Managing Soil Quality for Pasture Sustainability

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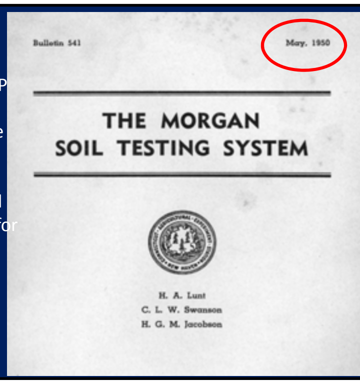
PRESENTATION OUTLINE

1. History and evolution of routine soil testing
2. Soil function and soil health concepts
3. Soil health indicators
4. Factors affecting soil health
5. Limitation and opportunities

HISTORY OF SOIL TESTING

- 1894: citric acid extraction for P (Dyer)
- 1930: procedures to determine water soluble and readily available P
- 1940: increased interest in soil testing as a management tool for fertilizer management
- 1953: Mehlich 1 method for highly weathered soils


Bulletin 541 May, 1950

THE MORGAN SOIL TESTING SYSTEM

H. A. Lunt
C. L. W. Swanson
H. G. M. Jacobson

PURPOSE OF SOIL TESTING

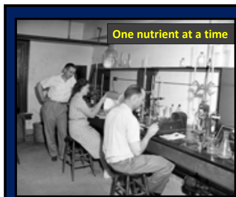
1. Measure the nutrient content or availability of the soil
2. Identify nutrient deficiencies
3. Predict crop response to added nutrients
4. Build a nutrient management plan

The amount of nutrients extracted by a particular extraction procedure <u>is not a direct measure of total nutrients in the soil</u>. It is an index that provides a prediction of the relative nutrient-supplying capacity of the soil compared to the crop needs, usually on a growing season basis. It works best for relatively non-mobile nutrients, such as P, K, Mg.

Soil Testing

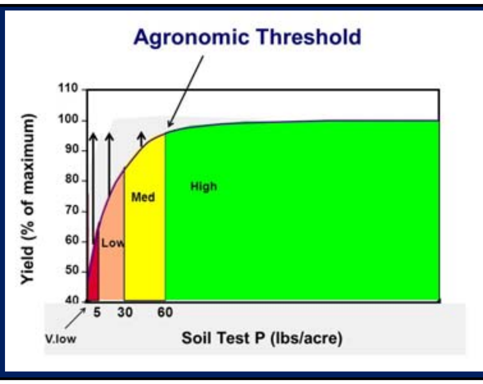
M. Silveira, Soil and Water Science, UF/IFAS Range Cattle REC

Easy to perform, cheap, adapted to a wide range of soil conditions



Evolution of soil testing continues as technological advances allow for improvements in analysis, correlation, and interpretation

Universal
Many elements



Soil Health Definition

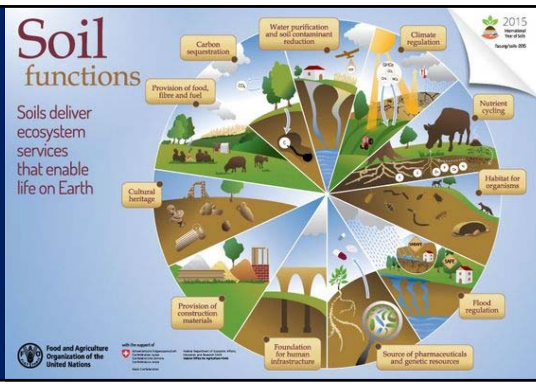
Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS, 2012)

The concept of soil health evolved throughout the 1990's in response to increased global emphasis on sustainable agriculture

Soil Functions

Soils provide 5 essential functions:

1. Regulating water
2. Sustaining plant and animal life
3. Filtering and buffering potential pollutants
4. Cycling of nutrients
5. Physical stability and support



