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Soil Health Testing and Practices

Science of Soil Health at NRCS

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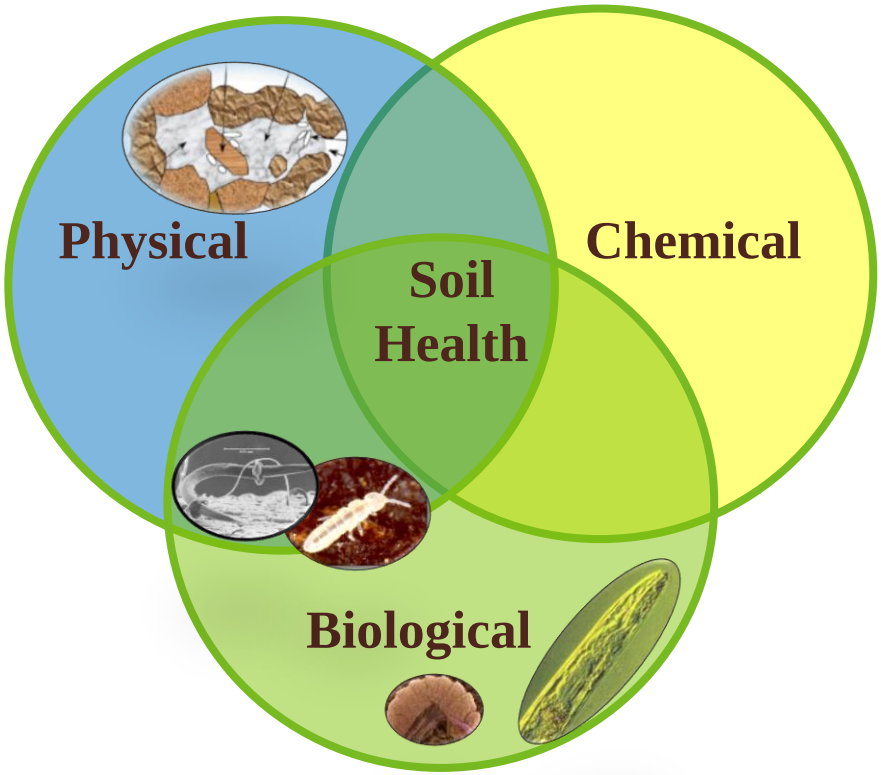
What is Soil Health?

The continued capacity of a soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS).



Goal: WIN-WIN Regenerative Soil Health Management Systems Become the Common Place on America's Working Lands

Reduced tillage, more rooting, higher diversity, surface cover

Aggregates rebuilt

Infiltration increases, wind and water erosion decrease

Less energy, inputs and tillage needed, more water stored, better rooting, more nutrient access, greater soil organism diversity, less disease

Better crop yields & quality; lower cost, risk, environmental impact; higher resilience

Field conditions more resilient and consistent

More SOC, nutrients, and top soil built

AWHC increases

SOC increases, rooting reduces compaction

Modified by Moebius-Clune and Cox from *Building Soils for Better Crops*

Translating Principles to Specific Management Systems

Geographically specific implementation challenges

For example

- **KS:** Is there enough water for a cover crop?
- **FL:** Will enough residue remain to suppress weeds?
- **CA:** how to economically justify a cover crop, when a high value vegetable crop could grow instead?
- **WY:** What management effort is economically worth while when climate variability strongly influences soil functioning?
- **Northeast relevant cover cropping challenges include:**
  - Is there enough growing season for cover crop establishment?
  - What variety will produce enough biomass given growing season left?
  - What varieties establish well under a cash crop?
  - How to adjust N rates for the next cash crop based on the cover crop
  - Will residue keep the soil too wet or cold in the spring?

→ **Gaps in the Science of Soil Health**

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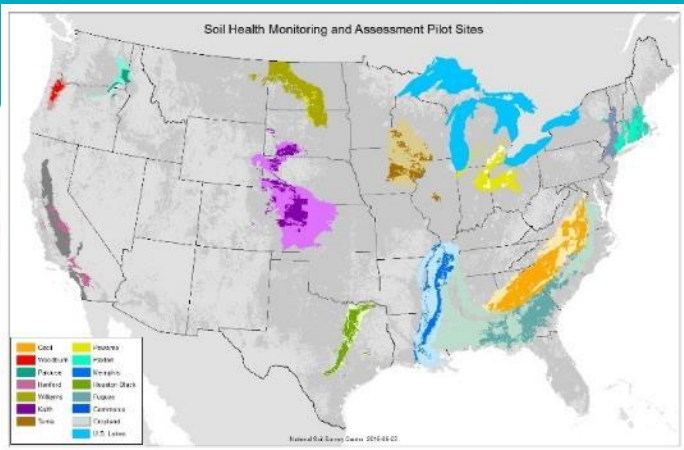
NRCS
Science of Soil Health Efforts

Strengthening the Science of Soil Health



Leveraging agency wide technical capacity and infrastructure, as well as partner resources to assess, monitor, and enhance Soil Health

Components:

1. *Evaluate existing literature on indicators and their interpretation & soil health management systems implementation*
2. *Leverage existing projects for data and field insights*
3. *Build and populate NRCS soils database with soil health data*
4. *Monitor soil health on representative benchmark soils and evaluate management impact and contribute to assessment*
5. *Develop soil health management decision tools and citizen science portal*

Opportunities for collaboration exist in every component

Goals

- **Long-term project to support the overall objectives of NRCS**
- **Advance the science that will support**
  - **Soil/climate based interpretation** of measures of soil health
  - **Recommendations** on soil health management approaches
  - **Quantification and communications of outcomes**: agronomic, environmental, and economic outcomes that are and can be achieved with management changes
  - **Integration** into tools for conservation planning and implementation available to NRCS and partners
  - **Broad nationwide adoption** of SHMSs

