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Soil Health
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Cropland In-Field Soil Health Assessment Guide

Natural Resources Conservation Service
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Acknowledgments

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Contents

Cropland In-Field Soil Health Assessment Guide

Considerations for Using the Assessment

The Cropland In-Field Soil Health Assessment is a diagnostic tool to help conservation planners determine and document if soil health resource concerns exist in a field. It should not be used to compare fields or monitor changes in a field over time, nor should it be considered a comprehensive assessment of all biological, physical, and chemical processes that are critical to soil function. Fields where multiple indicators that do not meet assessment criteria will likely benefit from a management system that includes as many soil health building practices as practical to maximize biodiversity, maintain presence of living roots and soil cover and minimize disturbance. See The Basics of Addressing Resource Concerns with Conservation Practices within Integrated Soil Health Management Systems on Cropland for more information.

It is not necessary to evaluate all 11 indicators, only those that will help to adequately assess a field's soil health and develop management alternatives if soil health resource concerns exist. There are many variables that affect how useful the indicators may be during any single field visit. Some indicators will be more interpretable and representative of soil health than others depending on site conditions, soil type, landscape position, climate, time of year, and production system. Each indicator has different optimal sampling times and conditions and should be recorded. The timing symbols associated with each indicator on the assessment worksheet provides a quick reference for the recommended conditions and time.

State technical specialists responsible for assessing soil health resource concerns related to conservation planning should communicate with the Soil Health Division to determine which indicators to assess under the local conditions. In addition, state and area specialists may need to adjust the assessment criteria of the indicators used to ensure they provide meaningful assessment information for local systems and conditions.

There are many important components of soil health that are not part of the in-field assessment, such as chemical properties (nutrients, pH, (EC), etc.), salinity, and soil organic matter (SOM). They are best measured by sending samples to a reputable soil testing laboratory. Quick in-field assessments of chemical properties (e.g., pH, EC) can be done to demonstrate, compare, and contrast the impact of management on nutrient cycling or differences within a field and determine whether further soil testing is needed (see Soil Health Educators Guide). Oil salinity can negatively impact soil health and should be evaluated as a resource concern and considered in a management plan where appropriate. The SOM depletion resource concern can be identified by tracking trends of SOM laboratory analyses over time or determining soil conditioning index (SCI) through an NRCS-approved method. Other physical and biological properties indicative of soil health can be assessed by laboratory methods as laid out in Conservation Evaluation and Monitoring Activity (CEMA) 216, Soil Health Testing.

Soil Cover

Importance: A significant factor in promoting soil health is keeping the soil surface covered, particularly during fallow and intercrop periods and before canopy closure.

How to assess: Estimate the percent of soil surface covered with dead plant material, organic mulch, or live plants at any time, but ideally right before planting the main cash crop. Take photographs of representative areas. The percent cover will look similar across different crops. Management and operation evaluations may be used to predict cover during critical erosion and fallow and intercrop periods. Both live crop canopy and crop residues during critical periods should be included.

Conservation practices to address the resource concerns associated with this indicator (includes but not limited to): 311, 328, 329, 340, 345, 484, 512, and 528 (see NRCS Conservation Practice Standards Information for details).

