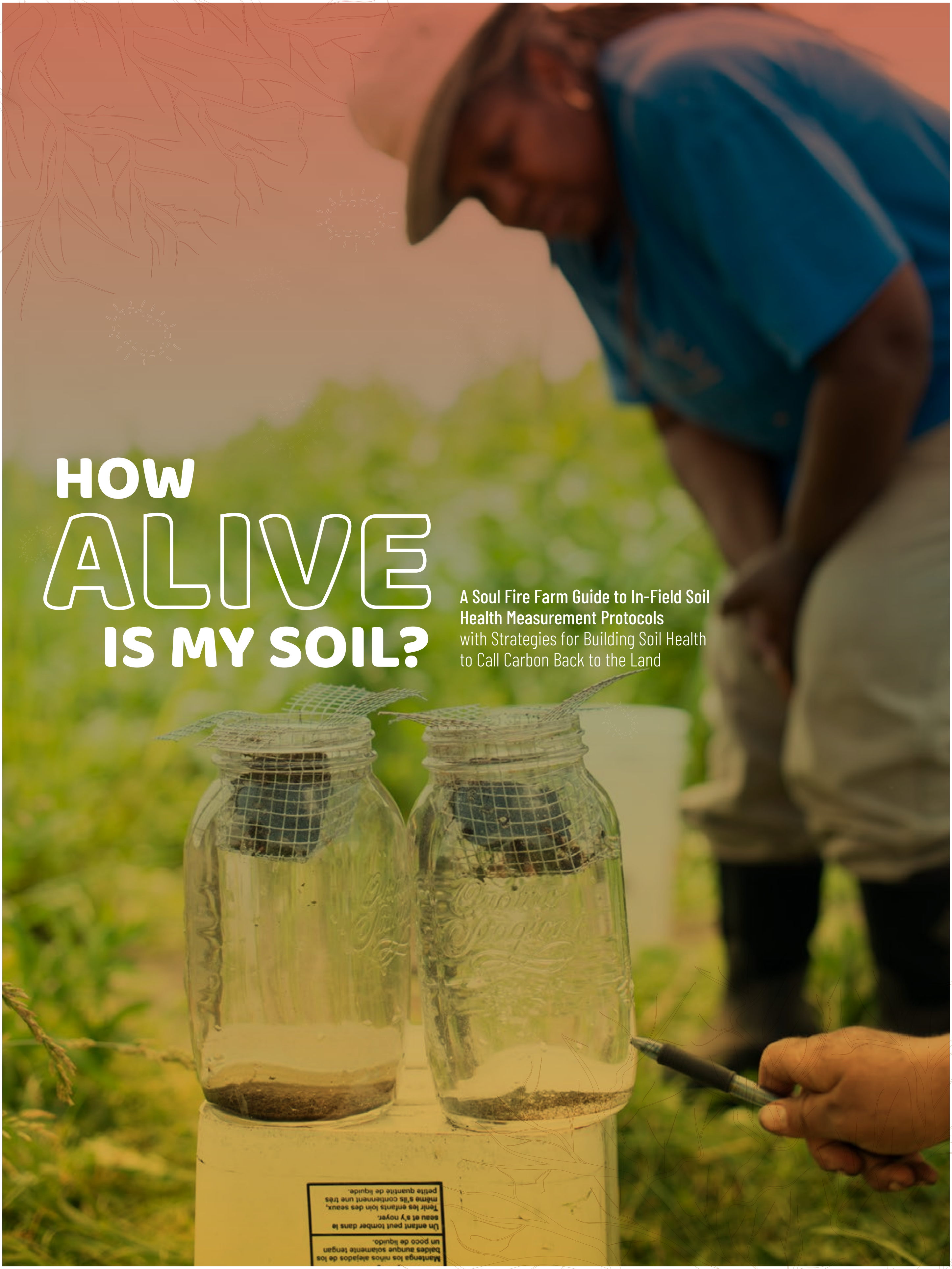

HOW ALIVE IS MY SOIL?

A Soul Fire Farm Guide to In-Field Soil Health Measurement Protocols
with Strategies for Building Soil Health to Call Carbon Back to the Land

CONTENTS

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Cover photo: Karen Washington at Rise and Root Farm observes soil during a slake test. Photo by Daniel Cardon

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> **"Our duty as earthkeepers is to call the exiled carbon back into the land and to bring the soil life home."**
>
> **Larisa Jacobson, Northeast Farmers of Color Land Trust**

As European settlers displaced Indigenous people across North America in the 1800s, they exposed vast expanses of land to the plow for the first time. It took only a few decades of intense tillage to drive around 50 percent of the original organic matter from the soil into the sky as carbon dioxide[1]. Agriculture continues to have a profound impact on the climate; along with forestry, deforestation, and other land use, it contributes roughly 24 percent of global greenhouse gas emissions[2].

The good news is that regenerative agricultural practices like minimal soil disturbance, organic production, compost application, the use of cover crops, and crop rotation as well as silvopasture systems that integrate nut and fruit trees, forage, and grasses can harness plants and soil to put carbon back where it belongs.

Soil is a living porous system made up of mineral and organic particles that interact with animals, fungi, bacteria, plant residue, water, and gases. Soil health refers to how well the soil is functioning from biological, physical, and chemical perspectives. Soil health impacts the quantity and quality of what we can produce on our farms and in our gardens, and it also affects how much carbon gets stored in the soil versus how much is released into the atmosphere. The amount of organic matter present in a soil (soil organic matter) is the foundation for how healthy a soil is. Soil organic matter is made up of approximately 58 percent carbon.

Since life is carbon based, carbon-containing molecules are a highly dynamic component of the soil ecosystem that is constantly changing forms. Plants take carbon dioxide out of the atmosphere, plant-derived organic carbon makes its way into the soil through root and litter inputs, life within the soil uses those inputs as food and energy to sustain their lives (decomposition), which leads to some of that carbon being released back into the atmosphere as carbon dioxide.

Taking a close look at the soil to understand its vitality and fertility isn't new. Long before the western study of soil science, Indigenous communities practiced—and still practice—methods of evaluating soil health, using characteristics like color or the presence of specific plants or insects that tell us something about the system as a whole. Based on these practices, soil scientists have created tests we can perform in the field to observe and measure signs of life.

