Compaction									
Tilth/Friability Mellowness									
Erosion									
Water Holding Capacity									
Drainage infiltration									
Crop Condition									
pH									
Nutrient Holding Capacity									
Other (write in)									
Other (write in)									

Field Notes/Inputs

Farm I.D. ____________

Field I.D. ____________ Date ________

Crop ____________ Acres ________

Inputs

Type *Quantity* *Price*

Fertilizer ____________

Lime ____________

Manure ____________

Cover Crops ____________

Pesticides ____________

Other ____________

Equipment Used ____________

Problems, Comments, Weather Conditions

____

Yields

Amount ____________

Units ____________

Moisture ____________

Price ____________

FIGURE 2.01. Example score card from the Maryland Soil Quality Assessment Book (1997) published by the Natural Resource Conservation Service (available online as a pdf file at bit.ly/NRCSSoilHealthCard).

TABLE 2.01. Potential indicators that were initially evaluated for use in the soil health assessment protocol.

Physical	Biological	Chemical
Texture	Root pathogen pressure assessment	Phosphorus
Bulk density	Beneficial nematode population	Nitrate nitrogen
Macro-porosity	Parasitic nematode population	Potassium
Meso-porosity	Potentially mineralizable nitrogen	pH
Micro-porosity	Cellulose decomposition rate	Magnesium
Available water capacity	Particulate organic matter	Calcium
Residual porosity	Active carbon	Iron
Penetration resistance at 10 kPa	Weed seed bank	Aluminum
Saturated hydraulic conductivity	Microbial respiration rate	Manganese
Dry aggregate size (<0.25 mm)	Soil proteins	Zinc
Dry aggregate size (0.25 - 2 mm)	Organic matter content	Copper
Dry aggregate size (2 - 8 mm)		Exchangeable acidity
Wet aggregate stability (0.25 - 2 mm)		Salinity
Wet aggregate stability (2 - 8 mm)		Sodicity
Surface hardness with penetrometer		Heavy metals
Subsurface hardness with penetrometer		
Field infiltrability		

Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences, School of Integrative Plant Science, Cornell University, Ithaca, NY 14853. http://soilhealth.cals.cornell.edu

Grower:
Bob Schindelbeck
306 Tower Rd.
Ithaca, NY 14853

Agricultural Service Provider:
Mr. Bob Consulting
rrs3@cornell.edu

Sample ID:	LL8
Field ID:	Caldwell Field- intensive management
Date Sampled:	03/11/2015
Given Soil Type:	Collamer silt loam
Crops Grown:	WHT/WHT/WHT
Tillage:	7-9 inches

Measured Soil Textural Class: **silt loam**

Sand: **2%** - Silt: **83%** - Clay: **15%**

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.14	37	
physical	Surface Hardness	260	12	Rooting, Water Transmission
physical	Subsurface Hardness	340	35	
physical	Aggregate Stability	15.7	19	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter	2.5	28	
biological	ACE Soil Protein Index	5.1	25	
biological	Soil Respiration	0.5	40	
biological	Active Carbon	288	12	Energy Source for Soil Biota
chemical	Soil pH	6.5	100	
chemical	Extractable Phosphorus	20.0	100	
chemical	Extractable Potassium	150.6	100	
chemical	Minor Elements Mg: 131.0 / Fe: 1.2 / Mn: 12.9 / Zn: 0.3		100	

Overall Quality Score: **51** / Medium

We used the following values to set thresholds for rating soil health indicators:

i. Scores between 0 and 20 are considered very low (red)

ii. Scores between 20 and 40 are considered low (orange)

iii. Scores between 40 and 60 are considered medium (yellow)

iv. Scores between 60 and 80 are considered high (light green)

v. Scores between 80 and 100 are considered very high (dark green).

