INTERPRETING SOIL HEALTH TEST RESULTS TO GUIDE MANAGEMENT FOR MISSOURI ROW CROPS

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ABSTRACT

Soil health testing provides an integrated measure of the physical, chemical, and biological properties that determine a soil's capacity to function as a living ecosystem. This study summarizes the interpretation framework developed by the University of Missouri Soil Health Assessment Center (SHAC) to help Missouri farmers understand their soil health test reports. Data are based on over 13,000 soil samples collected statewide, providing benchmarks for key indicators such as Total Organic Carbon (TOC), Permanganate Oxidizable Carbon (POXC), Soil Respiration, Wet Aggregate Stability (WAS), ACE Protein, Potentially Mineralizable Nitrogen (PMN), and soil texture. The SHAC soil health scoring system enables producers to assess biological activity, nutrient cycling, and soil structure while identifying management practices that improve soil function over time.

INTRODUCTION

Soil health is the foundation of productive and sustainable farming systems. Unlike conventional soil fertility tests, which focus on nutrient availability, soil health testing evaluates the physical, chemical, and biological functions that support long-term productivity (Zuber et al., 2020, 2021). In Missouri, variable soil types, climate conditions, and management histories impact soil function. The Soil Health Assessment Center (SHAC) developed a comprehensive soil health test and interpretation guide to support management decisions. This proceeding summarizes key indicators and interpretation methods used by SHAC and outlines management recommendations based on measured soil health categories.

MATERIALS AND METHODS

Soil samples were analyzed at the University of Missouri Soil Health Assessment Center following standardized laboratory protocols. Indicators measured included Total Organic Carbon (TOC), Permanganate Oxidizable Carbon (POXC), 3-Day Soil Respiration, Wet Aggregate Stability (WAS), ACE Protein, and Potentially Mineralizable Nitrogen (PMN). These indicators were scored from 1 to 5 and categorized as Very Low, Low, Medium, High, or Very High based on percentile rankings of over 13,000 soil samples representing Missouri's major soil regions (Table 1). A composite soil health score was calculated as the mean of individual indicator scores.

RESULTS AND DISCUSSION

Total Organic Carbon: It measures the amount of carbon in soil organic matter (SOM). It's a key indicator of long-term soil health, affecting nutrient cycling, soil structure, water-holding capacity, and biological activity. A higher TOC indicates better soil fertility and resilience.

Permanganate Oxidizable Carbon: POXC represents the active, easily available portion of soil organic carbon for microbes. This fraction responds quickly to management changes and serves as an early indicator of changes in soil health. Higher POXC values typically reflect better biological activity, nutrient cycling, and soil structure.

Soil Respiration: Soil respiration quantifies CO_2 released from soil over a short incubation period. It reflects microbial activity and the breakdown of organic matter. Higher values indicate the presence of active microbes and healthy soil processes. Practices such as reduced tillage, cover crops, and organic amendments enhance soil respiration.

Wet Aggregate Stability: WAS indicates the ability of soil aggregates to resist breakdown when exposed to water. Higher WAS means better soil structure, improved water infiltration, and lower erosion risk. Increasing SOM and microbial activity through cover crops and reduced tillage improves WAS.

ACE Protein: It measures easily extractable organic nitrogen (amino acids and peptides) that feed soil microbes. It reflects the soil's ability to supply nitrogen through SOM decomposition. Practices that build SOM—like cover crops and manure—boost ACE Protein levels and overall soil nitrogen cycling.

Potentially Mineralizable Nitrogen: PMN estimates the amount of organic nitrogen that can be converted to plant-available forms by microbes. High PMN signals strong microbial activity and potential for natural nitrogen supply, without requiring heavy fertilizer inputs. Influenced by SOM, moisture, temperature, and management practices such as cover cropping, reduced tillage, and organic amendments.

Soil Texture: Soil texture reflects the relative proportions of sand, silt, and clay present in a soil sample, which determines its textural classification. This classification affects important soil characteristics, including porosity, water-holding capacity, drainage, root penetration, and nutrient retention. Information on soil texture helps inform decisions about crop selection, nutrient and water management, and tillage practices. Soil texture is measured only once at a given location, as it changes very slowly over time, in the order of decades or centuries, under natural conditions.

