Soil Carbon Grower
On-Site Test Protocols & Data Sheets V. 4

The NOFA/Mass Soil Carbon Grower On-Site Test Protocols, Manual, and Data Sheets adapted from Carbon Proxy Tests by Caro Roszell, NOFA/Mass Education Director and C. Carbon Proxy Tests developed and adapted by Jack Kittredge, NOFA/Mass Soil Carbon Analyst, from protocols used by Cornell University, Ohio State University, Natural Resource Conservation Service (NRCS), Woods End Laboratory, and the Soil Carbon Coalition.

For more information on the Soil Carbon Grower On-Site Test Protocols, the Soil Carbon Proxy Tests, or for soil carbon technical assistance, contact Caro Roszell, caro@nofamass.org.

Carbon, the element of life, is notoriously interactive. Carbon is *labile*, meaning it forms and breaks bonds with other elements constantly. That ability is why carbon is such a good building block for life, and is found in all living things. Soil—formerly thought of as simple geology and chemistry—is now understood, too, as a biologically active environment. Soil health can be understood as the amount and diversity of life harbored in the soil, and the living portion of soil—its organic matter—is about 57% carbon. Therefore, we can say that soil carbon and soil life are reliable *proxies* for each other.

The labile nature of carbon makes it difficult to isolate and measure well. Carbon in soil, unless fossilized somehow, is constantly changing: being deposited or exuded by organisms, being metabolized by organisms, being respired, oxidized, synthesized, decomposed. So there are few direct lab carbon tests, and those that exist (such as Loss on Ignition, which heats soil to 550 degrees Celsius) don't distinguish between types of carbon in the soil, are expensive, and don't give you immediate results.

Another approach—the one we take with these tests—is to observe the soil as an ecosystem, and directly measure the aspects of soil biology that are due to the presence of carbon. Those soil features act as *proxies* for soil carbon. Most of the data we take is on the indicators of life in the soil, and these indicators become more prominent as the carbon level in the soil increases—so measures of biological vitality serve as proxy measures for carbon levels. Such tests are inexpensive, can be done on the farm, and can give immediate results.

By learning to observe the living / carbon component of your soil, you can learn to see the impacts of different crops, management practices, inputs, and weather conditions on your soil health. This will help you learn what practices are best for building your soil health on your particular land within your particular farm goals and farm systems.

How to Get Started

These tests can be taken once a year, or multiple times per year. Since soil is so variable, it's important to choose a limited number of specific test locations, and test the same locations repeatedly to track changes over time. For each test location, measure from permanent landmarks, draw yourself a map to that spot, and repeat tests within the same few square feet over time. We recommend taking a baseline test per site per year, but it also may be useful to test those sites after specific management actions, such as tilling, growing a cover crop, covering soil with landscape fabric or mulch for some months. You will find that results vary by time of year due to seasonal variations in biological activity. If taking tests annually to track change over time, record weather conditions and take the tests at the same time of year under similar temperature conditions each year.

Content

Tests 1-5 can be performed with simple materials available at home, on the farm and from typical hardware stores. If you have questions about where to get or how to make any of the materials, contact education@nofamass.org. Tests 6 & 7 can be performed with purchased lab kits (see below for where to order). Depending on your location, we may be able to provide a sample selection of the purchased kits at cost (contact education@nofamass.org).

Materials List

Basic Equipment:	NOFA/Mass Soil Carbon Observation Kit (available at cost by request, contact education@nofamass.org for inquires) or sourced separately:

• Surveyors's Tape or Long Measuring Tape
• Kitchen Scale (1/10 grams)
• Shovel
• Trowel
• Hammer or Mallet
• Scrap Lumber, at least 7" long
• Sheet of Plastic Wrap
• Small Mug / Cup / Bowl
• Tap Water
• Clipboard
• Writing Utensil
• 2 Clean Mason Jars
• 2 Strips of ¼" Hardware Cloth, bent to fit inside the mouth of the mason jars
	• Storage Box
	• Tests Manual and Data Sheets
	• Probe Thermometer for Soil Temperature
	• Observation Hoop
	• Solvita Soil Respiration Test Kit
	• Black Plastic Sheet (2.5'x2.5')
	• Infiltration Cylinder (6" sewer pipe cut to 10cm, sharpened on one end)
	• Cup Sieve
	• Soil 1 Active Carbon Kit
	    ○ Color Chart
	    ○ Reagent Solution
	    ○ Pipette
	    ○ Marked Glass Jar