Indicators of soil health at landscape level

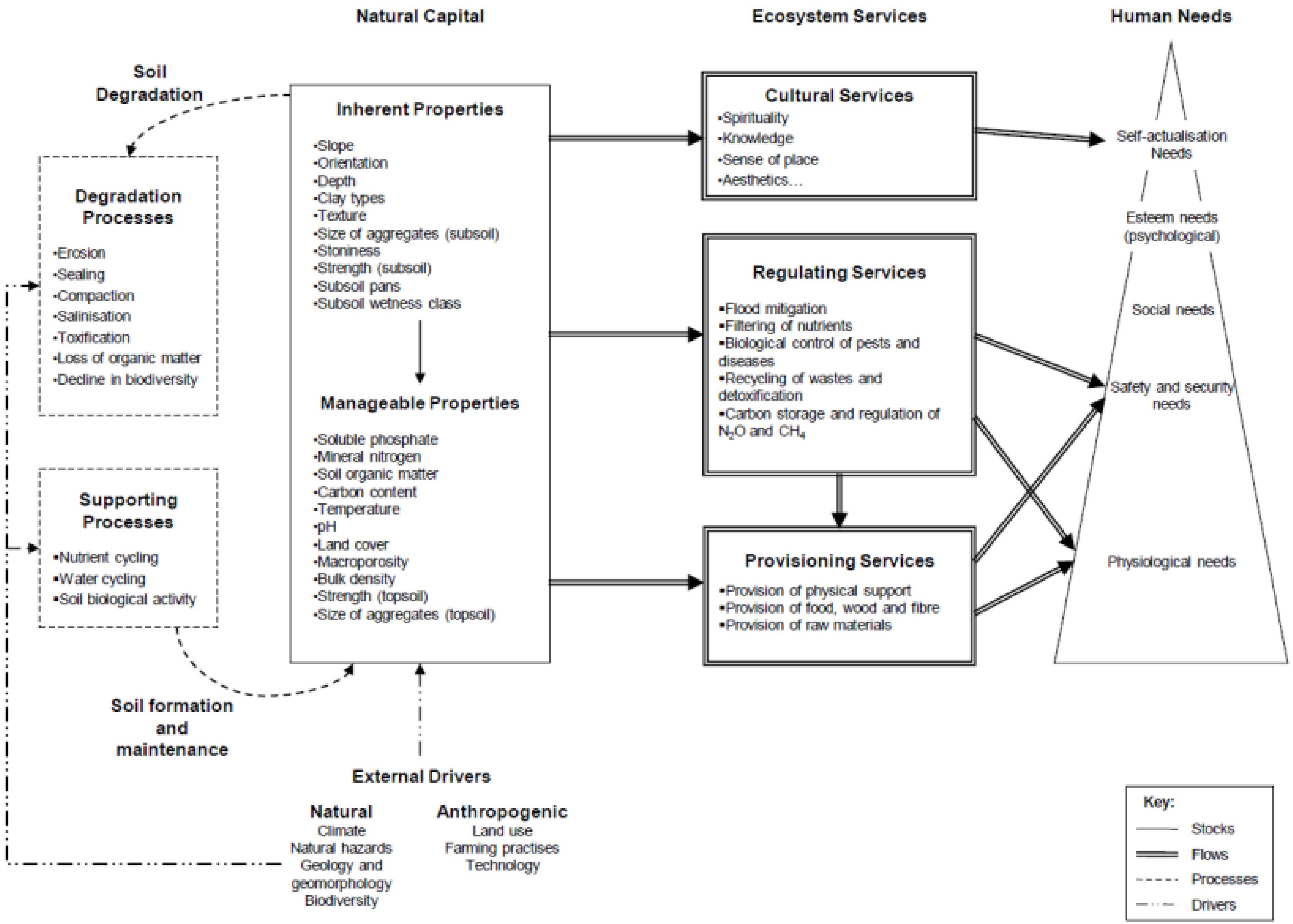


Figure 6. Conceptualisation of soil ecosystem services.
Source: Dominati 2011

Soil organic matter

Soils with high organic matter tend to require lower farm inputs, and be more resilient to drought and extreme rainfall.

Organic matter management is part of soil health management.