This guide presents soil testing methods that can be performed in the field by farmers, gardeners, or anyone who desires to understand and appreciate soil from a different perspective. While these tests aren't intended to be a replacement for sending soil to a lab, they can be considered complementary to annual or biannual lab analysis.

The more you familiarize yourself with the tests, the easier it becomes to understand what each of them can show you. In most cases these tests can be performed by one person, but it can be helpful and it's certainly more fun to do them with someone else. If you are part of a farming team or community, please share the experience of learning the story of your soil with others.

Secondly, this guide presents management practices that are known to build and maintain soil health and store more organic carbon. Take what interests you and will work for your farm and available resources.

1 Soil Organic Matter in Temperate Agroecosystems: Long Term Experiments in North America, eds. Eldor A. Paul et al. (CRC Press, 1996).

2 Gensuo Jia et al. "Land-climate interactions," in Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, eds. Valérie Masson-Delmotte et al. (Intergovernmental Panel on Climate Change, 2019), 133, https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/05_Chapter-2.pdf.

In-Field Soil Health Measurement Protocols

In order to build soil health to grow flourishing plants (and people) and to store organic carbon, we first need to know what we're working with. Maintaining a vibrant ecosystem in healthy soils or welcoming life back to degraded soils begins with an evaluation of existing conditions. Learning how to measure soil health helps to build an understanding of and appreciation for the natural processes taking place. Identifying constraints that aren't obvious by day-to-day observation provides information to support management decision making.

The tests included in this guide can be performed in the field. The Earthworm Count, Infiltration, and Slake tests can be done with tools found at home or at a hardware store. The Soil Color, Soil Hardness, Microbial Biomass, and Soil Respiration tests require specialized equipment that can be found online from specialty dealers or from a lab.

Getting Started

The first step in testing is understanding your goal. Would you like to compare the quality of the soil in one field to another? Are you interested in tracking change over time to see how different management practices impact soil health and soil carbon?

The second step is to make a decision on what tests to perform given your assessment goals. This guide provides a description of each test, including an explanation of what the results tell you. These descriptions can help guide your assessment plan. You may decide to choose one test location to perform each of the tests, or selecting one or two of the tests may be sufficient if you have one aspect of soil health that you want to assess—such as compaction.

There are many factors that influence soil health, including the inherent soil type, or what the soil is naturally like in that space. This can vary even within one farm. It is helpful to know what your soil type is in order to understand its natural tendencies, how it behaves, and what it needs to thrive in order to do different types of farming. You can find your soil type through **Soil Web** or **Web Soil Survey**. Spanish language instructions for using Web Soil Survey are available in the **Web Soil Survey Version 3.0 Brochure in Spanish**.

Outcomes from any soil test, whether sent to a lab or assessed in the field, are influenced by inherent soil type as well as management. While it's helpful and encouraged to discuss results and soil testing experiences, especially with other farmers in your region, it's important to remember that each farm is unique and has its own history.

When to test

It is recommended to test in spring or in fall. Many of these tests call for "field moist" conditions which is generally considered one or two days after a significant rain or irrigation event. Though these tests can be performed in the summer, the warmer temperatures and dry conditions can affect results. For instance, earthworms often burrow deeper into the soil when conditions are hot and dry. The results of an earthworm count in these conditions may not reflect the number of worms working magic in the soil throughout a given year.

Testing every year in the same location and under similar weather and field conditions can be helpful to understand the health of your soil and to track change over time. However, change in results may take 3 to 5 years to appear as you alter your management practices.

Where to test

You can choose to test an individual space where you'd like to track change over time. Or, you can test two different spaces to see what you can learn from the contrast. For example, if you've had one field under production for five years, it might be interesting to test an undisturbed area to see how the spaces differ. Record detailed location descriptions and GPS coordinates to help you navigate to the same test site in subsequent years.

"I want to know the story of my soil."

Rafael Aponte,
Rocky Acres Community Farm

Field Notes

Documenting details about your test site location, weather conditions, irrigation events, and management history will help you to test under similar conditions in the future and to track change in a specific location. Fill in as much information as you have available.

Farm Name

Test(s) Performed by

Date of Test

Test Site Address

Weather & Temperature

Field ID

Crop(s)

Date of Last Rain or Irrigation Event

GPS Coordinates or Description of Location to Re-visit at a later date

(You can record GPS Coordinates using a mobile app such as **Gaia GPS** or **Google Earth**)

Latitude

Longitude

Description of location (example, center of row 15, field 3) or a hand drawn map

Soil Type (if known, example "Honeoye")

Soil Texture (if known, example "Silt Loam")

NRCS has a **Guide to Texture by Feel** that you can use to identify soil texture in the field.

Soil Temperature

A meat thermometer found at a grocery store or online can be used to take soil temperature.

Management History

Include information 3 years back, if known, for each test site.

THIS YEAR	1 YEAR AGO	2 YEARS AGO	3 YEARS AGO
Tillage Events (Circle all that apply and indicate the # of events per year) **Plow** ___________ **Harrow** ___________ **Cultivation** ___________ **Broadforked** ___________ **Spade turned** ___________ **Pasture** ___________ **Hayed** ___________	**Tillage Events** (Circle all that apply and indicate the # of events per year) **Plow** ___________ **Harrow** ___________ **Cultivation** ___________ **Broadforked** ___________ **Spade turned** ___________ **Pasture** ___________ **Hayed** ___________	**Tillage Events** (Circle all that apply and indicate the # of events per year) **Plow** ___________ **Harrow** ___________ **Cultivation** ___________ **Broadforked** ___________ **Spade turned** ___________ **Pasture** ___________ **Hayed** ___________	**Tillage Events** (Circle all that apply and indicate the # of events per year) **Plow** ___________ **Harrow** ___________ **Cultivation** ___________ **Broadforked** ___________ **Spade turned** ___________ **Pasture** ___________ **Hayed** ___________
Tarps	**Tarps**	**Tarps**	**Tarps**
Mulched **List Materials:**	**Mulched** **List Materials:**	**Mulched** **List Materials:**	**Mulched** **List Materials:**
Cover Crops **List Species:**	**Cover Crops** **List Species:**	**Cover Crops** **List Species:**	**Cover Crops** **List Species:**
Compost **Manure**	**Compost** **Manure**	**Compost** **Manure**	**Compost** **Manure**
Other amendments (List names below) organic or chemical fertilizers, foliar feeding, etc. ___________________ ___________________ ___________________ ___________________	**Other amendments** (List names below) organic or chemical fertilizers, foliar feeding, etc. ___________________ ___________________ ___________________ ___________________	**Other amendments** (List names below) organic or chemical fertilizers, foliar feeding, etc. ___________________ ___________________ ___________________ ___________________	**Other amendments** (List names below) organic or chemical fertilizers, foliar feeding, etc. ___________________ ___________________ ___________________ ___________________

List any constraints you've identified. Possible constraints include compaction, soil crusting, ponding, etc.

