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Rocky Mountain Region In-Field Soil Health Assessment Guide

Integrated Rocky Mountain-Region Innovation Center for Healthy Soils (IN-RICHES)
2023

About IN-RICHES

At IN-RICHES, our mission is to create systems level change that scales regenerative soil health systems in the Rocky Mountain region and beyond.

IN-RICHES takes a holistic approach to soil health, integrating cutting-edge science, practical knowledge, policy, and community engagement to make climate-smart decisions.

We collaborate with researchers, land managers, policymakers, and other stakeholders to develop and implement innovative solutions.

We believe that healthy soils are the foundation of a resilient and sustainable food system, a thriving environment, and a prosperous society.

For more information, visit our website at inrichsoil.com.

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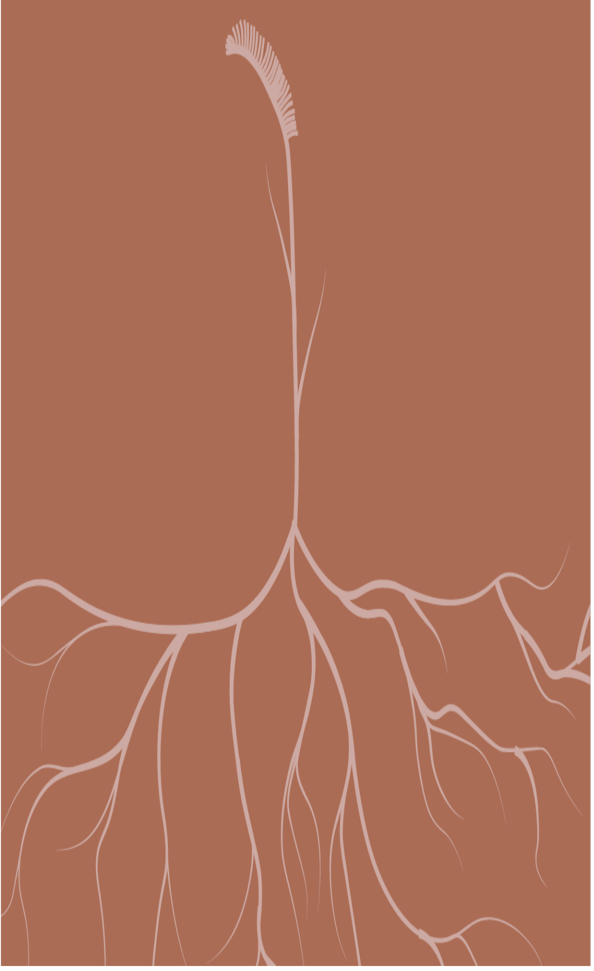
Table of Contents

Introduction

The purpose of the Rocky Mountain Region Soil Health In-Field Assessment Guide is to provide a standardized and comprehensive manual for conducting soil health assessments in the region. The manual aims to serve as a valuable resource for extension agents, agronomists, producers, and other stakeholders who are actively engaged in improving soil health and sustainable land management practices.

Objectives of this Guide



1 Facilitate Consistent In-Field Assessments

The manual aims to establish uniformity in the assessment process, to ensure that the data collected is reliable, comparable, and consistent across different locations and over time.

2 Support Sustainable Land Management

By offering guidance on best practices for soil health improvement, this guide aims to promote sustainable land management practices. These practices can mitigate soil erosion, increase water-use efficiency, reduce nutrient losses, and enhance the overall resilience of agricultural systems to various environmental challenges.

3 Promote Soil Health Awareness

The guide seeks to raise awareness about the significance of soil health in agricultural productivity, environmental sustainability, and overall ecosystem health. By providing relevant information and assessment guidelines, it encourages stakeholders to understand and prioritize soil health improvement.

4 Encourage Long-Term Monitoring & Adaptation

Building and maintaining healthy soils is an ongoing process that requires continuous monitoring and adaptive management. This guide aims to encourage stakeholders to implement long-term monitoring and make necessary management adjustments to sustain achievements over time.

5 Empower Stakeholders with Knowledge

Through detailed explanations of soil health indicators, assessment techniques, and best practices, the manual aims to empower stakeholders with the knowledge to make informed decisions.

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Water Management & Quality

Healthy soils improve water infiltration and retention capacities. They help mitigate the impacts of drought and heavy rainfall events, reducing soil erosion and surface runoff.

Food Security

Cultivating soil health is essential for global food security and preserving environmental integrity. As the population increases, sustainable soil management is critical to meet increasing food demand.

Soil health is fundamental to the productivity, resilience, and sustainability of agricultural and natural ecosystems.

Resiliency

Soils with good structure and organic matter are more resilient to extreme weather events. They can better withstand fluctuations in temperature, moisture, and other environmental stressors.

Biodiversity & Ecosystem Health

A thriving soil ecosystem supports a diverse range of microorganisms, fungi, and other soil-dwelling organisms that contribute to agroecosystem health and resilience.

Enhanced Crop Productivity

Healthy, nutrient-rich, biologically-active soils provide essential elements for plant growth, which may increase crop productivity and profitability.

Carbon & Climate Change Mitigation

Healthy soils capture and store carbon dioxide from the atmosphere. This helps mitigate the impacts of climate change by reducing greenhouse gas concentrations in the air.

Key Components of Soil Health

The key components of soil health revolve around understanding soil's overall quality, functionality, and capacity to support sustainable agriculture and ecosystem functions. The key components of soil health include:

Soil Organic Matter (SOM) Content
Soil organic matter influences soil structure, nutrient cycling, water retention, and microbial activity. Often higher levels of SOM contribute to improved soil fertility and resilience to environmental stresses.

Nutrient Cycling
Healthy soils efficiently cycle nutrients, ensuring that plants have access to essential elements for growth.

Soil Biological Activity
Healthy soil ecosystems support robust biological activity, contributing to nutrient cycling and overall soil health. This includes the presence and diversity of soil organisms, including bacteria, fungi, earthworms and other beneficial macro-and microfauna.

Soil Structure and Aggregation
Soil structure refers to how individual soil particles are arranged and aggregated. Well-aggregated soils provide pore spaces for air and water movement, which enhances root growth, soil aeration, and water infiltration. Good aggregation also decreases soil erosion risk.

Soil Infiltration Rates & Water Holding Capacity
Soil infiltration measures the rate at which water enters the soil, which influences water availability for plants and the risk of runoff and erosion. Soils with higher water holding capacity can better withstand drought conditions.

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How to use this guide

The guide should be used as a reference for the in-field scorecard found in **Appendix A**. It provides detailed instructions, informative links, and relevant decision-making suggestions. This assessment can be done annually. Taking pictures will help you track your progress.

It is divided into sections following the assessment workflow, beginning with surface visual observations, and then moving to belowground measurements, which require more tools and data collection.

It is recommended you read through all the assessment steps and watch the relevant linked video tutorials before taking measurements in the field. *It's also helpful to know soil pH, Cation Exchange Capacity (CEC) and texture before you begin*, as this will influence water holding, nutrient holding capacity/leaching, erodibility, workability, root penetration, porosity, and yield potential. **Appendix A** includes a 'determine texture by feel' guide, if soil texture is unknown.

After you have read through the guide and documented your soil conditions on the scorecard, reference the suggested NRCS management practices that will address the issue, and then use the worksheets in **Appendix B** to guide your management decisions.