Ultimately: Approach for use by NRCS & beyond

based on decades of work by ARS and university (NIFA) scientists, similar to standard soil test recommendation approach

Conservation Planning Process and Soil Health

1. Identify Problems
2. Determine Objectives
3. Inventory Resources*
4. Analyze Resource Data
5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions
8. Implement Plan
9. Evaluate Plan*

- Planning Criteria & Field Assessment
- Measure SH Indicators & Interpret status relative to soil/climate
- Plan management to address constraints
- Implement
- Monitor, Evaluate

NRCS Resource Definitions

Resource Concern: An expected degradation of the soil, water, air, plant, or animal resource base to the extent that the sustainability or intended use of the resource is impaired.

Planning Criteria (PC): …Used to determine whether or not there is a resource concern associated with a specified land use….

NRCS Definitions

Screening: Use of available information to identify sites with conditions that have little or no probability of needing additional treatment to address the specific resource concern.

Screening may utilize available soils data, management information from the farmer, visual observations, and/or site conditions.

Assessment: The act of assessing the physical condition or extent of management applied.

NRCS Soil Resource Concerns*

- Sheet and rill erosion
- Wind erosion
- Ephemeral gully erosion
- Classic gully erosion
- Bank erosion from streams, shorelines or water conveyance channels
- **Compaction**
- **Organic matter depletion**
- **Concentration of salts or other chemicals**
- **Soil organism habitat loss or degradation**
- **Aggregate instability**

*Near final draft, with minor modifications remaining

Planning Criteria

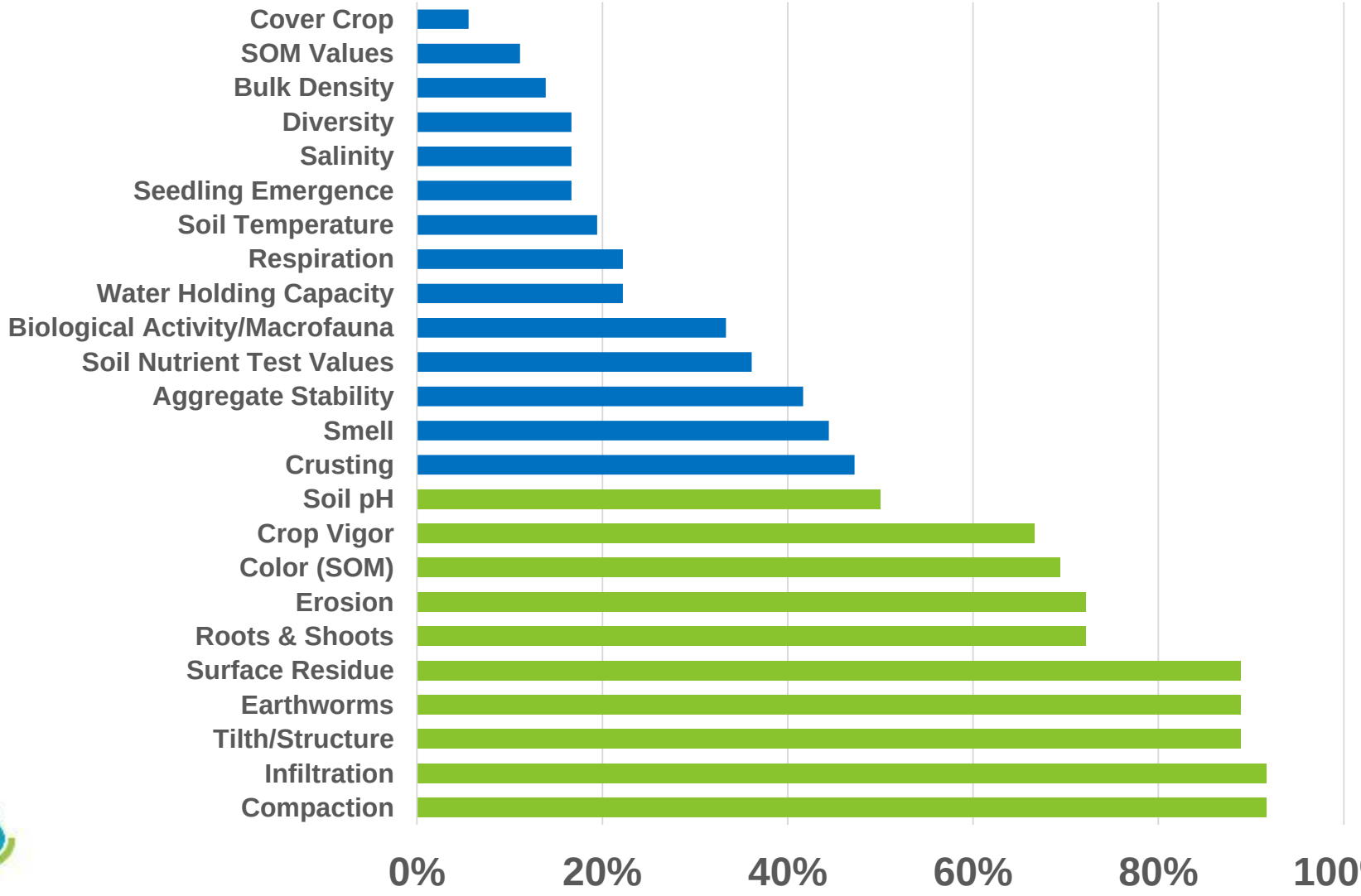
Resource Concern	Description	Objective	Land Use
Compaction	Management-induced soil compaction at any level throughout the soil profile resulting in reduced: • rooting depth and structure • plant growth • soil biological activity • water infiltration and water holding capacity • aeration • soil habitat	Reduce compaction	• Crop • Forest • Associated Ag Land • Designated Protected Area • Other Rural Land