Soil Surface Observation

Photo by William Cecio

Observing the surface of the soil can tell us a little about what might be going on below. Noting the amount of covered versus bare soil and the diversity of plant, insect, and other biological life is a great first step to exploring the soil. More variety in the vegetation and less bare soil leads to an increase in soil health.

List the plants you see:

A mobile app like **Seek by iNaturalist** can help you to identify any plants of which you are unfamiliar with their name. If you are unable to name a type of plant, count the number of different species you see.

List other signs of life in the soil such as fungus, worm castings, animal excrement, insects:

How much covered ground is there, compared to bare soil? A mobile app such as **Canopeo** can help to estimate the percent of vegetation cover.

In-Field Soil Health Measurement Protocols

Earthworm Count

Infiltration

Slake

These tests can be performed with materials or tools found around your home or farm, or at a hardware store.

Earthworm Count

Earthworms provide many benefits to soil, including improving infiltration and contributing to healthy soil structure. They travel through the soil creating burrows which allow water to infiltrate and provide pathways for roots to grow. Earthworms move organic matter deeper into the soil, making it available to microbial life below. Earthworms eat plant residues, bacteria, fungi, and algae and tend to live where these are available.

Earthworms retreat to deeper layers of the soil in dry or cold conditions, so this test is best done in the spring or fall.

Photo by William Cecio

Photo by Daniel Cardon

Equipment Needed:

- Shovel or trowel
- Container for collecting worms
- Small tarp or bin for collecting soil
- Measuring tape or ruler

Estimated time to complete: **10 - 15 minutes**

1. **Measure, mark, and dig a 1 ft x 1 ft x 1 ft hole, placing soil from the hole into a bin or onto a tarp.**
2. **Place a small handful of moist soil in the earthworm collection container and set aside.**
3. **One handful at a time, sift through the soil set aside from inside the hole. Place each earthworm in the collection cup. Once sifted, the soil can be returned to the hole.**
4. **After you've picked through all of the soil, count and record the number of earthworms in the collection cup and record. Return the counted worms to their home in the soil, making sure they are covered with a small amount of moist soil to protect their delicate skin.**

Location Description:

____

____

____

____

 # Worms found in the hole: ____________

Infiltration

Infiltration rate is a measure of how quickly water sinks into the soil. Faster infiltration rates generally indicate good soil structure and porosity. Water absorbing into the soil too slowly can lead to ponding or erosion, which can be problematic to production. This test simulates exposure of one inch of water to the soil. Generally, an infiltration time under 10 seconds is considered a sign of good health, while a recorded time of over a minute can indicate poor soil structure or compaction.

Inherent Soil Type and Infiltration

- Water will typically infiltrate through a sandier soil faster than a soil containing larger amounts of clay.
- Infiltration rate is highly variable across a field and can be biased by channels in the soil formed by roots or earthworms.

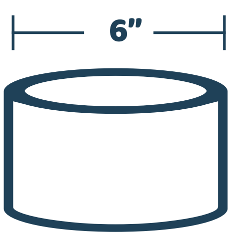
Equipment Needed:

- Infiltration Ring
- Measuring cup, graduated cylinder, or other container with milliliter (ml) markings
- Mallet or hammer
- Scrap piece of wood
- Approximately 444 ml water (1 inch of water in a 6" diameter ring)
- Plastic wrap
- Stopwatch or Timer

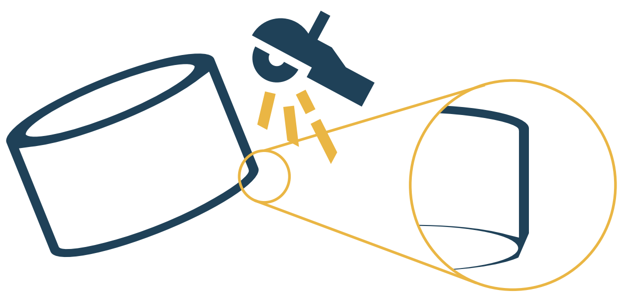
Estimated time to complete: **~3-60 minutes** depending on soil conditions

Make (or Purchase) Infiltration Ring

1 Cut a 6" diameter piece of sewer pipe or steel cylinder, at least 3 inches deep.



2 Sharpen the end with an angle grinder or other tool, so that you can drive the ring into the ground.



or Alternatively, **Soil Carbon Coalition** sells stainless steel infiltration rings (a pair for $45)

Infiltration

Photos by William Cecio

1. **Clear a level surface on the soil at your test site at least the size of the infiltration ring. Brush aside any mulch or residue, and cut back any vegetation.**

2. **Place the ring on the soil and place the scrap piece of wood across the top of the ring. Drive the ring an inch or two into the ground by pounding the wood with the mallet or hammer. Take care to keep the ring as level and even as possible. Set the wood and mallet or hammer aside.**

3. **Line the surface of the soil inside of the ring with a piece of plastic wrap that is large enough to come up the sides of the ring.**

4. **Pour the water into the ring, containing it within the plastic wrap.**

5. **Gently pull out the plastic wrap and start timing as soon as it has been removed.**

6. **Stop the timer once the water has absorbed and the surface of the soil is glistening.**

Location Description:

____

____

____

____

Infiltration Time: ________________

Slake

The slake test provides an opportunity to observe how well soil aggregates, clumps of soil particles, hold together when exposed to water. More stable soil aggregates will hold together better and provide resistance to erosion. Whereas, surface soil aggregates with poor stability breakdown into individual soil particles during rainfall events. These individual silt and clay particles can be carried away by water (erosion) and can resettle, clogging pores in the soil. When the clogged surface soil dries, it can form a crust at the soil surface, which can make it hard for seedlings to emerge. Soils that have higher organic matter levels tend to have greater aggregate stability, but this is not always the case.