Soil Function

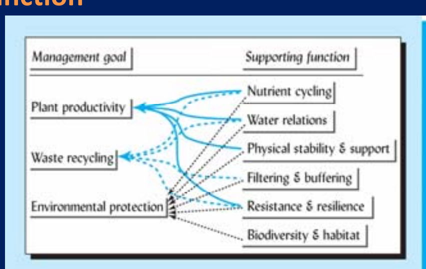


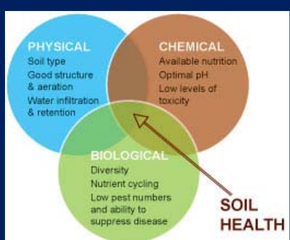
FIGURE 20.1 Examples of broad soil management goals and more specific soil functions that support these goals. The plant productivity management goal aims to maximize the quantity and quality of desired plant production (crops, forage, timber, or native vegetation). The waste recycling goal aims to use the soil efficiently as a means to safely and beneficially deal with manure, sewage sludge, effluent or other "wastes." The environmental protection goal aims to detoxify, immobilize, or isolate potential contaminants to protect air and water resources and the terrestrial food web. For example, a forest manager aiming to maximize timber production (plant productivity) would assess soil quality using indicator properties associated with nutrient cycling, water relations (ability to absorb, store, and release water), physical stability and support, and resistance and resilience functions. [Modified from Andrews et al. (2004)]

Indicators of soil health and related soil functions (Source: National Research Council, 1993).

	Soil Function		
Soil Property	Crop Production	Regulate Water Flow	Buffer Environmental Change
Nutrient availability	direct	indirect	direct
Total organic carbon	indirect	indirect	direct
Labile organic carbon	indirect	direct	direct
Texture	direct	direct	direct
Water holding capacity	direct	direct	indirect
Soil structure	direct	direct	indirect
Rooting depth	direct	indirect	indirect
Salinity	direct	direct	indirect
Acidity/alkalinity	direct	direct	indirect

Soil Health or Quality

Many interrelated physical, biological, and chemical properties determine the *health* of a soil



Soil Health or Quality

Many interrelated physical, biological, and chemical properties determine the *health* of a soil

A "healthy agriculture soil" is one that is capable of supporting the production of food and fiber, to a level and with a quality sufficient to meet human requirements, together with continued delivery of other ecosystem services that essential for maintenance of quality of life for humans and the conservation of biodiversity (Kibblewhite et al., 2008)

Improving soil health can have a large influence on profitability by:

- increasing plant vigor and yield
- reducing risk of yield loss stress (e.g., drought, pests pressure)
- reducing input costs (e.g., less tillage, fertilizer, and pesticides use)

Soil Health Indicators:

- Easy to measure
- Measure changes in soil functions
- Encompass chemical, biological, and physical properties
- Accessible to many users and applicable to field conditions
- Sensitive to variations in climate and management

TABLE 20.1 Selected Biological, Chemical and Physical Indicator Properties for Determining the Quality of Health of a Soil

The soil ecological functions are further explained in Figure 20.1 and some of the listed indicator properties are evaluated in terms of soil quality score in Figure 20.2.