For convenience we have broken the lists into common items and items that must be sourced or fabricated (see sourcing info below) or arranged to be acquired from NOFA/Mass. Contact education@nofamass.org for help sourcing items or to inquire about the Soil Carbon Observation Kits. One item you may not have at home is a scale capable of weighing in tenth-gram increments; if not, there are many affordable scales available online.

Refills and Digital Copies of this Content:

Solvita Basic Field CO2 Test #2361:
Woods End Laboratories, Inc. 290 Belgrade Road Mt. Vernon, ME 04352,
207-293-2457, www.woodsend.com, www.solvita.com
***Cost Note**: After your first kit you can wash and reuse the test jars and request to order just the test gels.*

Active Carbon Test / Soil Quality Field Test:
Available at Soil 1: https://soil1.com, different sized kits available.

Digital copies of this manual and forms: Downloads available at
https://www.nofamass.org/carbon/

1) Surface Biology (Observation Hoop)

A NOFA/Mass Carbon Program Soil Test Protocol

based on work by the Soil Carbon Coalition

Purpose: To make note of surface observations in a single spot of land to track changes over time in biological diversity of plant and animal activity, and percentage of bare ground. More diversity and less bare ground are correlated with increasing soil health.

Frequency: At least annually at same time of year

Locations: As many growing areas as you would like to observe

Duration: 30 minutes

Equipment:

Plastic or metal hoop, about 30" in diameter, Camera
Clipboard
Pen or pencil
Data sheet to fill out and record below data

Protocol:

- Choose and record location(s) to observe
- In each location:
    - Record location and date
    - Place hoop on ground and photograph it: from top, showing detail of contents, and from side showing horizon
- Make observations and record:
    - Estimated % of bare soil in hoop
    - Types and amounts of various plants (grasses, forbs, legumes, etc.)
    - Types and % of mulch or duff / dead plants
    - Types and amounts of other life (molds, moss, lichen, fungi, worms, insects)

1. Observation Hoop Data Sheet

Date of Test _______________ Name of Tester_____________________________________

Address of Test ____

Exact Location of Test____

____

Other Site Notes: ____

Soil Temperature _____________________________________

Estimated Bare Soil % in Hoop _________________________

Plants present:

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Type____________________________________ Number Present____________ Percent of Soil Covered with These________

Other life present:

Type_______________________________________ Number Present_____________ Percent of Soil Covered with These_________

Type_______________________________________ Number Present_____________ Percent of Soil Covered with These_________

Type_______________________________________ Number Present_____________ Percent of Soil Covered with These_________

Type_______________________________________ Number Present_____________ Percent of Soil Covered with These_________

Type_______________________________________ Number Present_____________ Percent of Soil Covered with These_________

Understanding Your Results

When plants photosynthesize, they turn CO2 and light into carbon-rich carbohydrates (sugar) and water. A portion of (sometimes over half) the liquid carbohydrates made by the plants are exuded into the root zone to feed soil microbes. In return, soil microbes give minerals from the soil to the root. It's a trading system—an underground economy.

All species of plants have specific microbes that they have evolved to trade best with—and some microbial species only work with specific plant species. The more diversity of species growing on the soil, the more biodiversity will be supported in the root zone and wider soil ecosystem.

Dead plants don't photosynthesize but microbes can shelter in dead or dying roots for varying lengths of time, and the microbial population may be preserved. Dead plants also protect the soil and provide shelter for soil life, where bare soil more quickly dries out and becomes inhospitable.

Also, living plants re-capture some of the carbon that comes out of the soil through microbial respiration, preventing it from escaping into the atmosphere. So, the more the soil is covered with plants, the more CO2 is directed into the soil. Both percentage of soil covered and the diversity of plant cover contribute to the total possible soil life.