In this test, soil collected from the test site is compared to soil collected from a nearby, undisturbed area, such as a perennial border, fencerow, or grassy area that hasn't been tilled.

Equipment Needed:

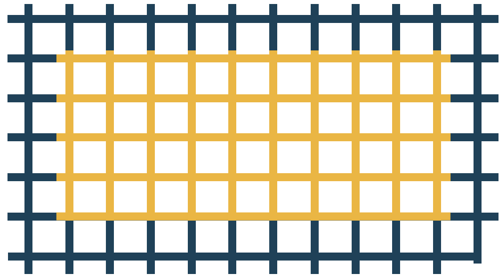
- Shovel, trowel, or soil knife
- 2 clear wide-mouth containers, at least 32 oz volume, such as wide-mouth canning jars
- Stopwatch or Timer
- 2 soil cages made from hardware cloth strips or similar material
- Tap water to fill each jar

Estimated time to complete:

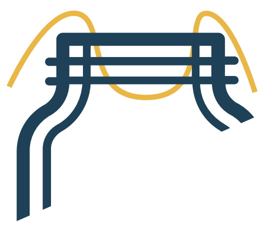
10-15 minutes

Make a Soil Cage

1 To make a soil cage, cut a 2″ x 10″ strip of ¼″ or ⅛″ hardware cloth, chicken wire, or other wire mesh material.



2 Bend each end of the strip so that it can hook onto the sides of the container.



You will need two soil cages to perform the Slake Test.

Slake

Photo by William Cecio

1. Fill the two clear containers with water and set aside
2. At the testing site, drive a shovel, trowel, or soil knife into the soil and pull out a slice of soil. From this slice, carefully select a chunk of soil from within the top 4 to 6 inches of the soil. Set aside, and avoid crushing the chunk of soil.
3. Repeat at the comparison site, choosing a site that hasn't been disturbed, such as a perennial border or grassy area. Take care to keep track of which soil sample is which.
4. Place each chunk of soil into a soil cage. At the same time, carefully submerge the soil into separate containers of water, hooking onto the sides of each container so that they remain submerged and are held within the top half of the container. Start a timer.
5. Watch to see which soil holds together and which one falls apart. After one minute, take a photo for future reference.
6. Estimate the percentage of each soil chunk remaining after one minute.

Location Description:

___

___

___

___

Describe location of the comparison site:

___

___

___

Estimate the percentage of soil remaining intact:

Test site: ____________ **Comparison site:** ____________

In-Field Soil Health Measurement Protocols

Soil Color

Soil Hardness

Microbial Biomass

Soil Respiration

These tests require specialized equipment that can be found online from specialty dealers or from a lab.

Soil Color

Photo by Soul Fire Farm

In this test we use color as an indicator for soil organic matter, which is responsible for giving soil its darker color. Organic matter is the portion of the soil that comes from living and once living organic material. As described above, soil organic matter is approximately 58 percent carbon.

In this test, a sample of soil is held next to a Munsell Soil Color Chart to find a visual match and is assigned a corresponding Munsell notation.

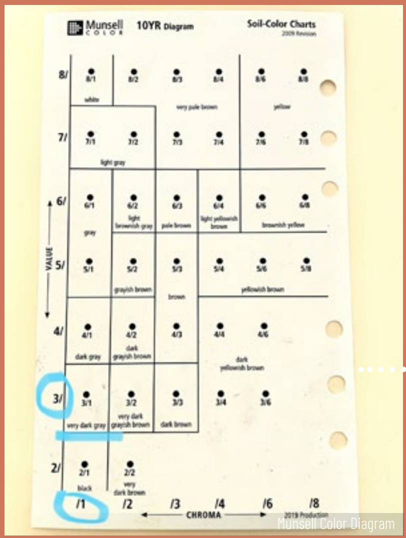
Equipment Needed:

- Soil Knife or trowel
- Small bucket or other container for collecting soil
- Spray bottle with water
- Munsell Soil Color Chart (Purchase here for $75)

Estimated time to complete: **10 minutes**

Soil Color

Photo by William Cecio



Munsell Color Diagram

1. Using a soil knife or trowel, collect 10 small soil samples from an area that represents the same soil type and management history. Gather the soil from the surface layer, 0 to 8 inches, and combine in the bucket, mixing well.
2. The soil should be moist and hold together, but not wet. Moist soil will not glisten in the sunlight. If the soil is too dry, use the spray bottle to moisten.
3. Take a handful of soil and make a ball.
4. In the sunlight, hold the ball of soil behind the holes in the Munsell 10YR Chart.
5. Match the color of the soil to the color in the Value section of the chart that runs vertically. Note the number associated with the Value. On the Munsell 10YR chart, this will be a number between 2 and 8.
6. After a Value has been determined, match the color of the soil to a Chroma color chip in the corresponding Value row. Chroma color chips run horizontally and on the Munsell 10YR chart will include numbers 1, 2, 3, 4, 6, and 8.
7. Record the Value and the Chroma. For example 3 / 1.
8. On the 10YR Diagram card, find the Hue that corresponds

Value = Lightness or Darkness

Chroma = Intensity/Vibrancy

Value: ________________ **Chroma:** ________________

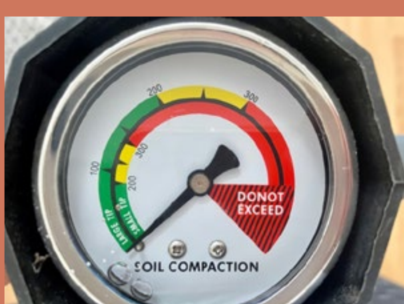
Soil Color Identified: ______________

Soil Hardness

Soil hardness is a measure of how much resistance to penetration exists in the soil. Soil hardness impacts how easily roots, Mycorrhizal fungi, and other life can grow and move through the soil. Compaction occurs when large pores in a soil collapse into smaller micropores, often as a result of tillage or the use of heavy equipment, especially on wet soils. Compacted soils can lead to runoff, erosion, poor water holding capacity, slow drainage, and can keep roots from accessing nutrients.