Planning Criteria

Screening Level	Planning Criteria (indicator/threshold)	Assessment Tools
Soil Compaction is not a problem AND Activities do not cause soil compaction problems	A Soil Health Management System (SHMS) that addresses compaction is being followed **AND** No platy structure or restrictive layers **AND** No evidence of thickened roots or J-roots **OR** no restricted layers exceeding 300 PSI at field capacity have been identified	Client input/planner observation **NRCS In-Field Soil Health Assessments** Cards Shovel Penetrometer Metal Rod

In Field Soil Health Assessment

Survey of all States of Indicators used on State Soil Health Cards



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Draft In Field Soil Health Assessment

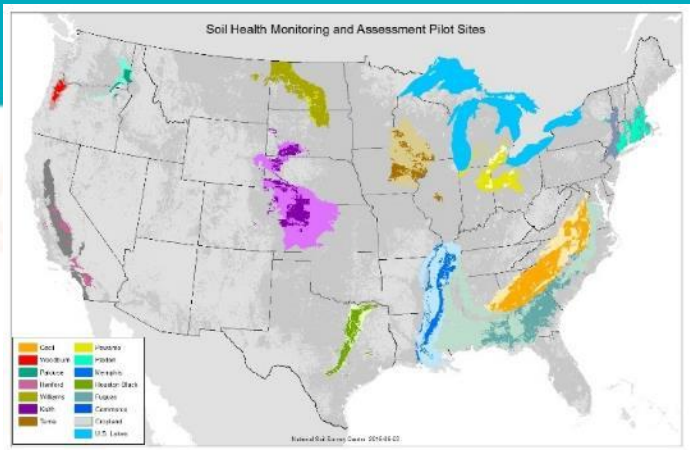
In-Field Assessment

Indicator	Description	Resource Concern Addressed
Surface Crusting	Crusts form after rain or irrigation on soils with poor aggregation. They can negatively impact infiltration, runoff and plant emergence.	1. Soil organism habitat loss or degradation 2. Aggregate instability 3. Compaction

In-Field Assessment

Method	Procedure for Validation	Rating
Typically evaluated when soil dries after a rainfall/irrigation event Note whether crusts are throughout the field or only in patches. • Evidence of ponding • Poor crop emergence uneven stand • Farmer interview of management system	• Visual observation • Photo	Rating based on if the field impacted with evidence of crusting: • Yes • No

Strengthening the Science of Soil Health



1. & 2. Evaluate and leverage existing literature and projects – *publish reviews, tech notes, training materials on priority soil health topics and integrate into the way NRCS does business.*

a) **Indicators and preferred methods for standardization** – internal white paper in review with NIFA and ARS
b) **Meta analysis for preliminary interpretations** – ARS agreement obligated
c) **Metadata needs** – have been compiled
d) Insights on regionally/cropping system adapted data-based soil health management **systems implementation**

Need for Standardization of Soil Health Assessment

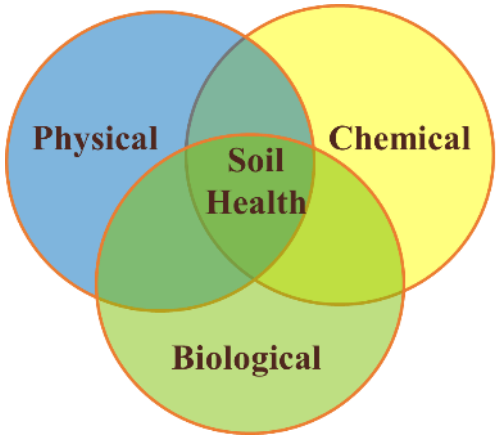
Soil health assessment (or measurement and interpretation) and monitoring protocols are largely non-existent and/or non-standardized beyond nutrient testing:

- Sampling protocols
- Indicator choice
- Laboratory Methodology
- Interpretation
- Management Recommendations

(Friedman, 2001; Bastida et al., 2008; among many others)

Criteria for Indicators

- Scientific, agronomic, environmental relevance
- Represent diverse processes
- Sensitive to agricultural management
- Ability to show short term change
- Standardized methods
- *Easy and inexpensive to sample & measure*
- *Repeatable*
- *Minimal infrastructure/investment*
- *Interpretations accessible to many users*
- ***Actionable:** ability to provide science based indicator-informed recommendations for management*



(Doran et al., 1994; Larson and Pierce, 1991; Mausbach and Seybold, 1998; Moebius et al., 2007; Bastida et al., 2008; Moebius-Clune 2010)

Soil Health Assessment

Standard soil testing beyond nutrient availability needed to facilitate interpretation progress and use in national policy, programs, tools. Need indicators that inform about functioning of:

- Organic matter cycling and C sequestration
- Soil structural stability and water partitioning
- General microbial activity
- Carbon food source
- Bioavailable nitrogen
- Microbial community structure and diversity

NRCS/ARS/NIFA supported white paper completed based on multi-organizational collaboration to recommend current best available indicators/methods for the above as a minimum dataset

White Paper on Proposed SH Methods

D. Stott drew from strawpapers developed by university and ARS collaborators by July 2016, with funding and Soil Renaissance meeting convening support from Noble Foundation, Farm Foundation, and Soil Health Institute