Intrinsic and Dynamic Soil Properties

Most Closely Associated Soil Ecological Functions								
Nutrient cycling	*Water relations*	*Stability-support*	*Buffering-filtering*	*Resilience-resistance*	*Biodiversity habitat*	*Property symbol*	*Property Description*	*Related book sections*
						Biological Properties		
				X	X	MI	Maturity index of nematode trophic levels	Sections 11.2, 11.6
				X	X	qCO_2	Respiration (per unit microbial biomass per day)	Section 20.8
			X		X	MBC	Microbial biomass carbon	Sections 12.2, 20.8
X						MBP	Microbial biomass phosphorus	Sections 14.4, 20.8
X			X			PMN	Potentially mineralizable nitrogen	Section 13.3
X	X			X	X	Active C	Organic carbon oxidized by 0.02 *M* $KMnO_4$	Sections 12.2, 12.6
						Chemical Properties		
X			X		X	Soil test P	Available phosphorus by soil test (e.g. Mehlich 3)	Section 16.11
X			X	X		P_{sat}	Saturation of P fixing capacity ((Al+Fe)/P)	Section 16.12
X			X		X	Soil test K	Available potassium by soil test (e.g. Mehlich 3)	Section 16.11
X			X	X	X	Soil pH	Soil pH (in 1:1 water solution)	Section 9.5
	X	X		X	X	EC	Electrical conductivity	Section 10.4
X	X	X	X	X	X	SAR	Sodium absorption ration	Section 10.4
X	X	X	X	X	X	TOC	Total organic carbon	Section 12.6
X			X	X		CEC	Cation exchange capacity	Section 8.9
						Physical Properties		
X	X	X	X	X	X	AGG	Aggregate stability to slaking when wetted	Section 4.5
X	X	X		X	X	D_b	Bulk density	Section 4.7
X	X	X	X	X	X	Depth	Depth to root limiting layer	Sections 5.9, 17.2
	X		X	X	X	AWC	Plant-available water-holding capacity	Sections 5.4, 5.8
	X	X	X	X		*S*	Infiltration capacity (sorptivity)	Section 5.6
	X	X		X	X	Sand	Percentage of sand in the mineral fraction	Section 4.3
X	X	X	X	X	X	Clay+Silt	Percentage of clay + silt	Section 4.3

Based on concepts in Andrews et al. (2004); Eigenberg et al. (2006); Karlen et al. (2006); Weil et al. (2003). For many of the methods, see Doran and Jones (1996).

TABLE 20.2 Simplified Example of How Indicator Properties Can Be Combined to Give Soil Quality Indices[a]

For simplicity, only two examples of indicator properties are given for each ecological function. Note that an indicator (AGG in this example) may be used for more than one function. In the SQI all indicators and functions are given equal weight. In the SQI_w nutrient cycling is weighted to be 2 times as important as the other functions.

Management Goal	*Supporting ecological function*	*Indicator property*	*Measured value*	*Indicator score (S)*	*Weighting factor (w)*	*Weighted indicator score ($S \cdot w = S_w$)*
Plant production	Nutrient cycling	Soil test P	80 mg P kg $soil^{-1}$	10	2	20
		PMN	20 mg N kg $soil^{-1}$	8	2	16
		etc.	...	...	...	...
	Water relations	AGG	30%	8	1	8
		AWC	20 g H_2O g $soil^{-1}$	8	1	8
		etc.	...	...	...	...
	Physical stability	AGG	30%	8	1	8
		Db	1.4 Mg m^{-3}	6	1	6
		etc.	...	...	...	...
	Resilience	TOC	25 g C kg $soil^{-1}$	4	1	4
		SAR	1.0	9.5	1	9.5
		etc.	...	...	...	...
			Sum of scores or factors =	61.5	$n_w = 10$	79.5
				Average of S = 61.5/8 = 7.7 Unweighted Soil quality index (SQI) = 7.7 × 10 = 77		**Average of S_w = 79.5/10 = 8.0 Weighted Soil quality index (SQI_w) = 8.0 × 10 = 80**

[a] Indicator abbreviations are explained in Table 20.1. See Box text for equations to calculate SQI and SQI_w. See Figure 20.2 for typical curves used to convert measurements to indicator scores.