A tool known as a penetrometer gauges penetration pressure in soils and the readings are recorded as pounds per square inch (psi). Most plant roots are unable to penetrate soils with a penetrometer reading of 300 psi or greater. This test is most useful in fields where tillage or equipment traffic is more frequent or any other space more likely to have compaction.

This test should be performed one to three days after a significant rain. It's also important to note that this tool isn't very effective in soils that have a lot of rocks.



Equipment Needed:

Penetrometer
(Purchase online or ask an Extension office or other Agricultural Service Provider if there is one you can borrow)

Soil Hardness

1. Use the smaller tip, in most cases. The larger tip is used for very soft soil.
2. Press the penetrometer into the soil slowly, at an approximate rate of 1 inch per second. The penetrometer shaft has notches every three inches. As you drive the penetrometer through the soil, read the gauge as each three inch section of the shaft enters the soil. Make sure you are reading the section of the gauge corresponding to the size of the tip you are using. For the smaller tip, this is the inner scale. Record your readings at 0 to 6 inches and 66 to 18 inches.
3. The number of readings in a field depends on the accuracy you desire. It is recommended to average the total of three readings.
4. Note the depth at which the probe reaches compaction, when it can't drive any farther into the soil.

	ATTEMPT 1	ATTEMPT 2	ATTEMPT 3	AVERAGE
PSI at 0-6"				
PSI at 6-18"				

Compaction begins at _________ inches.

Location Description:

Microbial Biomass

Courtesy of microBIOMETER

Soil microbes release sticky compounds that help bind soil particles together into bigger soil clumps, or aggregates. For this test, we use a microBIOMETER® kit, which contains a salt and detergent extraction solution that releases the microbes from soil particles. After the microbes are separated from the soil, their biomass can be measured. The microBIOMETER® system utilizes a mobile app to read the color contrast of the microbes in solution against a special test card, and provides the resulting microbial biomass.

The microBIOMETER® instruction manual notes that biochar applied within 6 months before testing may affect results. The mobile app provides step-by-step instructions for ease of use. Note: the timer function within the app will not continue once your screen shuts off, if you have power saving settings applied. We recommend using your phone's timer or another timekeeping device.

Equipment Needed:

- **microBIOMETER® Field Test**
- **Smart Phone with microBIOMETER® mobile app installed**
- **Small Bucket or Container**
- **Soil Knife or Trowel**

Estimated time to complete: **25-30 minutes**

Microbial Biomass


Photo by William Cecio


Photo by Daniel Cardon


Photo by Soul Fire Farm

1. Before beginning the test, make sure you've downloaded and installed the microBIOMETER® mobile app.

2. Using a soil knife or trowel, collect 10 small soil samples from an area that represents the same soil type and management history. Gather the soil from a depth of 2 to 5 inches, and combine in a small bucket or container, mixing well. Soil should be moist. Collect 2 to 3 days after a significant rain or irrigation event.

3. Prepare the extraction liquid. Tear the powder packet open and place the extraction vial upside down on top of the open packet. Invert and tap to empty the contents into the vial. Using the small capped measurer, add 9.5 ml of water to the extraction vial.

4. Select a handful of soil from the mixed soil in the bucket. Sift the handful of soil using the included sifter. Shake to remove debris and collect the sifted soil in the provided plastic bag.

5. Measure the soil by filling the soil sampler syringe to ~1ml with sifted soil. Compress against your finger to 0.5 ml, remove any excess from the end, and eject into the extraction vial. The accuracy of your readings depends on the consistency of the soil volume and compaction.

6. Compacted soil (especially clay) must be broken up using the included metal spatula. Allow the tube to rest in the hole in the kit, insert the whisker, turn on, and allow to mix for 30 seconds. You do not need to touch the whisker while mixing.

7. Allow the soil to settle. This occurs in 2 stages. After mixing, allow the liquid to rest for 5 minutes. Tap the bottom of the tube on a hard surface to coax floating debris to settle. Allow to settle for an additional 15 minutes. Soil particles will settle to the bottom, creating a microbial suspension above.

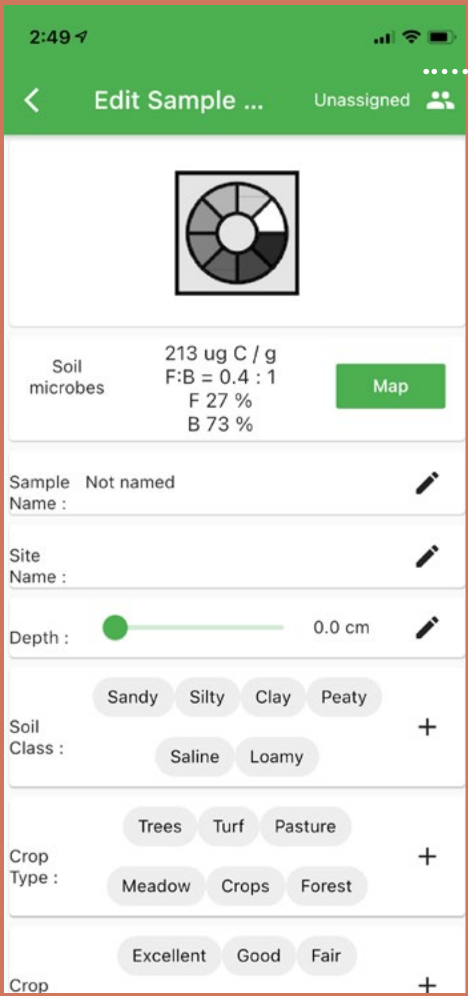
8. Sample microbes. Use a small pipette to draw up liquid from about half an inch below the surface. Squeeze the pipette before entering to avoid blowing bubbles. Avoid any floating debris and foam at the edges.

9. Place drops on the test card. Carefully apply 3 drops to the sample window. Allow each drop to soak in fully before applying the next. Analyze with the app within 2 minutes.