Remember, accuracy starts at sampling. It is important to sample at a consistent depth, randomize sampling locations within a field (or grid sample), and take the field average. Also compare field results with natural or undisturbed areas, this will provide a baseline for the assessment and allow for soil health to be evaluated over time.

Essential tools and equipment

- Shovel/spade
- Wire flag
- 6in diameter ring, 5 ¼ in length (or manufactured infiltrometer)
- 2in diameter ring, 2in in length (or manufactured bulk density ring)
- Plastic wrap
- Block of wood
- 500ml plastic bottle or graduated cylinder
- Square frame or quadrat
- Wire mesh
- Water
- Small hand lens or phone clip on lens
- Refractometer
- Garlic press
- Texture by feel guide (Appendix A)
- Soil Health Score Card (Appendix A)
- Camera or phone

Surface Conditions

Photo Credit: Kara Armano

Plant Living Diversity

A diverse plant community provides a range of ecological benefits that positively impact soil health and overall ecosystem functions. A more diverse plant community provides food and shelter for beneficial organisms, including a diverse soil microbial community

Assessment

You will estimate the number of different types of crops/plants that are currently growing in the chosen field. This includes crops, cover crops, weeds, and native vegetation. The assessment could be done multiple times a year.

Steps:

1. Choose a representative site that captures field variation. Alternatively, assess multiple sites and average findings.
2. Within a 20 ft radius, count the number of different plant species currently growing.
3. Ranking
    - 3+ types of crops/forage or plant species within sight
    - 2-3 different plant species/crops/forage
    - Monoculture or bare ground

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*See Appendix A for scoring

Plant Living Diversity (cont.)

NRCS Practices that Address Resource Concern

Conservation Cover (327)
Alley Cropping (311)
Conservation Crop Rotation (328)
Field Border (386)
Pasture and Hay Planting (512)
Wildlife Habitat Planting (420)

Figure 1. Winter wheat with under sown red clover. Image reproduced from from University of Nebraska Extension Service.

Figure 2. A wide vegetative zone between the crop field and shrubs creates a field border that provides higher quality habitat for beneficial wildlife (e.g. pollinators). Image reproduced from University of Missouri Extension Service.

Soil Cover

Soil cover plays a vital role in preventing soil erosion, reducing water runoff, maintaining soil moisture, and providing a habitat for beneficial organisms. It protects the soil surface from the impact of rainfall and wind, minimizing soil disturbance and loss of valuable topsoil.

Assessment

Soil cover is measured by estimating the proportion of soil surface covered by vegetation, crop residue, or other materials. It is commonly referred to as percent soil cover.

Steps:

1. Select multiple random sampling sites within the field, ensuring that they represent the field conditions.
2. Use a square frame or quadrat of known dimensions to help visualize the area. Place the frame at each sampling site. You may also mark out a standardized unit with flags, tape, or some other marker.
3. Visually assess the proportion of the frame that is covered by living vegetation, crop residue, or other materials. Avoid including bare ground or non-vegetated areas in the estimation.
4. Ranking (Percent of ground covered)
   - 75% or more
   - 25-75%
   - Less than 25%

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*See Appendix A for scoring

Soil Cover (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Conservation Crop Rotation (328)
Cover Crop (340)
No-till, Residue and Tillage Management (329)

Reduced Till, Residue and Tillage Management (345)
Mulching (484)
Pasture and Hay Planting (512)
Prescribed Grazing (528)

Figure 3 Crop residue at various percentages of cover. Image by Iowa State University.

Figure 4 Cover crop (right) protects the soil surface from rain, preventing soil erosion. Photo Credit: Megan Machmuller.

Brix

Brix is a measure of the soluble solids content in plant sap, primarily consisting of sugars, minerals, and other compounds. Brix is an indirect indicator of soil health because healthy soils support quality crops. Assessing Brix levels in plants can give insights into the plant's nutritional status, overall health, and indirectly indicate the soil's ability to provide essential nutrients.

Assessment

To measure Brix, you'll need a refractometer and a garlic press.

Steps:

1. Collect vegetation from desired crop or pasture to assess. Be sure to take clippings from multiple plants to get good representation of the crop/pasture's conditions.
2. Rip the plants into small pieces and then use the garlic press to crush the sample to extract sap or juice.
3. Open the cover of the refractometer and place a few drops of the extracted sap on the prism (usually found at the end of the refractometer)
4. Look through the eyepiece of the refractometer and focus until you see a clear line between light and dark areas (boundary line)
5. Read the brix value where the line intersects with the scale
6. Ranking
   - Good= 12+ (grasses), 14+ (legumes & fruits)
   - OK= 8-11
   - Low=<8

Brix (cont.)

NRCS Practices that Address Resource Concern

Conservation Crop Rotation (328)
Cover Crop (340)
Forage Harvest Management (511)
Wildlife Habitat Planting (420)
Mulching (484)
Irrigation Water
Management (449)
Pest Management Conservation System (595)
Nutrient Management (590)
Soil Carbon Amendment (336)

Figure 5 Squeezing plant sap onto refractometer for brix measure.

Surface Crusting

Surface crusting refers to the formation of a compacted layer on the soil surface, which can occur due to raindrops, irrigation, or other erosive forces. It is a common issue in soils with low organic matter content, low vegetation cover, and intense rainfall events. Crusting can inhibit seed emergence, and reduce water flow, gas exchange, and limit biological activity.

Assessment

Surface crusts can be present at any time throughout the day, or only found in isolated patches. It's best to look for crusting after a rain or irrigation event, or before the next tillage event.

Steps:

1. Walk through the field in the morning, mid-day, and late afternoon to visually inspect the soil surface for signs of crusting.
2. Look for a compacted layer on the soil surface, crusts will remain intact when picked up.
3. Ranking (Percent of ground covered)
    - No evidence of soil crusting.
    - Surface crusting in isolated patches.
    - Crusting throughout the field.

*See Appendix A for scoring

Surface Crusting (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
No-till, Residue and Tillage Management (329)
Reduced Till, Residue and Tillage Management (345)
Mulching (484)
Pasture and Hay Planting (512)
Prescribed Grazing (528)
Saline and Sodic Soil Management (610)

Figure 6 Crusting with uneven emergence. Image reproduced from from University of Minnesota Extension Service. Photo Credit: Angie Peltier.

Ponding

Ponding refers to the accumulation of water on the soil surface after rainfall or irrigation, resulting in temporary waterlogging. Standing water or evidence of surface runoff on the soil resulting from poor infiltration can be an indication of poor aggregate stability, poor soil structure, and/or compaction. It can also be a result from naturally occurring conditions such as an impermeable soil layer close to the surface. It has a negative effect on nutrient cycling, water and root penetration.

Assessment

The best time to look for evidence of ponding is after a rain or irrigation event. The field should be assessed within 24 hours of the event.

Steps:

1. Walk the chosen field within 24 hours of the last rainfall or irrigation event.
2. Identify areas where water remains on the surface on the soil. Look for a compacted layer on the soil surface, crusts will remain intact when picked up.
3. Ranking
   - No evidence of ponding.
   - Small puddles (<1m diameter) in isolated spots.
   - Ponding area spread over wide area.