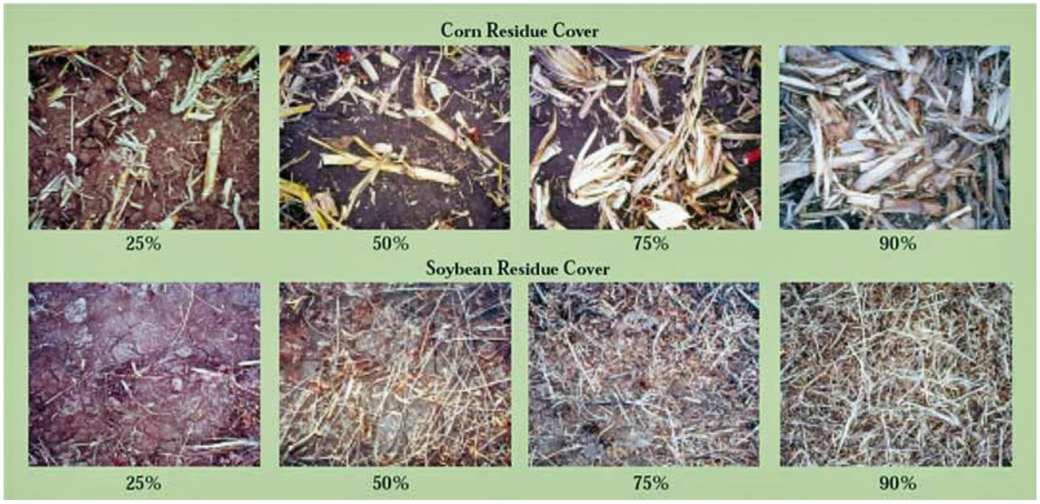

Figure 1: Crop residue at various percentages of cover

Residue Breakdown

Importance: Residue breakdown is the biological shredding, fragmenting, cycling, or decomposition of previous crop residue. The rate at which residue decomposes can be an indicator of management-influenced biological activity. Other factors that can influence the rate of residue breakdown include C:N ratio of the plant residue, crop type, residue size, residue orientation (standing or flat), residue amount, tillage, and environmental conditions (e.g., climate, recent weather) during residue decomposition.

How to assess: Examine the existing residue cover for signs of decomposition, shredding, and incorporation by soil organisms. Note the depth of litter and color and condition of most recent residue. Take photographs of representative areas. The threshold guidance may need to be adjusted for local conditions. Breakdown depends on management, recent weather, climate, soil, and crop type. Interview the producer for information about management, residue age, and plant types. This indicator can be assessed at any time but may not be as useful after full-width conventional tillage since very little residue may be present.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 328, 329, 340, 345, 528, 590, and 595.

Surface Crusting

Importance: Surface crusts, resulting from poor aggregate stability, can develop after rainfall or irrigation events when soil is tilled and left uncovered. Crusting can also occur in sodic (high sodium) or saline (high salts) soils and can be a result of management. Crusts can prevent seedling from emerging and reduce water infiltration. Additionally, crusts can inhibit soil organism habitat, gas exchange, and nutrient cycling.

How to assess: Determine if crusts are present throughout the field or only in patches. Crusts remain intact when they are picked up. Physical crust assessments are best done after irrigation or rain and before tillage. Assess for physical crusts after irrigation or rain and before next tillage. This indicator can be assessed at any time but may not be as useful after full-width conventional tillage. assessed.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 329, 340, 345, 484, 512, 528, and 610.

Figure 2: Top view of surface crusting (left).

Figure 3: Wheat seeds germinated below the soil, but the shoots were unable to break through the hard surface crust (right).

Figure 4: Ponding on cropland

Figure 5: Preparing soil infiltration test

Ponding and Infiltration

Importance: Ponding or evidence of surface runoff on the soil due to poor infiltration can indicate poor aggregate stability, crusting, lack of cover, poor soil structure, or compaction. Slow infiltration can also result from naturally occurring conditions such as a fragipan or other slowly permeable soil layer close to the surface or a clayey surface or subsurface soil texture. This leads to runoff, erosion, and crop damage. Ponding negatively impacts nutrient cycling and water quality. It can also impact flooding and limit gas exchange.

How to assess: Observation method and infiltration method.

Observation method: The best time to assess for ponding is within 24 hours of a rainfall or irrigation event. Determine if ponding occurs throughout the management unit or only in patches. Ponding can result from surface crusting, low infiltration, inherent soil properties, or landscape position. Interview the producer about these indicators to determine the extent and severity of ponding.

Infiltration method: An optional, more time-consuming method is to conduct an infiltration test. This can be done by either a comparison method or a timed test. Select a location that avoids headlands, turning rows, traffic lanes, and wheel tracks. In most soils, water should infiltrate in 30 minutes or less. Refer to the Soil Quality Test Kit Guide (SQTKG) for instructions on how to conduct this test.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 328, 329, 333, 340, 345, 449, 511, and 528.

Penetration Resistance

Figure 6: Applying slow, steady pressure when pushing penetrometer into soil.

Importance: Soil compaction in agricultural systems can result from repeated wheel or hoof traffic or repeated tillage at the same depth. Compaction inhibits water movement and gas exchange through the soil in addition to interfering with root growth, soil organism habitat, nutrient cycling, plant productivity, and health.