Microbial Biomass

10 Analyze with the app. Place the testcard on the appropriate spot on the backing card included in the kit. The app will first ask you to name the sample. Then it will automatically image the testcard and provide a reading. Align the blue square on the screen with the square on the testcard. When correct imaging is occurring the blue square turns green. A sample details screen will appear allowing you to enter sample specific information for your records.

11 Record the microbial biomass value and the corresponding interpretation located within the app and the sheet provided with the microBIOMETER® kit.



Ranges for Soil Microbial Readings

	Low	Fair	Good	Excellent
Agricultural Soil	Less than 200	200-400	400-600	600+
Container Soil	Less than 500	500-700	700-1200	1200+
Compost	Less than 500	500-700	700-1200	1200+
Compost Tea	Less than 20	20-30	30-60	60+
Compost Extract	Less than 30	30-40	40-80	80+

Courtesy of microBIOMETER

Location description:

____

____

____

____

Value: ____________

Interpretation (circle): Low Fair Good Excellent

Soil Respiration

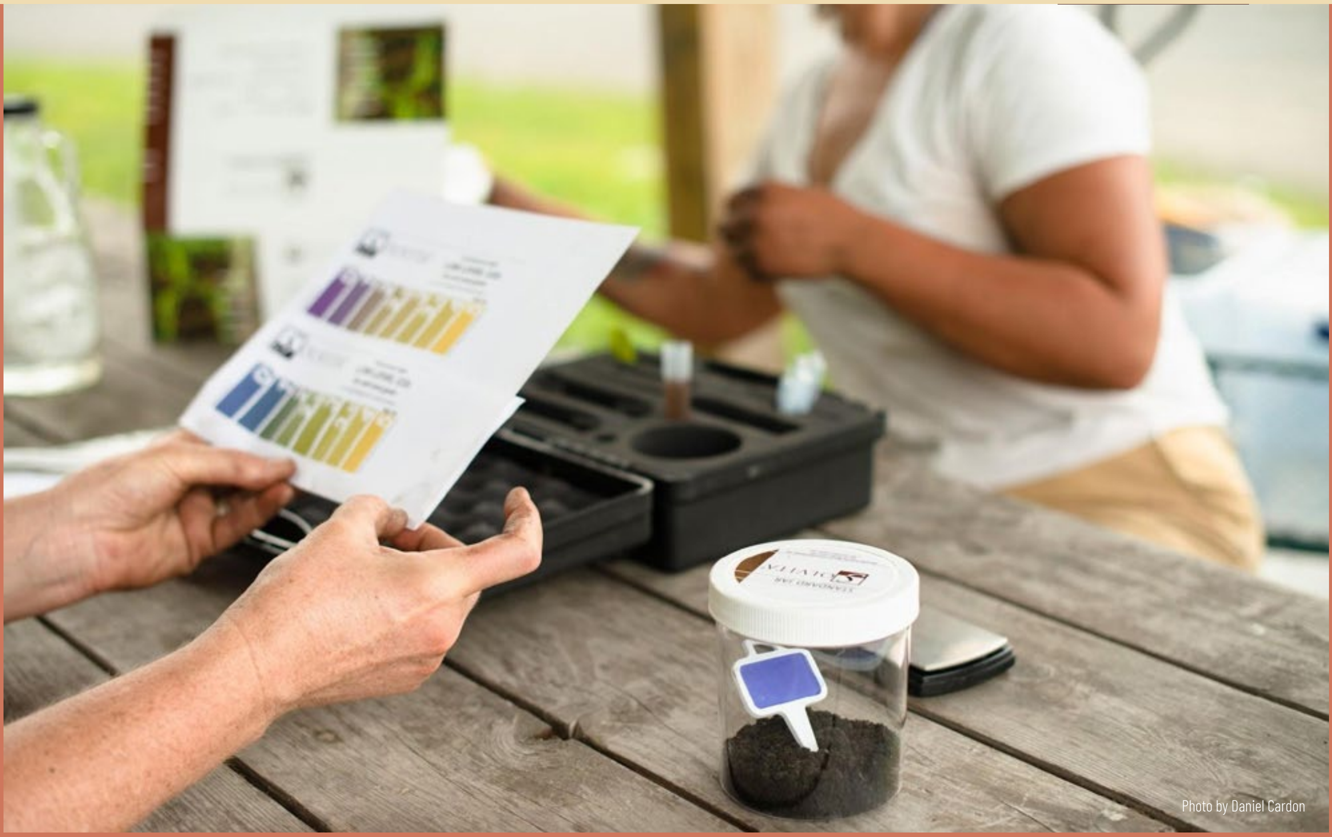


Photo by Daniel Cardon

Soil microbes ingest and process organic matter (food and energy) and exhale carbon dioxide (CO2). We can measure the amount of carbon dioxide respired using a Solvita field kit. The amount of CO2 measured with a Solvita probe can serve as an indicator of the potential microbial activity in a soil.

This test is best performed 2 to 5 days after a normal rainfall or irrigation event after water has infiltrated evenly. If soil is sampled too dry or too wet, it may produce lower respiration. Perform the test shortly after sampling.

Equipment Needed:

- **Solvita Basic CO2 Test ($99)*** – **Purchase here**
- **Sieve**
- **Small Bucket or Container**
- **Soil Knife or Trowel**
- **Container to place sieved soil**
- **Soil or Meat thermometer**
- **Kitchen scale**

Estimated time to complete: 24-26 hours

***When ordering a kit online, the Spanish Field Test Manual may be requested in the Order Notes section at checkout. Additional Spanish Field Test Manuals may be purchased from the Solvita online store.**

Soil Respiration

Photo by Soul Fire Farm

Photo by Soul Fire Farm

1. Using a soil knife or trowel, collect multiple small soil samples from an area that represents the same soil type and management history. Gather the soil from the top 0 to 6 inches, and combine in the bucket. Handle carefully, trying not to crush or grind the soil. Record the soil temperature at each sample site.
2. Gently sieve the soil to remove rocks, roots, or other debris.
3. Mix the soil from the locations sampled together.
4. Place test jar on the kitchen scale, set tare to zero, and add 90 grams of the fresh, moist soil to the jar.
5. Open the foil pouch and, without touching the gel surface, insert the test probe into the soil in the jar. The gel may be separated from the probe. If this is the case, carefully place it back onto the probe using the foil pouch, a clean instrument, or otherwise, without touching the gel with your fingers.
6. Screw the jar lid on tightly and record the start time
7. Temperature control is important. Keep the jar at roughly 70˚ F.
8. After 24 to 25 hours, remove the probe and compare the color of the gel to the color chart included with the kit. Note the number that corresponds to the color.
9. Interpret the results using Table 1 in the manual (see below).
10. If the soil temperature was not 70˚ F, adjust the values using the conversion factor found in Table 2 of the manual.