*See Appendix A for scoring

Ponding (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Conservation Cover (327)
Deep Tillage (324)
Conservation Crop Rotation (328)
No-till, Residue and Tillage Management (329)
Amending Soil Properties with Gypsum Products (333)
Cover Crop (340)
Reduced Till, Residue and Tillage Management (345)
Irrigation Water Management (449)
Forage Harvest Management (511)
Pasture and Hay Planting (512)
Prescribed Grazing (528)

Figure 6 (a) Photos of flooded corn fields in Missouri, (b) flooded soybean fields in Mississippi, (c) mud deposition on soybean plants after flooding, (d) and complete plant loss in low-lying flooded areas in corn plots.

Erosion

Erosion is the physical loss of soil from the landscape which contributes to desertification. It's a gradual process where water or wind detaches soil particles from the bulk soil, which is then lost to waterways or contributes to dust storms when removed by disturbance (e.g. wind or mechanical).

Assessment

Water erosion should be assessed visually in the field and surrounding area (edge of field and adjacent drainages), ideally following a rain or irrigation event. Wind erosion is best assessed during, or immediately following, a wind turbulence event.

Steps: Water Erosion

1. Walk the edge of field after a rain event, or during an irrigation even, particularly the associated drainage areas.
2. Note if water runoff looks muddy or clumps of vegetation are floating downstream.
3. Look for cracks or gullies, barren spots, sunken or spongy areas, and structural cracks.
4. Ranking:
   - Runoff is slightly muddy and there are small clumps of floating vegetation
   - Runoff is dark and muddy, there are cracks and spongy areas near edge of field.
   - Major gully or stream bank erosion.

Steps: Wind Erosion

1. During, or immediately following wind turbulence, note signs of soil drifts, sand blasting, and bare patches .
   - ** Install erosions pins or pegs in soil at selected locations to measure erosion rates over time.
2. Ranking
   - No dust clouds or soil accumulation along fence lines during (or following) wind turbulence.
   - Small dust clouds visible, sandblasting evidence on plants.
   - Large bare patches present, soil accumulation along fence lines or snowbanks. Soil has drifted appearance.

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*See Appendix A for scoring

Erosion (cont.)

NRCS Practices that Address Resource Concern

Terrace (600)
Grassed Waterway (412)
Windbreak/Shelterbelt Establishment and Renovation (380)
Riparian Forest Buffer (391)
Conservation Crop Rotation (328)
Filter Strip (393)
Dam (402)

Grade Stabilization Structure (410)
Reduced Till, Residue and Tillage Management (345)
No-till, Residue and Tillage Management (329)
Conservation Cover (327)
Cover Crop (340)
Mulching (484)
Contour Farming (330)

Figure 8 Soil has drifted appearance and accumulated along fence lines after wind turbulence event.

Figure 9 Large dust cloud over agricultural fields during a wind turbulence event.

Soil Structure & Water Movement

Compaction

Compaction (or penetration resistance) is the process of reducing the volume of soil by compressing its particles. High penetration resistance restricts plant root growth, water infiltration, gas exchange and nutrient availability.

Assessment

The assessment should be performed with a handheld penetrometer, or a wire flag. The best time to assess penetration resistance is when soil moisture is close to field capacity. See the informational video for tips on measuring compaction.

Steps:

1. Choose 3 random locations in your field.
2. Insert the penetrometer or the end of the wire flag vertically into the soil. Apply steady and even pressure into the top 6 in of soil.
3. Record penetrometer resistance or note degree of resistance felt with the wire and compare it to an uncompacted area.
4. Ranking
   - 25-100 psi (little resistance or compaction)
   - 100-150 psi (moderate resistance)
   - >150 psi (soil feels compacted)

*See Appendix A for scoring

Compaction (cont.)

NRCS Practices that Address Resource Concern

Conservation Crop Rotation (328)
No-till, Residue and Tillage Management (329)
Controlled Traffic Farming (334)
Cover Crop (340)

Reduced Till, Residue and Tillage Management (345)
Forage Harvest Management (511)
Prescribed Grazing (528)
Alley Cropping (311)

Figure 10. Measuring penetration resistance in a field using a handheld penetrometer.

Bulk Density

Bulk density is a measure of soil density. It is the amount of soil particles and pore spaces in a given volume of soil. Bulk density, along with porosity, give a good indication of suitability for root growth and soil permeability.

Assessment

The soil bulk density is the weight of dry soil (g) divided by the total soil volume. A low bulk density is desirable for optimal air and water movement. Ideal ranges vary by soil texture. To perform this test, you will need a small metal ring or PVC pipe (ideally 2in diameter, 2in length), a mallet, soil knife, and piece of wood.

Steps:

1. Located several undisturbed spots in a field where you can take a sample.
2. Place metal ring (or PVC pipe) on soil surface and place a piece of wood over the ring to ensure pushing ring into soil is uniform.
3. Drive the ring into the soil at a 3-inch depth.
4. Excavate ring with soil knife or spade carefully.
5. Remove any excess soil or roots to ensure accurate volume, place in plastic bag.
6. Use an oven-proof container to hold the soil sample. Weigh the container before placing the soil into the container (W1).
7. Dry for 2 hours in oven at 105 ºC or until weight no longer changes.
8. When the soil is dry, weight the container and sample again (W2).
9. Use the recorded weights to calculate bulk density (see next page).

*See Appendix A for scoring

Bulk Density (cont.)

Bulk Density Calculation:

Soil volume= ring volume
Measure the height of the ring to nearest cm, measure the diameter of the ring and divide by 2 to get the radius.
Ring volume cm^3 = $3.14 \times r^2 \times$ ring height.
Dry Soil weight (g)= W2-W1

$$Bulk\ Density = \frac{g}{cm^3} = \frac{Dry\ soil\ weight}{Ring\ volume}$$

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Conservation Crop Rotation (328)
No-till, Residue and Tillage Management (329)
Amending Soil Properties with Gypsum Products (333)
Cover Crop (340)
Reduced Till, Residue and Tillage Management (345)
Forage Harvest Management (511)
Prescribed Grazing (528)

4)

Figure 11 Driving a metal ring into the soil using a mallet and wood block.

Figure 12 Removing excess soil after excavating ring

For a comprehensive overview of soil bulk density, see the USDA NRCS Soil Quality Guide.

Water Stable Aggregates

Water-stable aggregates are clusters of soil particles that are bound together, resisting disintegration when exposed to water. The stability of soil aggregates in the presence of water is important to resist erosion, encourage plant root growth, to protect soil organic matter, aid in water infiltration, and reduce water surface runoff.

Assessment

The slake test is a simple and effective method to assess water stable aggregates. To perform this test, you will need a clear glass jar (ideally a large mouth mason jar), chicken mesh wire (or something similar) and water.

Steps:

1. Collect undisturbed soil sample from different locations in a field from a 6in depth.
2. Fill a glass jar with water. Break off a ping-pong ball sized clod of soil from a depth of 3-6 in.
3. Place the clod into a chicken wire basket and suspend into the jar, fully submerged in water.
4. Set the timer for 30 minutes.
5. After 30 minutes, examine soil soil clod and water clarity.
6. Ranking
    1. Clods remain in-tact (high aggregate stability)
    2. Clods exhibit some breakage; water is slightly murky (moderate stability)
    3. Clods disintegrate; water is murky (poor aggregate stability)

*See Appendix A for scoring

Water Stable Aggregates (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Conservation Crop Rotation (328)
No-till, Residue and Tillage Management (329)
Amending Soil Properties with Gypsum Products (333)
Controlled Traffic Farming (334)
Cover Crop (340)
Reduced Till, Residue and Tillage Management (345)
Forage Harvest Management (511)
Prescribed Grazing (528)

Figure 13 Slake test depicting poor aggregate stability (left) and high aggregate stability (right).