2) Earthworm Count

A NOFA/Mass Carbon Program Soil Test Protocol
based on work by NRCS and Cornell University

Purpose: Earthworm burrows improve infiltration and their castings improve aggregation, nutrient availability to plants, cation exchange capacity, and soil organic matter. Because they eat microbes in the soil (primarily bacteria, also fungi, nematodes and protozoa) their population is a visible indicator of the invisible life present in the soil—the more food is present, the higher the worm population supported. An increase in the number of worms in the soil is a strong indicator
of improving soil health.

Frequency: At least once a year at same time of year, or throughout the season
Locations: avoid places where their population is affected by local conditions – compost piles, unusually dry spots, or saturated soil.
Duration: 30 minutes
Equipment:

- Hand trowel or shovel
- Container for worm collection and cleaning
- Small tarp
- Clipboard
- Pen or pencil
- Data sheet to fill out and record data

Protocol:

- Choose and record location(s) to observe
- Measure a square-foot plot and dig down 12 inches, piling dirt on tarp and minimizing damage to earthworms
- Once the hole is fully dug, carefully pick through the displaced soil, placing worms in collection cup
- Count and record the number of earthworms sorted
- Rinse the worms briefly in water and return them to the hole, crumbling the dirt on top

2. Earthworm Count Data Sheet

Date of Test ___________________________ Name of Tester
____

Address of Test
____
____

Exact Location of Test
____
____

Other Notes about site
____

Number of worms found in soil from 12” cubic hole: _________________________worms

Understanding Your Results

Earthworms prefer moist soils that have plant residues and organic matter for food. Different species of worms eat different things but generally worms eat plant residues, algae, bacteria and fungi. Worms can therefore be a good visual indicator of the presence of other soil life, as the worms will move to where there are microorganisms to consume.

Healthy soils will generally show earthworm numbers of at least 10 per cubic foot of soil. At NOFA/Mass we have found up to 50 in a cubic foot of soil.

It is important to note, however, that worms tend to be more present in farm and garden soils when they are cooler; when soils are hot and/or dry they may migrate to cooler soils at field edge. Like all of the tests, it’s important to compare numbers from tests taken at the same time of year.

Also, at NOFA/Mass we have found that oftentimes a very healthy biologically active garden soil, when part of an integrated / agroforestry system, may not show many earthworms in annual growing areas if the site has dense, integrated perennial areas as the worms may spend more time near the perennials. Test a few different areas around your test location for comparison.

This is a test to take often and consider in context of other indicators.

3) Digging a Hole: Soil Aggregation, Type, and Horizons

A NOFA/Mass Carbon Program Soil Test Protocol

based on work by NRCS and Cornell University

Purpose: To make note of sub-surface observations in a single spot of land to track changes over time in topsoil depth, root depth, resistance, structure, aggregation, and texture. More aggregation and less compaction are signs of increasing carbon and health.

Frequency: at least annually at same time of year

Locations: as many growing areas as time permits

Duration: 45 minutes

Equipment:

- Shovel
- Tape Measure
- Camera
- Tap water
- Clipboard
- Pen or pencil
- Data sheets to fill out and record below data

Protocol:

- Dig a hole about a foot deep
- Cut a slice of soil from a wall and lay it on the ground
- Make observations and record:
    - Depth of topsoil from surface (look for color changes -- topsoil is usually darker) Fig 11.1
    - Depth and quality of plant roots (are they branched with root hairs? If not, soil oxygen may be low)
    - Do roots grow sideways or are they balled up? (may indicate hardpan or compaction – note where)
- Probe side of hole with the end of your writing utensil at different horizons. Note where changes in resistance (compaction?) occur.
- Mark soil slice at 4” and 8”, making 3 sections. Note aggregation and soil type for top, middle, and lower sections, using the following procedure:

Figure 11.1

Type: **Granular** (Fig 11.3), **Blocky** (Fig 11.4), or **Platy** (Fig 11.5). If no aggregates appear, note whether soil is **Single-grained** (Fig 11.6) or **Massive** (Fig. 11.7)

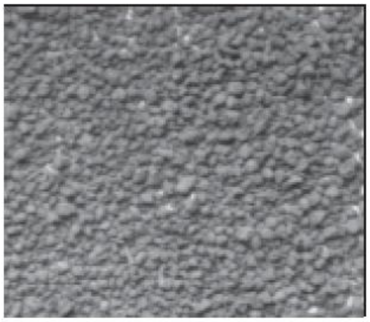


Figure 11.3 Granular: imperfect spheres, usually sand-size.

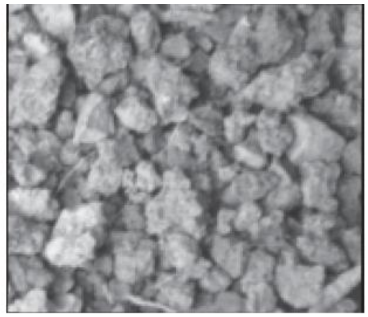


Figure 11.4 Blocky: imperfect cubes with angular or rounded edges.

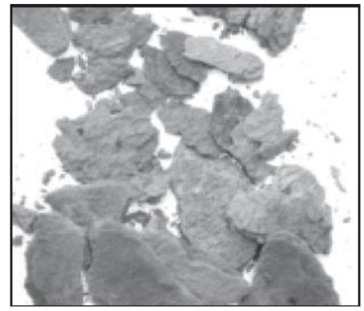


Figure 11.5 Platy: a flattened or compressed appearance.

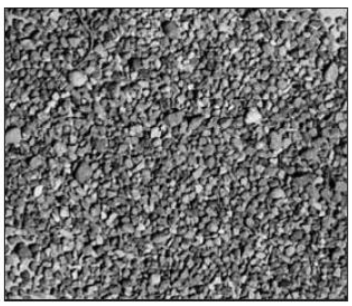


Figure 11.6 Single grain: unconsolidated mass such as loose sand.

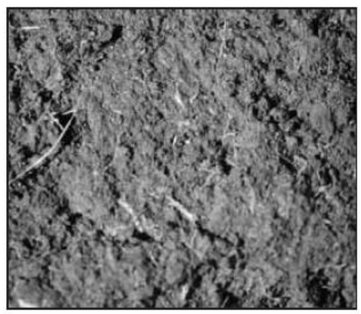


Figure 11.7 Massive: cohesive mass.

If aggregates appear note their size. If structure is granular, note if **Fine** (Fig 11.8), **Medium** (Fig 11.9), or **Coarse** (Fig 11.10)

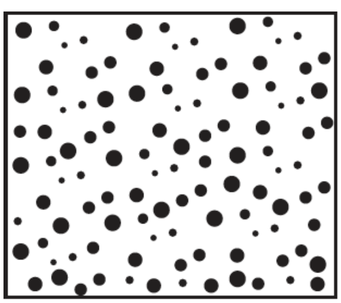


Figure 11.8
Fine: < 2 mm.

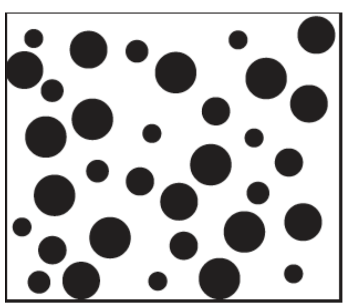


Figure 11.9
Medium: 2 to 5 mm.

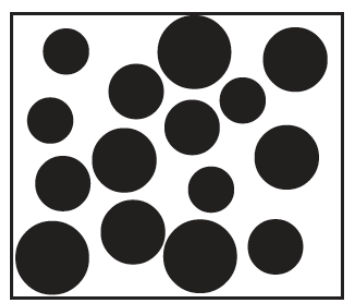


Figure 11.10
Coarse: 5 to 10 mm.

If structure is blocky, note if **Very fine** (Fig. 11.11), **Fine** (Fig 11.12), or **Medium** (Fig 11.13).