Soil Respiration

Location Description

____

____

Soil temperature: ____________________

Date/Time the probe inserted into soil in jar: ____________________ **(Read 24-25 hours later)**

Table 1:

Color # of gel compared to color chart: ____________________

CO2- C lbs / acre/ day result: ____________________

Table 2:

Soil temperature conversion factor ____________________

Final result:

Color # of gel adjusted by Table 2 conversion factor:

____

INTERPRETING CO2 RESPIRATION

The following table shows a soil biological activity curve in the range expected for moist cultivated soils measured at ambient temperature of 20-22°C (68-72°F). In situ (in-field) results may differ by a temperature factor shown in Table 2.

Table 1: Interpretation - Respiration in Test Jar at 20-22°C (68-72°F)

A	Color 0 - 1.0 Blue-Gray	Color 1.0 - 2.5 Gray-Green	Color 2.5 - 3.5 Green	Color 3.5 - 4.0 Green-Yellow	Color 4.0 - 5.0 Yellow	Color 5.0 - 6.0 Bright Yellow
B	Extreme LOW ACTIVITY Associated with extremely depleted soils	LOW ACTIVITY Marginal biological activity with low OM (organic matter)	MEDIUM-LOW ACTIVITY Medium active and may be accumulating OM	IDEAL ACTIVITY Active microbe population and good OM supply	MED-HIGH ACTIVITY Very active biologically with very high OM turnover	VERY HIGH ACTIVITY High biological activity with excellent supply of OM
C	ESTIMATED EMISSIONS (FLUX) OF CO2-C as kg/ha or lb/acre					
	0.5 - 1	1 - 5	5 - 15	15 - 25	25 - 60	60 - 160
D	INTERNATIONAL EMISSIONS (FLUX) OF CO2 as grams / m^2 / day					
	0.2 - 0.4 g/m^2	0.4 - 2.0	2.0 - 6.0	6.0 - 10.0	10 - 25	25 - 65

A: Color Reading of gel (this matches the official Solvita visual color key).

B: Suggested guideline to describe biological soil condition of cultivated soils.

C: Standard units to report respiration (see also Table 3, column D). Units are CO2-C. Results depend on a variety of factors such as depth of sampling, soil temperature and field-moisture.

D: International Metric Units based on CO2. For row C the units are CO2-C (i.e as carbon). Use 3.7 to get to CO2 (carbon dioxide) from CO2-C or 0.273 to go from CO2 to CO2-C.

Table 2: Conversion from room temperature (70F/20C) to actual temperature as measured in the field at sampling*

Actual Temp:	40°F / 5°C	50°F / 10°C	60°F / 15°C	70°F / 20°C	80°F / 30°C
Divide by to get actual field result	4	2	1.5	1	0.5

Example of using Table 2: If soil temperature when sampling is 60°F/10°C, and you ran the test at standard 70°F/20°C, then take the CO2-C lb/a result, divide by 1.5 then go to Table 1. See Solvita.com for the on-line calculator which makes continual adjustments for respiration at any given temperature. Conversely use the index to convert CO2 rates performed at non-standard results back to standard 70°F/20°C data.(*https://solvita.com/soil/basal-co2-guide*)

Soil Organic Carbon Sequestration Strategies

Regenerative agriculture harnesses the power of plants and their unique process of photosynthesis to draw carbon dioxide out of the atmosphere and into plants and eventually soils. At the heart of this system is an emphasis on rebuilding soil organic matter and creating vibrant soil ecosystems. When we build a nourishing habitat for the living organisms in the soil, we reap the benefits of their services which include carbon sequestration and forming a fertile foundation where plants can grow.

George Washington Carver was one of the first agricultural scientists to advocate for regenerative practices such as crop rotation, minimizing soil disturbance, increasing plant diversity, nutrient-rich mulching, and the use of leguminous cover crops. **These practices** welcome thriving, biodiverse soil communities, which can then work to build healthy soils and capture carbon.

To build a welcoming habitat, minimize disturbance and keep the ground covered as often as possible. From earthworms to fungal mycelium, nitrogen fixing bacteria to legume roots, we can't expect these folx to do their handiwork if we disrupt it by digging, overturning, or using other methods of agitation.

To feed these hardworking folx, provide them with organic matter, which is mostly carbon, and comes in many forms. We need a diverse community of soil organisms to perform a variety of roles. Some of these members of the soil community have established relationships with specific plants. Use diversity in plants to increase diversity in the soil, and keep living roots in the ground. Adding organic matter in any form is appreciated, whether compost, animal manure, the green manure of a cover crop, or any other type of organic amendment.

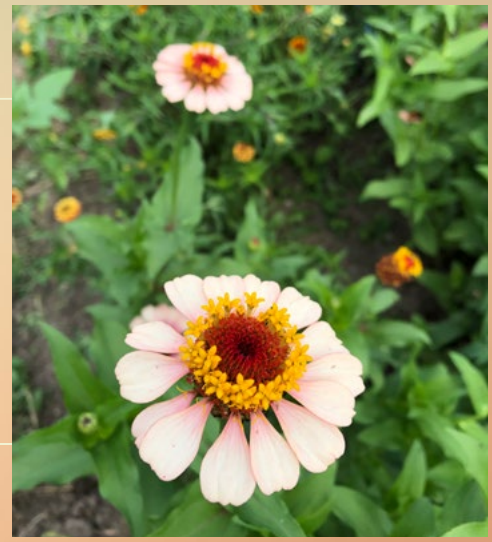
Minimize Disturbance

Using a no-till system, reducing tillage events, and tilling to a shallower depth help to maintain balanced soil ecosystems. Reducing tillage also slows the release of carbon dioxide into the atmosphere. Incorporating cover crops, tarping, mulches, and sheet composting are alternative tools to using mechanical tillage for bed preparation and weed control.