Water Infiltration

Assessing water infiltration rate is crucial for understanding how quickly water can enter the soil, which directly impacts soil health and agricultural productivity. The rate of water infiltration is a key indicator of soil's ability to absorb and store water, which is vital for plant growth, groundwater recharge, and flood mitigation

Assessment

The most common method to assess water infiltration rate is the double-ring method. To perform this test, you will need a two metal rings or PVC pipe (one larger in diameter), a mallet, plastic wrap , timer, and block of wood. Alternatively, you can purchase a manufactured double ring infiltrometer. You should also know your soil type.

Steps:

1. Drive both rings into ground (with the smaller ring inside) 6-8 inches using a wood board and hammer to ensure its level.
2. Fill outer ring with water.
3. Cover the soil surface of the inner ring with plastic wrap.
4. Insert a ruler inside the inner ring so that it's flush with the soil surface.
5. Add a standardized amount of water into the inner ring (on the plastic wrap).
6. Slowly pull the plastic away and immediately start your timer.
7. Stop timer when the water completely drains or after 15 minutes and measure remaining water depth (mm water).
8. Use equation (next page) to calculate infiltration rate.
9. Ranking:
    - Coarse Sand: Good>0.8, Ok=0.79-0.6, Low=<0.59
    - Sandy Loams: Good=>0.7, OK=0.69-0.55, Low=<0.04
    - Loams: Good=>0.35, OK=0.34-3, Low=<0.02
    - Clay: Good= >0.2, OK= 0.19-0.1, Low= <0.09

*See Appendix A for scoring

Water Infiltration (cont.)

Infiltration Rate Calculation:

$$Inflitration\ rate\ \left(\frac{in}{hr}\right) = \frac{\frac{mm\ water}{15\ min} X \frac{60\ min}{1\ hr}}{25.4}$$

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Conservation Cover (327)
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Cover Crop (340)
Reduced Till, Residue and Tillage Management (345)
Irrigation Water Management (449)
Forage Harvest Management (511)

Figure 14. Driving double rings into ground.

Figure 15. Adding known volume of water to the inner ring over the plastic wrap

Soil Biology

Plant Root Structure

Plant roots are a direct reflection of soil conditions, making them a valuable indicator of soil health. Healthy root systems indicate well-structured soil with optimal nutrient cycling, water availability, and aeration. Robust root systems are also indicators of microbial activity, which contributes to disease defense and system stability.

Assessment

To examine plant root structure, you will need a spade/shovel.

Steps:

1. Choose several random spots within your field. Carefully insert your spade into the soil to a depth of approximately 6 inches.
2. Dislodge the soil, being careful to keep the root systems intact.
3. Inspect the root system both within the sampled soil, and within the hole.
4. Note the firmness of the roots and if there are any signs of decay.
5. Note the density of roots, their color, length and direction. Are they growing all directions, or do they look stunted and/or growing horizontally?
6. Ranking
    - Roots are growing in all directions and feel firm to the touch; can visually see root hairs.
    - Roots are slightly stunted, growing more horizontally than vertically.
    - Visual hard pan; roots are clearly being pushed upward; there are signs of decay.

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Plant Root Structure (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Cover Crop (340)
Conservation Crop Rotation (328)
No-till, Residue and Tillage Management Controlled Traffic
Farming (334)

Pasture and Hay Planting (512)
Prescribed Grazing (528)
Nutrient Management (590)

Figure 16 Roots hold soil intact, growing in all directions, root hairs are visible.

Biological Diversity

A diverse soil ecosystem consists of various microorganisms (bacteria, fungi, protozoa), microfauna, and nematodes. These organisms contribute to nutrient cycling, organic matter decomposition, disease suppression, and overall soil fertility. Monitoring soil biological diversity helps assess the sustainability and resilience of soil ecosystems, which in turn impacts plant health, crop productivity, and environmental well-being.

Assessment

While much of soil biodiversity cannot be seen with the naked eye, there are still visual indicators of diversity. For this assessment, you will need a spade (or shovel). You may find having a small magnifying glass also helpful.

Steps:

1. Dig a hole using the shove or spade. The depth of the hole should match the root zone (6-12 inches deep).
2. Dislodge the soil, being careful to keep the root systems intact.
3. Inspect the root system and hole for signs of life. Use a handheld lens or camera lens to magnify small organisms.
4. Count the number of macroinvertebrates and earthworms.
5. Look for fungi hyphae, which appear as thin, white silky fibers
6. Ranking
    - Earthworms: abundant (at least 10); few (2-9); sparse (0-1)
    - Macroinvertebrates: clearly evident; few evident upon close examination; or no visible biological activity
    - Fungal hyphae: clearly evident; few evident upon close examination; none visible.

*See Appendix A for scoring

Biological Diversity (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Cover Crop (340)
Conservation Crop Rotation (328)
No-till, Residue and Tillage(329)
Cover Crop (340)
Reduced Till, Residue and Tillage Management (345)
Mulching (484)
Forage Harvest Management (511)
Prescribed Grazing (528)
Nutrient Management (590)

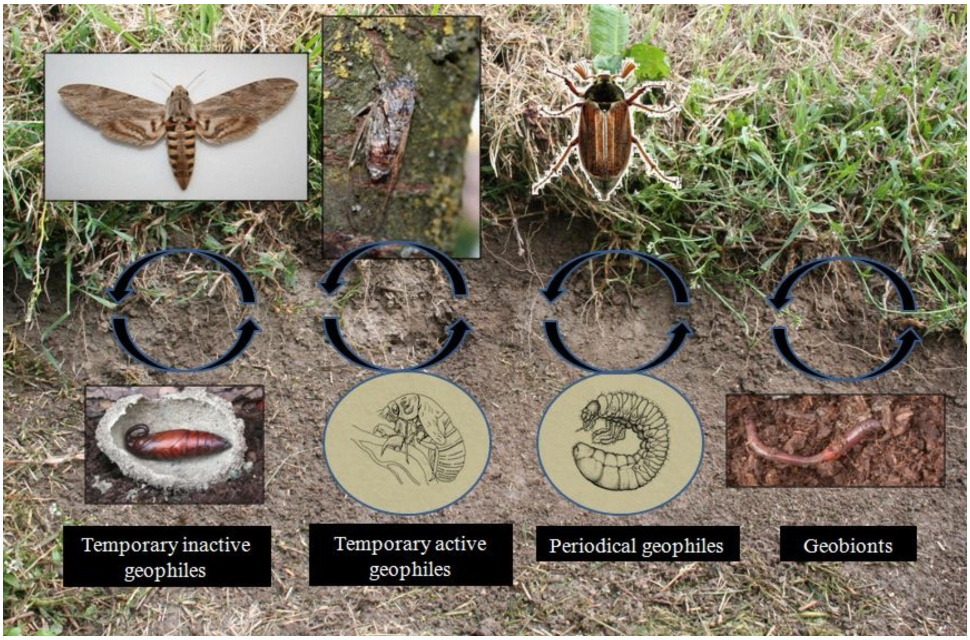

Figure 17. The main four grouping soil invertebrates found in agricultural soil. Each group has a different life strategy and cycle. Image sourced from Biodiversity Conservation and Utilization in a Diverse World.

Figure 18. Fungal Hyphae appear white and spindly, usually associated with roots.