How to assess: Penetration resistance increases as soils dry; therefore, the ideal condition to assess is at field capacity. Management-induced compaction typically occurs at depths of 2–8 inches but may be deeper depending on soil type and management. Resistance to penetration should be checked at eight to ten randomly selected spots in the field. Make sure that the soil is the same soil type for the assessment area. Use one of these methods:

Wire flag method: Hold a wire flag near the flag end and insert it into the soil, observing how much force (resistance) it takes to push it in. Compare the resistance to a known noncompacted area, such as in a fence row or other non-impacted field border. This test is better suited when soil moisture is near field capacity. Refer to section 11 of the SQTKG.

Penetrometer method: Use a penetrometer by applying slow, steady, vertical downward force so the rod sinks at a rate of 1 inch per second. During this, observe the pressure gauge reading. Record the depth of the upper and lower boundaries of restrictive layers and the resistance pressure from the pressure gauge. Use the 0.5-inch cone for silty, clayey, and loamy soils and the 0.75-inch cone for sandy soils. If the penetrometer reading is negative, dig in that area to ensure that it is soil and not a rock. This test is better suited when soil moisture is near field capacity. See the Wisconsin University YouTube tutorial for more information.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 328, 329, 334, 340, 345, 511, 528, and 336.

Water-Stable Aggregates

Importance: The stability of soil aggregates in the presence of water is important for water infiltration and storage, air exchange, plant root growth, soil organism habitat, SOM, soil erodibility, nutrient cycling, plant productivity and health, water quality, and flooding. This indicator is tied to many other resource concerns.

How to assess: Assessment of water-stable aggregates can be done in-field or in a laboratory setting. Coarse textured soils may not develop aggregates easily and semi-arid and arid climates due to lack of rainfall may also be limited in their ability to form water stable aggregates. Issues with salinity will cause soils to disperse. Some soils are more chemically prone to strong aggregation and may give false-positive results. To assess for water-stable aggregates, use the cylinder, strainer, or SQTKG method.

Cylinder method: Take a soil ped about the size of a golf ball from the surface just below any residue, then air dry it. You may have to take it back to the office to perform the test after it has dried. Fill a container with water. Place the dried ped in a strainer basket and submerge it in the container. After 5 minutes, check whether the water is cloudy or clear and estimate the percentage of the ped that is still intact. Highly degraded soils tend not to break apart or dissolve because high bulk density does not allow water to enter, affecting how aggregates respond to water. You may be able to remove the intact ped and break it apart. Observe if the center of the ped is saturated or dry.

Strainer method: Take a sample from the soil surface and crumble any large peds to pea size or slightly smaller; don't grind too fine. Place the soil in a sink strainer or small wire colander. The soil should be level with the top of the strainer. Submerge it in a bowl of water for about 1 minute, so that the soil becomes fully saturated. Turn the strainer upside down on a flat surface. Soils with good aggregate stability will remain intact with aggregates apparent, while soils with poor aggregate stability will slump and have a pudding-like consistency. This method can be used with soils that are not air dry but are at field capacity or less. You may also note the clarity of the water as an indicator. This method is the easiest to do in field.

SQTKG method: See Soil Stability Test, pages 10 through 28, on how to use the slake box for procedure and scoring. This method can be used with dry to field capacity soil moisture.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 328, 329, 333, 334, 340, 345, 511, 528, 590, 595, and 336.

Figure 7: Close up (left) and wide (right) view of cylinder method.

Figure 8: Slake box.

Figure 9: Sink strainer method showing water-stable aggregates (left) and unstable aggregates (right).

Soil Structure

Figure 10: Platy structure

<u>Importance</u>: Soil structure affects water infiltration, which impacts flooding, gas exchange, plant rooting, nutrient cycling, plant condition and health, and soil organism habitat. Local, naturally occurring conditions will also affect structure.

<u>How to assess</u>: Examine the soil structure for granular, massive, or platy in horizons of the top foot of soil. This indicator can be assessed at any time but may not be as useful after full-width conventional tillage because the structure will be damaged, resulting in a false positive for granular structure. Comparing the soil to the official soil series description may help indicate the potential of that soil, depending upon location.

- Granular structure is typically associated with soils rich in organic matter and good aggregation. Sandy soils are less likely to exhibit granular structure.
- Massive is a condition where nearly all visible granular structure is lost, leaving a very dense unconsolidated soil layer with very little pore space.
- Platy structure is characterized by distinct layers that can be separated along the horizontal plane and is typically associated with a compacted layer or E horizons. For more information on different types of soil structure, see “(Soil) Structure” in the Field Book for Describing and Sampling Soils Version 3.0 (beginning on page 2-52) or Section 11: Soil Physical Observations and Estimations in the SQTKG.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 328, 329, 334, 340, 345, 511, and 528.