SOIL PROCESS	SOIL HEALTH INDICATORS	METHODS CONSIDERED	NOTES
Organic Matter Cycling & C Sequestration	Soil Organic Carbon Content	Dry Combustion	**Preferred Method** See Nelson and Sommers, 1996; KSSL Manual, pp. 464-471
		Wet Oxidation (among others)	Gives same numbers as dry combustion, but has chemical wastes and is more labor intensive.
Soil Structural Stability and Water Partitioning	Aggregation	ARS Wet Macroaggregate Stability	**Preferred Method** Based on Kemper & Rosenau method and used by the ARS/GRACEnet/CEAP/REAP cross-location projects; some variations; most used in the scientific literature.
		NRCS Wet Aggregation	Based on Kemper & Rosenau (1986), using the pre-wetting of samples; used less in the science literature. See KSSL manual, pp. 213-216.
		Cornell Sprinkle Infiltrometer	Used by CASH; may not be suitable for high volume labs. Schindelbeck et al., 2016, (Code CSH03).

White Paper on Recommended Methods

D. Stott drew from strawpapers developed by university and ARS collaborators by July 2016

SOIL PROCESS	SOIL HEALTH INDICATORS	METHODS CONSIDERED	NOTES
General Microbial Activity	Short-term Carbon utilization (AKA respiration)	CO2 respired, 4 da incubation (among others)	**Preferred Method**. See Schindelbeck et al., 2016 (Code CSH06). A 4-day soil incubation (with a base trap; CO2 measured via titration, change in electrical conductivity, or gas chromatography).
General Microbial Activity	Metabolic Activity (AKA enzyme activity) A suite of enzymes is recommended	B-Glucosidase (BG)	**Preferred Method** Deng and Popova (2011). Involved in the C-cycle.
		N-acetyl-b-D-glucosaminidase (NAG)	**Preferred Method** Kandeler et al. (2011). Involved in the C-cycle.
		Phosphomono-esterases (Acid/Alkaline Phosphatase)	**Preferred Method** Acosta-Martinez and Tabatabai (2011). Involved in the P-cycle. Both present in all soils, with acid Pase dominating in soils ≤7.2 and alkaline Pase in soils >7.2.

Currently Internal NRCS White Paper on Recommended Methods

D. Stott drew from strawpapers developed by university and ARS collaborators by July 2016

SOIL PROCESS	SOIL HEALTH INDICATORS	METHODS CONSIDERED	NOTES
Carbon Food Source	Readily Available Carbon Pool	Permanganate oxidizable carbon	**Preferred Method**. Based on Weil et al. (2003). See KSSL Manual, pp 505-509; Schindelbeck et al., 2016, (Code CSH04). Used by CASH.
		Cold/Hot Water extractable organic carbon (WEOC) (among others)	Cold WEOC is used by the Haney test – good for a snapshot of what is currently available but does not show season-long availability. Hot WEOC used in others; US research community abandoned it in the 80s
Bioavailable Nitrogen	Available Organic Nitrogen Pool	Autoclaved Citrate Extractable (ACE) Protein content (among others)	**Preferred Method**. Modified from Wright and Upadhyaya (1998); See Schindelbeck et al., 2016, (Code CSH07).
Microbial Diversity	Community Structure	Phospholipid Fatty Acid (PLFA) or Ester-linked fatty acid methyl ester profile (EL-FAME) among others	PLFA is the older of the two methods and is offered by some commercial labs. EL-FAME is a new method and is about 1/3 the cost, but doesn't give as much information (esp. on AMF mycorrhizae). Both methods give a coarse community structure, but other methods available are considered to still be in the research realm. An SOP still needs to be developed – suggest U. Missouri soil test lab.

An Example: Assessment of Aggregate Stability

Measured Value – 10% stable

Score – 20 on a scale of 0-100

Interpretation – aggregate stability is too low for the soil type/climate and identified as a resource concern

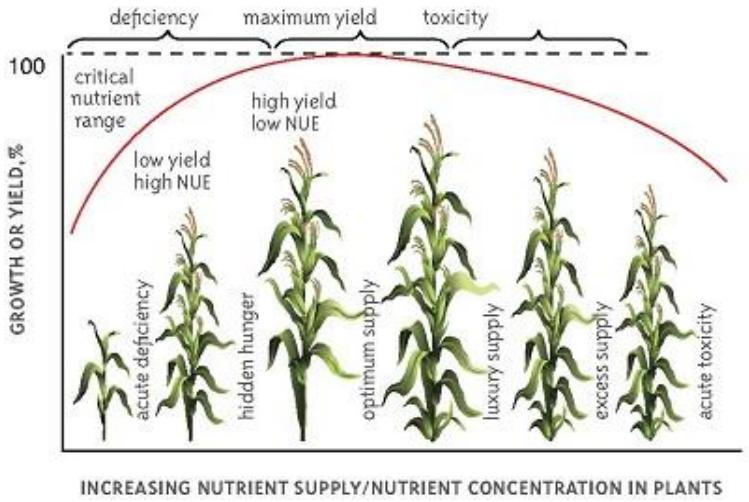
Management Suggestion – Building more stable aggregates through appropriate cover crops, improved crop rotation, integration of livestock and/or manure into the system, mulches, surface residue, etc