Microbial Activity

Soil microorganisms breakdown organic materials, driving the fundamental process of decomposition. The rate of decomposition reflects the activity of beneficial microbes, such as bacteria and fungi, which are essential for nutrient cycling and maintaining soil fertility.

Assessment

The "soil your undies" test is a fun and educational way to assess the level of biological activity and decomposition happening in your soil. This test takes 2-3 months to complete. It should be performed during the warm months of the year, ideally the crop growing season. You will need a shovel (or spade), a piece of 100% cotton, white, natural cloth (underwear, t-shirt, or similar), and a flag/marker.

Steps:

1. Choose several random spots within your field. Dig a hole approximately 6-8 inches deep at each site.
2. Lay the fabric completely flat in the hole, and fully cover it with soil.
3. Mark the location of the buried fabric with a marker or flag for easy identification.
4. Leave the fabric for 2-3 months.
5. After 2-3 months, carefully dig up the buried fabric from each test site and examine the fabric for the level of decomposition.
6. Ranking
   - The fabric as many holes and little structural integrity.
   - The fabric has many holes, but still intact.
   - The fabric has few holes, the original structure is fully recognizable.

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*See Appendix A for scoring

Microbial Activity (cont.)

NRCS Practices that Address Resource Concern

Alley Cropping (311)
Cover Crop (340)
Conservation Crop Rotation (328)
No-till, Residue and Tillage Management Controlled Traffic
Farming (334)

(512)
Prescribed Grazing (528)
Nutrient Management (590)

Figure 15. Results of the "Soil Your Undies" challenge on the Volsen farm in Minnesota. Each pair of "undies" was buried in soil under different management: 3 years no-till and cover crops (upper left), strip-till with a cocktail cover rotation (lower left), conventional (middle), and minimum tillage with a cover crop (upper right). Decomposition was greatest under conservation management practices, indicating greater microbial activity (Photo Credit: Amanda Volsen).

Linked Resources

IN-RICHES Website

https://www.inrichsoil.com

Randomized Sampling Procedures

https://www.css.cornell.edu/courses/260/Soil%20Sampling%20Procedures.pdf

Penetration Resistance (Measuring Compaction):

https://www.youtube.com/watch?v=GpDPwfABfRo

Brix Test:

https://www.youtube.com/watch?v=sYwnMIrr4AE
measuring brox video

Refractometer

https://www.thenaturelifeproject.com/fix-your-brix/

Slake Test:

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Double Ring Infiltration Test

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Infiltrometer

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Soil Your Undies Test:

https://www.youtube.com/watch?v=luTZ5gaJGKM

Recommended NRCS Practices

- Alley Cropping (311)
- Deep Tillage (324)
- Conservation Cover (327)
- Conservation Crop Rotation (328)
- Contour Farming (330)
- No-till, Residue and Tillage Management (329)
- Amending Soil Properties with Gypsum Products (333)
- Controlled Traffic Farming (334)
- Soil Carbon Amendment (336)
- Cover Crop (340)
- Reduced Till, Residue and Tillage Management (345)
- Windbreak/Shelterbelt Establishment and Renovation (380)
- Field Border (386)
- Grade Stabilization Structure (410)
- Grassed Waterway (412)
- Wildlife Habitat Planting (420)
- Mulching (484)
- Irrigation Water Management (449)
- Forage Harvest Management (511)
- Pasture and Hay Planting (512)
- Prescribed Grazing (528)
- Nutrient Management (590)
- Pest Management Conservation System (595)
- Terrace (600)
- Saline and Sodic Soil Management (610)

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Figure 1
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Figure 2
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Figure 3
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Figure 4
Photo Credit: Megan Machmuller

Figure 5
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Figure 6
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Figure 7
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Figures 8 & 9
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Figure 10
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Figure 11 & 12
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Figure 13
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Figure 14
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Figure 15
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Figure 16
Photo Credit: Alexandra Firth