Soil Color

<u>Importance</u>: Color can indicate loss or accumulation of SOM, which influences most aspects of soil function, with higher SOM contents generally improving soil function. Typically, loss of SOM results in lighter colors and accumulation results in darker colors.

<u>How to assess</u>: Soil color can indicate different soil mineralogy and organic matter. Color can be assessed by using a Munsell color chart, smartphone app, or field versus fencerow comparison. Regardless of method chosen to assess color, be sure to compare the same soil type.

Figure 11: Using a Munsell Color chart to determine soil color.

Munsell color chart method: Use a Munsell Color chart and soil survey pedon description, which can be found on Web Soil Survey. The value is the number that reflects soil darkness. For example, a soil with color 10YR 3/6 is darker than a 10YR 5/6 soil. For the 10YR 5/6 sample, 10YR is the hue, 5 is the value, and 6 represents the chroma (brightness). Lower values are darker than higher values. This method can be used for dry or moist samples. The results should be compared to the official series description. For instructions on describing soil colors, see "Soil Color" in the Field Book for Describing and Sampling Soils Version 3.0 (beginning on page 2-8).

Smartphone app method: Use a soil app such as the LandPKS mobile app to determine soil color. The soil surface should be flat and dry or, if that is not possible, uniformly moist but not glistening. The reference and the soil should be in the same plane. Ensure that there are no internal shadows (e.g., dark areas between aggregates or microaggregates).

Figure 12: Determining soil color using a soil app on a smartphone.

Field versus fencerow comparison method: In a few locations, compare the relative color of soil from the field to a fencerow or other non-cropped, undisturbed perennial vegetation which may be found at the field edge in the same landscape position. Exceptions to this are in semi-arid environments where irrigation and fertility in agronomically managed soils can lead to higher SOM levels compared to fencerows.

Figure 13: Healthy soil in a cover crop mixture (left). **Figure 14:** Using a sharpshooter to extract a slice of soil (middle). **Figure 15:** Comparing relative color changes (right).

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 327, 328, 329, 340, 345, 512, 528, 590, and 336.

Plant Roots

Importance: Plant roots exude simple and complex carbohydrates, amino acids, and proteins that provide food and habitat to the microbial communities, which in turn builds soil structure by forming soil aggregates. Root channels can remain from season to season, function as areas of carbon concentration and biological activity (see Biopores in this technical note), improve infiltration, help store water, reduce soil erosion, and create pathways for gas exchange after senescence.

How to assess: Observe growth patterns of actively growing roots in the top 0–8 inches or deeper, depending on the crop. This is best done during times of active desirable plant growth and adequate soil moisture.

Things to look for:

- Healthy roots are abundant, deep, uninhibited by restrictive layers, and well-branched.
- Roots are not balled up, growing sideways, or J-rooting. Lateral root growth indicates a hardpan or compacted layer (see figure 17).
- Roots have fine root hairs; a lack of them indicates oxygen deprivation in the root zone.
- Rhizosheaths: roots that are covered in a soil film. Rhizosheaths are highly species- and environment-dependent (e.g., brassicas and many broadleaf weeds do not tend to form rhizosheaths). May indicate the presence of beneficial soil biology colonization.
- Roots are entangled and enmeshed with soil aggregates.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 328, 329, 334, 340, 345, 512, 528, 590, and 336.



Figure 16: Healthy rhizosheaths on an 8-week-old winter cereal rye seeded early fall with no nitrogen (left).

Figure 17: J-rooting of cover crop roots resulting from a soil restrictive layer (middle).

Figure 18: Fine roots (right).

Biological Diversity

Importance: Soil organisms influence all aspects of soil function including but not limited to aggregation, water dynamics, nutrient cycling, and pest suppression.

How to assess: Examine the residue or soil for the presence of soil organisms, including crop pests. Restrict observation to the area of the soil surface represented by the assessment area. Take a shovel full of soil and look for soil organism within that sample and the residue at the top of that sample. Fungal hyphae will appear as white to light tan threads or masses with a hand lens. Look for active nodules if legumes are growing, meso- and macro-invertebrates such as earthworms or earthworm middens, mites, springtails, millipedes, roundworms, beetles, and ants. The best time to assess is during spring or fall or other times when soils are moist to field capacity. The biological hotspots, aggregate surfaces, residue, plant roots, porosity and structure, and biopores, may be used if no soil biology is apparent to determine if the potential and habitat for soil biology is possible. Temperature will also affect the presence and activity of organisms. Additional soil macrofauna photos can be found in "Key on Soil Macrofaunda" in the Soil Macrofauna Field Manual (beginning on page 85).