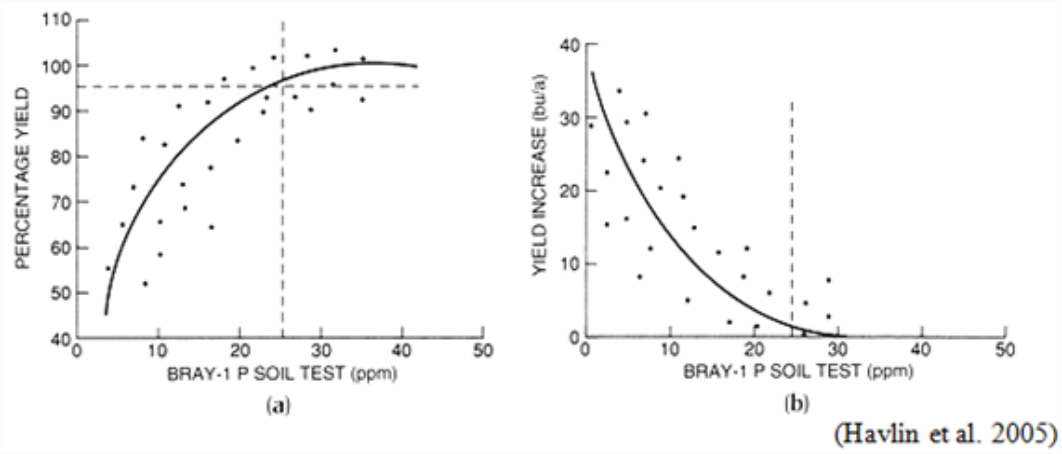
Management Decision – based on production system and producer preferences

SCORING METHODS

EXPERT OPINION/DATA

- Use research that has established ***outcome-based thresholds (e.g. likelihood of yield response to fertilizer at soil test thresholds)***





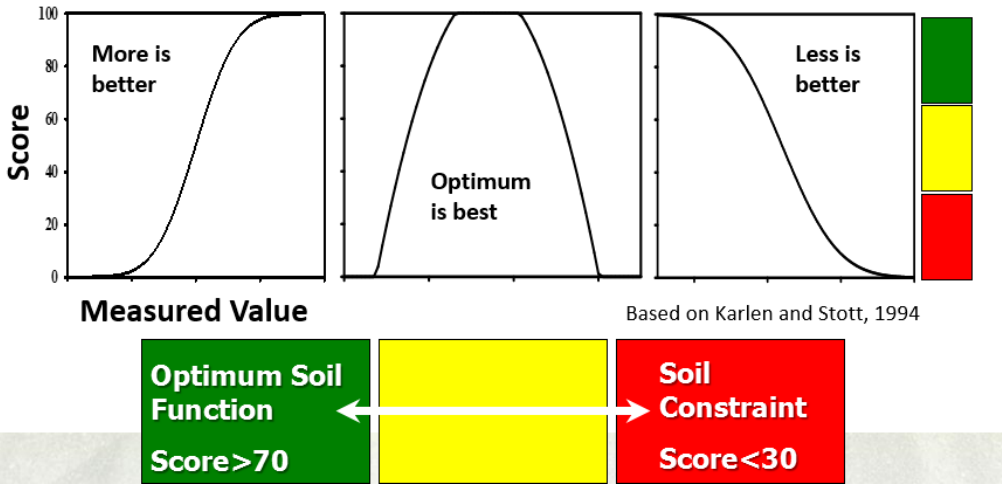
(Havlin et al. 2005)

SCORING METHODS for new indicators

LOCAL CONDITIONS

- Analogous to standardized testing and medical approaches
- Calculate mean and standard deviation within a group
- Assess where individual falls in frequency distribution
- **Can be done based on a regional dataset before outcome thresholds are identified**

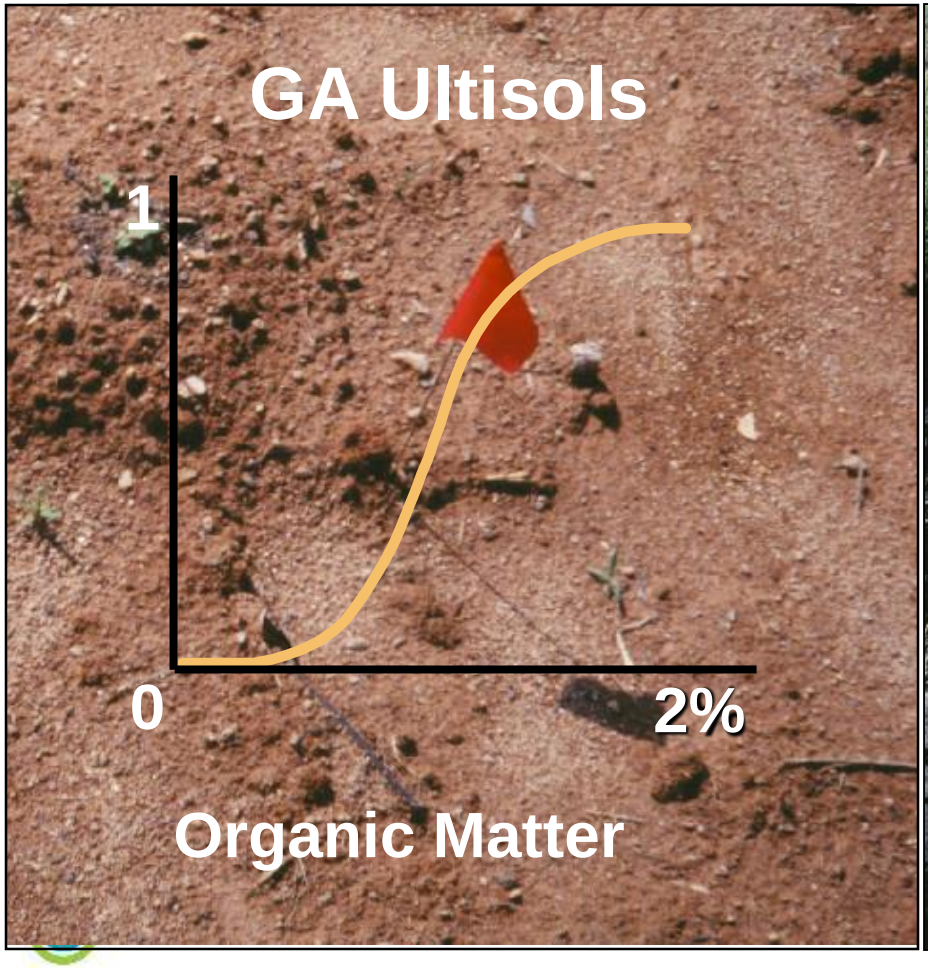
3 types of Scoring Functions interpret degree of soil process constraint:

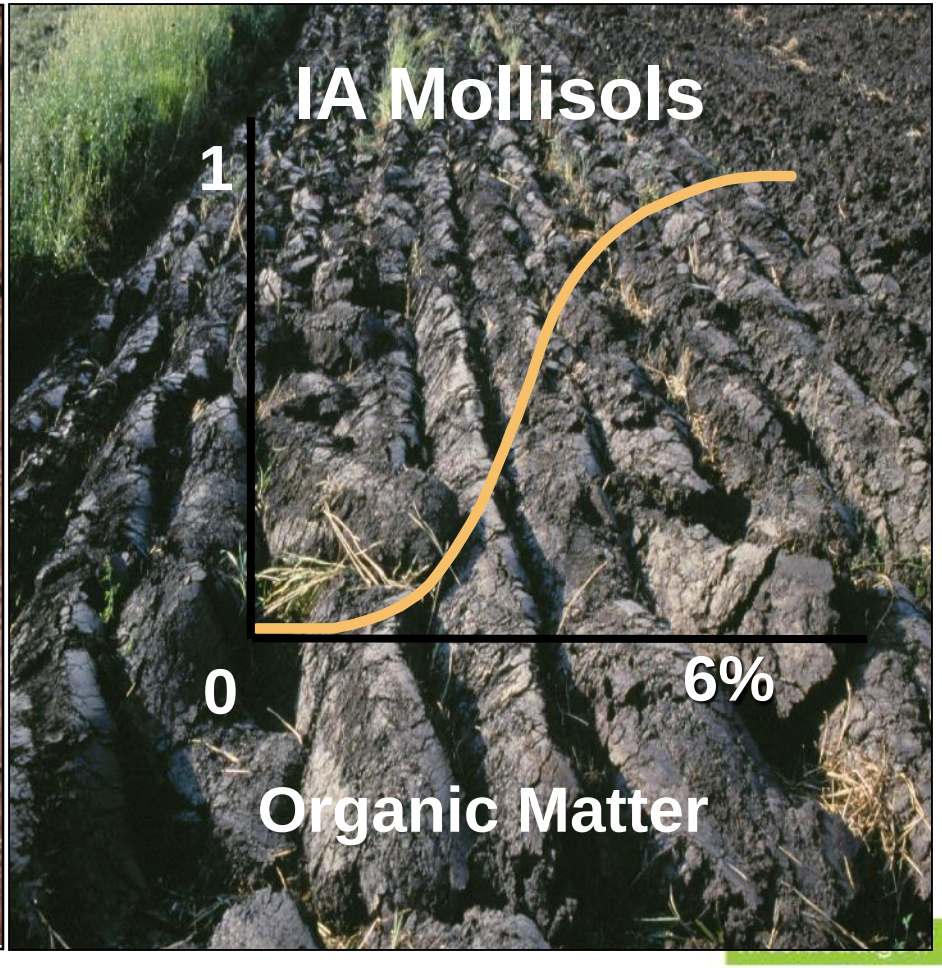


Based on Karlen and Stott, 1994

b) Indicator Interpretation via soil based scoring functions

Agreement w ARS: collaborate w ARS and several Universities to continue literature review, compile data from literature and existing projects, continue development of SMAF





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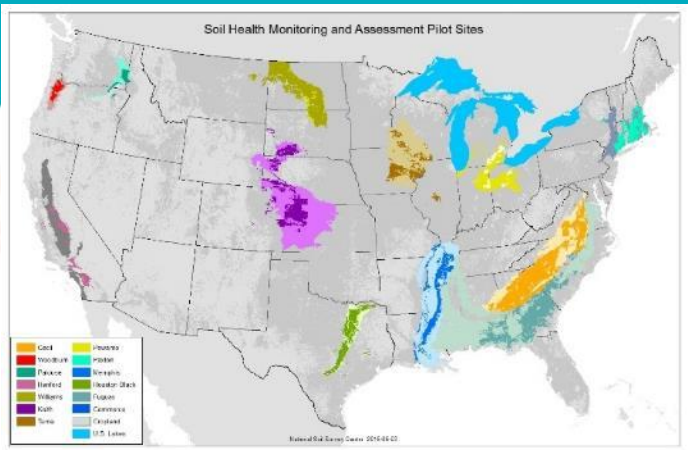
Strengthening the Science of Soil Health