Figure 17
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Figure 18
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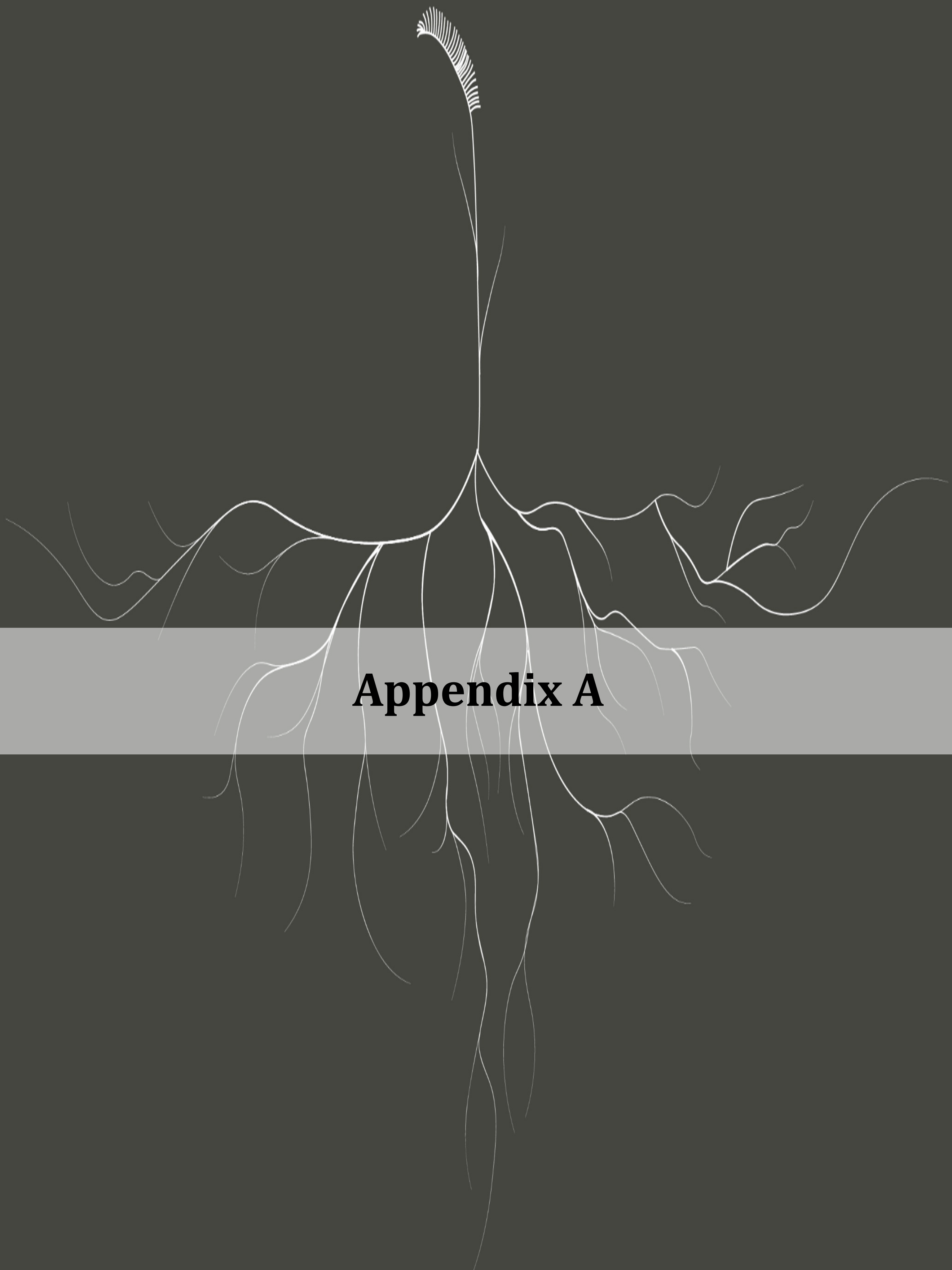
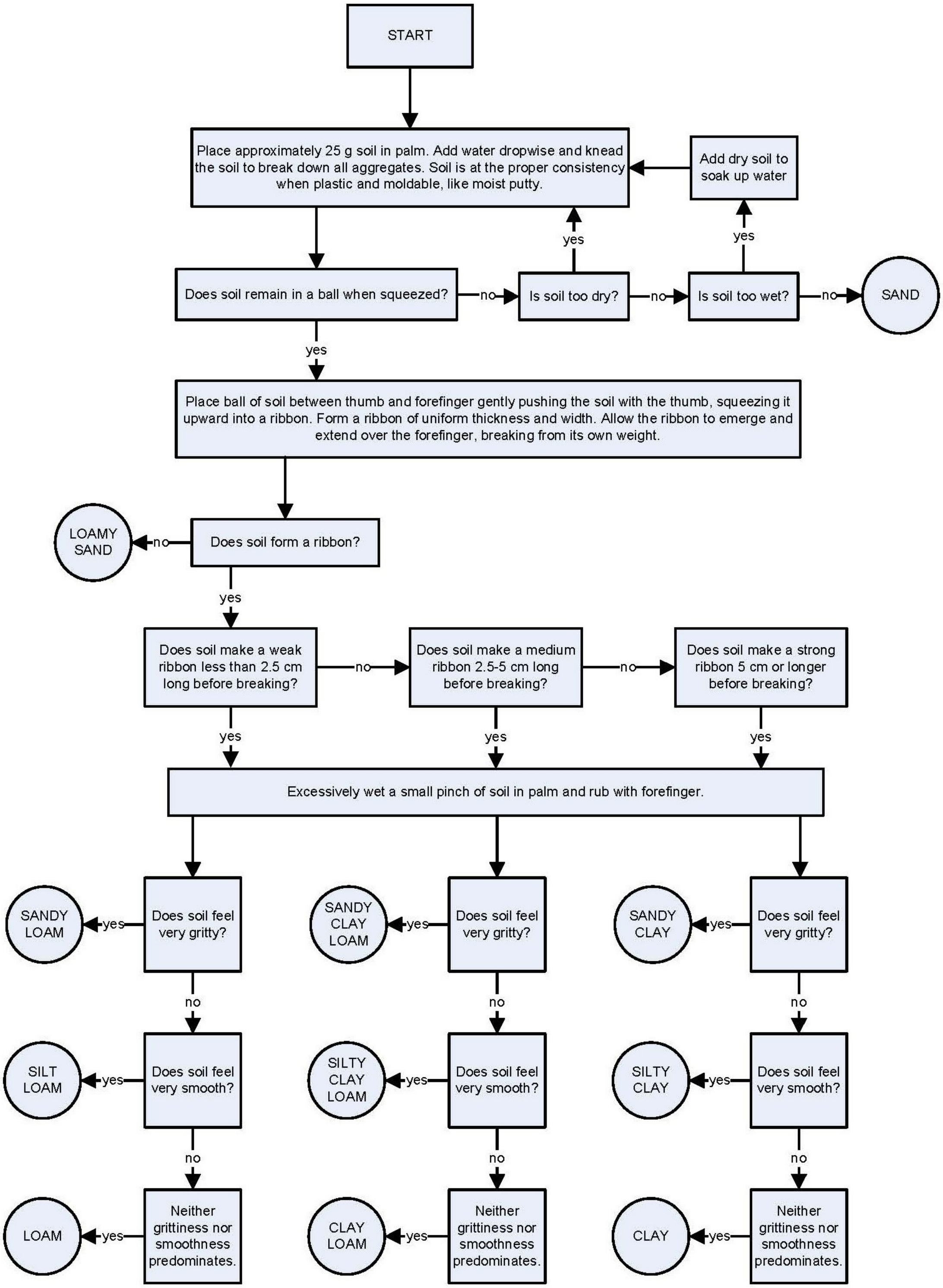
Appendix A



Guide to Texture by Feel

Modified from S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55.



Texture class is one of the first things determined when a soil is examined. It is related to weathering and parent material. The differences in horizons may be due to the differences in texture of their respective parent materials.

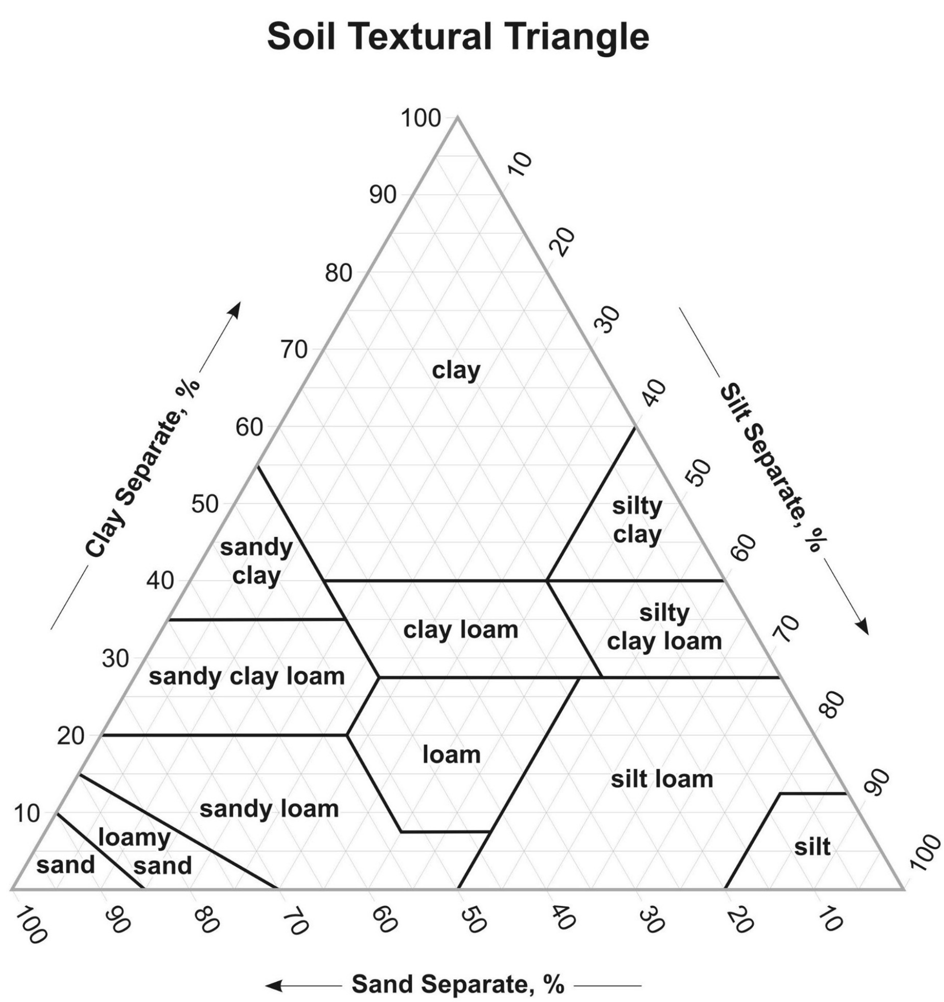
Texture class can be determined fairly well in the field by feeling the sand particles and estimating silt and clay content by flexibility and stickiness. There is no field mechanical-analysis procedure that is as accurate as the fingers of an experienced scientist, especially if standard samples are available. A person must be familiar with the composition of the local soils. This is because certain characteristics of soils can create incorrect results if the person does not take these characteristics into account.