Photo by Daniel Cardon

Apply Organic Amendments

Composts and animal manures increase the organic matter available to the biological communities in the soil and can also provide cover to bare soil. Adding organic matter improves soil structure, infiltration, and water-holding capacity, among other benefits.



Rotate Crops

Rotating crops supports biodiversity in the soil, while reducing disease, insect, and weed pressure. Aim to transition between crops quickly to maximize days in living cover. Keep cover crops in your rotation. To increase soil biodiversity and prevent the buildup of disease don't follow a crop with a crop from the same plant family. . Incorporating diverse plants in rotation means you will reap the benefits of a diverse set of plants and their accompanying root structures, nutrients, and beneficial microorganisms. Perennial forage crops like red clover, alfalfa, etc. are great ways to let the soil rest in between higher value annual crops.

Additional Resources:
Crop Rotation on Organic Farms
Rotación de Cultivos en Sistemas Agrícolas Orgánicos

Plant Cover Crops

Cover crops are plants that are typically not grown for human consumption, but for a number of benefits they provide. They increase organic matter, stabilize soil aggregates, prevent bare soil, improve infiltration, break up compaction, increase the diversity of microorganisms, and keep living roots in the soil. Cover crops include a wide variety of diverse species that can be grown as a single species crop, as a cover crop mix, or intercropped with other annual or perennial crops.

Additional Resource:
Managing Cover Crops Profitably

Grow Shrubs and Trees

By integrating trees into our agricultural systems, we can store significant amounts of carbon in tree biomass. Agroforestry systems such as alley cropping, forest farming, and silvopasture increase the potential for carbon sequestration on farms by storing significant amounts of carbon in the trees themselves. Adding perennials and woody plants, such as shrubs, similarly add diversity. Perennials and trees both increase the days in living cover.

Additional Resource:
Agroforestry @ Cornell Small Farms | **¿Qué es Agroforestería?**

Include Livestock

With good management, incorporating animals into a farm system increases soil biodiversity, fertility, water retention, and organic matter. Animals should be rotated in order to prevent overgrazing, which can lead to bare soil or loss of plant diversity. Rotational grazing encourages the animals to eat a wider variety of forage, helping to maintain plant and soil diversity, and allow plants to regrow while animals are in other areas. Grazing systems differ by farm and by animal species.

Additional Resource:
Pastures for Profit: A Guide to Rotational Grazing

Mulch

Mulching with organic materials or fabric keeps soil covered, retains moisture, suppresses weeds, and helps to regulate soil temperature. Organic mulches increase soil organic matter, boosting soil aggregation. Dead cover crop material can serve as an effective mulch.

Glossary

carbon
A chemical element that is one of the basic building blocks of life. It exists on Earth in solid, gas, or dissolved molecules.

carbon dioxide (CO2)
A heat trapping gas produced by human activities (such as burning fossil fuels for energy) and natural processes (i.e. decomposition of organic matter and plant respiration).

carbon sequestration
The process of stabilizing organic carbon in soil or trees to reduce the net amount of carbon dioxide that is released to the atmosphere. Carbon sequestration has the potential to be part of the solution for reducing the net amount of carbon dioxide released to the atmosphere and thereby mitigate some of the effects of human-made climate change.

compaction
A condition in which soil particles are pressed together and soil pore space is reduced. Water moves through pores in the soil, which means compacted soils result in slower infiltration rates and poor drainage. Compaction is typically caused by tillage and heavy equipment traffic.

composite soil sample
A mixture of soil samples that together represent a defined area of interest.

infiltration rate
How quickly water moves downward through the soil.

Mycorrhizal fungi
Fungi with (usually) mutually beneficial relationships with the roots of plants, in which the fungi provide the roots with water and minerals in exchange for sugars from the plant, made by photosynthesis.

penetrometer
An instrument used to measure soil compaction. The pressure gauge indicates pressure in pounds per square inch (PSI).

soil
A mixture of minerals, water, organic matter, air, and soil life (microorganisms and fauna). Soil lays on the surface of the earth and serves as a medium for plant growth.

soil aggregates
Groups of soil particles held together into pieces that contribute to the overall structure of the soil. Soil biology including organic matter, microorganisms, and earthworms encourage aggregation in the soil, which results in healthy soil structure. When you hold a handful of surface soil that is broken up into pieces, you are looking at soil aggregates.

soil biology
The living components of the soil

soil health
The capacity of the soil system to support essential functions and services (i.e. cycling of nutrients, production of plants, storage of water, organic carbon, and nutrients, transmission and purification of water, etc.)

soil organic matter (SOM)
The total amount of organic matter in a soil. Soil organic matter is made up of living organisms, dead plant litter and microbial remains, and more stable organic material that is protected against decomposition. SOM makes up between 1% and 5% of most soils.

soil respiration
A measure of carbon dioxide that is released from the living material in soil. Soil microbes release CO2 when decomposing organic matter.

soil structure - The arrangement of soil particles and soil aggregates. Healthy soil structure provides a foundation for water to infiltrate, roots to penetrate, nutrient distribution, and a number of other functions that contribute to soil health and carbon sequestration.

Additional Resources

Building Soils for Better Crops - Ecological Management for Healthy Soils

https://www.sare.org/resources/building-soils-for-better-crops/

Comprehensive Assessment of Soil Health - The Cornell Framework

https://soilhealth.cals.cornell.edu/training-manual/

Cornell Small Farms

https://smallfarms.cornell.edu/

Farming While Black

https://www.farmingwhileblack.org/

Natural Resources Conservation Service (NRCS) Soils

https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

NOFA/Mass Soil Carbon Grower On-Site Test Protocols

https://www.nofamass.org/wp-content/uploads/2021/05/NOFAMass-Carbon-Proxy-Test-Manual.pdf

Soil Carbon Coalition

https://soilcarboncoalition.org/

Vida Cycle

https://soils.vidacycle.com/soil-tests/

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Please share widely. **How to use Soul Fire Farm materials with integrity.**

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