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 328, 329, 340, 345, 484, 511, 528, 590, 595, and 336.

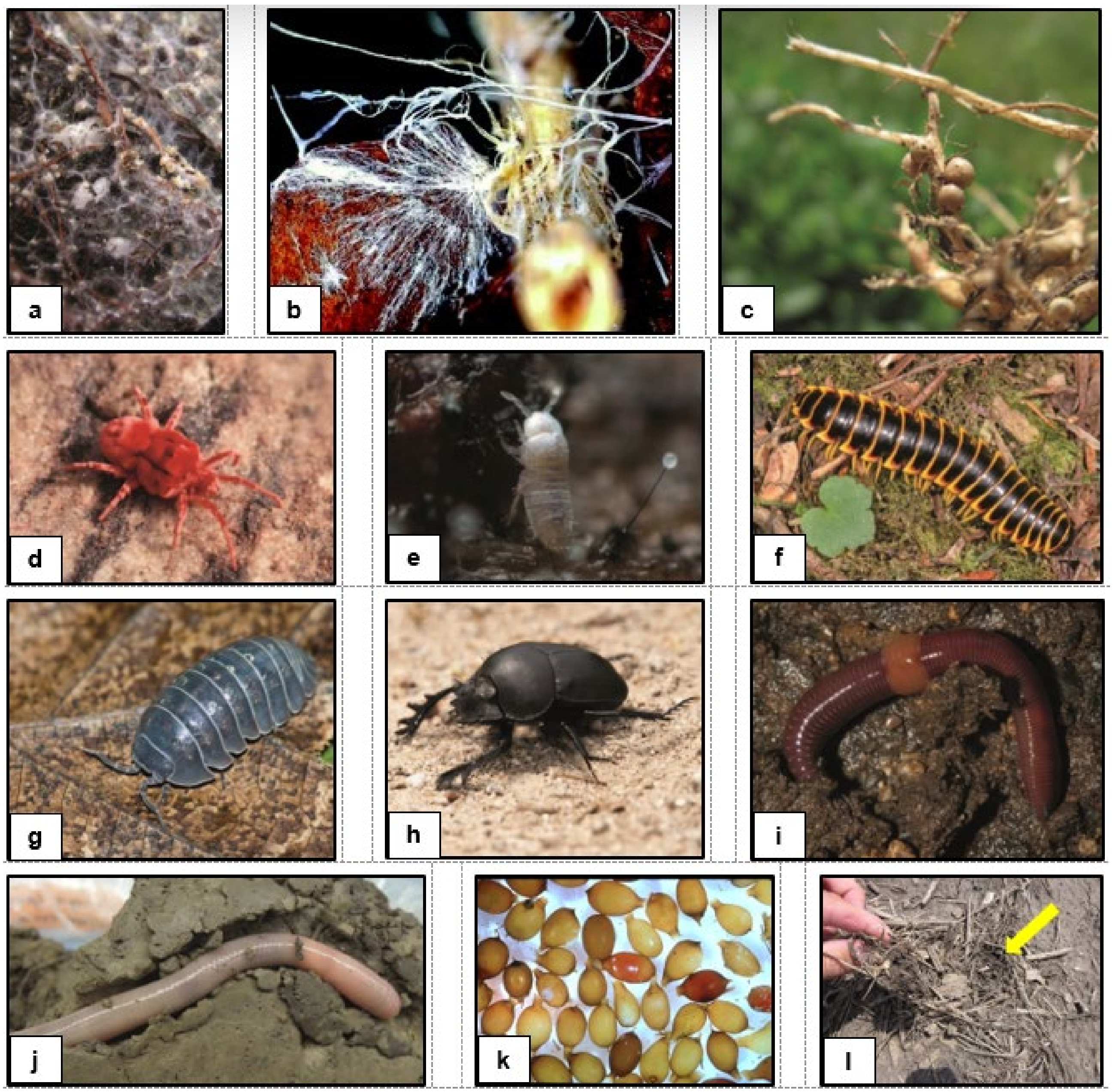

Figure 19: a) Ectomycorrhizal fungi covering plant roots, b) white mycelium of saprophytic fungi surrounding a leaf, c) nodules on roots formed by rhizobia bacteria, d) mite (Arachnida), e) springtail (Collembola), f) millipede (Diplopoda), g) woodlice/pill bug (Oniscidea), h) dung beetle (Scarabaeoidea), i) anecic earthworm – deep burrowing (Lumbricus terrestris), j) endogeic earthworm – topsoil dwelling (Aporrectodea spp.), k) earthworm cocoons, l) removing upper layer of residue from an earthworm midden