In some environments clay aggregates form that are so strongly cemented together that they feel like fine sand or silt. In humid climates iron oxide is the cement. In desert climates silica is the cement and in arid regions lime can be the cement. It takes prolonged rubbing to show that they are clays and not silt loams.

Some soils derived from granite contain grains that resemble mica but are softer. Rubbing breaks down these grains and reveals that they are clay. These grains resist dispersion and field and laboratory determinations may disagree.

Many soil conditions and components mentions earlier cause inconsistencies between field texture estimates and standard laboratory data. These are, but not limited to, the presence of cements, large clay crystals, and mineral grains. If field and laboratory determinations are inconsistent, one or more of these conditions is suspected.

Soil Textural Triangle



Soil Health Assessment & Scorecard

Date:

Field ID:

General Info	Management History: (crop rotation, tillage, fallow season management, etc.)		
	Soil testing: Accuracy starts at sampling. It is important to sample at a consistent depth, randomize sampling locations within a field (or grid sample), and take the field average. Compare field results with soils sampled from natural or undisturbed areas, this will provide a baseline for the assessment and allow for soil health to be evaluated over time. It's helpful to have your soils tested at a laboratory to provide context and aid in decision making.		
	Soil Texture (See Appendix A if unknown)::		
	pH (If known): CEC (If known):		
	Recent Rainfall: Consider recent rainfall in relation to surface ponding, texture, etc.		
	Indicator	**Score**	**Instructions**
1. Visual Assessment of Surface Conditions	**Living Plant Diversity** 3= 3+ types of crops/forage or browse within sight 2=2 types of crops within sight 1=monoculture		Within a 20 ft radius, count the number of different plant species currently growing.
	Soil Cover 3 = 75% or more 2 = from 25 to 75% 1 = less than 25%		Use a square frame or quadrat of known dimensions to help visualize the area. Visually assess the proportion of the frame that is covered by living vegetation, crop residue, or other materials.
	Brix test of vegetation 3=12+ for grasses, 14+ for legumes and fruits 2=8-11 1=<8		Use steel garlic crusher to squeeze juice from plant; place on refractometer lens, hold to sun to read. Only test midday; consider current and recent cloud cover.

	Indicator	Score	Instructions
1. Visual Assessment of Surface Conditions	**Surface crusts** 3 = No evidence of surface crust 2 = Surface crust is isolated patches 1 = Surface crust throughout the field		It’s best to look for crusting after a rain or irrigation event, or before the next tillage event. Look for a compacted layer on the soil surface, crusts will remain intact when picked up.
	Ponding 3= no evidence of ponding 2=Small puddles (<1m diameter) in isolated spots 1=ponding area spread over large portion of field		Walk the chosen field within 24 hours of the last rainfall or irrigation event. Identify areas where water remains on the surface on the soil.
	Water Erosion 3=Runoff is slightly muddy and there are small clumps of vegetation 2=Runoff is dark and muddy, there are cracks and spongy areas near edge of field 1= major gully or stream bank erosion visible		Assessed visually in the field and surrounding area (edge of field and adjacent drainages), ideally following a rain or irrigation event. Look for cracks or gullies, barren spots, sunken or spongy areas, and structural cracks.
	Wind Erosion 3= No dust clouds or soil accumulation along fence lines during (or following) wind turbulence 2=Small dust clouds visible, sandblasting evidence on plants 1= Large bare patches present, soil accumulation along fence lines or snowbanks. Soil has drifted appearance.		Assessed during, or immediately following, a wind turbulence event. Note signs of soil drifts, sand blasting, and bare patches. *** Install erosions pins or pegs in soil at selected locations to measure erosion rates over time
2. Soil Structure & Water Movement	**Compaction via Penetrometer (top 6 in)** 3= 25-100 2= 100-150 1= >150 **Compaction via wire flag (top 6 in)** 3=minimal resistance 2=moderate resistance 1=difficulty inserting flag		Use a hand-held penetrometer to assess compaction. If you don’t have access to one, a wire flag poked into the ground can work. Insert the penetrometer or the end of the wire flag vertically into the soil. Apply steady and even pressure into the top 6 in of soil. Record penetrometer resistance or note degree of resistance felt with the wire and compare it to an uncompacted area.