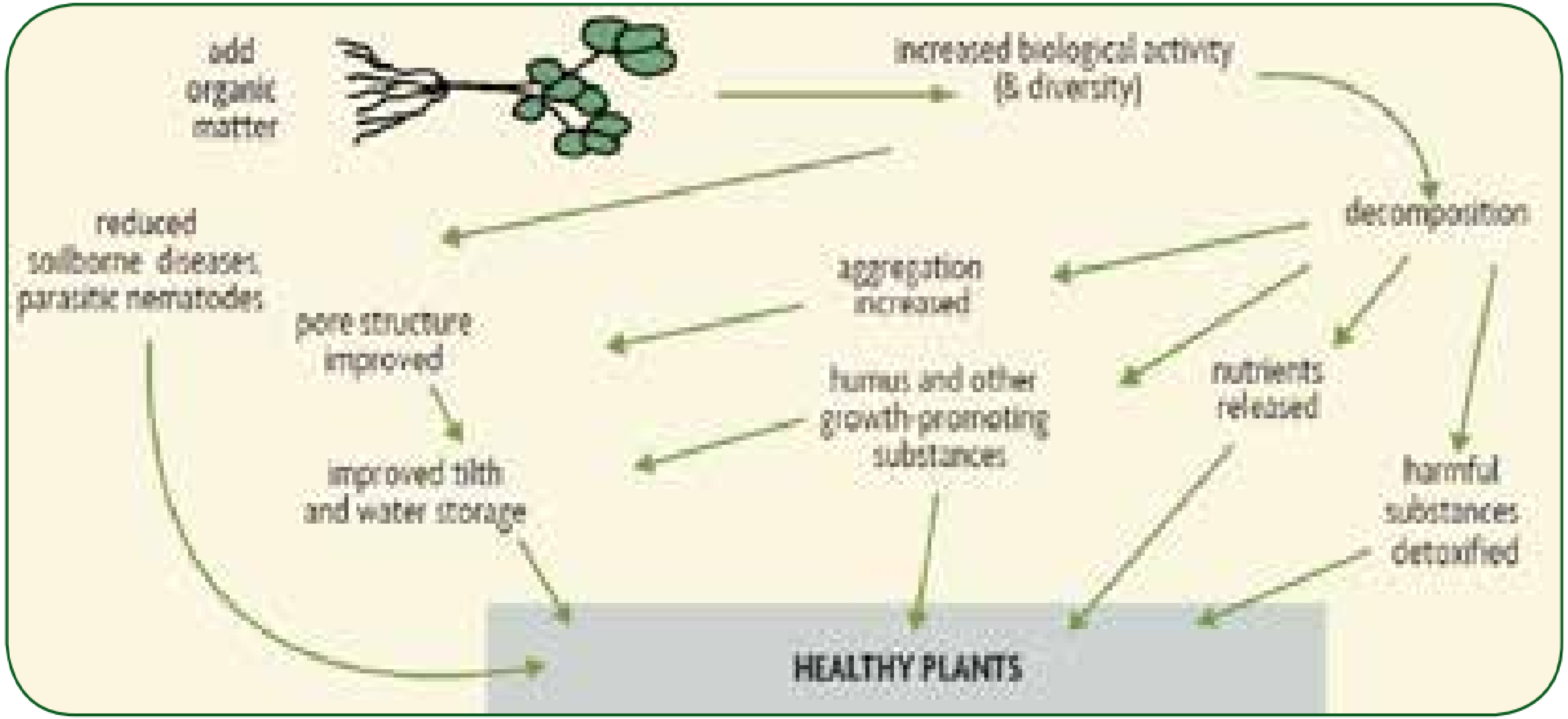


FIGURE 2.30. Adding organic matter results in a cascade of changes within the soil. *Source: Building Soils for Better Crops, 2nd Edition*

Soil pH

- Soil pH is a measure of how acidic the soil is, which controls how available nutrients are to crops.
- Optimum pH is around 6.2-6.8 for most crops (exceptions include potatoes and blueberries, which grow best in more acidic soil).
- If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop. If pH is too low, calcium, magnesium, phosphorus, potassium and molybdenum become unavailable.
- Lack of nutrient availability will limit crop yields and quality. Aluminum toxicity can also be a concern in low pH soils, which can severely decrease root growth and yield, and in some cases lead to accumulation of aluminum and other metals in crop tissue.
- In general, as soil organic matter (SOM) increases, crops can tolerate lower soil pH. Soil pH also influences the ability of certain pathogens to thrive, and of beneficial organisms to effectively colonize roots.