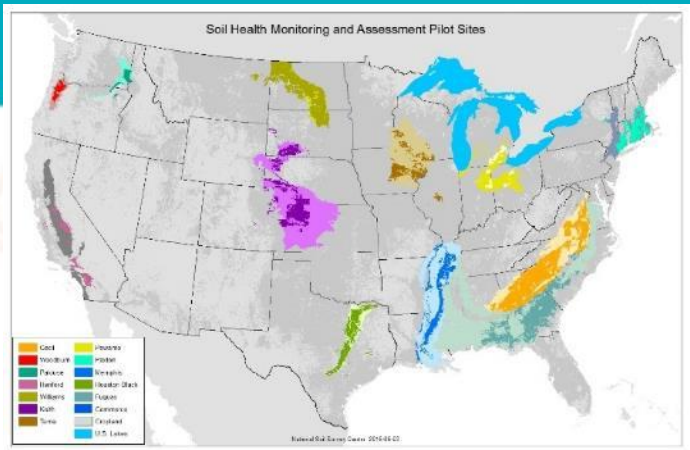


3. Build and populate NRCS soils database with soil health data

a) Decide on required metadata to facilitate effective interpretation (coming out of components 1 & 2)

- Soil Info (includes GPS, sampling time, depth, storage, etc.)
- Crop/land use info
- Fertilizer info
- Irrigation
- Residue management
- Tillage management
- Pastureland management
- Herbicide/pesticide management
- Outcomes (Yield, environmental, economic)

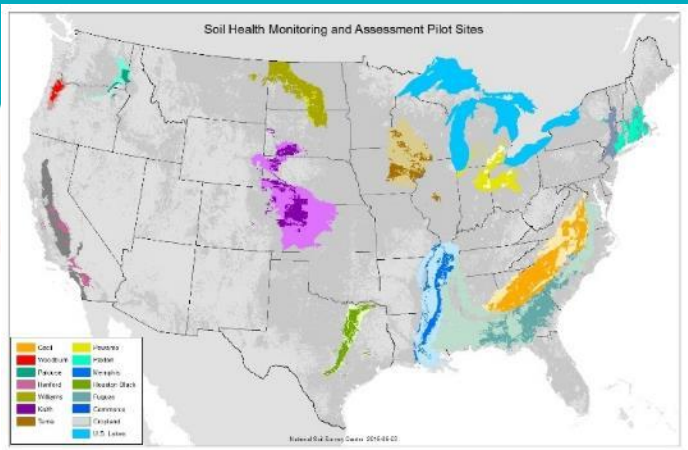
Strengthening the Science of Soil Health



3. Build and populate NRCS soils database with soil health data

a) Decide on required metadata to facilitate effective interpretation (coming out of components 1 & 2)
b) Build database to integrate capacity for dynamic soil properties and all desired metadata into soil survey implementation
c) Create mechanisms for populating database and populate from
    i. Literature
    ii. Existing projects
    iii. Benchmark sites
    iv. NRCS Field financial and technical efforts
    v. Citizen scientists
    vi. Other agencies and partners

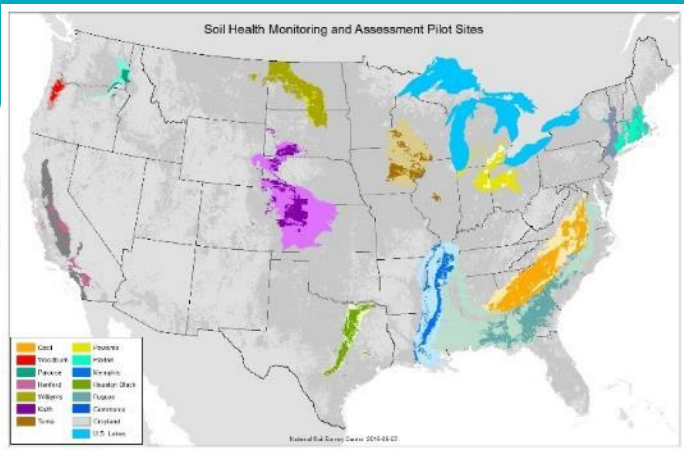
Strengthening the Science of Soil Health



4. Monitor soil health on representative benchmark soils and evaluate management impact and contribute to assessment

a) Statement of Work for agreements requires:
   i. Use Benchmark Soils – targeted soil systems based on identified gaps and importance
   ii. Include all chosen lab and in-field SH indicators using standard methods
   iii. Collect all required metadata
   iv. Measure SH in range of soil management systems, include high functioning soils to establish upper potential for soil health management systems
   v. Assess reliability/precision of methods
b) Funding for 5 benchmark sites provided from FY17
c) Study design by cooperators starts this winter
d) Further agreements pending future funding

Strengthening the Science of Soil Health



5. Develop soil health management decision tools and citizen science portal *– frameworks for 3 components in development:*

a) Field Tools for Conservation Planning to be integrated into the NRCS Conservation Delivery Streamlining Initiative (CDSI) effort
   i. ARS agreement to integrate with CDSI effort
   ii. Existing frameworks for delivery of information in consideration

b) Mobile Apps to contribute to the database
   i. In initial planning phase – may piggyback on ARS LandPKS efforts

c) Stakeholder Engagement in Citizen Science
   i. In initial planning phase
   ii. Mechanism for innovative producers to share management successes
   iii. Goal to allow multiple data sharing/compiling options across the soil health community, including answering economics questions

Plan Practices from In-Field & Laboratory Assessments

- **Lab assessment to help identify soil health constraints that are not discernable by in-field qualitative methods**
- **Holistic report including biological and physical health status to encourage adoption of soil health management *systems.***
- **Technical specs to guide planners and producers to conservation practices and detailed specifications.**
- **Improve monitoring and reporting of the effectiveness of the practice**

Planning Practices

Resource Concern	Short Term	Long Term	NRCS Practice
Aggregate Instability	• Incorporate fresh organic materials • Use shallow-rooted cover or rotation crops • Add compost, green manure, mulch	• Reduce tillage • Use a surface mulch • Incorporate perennial crop	(328) (329) (340) (484) (512) (528)