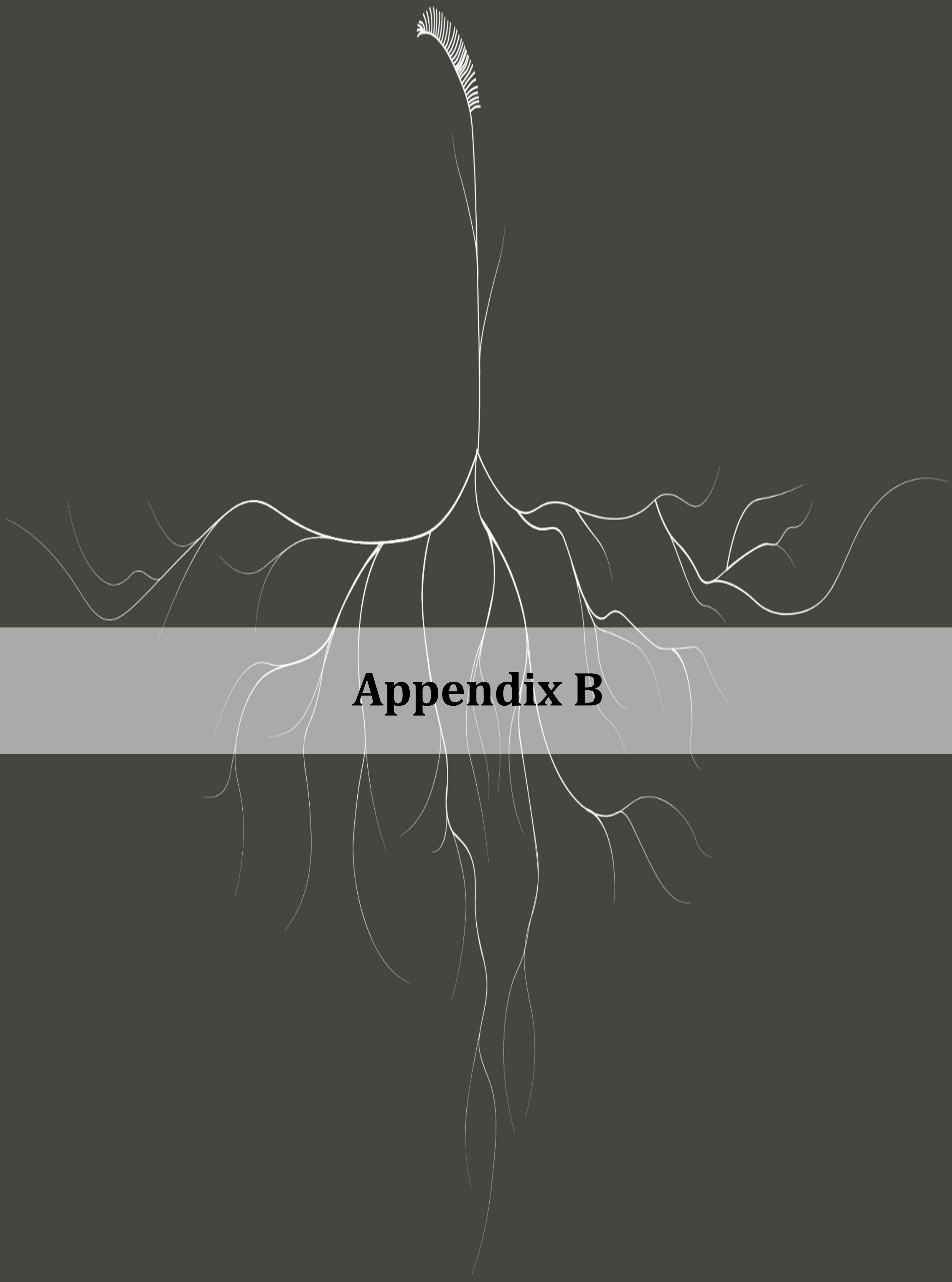
	Indicator	Score	Instructions
2. Soil Structure & Water Movement	**Bulk Density** Sandy: 3= <1.6 g/cm^3 2= 1.6-1.79 g/cm^3 1= >1.8 g/cm^3 Sandy Loams: 3= <1.4 g/cm^3 2= 1.4-1.79 g/cm^3 1= >1.8 g/cm^3 Loams: 3= <1.4 g/cm^3 2= 1.4-1.74 g/cm^3 1= >1.75 g/cm^3 Clay: 3= <1.10 g/cm^3 2= 1.2-1.55 g/cm^3 1= >1.56 g/cm^3		If necessary, wet soil manually, prepare a flat undisturbed soil surface, place metal ring on soil surface, place a piece of wood over the ring to ensure pushing ring into soil is uniform, hammer ring into soil, excavate ring with soil knife or spade carefully, remove any excess soil or roots to ensure accurate volume, place in plastic bag. Weigh an oven proof container (W1), remove soil from bag into container. Dry for 2 hours in oven at 105 degrees C or until weight no longer changes. When the soil is dry, weight the container and sample again (W2). Soil volume= ring volume Measure the height of the run to nearest cm, measure the diameter of the ring and divide by 2 to get the radius. Ring volume cm^3 = 3.14 x r^2 x ring height. Dry Soil weight (g)= W1-W2 $Bulk\ Density = \frac{g}{cm^3} = \frac{Dry\ soil\ weight}{Ring\ volume}$
	Water Stable Aggregates 3= clods remain intact 2=clods exhibit moderate stability 1=clods disintegrate		Fill a mason jar (or similar clear container) with water, break off a ping-pong ball sized clod of soil from a depth of 3-6 inches. Place the clod in a chicken wire basket and suspend into the mason jar, fully submerged. Examine the remaining clod and water clarity after 30 mins.

	Indicator	Score	Instructions
2. Soil Structure & Water Movement	**Water infiltration** Sandy: 3= >0.8 2= 0.79-0.6 1= <0.59 Sandy Loams: 3= >0.7 2= 0.69-0.55 1= <0.04 Loams: 3=>0.35 2=0.34-3 1=<0.02 Clay: 3=>0.2 2= 0.19-0.1 1= <0.09		Drive both rings into ground (the smaller of the two inside of the larger ring) 6-8 inches using a wood board and hammer to ensure its level. Fill outer ring with water. Cover the soil surface of the inner ring with plastic wrap. Insert a ruler inside the inner ring so that it's flush with the soil surface. Add a standardized amount of water into the inner ring (on the plastic wrap. Slowly pull the plastic away and immediately start your timer. Stop timer when the water completely drains or after 15 minutes and measure remaining water depth. $Inflitration\ rate\ \left(\frac{in}{hr}\right) = \frac{\frac{mm\ remaining\ water\ depth}{15\ min} X \frac{60\ min}{1\ hr}}{25.4}$
3. Soil Biology	**Root structure** 3= roots growing in all directions 2= roots slightly stunted, longer horizontally than vertical 1=visual hard pan, roots clearly being pushed upward		Inspect the root system both within the sampled soil, and what can be seen within the hole. Note the firmness of the roots and if there are any signs of decay. Note the density of roots, their color, length, and direction.
	Earthworms 3 = abundant (at least 10) 2 = few (2 to 9) 1 = sparse (0-1)		Number of worms or worm sign/cubic foot of soil
	Macroinvertebrates 3 = Clearly evident 2 = Few evident upon close examination 1 = No biological activity visible		A visual assessment of organisms (besides earthworms) we can see.

	Indicator	Score	Instructions
3. Soil Biology	**Fungal hyphae** 3 = Clearly evident 2 = Few evident upon close examination 1 = No biological activity visible		Visual assessment of mycorrhizal fungi, which appear as thin, white silky fibers.
	Microbial Activity (Soil Your Undies test) 3= fabric has many holes; little structural integrity 2= many holes but still intact 1= few holes; original structure recognizable		This test allows one to see microbial activity via decomposition. Bury the fabric at a 6-8 inches depth. The fabric should be laid flat and fully covered with soil. You could measure decomposition over 2 weeks, 1 month, or several months (3 months over growing season recommended).

	Total:		45-38= Good, many indicators of healthy soil. 37-30= Okay, soil health indicators present, but with some areas for improvement. <29= Low, soil is lacking positive indicators, many areas for improvement.

Scorecard adapted from: Beth H. Baker & Alexandra G. Firth, Mississippi Land Stewards In-Service Training, Research and Education to Advance Conservation and Habitat (REACH), Mississippi State University Extension.



Appendix B

Operation Reflections

General Soil Health Considerations

- What is your soil texture?
- How have soil conditions impacted your farms/ranch?
- How have you managed soil concerns in the past?

Weather & Climate

- Historically, how often have you delt with adverse environmental conditions (drought, flooding, etc.)?
- What is the range of your anticipated annual precipitation?
- What are the critical growth periods for your crops/rangeland forage/hay?
- What are the future forecasts of the region?

Water Resources

- Where do you usually source water?
- Are there any water quality or quantity concerns?
- What is your well capacity and ability to pump?

Financial Resources

- How do soil conditions impact your business plan?
- What is the cost of production for each of your enterprises?
- What is the financial risk if you change management practices?
- Are there any alternative markets that you can explore?

Worksheet adapted from: Managing Drought Risk on the Ranch: A Planning Guide for Great Plains Ranchers. The National Drought Mitigation Center, the University of Nebraska at Lincoln, South Dakota State University and Texas A&M Kingsville, 2014.

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Identifying Issues and Strategies

Worksheet 2

	Issue 1	Issue 2	Issue 3
Soil Health Issue			
Possible Strategy What are the potential management practices that could address this issue?			
Farm/Ranch Goal How will addressing this issue enable you to reach your operation's goal?			
Priority What is the feasibility and impact of the strategy?			
Potential Resources Given the cost or scale, do you need additional resources and/or partners?			

Worksheet adapted from: Managing Drought Risk on the Ranch: A Planning Guide for Great Plains Ranchers. The National Drought Mitigation Center, the University of Nebraska at Lincoln, South Dakota State University and Texas A&M Kingsville, 2014.