The statewide database revealed wide variability in soil health indicators across Missouri regions. Total Organic Carbon (TOC) ranged from less than 1% in degraded systems to over 3% in well-managed soils. Biological indicators such as POXC, ACE Protein, and PMN were highly responsive to management practices like reduced tillage, cover cropping, and manure use.

Table 1. Summary of six soil health indicator interpretation ranges, soil health status/implication, and percentile of Missouri (MO) soils under five different soil health categories.

Soil Health Category	Health Test Ranges	Soil Health Status/Implication	MO Soil* Percentile
Total Organic Carbon (%)			
1. Very Low	< 0.75	Severely depleted soil organic matter; limited nutrient retention, microbial life, and structure. High risk of erosion and compaction. Requires major restoration	0-5
2. Low	0.75 – 1.5	Reduced biological and physical functioning, suboptimal productivity. Indicates recent degradation or low input history.	6-25
3. Medium	1.6 – 2.5	Adequate carbon level for moderate productivity. Needs improvement for long-term sustainability.	26-80
4. High	2.6 – 3.5	Well-structured, fertile, and biologically active soil. Supports resilient cropping systems.	81-95
5. Very High	> 3.5	Exceptional soil quality may support ecosystem services beyond crop production (e.g., carbon sequestration). high microbial and nutrient potential.	96-100
Permanganate Oxidizable Carbon (POXC) (ppm)			
1. Very Low	< 200	Poor biological activity; depleted microbial food base. Often compacted or over-tilled soils, low fertility.	0-5
2. Low	200 – 400	Microbial activity and nutrient cycling are limited. Needs organic inputs and cover crops.	6-25
3. Medium	401 – 600	Moderate microbial function. Can support productivity with balanced management.	26-80
4. High	601 – 800	High biological activity and potential nutrient turnover. Indicates active soil management.	81-95
5. Very High	> 800	Very active microbial system; strong indication of biological soil health and carbon inputs.	96-100
3-Day Soil Respiration (mg CO_2 kg soil^{-1} 3-day^{-1})			
1. Very Low	< 300	Microbial dormancy indicates biological inactivity, possible compaction or low organic matter.	0-5
2. Low	300 – 550	Limited microbial turnover may indicate stress or need for organic inputs.	6-25
3. Medium	551 – 950	Functioning microbial system; moderate nutrient cycling and soil life.	26-80
4. High	951 – 1300	High biological activity and good organic matter decomposition.	81-95
5. Very High	> 1300	Very active system: excellent biological health but must be balanced to avoid rapid soil organic matter depletion.	96-100
Wet Aggregate Stability (%)			
1. Very Low	< 10	Very unstable soil structure; high erosion risk and poor water retention.	0-15

2. Low	10 – 25	Weak structure; likely surface crusting and low porosity.	16-50
3. Medium	26 – 45	Moderately structured; can support crops but is sensitive to disturbance.	51-75
4. High	46 – 70	Stable structure; good infiltration and microbial habitats.	76-95
5. Very High	> 70	Excellent aggregation; supports soil aeration, root growth, and resilience to stress.	96-100
Autoclaved Citrate-Extractable (ACE) Soil Protein (g kg^{-1})			
1. Very Low	< 2.5	Poor soil N mineralization potential: microbial biomass is limited.	0-5
2. Low	2.5 – 4.0	Low microbial nutrient access; needs OM input and less disturbance.	6-25
3. Medium	4.1 – 7.0	Moderate soil protein availability; balanced biological N cycling.	26-80
4. High	7.1 – 10.0	Good protein and nutrient cycling potential; resilient system.	81-95
5. Very High	> 10.0	High N mineralization and biological activity. May support N credits in management.	96-100
Potentially Mineralizable Nitrogen (ppm)			
1. Very Low	< 30	Very low N availability: likely N deficiency unless supplemented.	0-5
2. Low	30 – 60	Suboptimal N cycling: reliance on synthetic N expected.	6-25
3. Medium	61 – 100	Moderate potential for organic N release; supports partial N supply.	26-80
4. High	101 – 140	High N supply potential; supports reduced N fertilization.	81-95
5. Very High	> 140	Excellent N mineralization; may allow crediting N in recommendations.	96-100
*Based on over 13,000 cover crop cost-share data across different soil textures in Missouri			

Management Recommendations

The management recommendations based on the overall soil health score are provided.