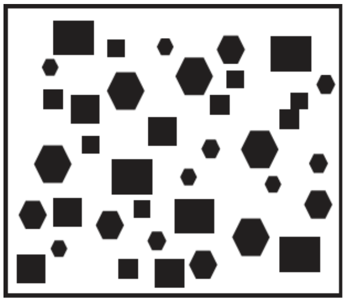


Figure 11.11
Very fine: < 5 mm.

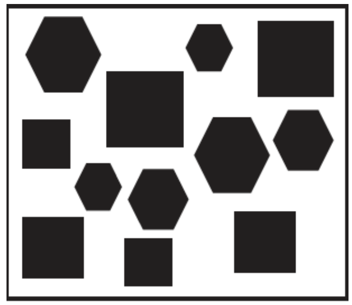


Figure 11.12
Fine: 5 to 10 mm.

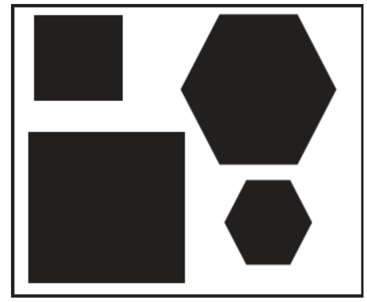


Figure 11.13
Medium: 10 to 20 mm.

If structure is platy, note if **Thin** (Fig. 11.14), **Medium** (Fig 11.15), or **Thick** (Fig 11.16)

Figure 11.14
Thin: < 2 mm.

Figure 11.15
Medium: 2 to 5 mm.

Figure 11.16
Thick: 5 to 10 mm.

Note the distinctness (grade) of the aggregates and what happens if they are removed.
Are they: **Weak** (Fig 11.17) -- barely observable in moist soil and if removed soil breaks into a few pieces, **Moderate** (Fig 11.18) – moderately well-formed and distinct in place, if removed many remain or **Strong** (Fig 11.19) – well-formed and very evident, if removed structure just breaks into more aggregates.