Biopores

Importance: Plant roots and earthworms leave behind large pores called biopores. These biopores are important for rapid air and water exchange They provide additional access to water and nutrient resources for improved plant health and productivity. Additionally, earthworm channels tend to be rich in organic matter, microbes, and nutrients, which helps with nutrient cycling. Old biopores provide excellent pathways for newly established roots and soil biology movement.

How to assess: Take a shovel full of soil and look for intact biopores. They will appear as channels, often connected to the soil surface. Biopores forming over multiple years are rich in organic matter and may appear darker than the surrounding soil. This indicator can be assessed at dry to field capacity soil moisture but will be easier to observe in moist to field-capacity soils.

Conservation practices to address the resource concerns associated with this indicator (including but not limited to): 311, 327, 328, 329, 340, 512, 528, and 550.

Figure 20: a) earthworm following biopore created by plant roots, b) earthworms creating biopores, c) taproots are characterized by a large, central, and dominant root, d) cross section of earthworm midden and biopore created by an anecic earthworm, e) biopore extending into subsoil

Field Tips

This section summarizes the instructions above. Please read the above instructions before considering this summary.

- Some indicators are influenced by or are a representative of soil health more than others depending on soil type, landscape position, recent weather, climate, time of year, and production system.
- Each indicator has different optimal sampling times or conditions, and these conditions should be noted. The timing symbols associated with each indicator on the assessment worksheet provides a quick reference for the recommended conditions and time for assessing that indicator.
- When conducting the assessment, compare the indicators in the assessment area to the same soil type in an adjacent fencerow or non-cropped perennial vegetated area.
- Previous instructions provide guidance for assessing each indicator and list conservation practices that may be included in a soil health management plan to address the resource concerns associated with each indicator.
- Soil cover, residue breakdown, surface crusts, and ponding are indicators that represent surface conditions across the assessment area.
- The remaining indicators are indicative of belowground soil health. Observe conditions by digging down to at least 12 inches and evaluating each indicator to determine if it meets the assessment criteria.
- Subsurface indicators are best confirmed by looking at more than one unique location in the management unit. If conditions are not consistent within the management unit for at least two locations, an additional site should be evaluated.
- Whenever possible, take photos for the assessment. These can be added to the customer folder along with the assessment area observations and notes.
- Soil moisture can be determined with a handheld soil moisture meter if available, or qualitatively as dry, moist, field capacity, or saturated. Use the Estimating Soil Moisture by Feel and Appearance publication.
- Soil texture can be estimated by using the Guide to Texture by Feel. Soil surveys can provide an estimate but should be verified in the field.

Useful Assessment Materials

- Shovel
- Wire flag
- 6-inch diameter ring, 5.25 inches in length
- Small sledgehammer or dead blow mallet
- Plastic wrap
- Block of wood
- 500 mL plastic bottle or graduated cylinder
- Stopwatch or timer
- Munsell Color Book
- Jornada/soil quality slake box
- Penetrometer
- Clear plastic cups or similar
- Wire sink strainers
- Water
- Small hand lens or phone clip on lens
- Texture-by-feel guide and Estimating Moisture by Feel
- Camera or phone

Management History - Interview

The following questions are offered as examples to guide a conversation with the client and help to understand current conditions, the client's management, and how these may contribute more thoroughly to existing soil health resource concerns. Answers to these and other similar questions will be helpful in assessing some of the indicators.