1. **Very Low Soil Health (overall score <1.76)**
    - Adopt no-till immediately to reduce erosion and preserve remaining topsoil.
    - Use cover crops intensively, ideally every year, with diverse species mixes to build organic matter and provide winter protection.
    - Apply high rates of manure, if nutrient tests indicate a need, to jump-start biological activity.
    - Diversify rotations with legumes and deep-rooted crops to improve aggregation and nitrogen cycling, avoiding monoculture systems.
    - Avoid bare fallow — maintain soil cover year-round.
    - Be patient, improvements may take several years, but erosion control and soil cover offer immediate benefits.

2. **Low soil health (overall score 1.76 – 2.75)**

- Maintain no-till and cover cropping; positive trends are beginning, but more improvement is needed.
- Maximize living roots year-round to enhance soil biology and structure.
- Ensure adequate fertility for both cover crops and cash crops to support biomass production.
- Diversify rotations with legumes and deep-rooted crops to improve aggregation and nitrogen cycling, avoiding monoculture systems.
- Incorporate organic amendments, like manure, to build soil carbon and nutrients.
- Minimize compaction via controlled traffic and cover crop roots.
- Avoid bare fallow — maintain soil cover year-round.
- Soil tests every 3-4 years to track progress and guide inputs.

3. **Medium soil health (overall score 2.76 – 3.75)**
    - Continue core practices: no-till, cover crops, and diverse rotations.
    - Introduce multi-species cover crop mixes (legumes + grasses + brassicas).
    - Optimize cover crop management, allowing more spring growth if it doesn't interfere with planting.
    - Continue organic inputs, focusing on manure for stable carbon. Consider adding carbon-rich amendments (e.g., biochar) if erosion or leaching is a concern.
    - Enhance nutrient cycling with practices like precision fertilization and split applications.
    - Manage crop residues in place to reduce disturbance and retain carbon.
    - Keep improving diversity above and below ground.
    - Avoid setbacks, such as deep tillage or long bare fallow periods.
    - Soil tests every 3-4 years to track progress and guide inputs.

4. **High soil health (overall score 3.76 – 4.75)**
    - Maintain current practices, no-till, cover crops, with continued diversity and minimal disturbance to preserve soil function.
    - Select cover crops strategically (e.g., legumes for nitrogen, grass for carbon) to support biological processes.
    - Monitoring nutrient levels, higher organic matter may support nutrient supply but also increases removal from high yields.
    - Fine-tune nutrient management using soil health data (e.g., credit more nitrogen if respiration, ACE protein, and PMN are high). Avoid over-application of synthetic nitrogen to maintain microbial balance.
    - Monitor long-term trends and weather-induced variability.
    - Trial innovative practices like companion cropping or biological amendments to further optimize.
    - Begin to document carbon sequestration gains if considering carbon markets.
    - Use flexible practices cautiously, allowing only occasional intensive tillage when necessary for weed and pest management.

- Stay proactive to maintain gains; soil can decline quickly without consistent management.

5. **Very High soil health (overall score >4.75)**
   - Continue all core soil health practices; these fields are high-performing assets.
   - Explore innovative practices like precision nutrient management, inter-seeding cover crops, or livestock integration.
   - Prevent degradation: watch for overuse of inputs, overgrazing, or tillage creep.
   - Monitor soil health metrics regularly (e.g., aggregate stability, microbial activity) to ensure continued success.
   - Educate and share: These soils could serve as benchmarks or demonstration plots.
   - Experiment carefully with new practices, documenting impacts.
   - Consider ecosystem service monetization (e.g., carbon credits, water quality credits).
   - Avoid complacency; high-functioning soils can degrade rapidly with mismanagement.
   - Protect long-term productivity by treating these fields as models of conservation and resilience.

CONCLUSIONS

The Missouri Soil Health Assessment provides a comprehensive framework for evaluating the biological, chemical, and physical health of soils. Interpreting soil health results in relation to statewide benchmarks enables producers to identify constraints and select suitable management practices. Practices such as reduced tillage, cover cropping, organic amendments, and crop rotation diversity are crucial for enhancing soil function and long-term productivity.

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