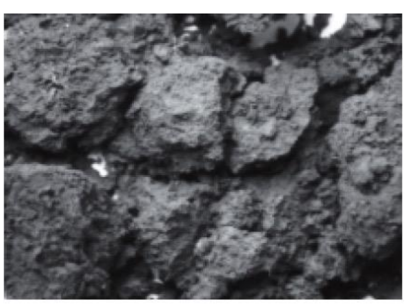


Figure 11.17

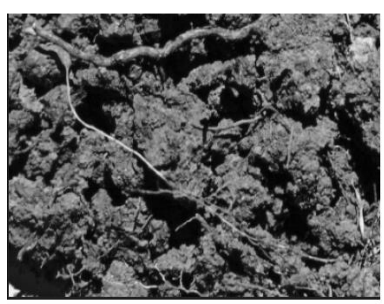


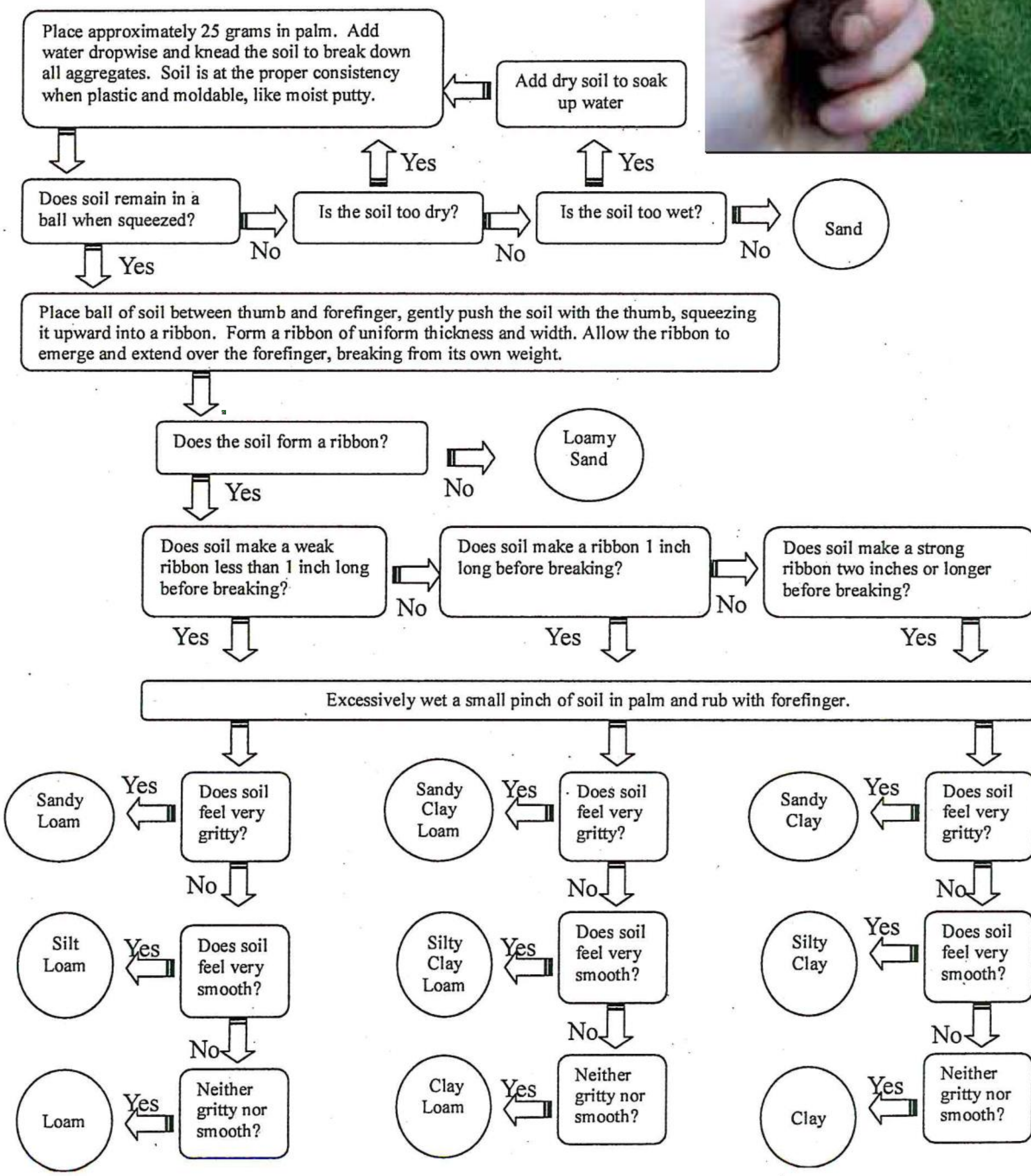
Figure 11.18

Figure 11.19

For each horizon, perform the “Texture By Feel” procedure and note the results:

Texture by Feel Procedure

Making a Ribbon



3. Digging a Hole Data Sheet

Date of Test _______________ Name of Tester_____________________________________

Address of Test

____

Exact Location of Test

____

____

____

Other Notes about site ____

____

Units: (circle one) Centimeters Inches

Depth of Top Soil ______________________ **Roots: Depth of Longest** ________________

Average Depth ____________________________

% Branched w/ Root Hairs ____________ **% Sideways or Balled up** _______________

Describe depth and thickness of any Compaction

____

____

____

Top Section - Soil Slice above 4" depth: If aggregates appear, their type and structure are (circle one descriptive term in each of 2 rows below):

Granular Blocky Platy

Fine Medium Coarse Very Fine Fine Medium Thin Medium Thick

If aggregates appear, they are (circle one distinctness or grade):

Weak Moderate Strong

If no aggregates appear, the soil is (circle one): Single Grained Massive

Judging the Texture by Feel it is (circle one):

sand loamy sand sandy loam silt loam loamsandy clay loam

silty clay loam clay loam sandy clay silty clay clay

Middle Section - Soil Slice at 4" to 8" depth: If aggregates appear, their type and structure are (circle one descriptive term in each of 2 rows below):