1. What is the crop rotation?
2. Describe your tillage system.
3. How long have you been in this management system and are you considering any changes?
4. For how many months per year is the soil surface at least 75 percent covered with plants, residue, or mulch?
5. Is cropland grazed? List animal type, number, and weight.
6. Are cover crops a consistent part of the cropping system? If yes, for how many years has the field been continually cover cropped?
7. How are the cover crops terminated?
8. What integrated pest management strategies are used (e.g., crop scouting, selective spraying, treated seeds)?
9. What nutrient management strategies are used (e.g., banding, split application, manure, biochar, compost)?
10. Is the field irrigated? If yes, what type of irrigation system and how many acre-inches are applied for each crop in the rotation described above?
11. Does water pond or run off during or immediately after typical rainfall or irrigation events? Where in the field?
12. Are there problems with crop emergence or early crop growth? Where in the field?
13. Is water management a concern (i.e., field too wet or too dry at planting)?

Other observations not captured in the assessment including plant condition and recent weather and landscape characteristics that may affect assessment results:

Attachments

A. Cropland In-Field Soil Health Assessment Worksheet
B. Cropland In-Field Soil Health Assessment Resource Indicator Decision Trees

Glossary of Terms

Aggregate. A group of primary soil particles that cohere to each other more strongly than to other surrounding particles due to biological, physical, and chemical processes.

Aggregate stability. A measure of the proportion of the aggregates in a soil that remain intact and do not easily slake, crumble, or disintegrate.

Assessment area. AA location representative of the management unit being assessed.

Biopore. Soil pores, created by plant roots, earthworms, or other soil organisms.

Clod. A compact, coherent mass of soil varying in size produced by management activities (plowing, digging, etc.), especially when these operations are performed on soils that are either too wet or too dry and usually formed by compression, or break off from a larger unit instead of cohering together like in aggregation.

Crust, physical. A surface layer ranging in thickness from a few millimeters to 3 centimeters that, when dry, are much more compact, hard, and brittle than the material immediately beneath it. Physical crusts form when the soil undergoes physical-chemical processes but not biological aggregation processes.

Crust, biological. An irregular living crust on the soil surface made of cyanobacteria, algae, lichens, liverworts, and mosses that commonly forms on otherwise barren arid-region soils.

Eluviation. The removal of soil material in suspension (or solution) from a layer or layers of a soil.

Horizon, E. Zone of leaching or depletion, usually characterized by lighter color and platy structure.

Horizon, soil. A layer of soil or soil material approximately parallel to the land surface that differs from adjacent genetically related layers in physical, chemical, and biological properties or characteristics (e.g., color, structure, texture, consistency, kinds and number of organisms present, degree of acidity or alkalinity).

Hyphae. Filaments of fungal cells. Many hyphae constitute a mycelium.

Management unit. A field or group of fields representing similar management, soils, and topography.

Ped. A unit of soil structure, such as a block, column, granule, plate, or prism, formed by natural processes (in contrast with a clod, which is formed artificially).

Pedon. A three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations.

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.

Rhizosheath. Structures composed of mucilage and soil particles that form a cylinder around the root.

Soil color, chroma. Brightness.

Soil color, hue. Color or shade.

Soil color, value. The lightness or darkness of tones or colors.

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

Structure, soil. The combination or arrangement of primary soil particles into secondary units or peds. The secondary units are characterized by size, shape, and grade (degree of distinctness).

Structure, granular. Imperfect spheres, usually sand-size.

Structure, blocky. Imperfect cubes with angular or rounded edges.

Structure, platy. A flattened or compressed appearance.

Structure, massive. A very dense, unconsolidated soil layer with very little pore space. Occurs when nearly all structure is lost.

Structure, single grained. Soil that has no structure and is at individual soil particle size. Common in sands.

Appendix

Aggregate Stability: Soil Health Assessment - Water Stable Aggregates

Aggregate Stability: How to Conduct the Field Slake Test

Biological Activity, Fungi, etc.

Compaction: Diagnosing Soil Compaction Using a Penetrometer

Compaction: Using a penetrometer to detect soil compaction

Estimating Soil Moisture by Feel and Appearance

Field Book for Describing and Sampling Soils Version 3.0

Guide to Texture by Feel

LandPKS mobile app for Determining Soil Color

NRCS Conservation Practice Standards

Residue Cover: Estimating Percent Residue Cover Using the Line-Transect Method

Residue Cover: Crop Residue Management for Corn and Soybean

Science and Technology Training Library (houses the soil health webinar series)

Soil Crusts: Soil Quality for Environmental Health

FAO Soils Bulletin, Chapter 5: Soil Crusting and Sealing

NRCS Factsheet: Principles for High Functioning Soils

Soil Health Educators Guide

Soil Quality Test Kit Guide

Soil Web App

Web Soil Survey