Soil Quality Test Kit

A simple test for active organic matter as a measure of soil quality

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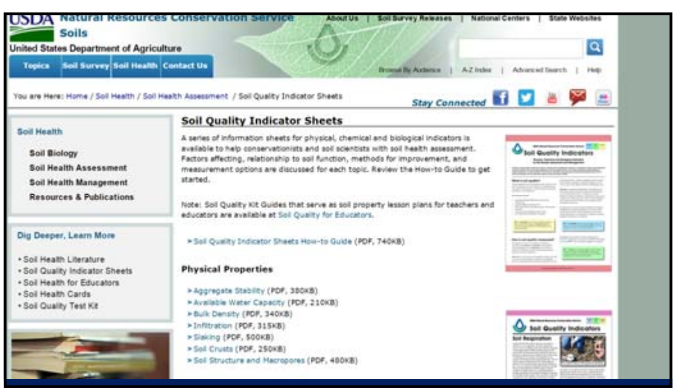
There is a need for farmers and growers to be able to evaluate soil quality in the field to help guide sustainability of agricultural management practices. Since soil organic matter (SOM) is the most widely acknowledged core indicator of soil quality, temporal changes in small but relatively active fractions of SOM may provide an early indication of soils' functional

light pink color. The lighter the color of the $KMnO_4$ solution after reacting with soil, the greater the amount of active organic matter content, and the better the quality of the soil. A 0.02M $KMnO_4$, air-dry soil (or 10 minutes of sunlight on a thin layer of crumbled soil spread in the field), and 2 minutes of shaking providing



Factors Affecting Soil Health

1. Soil type (parent material, topography, climate, vegetation)
2. Land management (erosion, alteration of soil water regimen, soil C)

Intrinsic characteristics (texture, depth) and variable factors such as pH, bulk density and soil organic matter content, which are influenced by land-use and management, then determine the prevailing condition of the habitat within the range for a particular soil. These fixed and variable abiotic factors interact with biotic ones to determine the overall condition of the soil system and its associated health.

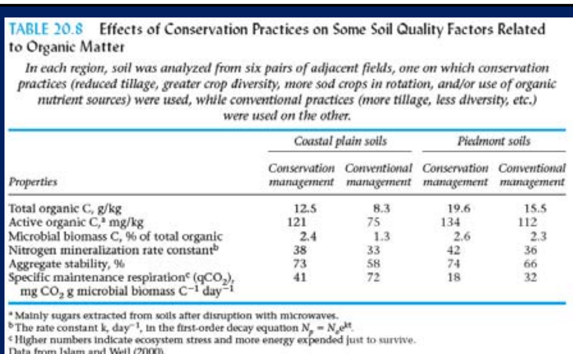


TABLE 20.8 Effects of Conservation Practices on Some Soil Quality Factors Related to Organic Matter

In each region, soil was analyzed from six pairs of adjacent fields, one on which conservation practices (reduced tillage, greater crop diversity, more sod crops in rotation, and/or use of organic nutrient sources) were used, while conventional practices (more tillage, less diversity, etc.) were used on the other.

	Coastal plain soils		Piedmont soils	
Properties	Conservation management	Conventional management	Conservation management	Conventional management
Total organic C, g/kg	12.5	8.3	19.6	15.5
Active organic C,[a] mg/kg	121	75	134	112
Microbial biomass C, % of total organic	2.4	1.3	2.6	2.3
Nitrogen mineralization rate constant[b]	38	33	42	36
Aggregate stability, %	73	58	74	66
Specific maintenance respiration[c] (qCO_2), mg CO_2 g microbial biomass C^{-1} day^{-1}	41	72	18	32

[a] Mainly sugars extracted from soils after disruption with microwaves.
[b] The rate constant k, day^{-1}, in the first-order decay equation $N_p = N_0 e^{kt}$.
[c] Higher numbers indicate ecosystem stress and more energy expended just to survive.
Data from Islam and Weil (2000).

Limitations

Assessment of soil health across agricultural systems, soil types and climatic zones presents major scientific and policy challenges

1. Lack of standard procedures
2. Results interpretation
3. High cost ($50-150/sample)
4. Economic factors may also limit the extent to which soil health concept can be adopted at a farm scale

Opportunities

❖ To date, our current economic system only rewards farmers for agricultural products they produce

❖ There is a growing recognition that agriculture and, more specifically, soil management can provide much more than food, fuel, and fiber

❖ Documenting critically important ecosystem services offers a potential for society to recognize farmers and land managers for the true value they provide to society

THANKS

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