Granular Blocky Platy

Fine Medium Coarse Very Fine Fine Medium Thin Medium Thick

If aggregates appear, they are (circle one distinctness or grade):

Weak Moderate Strong

If no aggregates appear, the soil is (circle one): Single Grained Massive

Judging the Texture by Feel it is (circle one):

sand loamy sand sandy loam silt loam loamsandy clay loam

silty clay loam clay loam sandy clay silty clay clay

Lower Section - Soil Slice below 8" depth: If aggregates appear, their type and structure are (circle one descriptive term in each of 2 rows below):

Granular			Blocky			Platy		
Fine	Medium	Coarse	Very Fine	Fine	Medium	Thin	Medium	Thick

If aggregates appear, they are (circle one distinctness or grade):

Weak Moderate Strong

If no aggregates appear, the soil is (circle one): Single Grained Massive

Judging the Texture by Feel it is (circle one):

sand loamy sand sandy loam silt loam loam sandy clay loam

silty clay loam clay loam sandy clay silty clay clay

Understanding Your Results

Generally, soils with higher organic matter tend to feel more like loams the higher the organic matter goes; experiment by performing the soil type by feel experiment on various soils around your land; the compacted soils in your driveway, finished compost, soil under perennials / trees, soils in your crop growing areas. What do you notice?

The size and prevalence of soil aggregates is an indicator of the presence and activity of longer-term soil biological activity. Aggregates are readily destroyed by mechanical activity on the soil, and need the presence of a mix of fungi and bacteria to form. Fungi are heavily impacted by tillage and are also less present in disturbed soils; therefore, soil disturbance destroys aggregates, releasing stabilized carbon—and repeated tillage makes it difficult for aggregates to re-form. Earthworms can help restore aggregation and soil structure by distributing bacteria through the soil.

On the farms we have tested so far, soil structure has ranged from no aggregation present (just loose sandy soil) to strong, medium blocky aggregates (aggregates are very prevalent with almost no loose, un-aggregated soil and relatively large in size). Farms with a history of tillage and chemical inputs have tended to have the weakest, smallest aggregates (if any) while no-tilled soils have had much stronger aggregation.

4) Infiltration

A NOFA/Mass Carbon Program Soil Test Protocol based on work by NRCS

Figure 3.1

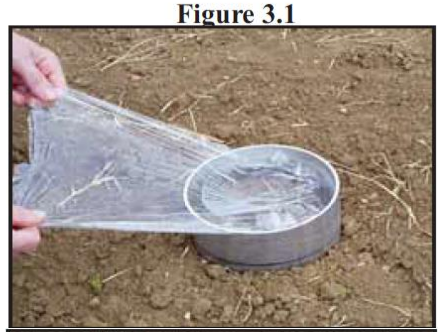


Figure 3.3

Purpose: To measure the capacity of soil to absorb water without puddling or running off causing erosion.
Better infiltration indicates more pores and aggregates, which means greater carbon, soil health, and water holding capacity.
Frequency: at least annually at same time of year. If the soil is already saturated allow it to dry out for a day.
Locations: As many growing areas or fields as desired
Duration: Up to 60 minutes, depending on infiltration speed
Equipment:

- Infiltration Ring: 6” diameter sharpened ring at least 3” long
- Approx. 444 ml distilled water
- Stopwatch or timer
- Plastic wrap
- Scrap lumber at least 7” long
- Mallet/ hammer
- Clipboard
- Pen or pencil
- Data sheet to record data

Protocol:

- Choose and record location(s) to observe
- Clear surface to be sampled of residue. Trim away vegetation.
- Using scrap lumber and hammer/mallet drive ring to depth of 3 inches
- Line soil in ring with plastic wrap, covering ring (Figure 3.1)
- Pour 1 inch of water (444mL if ring is 6”) into ring atop wrap
- Remove wrap by gently pulling it out (Figure 3.2) and note the time
- Record the time (in minutes) it takes when the water is gone and the surface is glistening
- If the surface is uneven, count the time until half the surface is exposed and just glistening (Figure 3.3)
- If soil is very dry, repeat the test. The 1st inch has wet the soil and the 2nd is a better infiltration test.