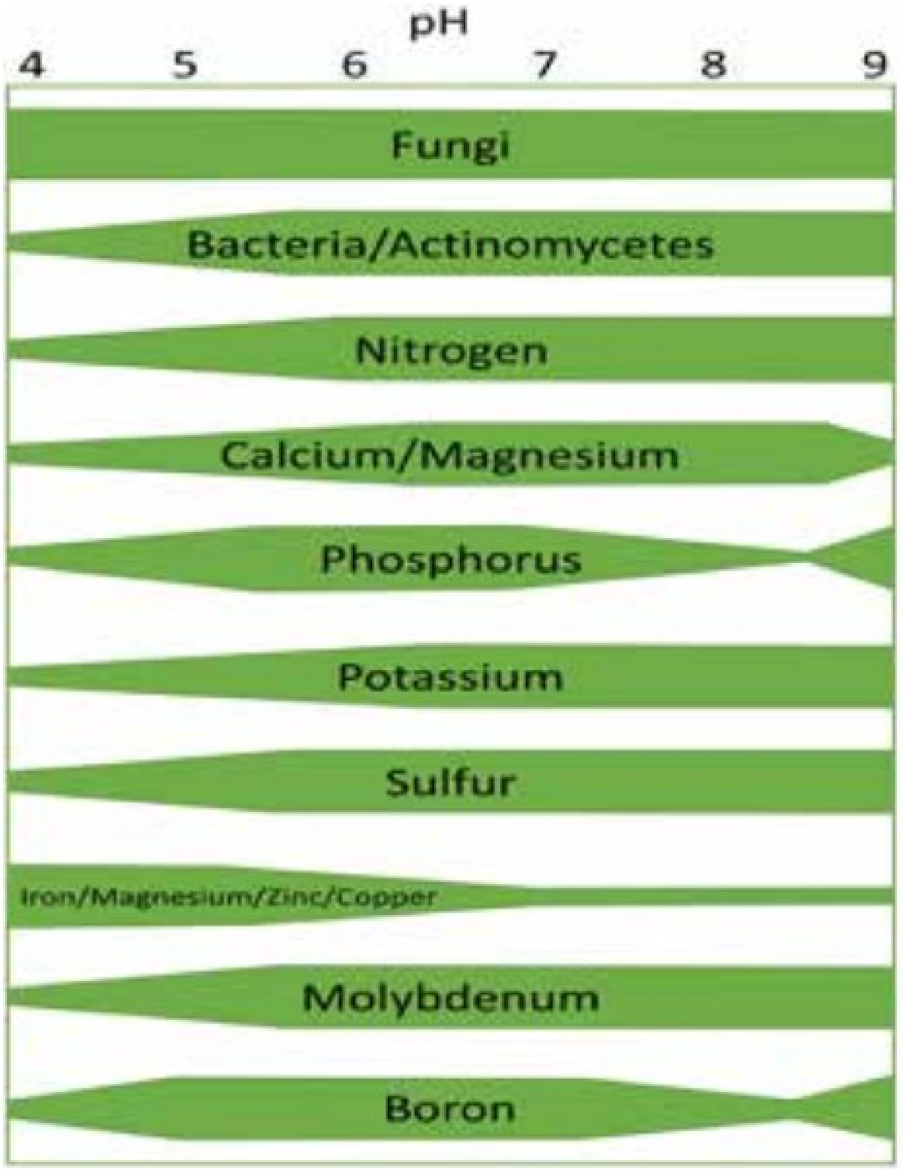
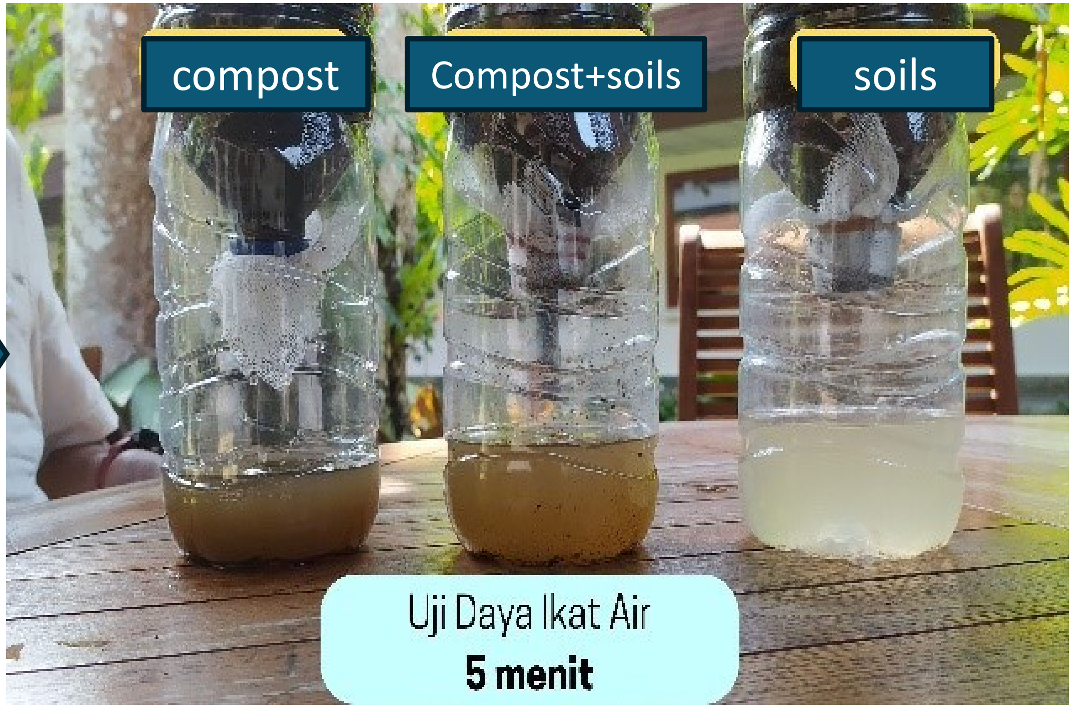


FIGURE 2.39. Relationship between soil pH and plant nutrient availability in soil solution. Modified from Brady and Weil (1999)

Testing the function of compost on soil health indicators (pH and water retention)

Let the water dripping for 5 minutes



- Measure the pH of the water of three treatments and compared the value of pH.
- Measure the height of the water to understand the water retention capacity of the compost.

Thank You

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