Assessments	Suggested Management Practices		Colorado NRCS Practice
	Short Term	Long Term	(code)
Physical Concerns			
Aggregate stability	• Incorporate fresh organic materials • Use shallow-rooted cover/rotation crops • Add compost, green manure, mulch	• Reduce tillage • Use a surface mulch • Incorporate perennial crops	(328) (329) (340) (484) (512) (528)
Available Water Capacity	• Add stable organic materials, mulch • Add compost or biochar • Incorporate high biomass cover crop	• Reduce tillage • Rotate with sod crops • Incorporate high biomass cover crop	(328) (329) (317) (340) (484) (512) (528)

Primary Practices

Practice	Purpose
Cover Crop (340)	• Maintain or increase soil health and organic matter content • Minimize soil compaction
Conservation Crop Rotation (328)	• Maintain or increase soil health and organic matter content
Residue and Tillage Management, No Till (329)	• Maintain or increase soil health and organic matter content
Residue and Tillage Management, Reduced Till (345)	• Maintain or increase soil health and organic matter content
Prescribed Grazing (528)	• Reduce soil erosion, and maintain or improve soil health.
Integrated Pest Management (595)	• Prevent or mitigate cultural, mechanical & biological pest suppression risks to soil, water, air, plants, animals & humans.

Secondary Practices

Practice	Purpose
Controlled Traffic Farming (334)	• Improve soil health, reduce compaction
Amending Soil Properties with Gypsum Products (333)	• Improve soil health by improving physical/chemical properties and increasing infiltration of the soil. • Improve soil health by ameliorating subsoil aluminum toxicity.
Mulching (484)	• Maintain or increase organic matter content
Conservation Cover (327)	• Improve soil health
Forage and Biomass Planting (512)	• Improve soil and water quality
Silvopasture (381)	• Improve soil quality • Increase carbon sequestration and storage

Secondary Practices

Practice	Purpose
Salinity and Sodicity Management (610)	Improve soil health by: • salt concentrations in the root zone • problems of crusting, permeability, or soil structure on sodium affected soils • soil salinization and/or discharge of saline water tables at or near the soil surface downslope from saline seep recharge
Subsurface Drain (606)	• Remove salts and other contaminants from the soil profile
Irrigation Water Management (449)	• Manage salts in the crop root zone
Sprinkler System (442)	• Improve condition of soil contaminated with salts and other chemicals

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4. Anticipated outcomes and opportunities

Key Outcomes – Opportunities to Collaborate

- **Standardized soil health measures**
  - Incentivize and facilitate public availability and adoption
  - Facilitate faster, better interpretation development
  - Facilitates data sharing nationwide
  - Used and interpreted at a national scale across many organizations
  - Protocol for updating methods w new science
- **Actionable, easily understood results**
  - Provided by SH assessments to make management decisions
  - For farmers, field staff, laboratories and ag service providers
  - Protocol for updating recommendations w new science
- **Integration of acquired findings into**
  - Conservation planning
  - Agency policy, program offerings, tools, and priorities
  - Trainings to inspire adoption of Soil Health Management Systems
- **Mobile apps and other state-of-the-art tools to leverage partner resources**
- **Broad collaboration** across USDA and beyond
- **Consistent message** to farmers from across the Ag Service Provider Community to speed adoption of SHMS
- **Benefits to Society at large**

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Return on our Nation's Soil Health Investment

Changing the Face of Agriculture and How We Feed our Nation

BENEFITS

- Water infiltration
- Less runoff, erosion, flooding
- Water storage and availability
- Soil organic matter
- Energy savings
- Nutrient cycling & pest suppression
- Resilience
- Biodiversity, groundwater, clean water and air …
- Long-term economic viability
- Sustained reliable productivity – to feed 9 billion

Photos: NRCS and Dorn Cox, 2012

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Thank you!

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Persons with disabilities, who wish to file a program complaint, please see information above on how to contact us by mail or by email. If you require alternative means of communication for program information (e.g., Braille, large print, audiotape, etc.), please contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

Supplemental Nutrition Assistance Program

For any other information dealing with Supplemental Nutrition Assistance Program (SNAP) issues, persons should either contact the USDA SNAP Hotline Number at (800) 221-5689, which is also in Spanish, or call the State Information/Hotline Numbers.

All Other Inquires

For any other information not pertaining to civil rights, please refer to the listing of the USDA Agencies and Offices.

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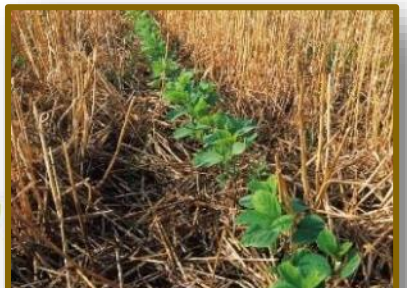
Questions and Discussion?

Contacts: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/soils/health/?cid=nrcseprd1315420



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Questions

- **What about measurement of biological activity – e.g. temp**
- **Will NRCS pay for the assessments?**
  - How many?
- **Will laboratories be ready to do these methods?**
- **What about other methods that NRCS hasn't selected?**
  - There are other good indicators of soil health
- **Will these tests work in all areas of the country, e.g. AZ?**
- **Aren't aggregate stability and soil organism habitat the same thing?**
- **How confident are you that the recommended practices will improve the properties measured by the lab indicators?**
- **How long would it be before you can expect changes**
- **How is a soil health management plan different from a conservation plant?**

Questions

- What about the science behind the in-field assessments. Has this been vetted?
- Soil Health Measurements seem to be pretty variable. Are you sure these results will give useful information?
- Will these take the place of standard fertility recommendations?
- My University soil test lab doesn't know how to interpret soil health test results. Who is going to explain the report?