4. Infiltration Data Sheet

Date of Test _______________ Name of Tester_____________________________________

Address of Test

____

____

Exact Location of Test

____

____

Other Notes about site

____

First Trial: **Second Trial**:

Time that plastic is removed ________________ __________________

Time that water is gone ____________________ __________________

Difference (time for infiltration) ______________ __________________

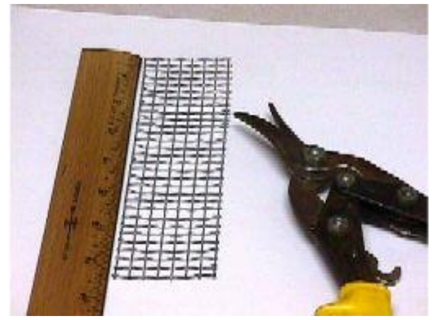
Understanding Your Results

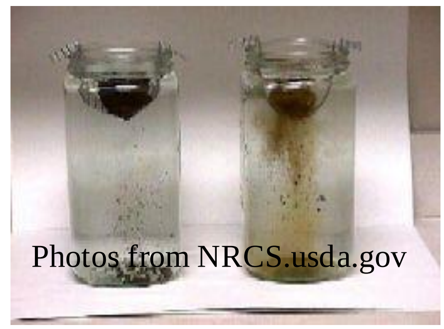
The amount of time that water takes to infiltrate the soil is a good indicator of healthy soil structure and porosity. This test simulates the fall of one inch of rain on a soil and the length of time that it takes to absorb the rain is a good way to test how well your soil is receiving rainfall. The longer the infiltration takes, the more likely your soil is to erode in heavy rain.

Generally, infiltration of 5-10 seconds for an inch of rain is very good—above a minute indicates a problem. Of course, sandy soil will generally infiltrate water much faster than a heavy clay one, so this test is best used on the same soil over time, to see how management is changing it.

5) Slake Test

A NOFA/Mass Carbon Program Soil Test Protocol
based on work by NRCS & Washington State University





Photos from NRCS.usda.gov

Purpose: To observe maturity of aggregates and resistance of aggregates in tested soil to erosion events and compare management practices on your land.
Frequency: at least annually at same time of year; conditions should be field-moist (not saturated soils)
Locations: Soil from testing location and comparison soil (ie. soil from a fencerow or perennial border)
Duration: 10-15 minutes
Equipment:

- Shovel
- 2 clear jars at least 32 oz
- 2 hardware cloth strips cut to fit to form a basket for the soil clod in the mouth of the mason jar
- Timer (smart phone)
- Tap water to fill each jar
- Clipboard
- Pen or pencil
- Data sheet to record data

Protocol:

- Collect a soil clod (sized to fit in the palm of your hand) from a hedgerow or area not used for annual crops near your growing area. About 4-6 inches is a good depth. This is Sample A.
- Get a second similarly sized chunk of soil from the test area soil in your crops garden or field, taken from the same rough depth as the first sample. This is Sample B.
- Fashion some wire mesh into a kind of basket hooked at the top of each jar that hold the soil submerged in the water but within the top half of the jar.
- Insert the wire meshes into each jar.
- Fill the jars with water.
- Submerge the tilled sample in one jar, and the untilled sample in the other.
- Watch to see which soil holds together and which one falls apart. The soil with poor structure is the one that will begin to fall apart.
- Record percentage of each clod remaining after 1 minute and 5 minutes

5. Slake Test Data Sheet

Date of Test ________________ Name of Tester______________________________________

Address of Test

____

Exact Location of Test

____

____

Where did you take the comparison sample [Sample A] from? Describe the spot:

____

Roughly what percentage of the soil clod remains on each mesh basket after 1 minute?

Sample A________________________Sample B____________________________________

Roughly what percentage of the soil clod remains on each mesh basket after 5 minutes?

Sample A________________________Sample B____________________________________

Optional: Roughly what percentage of the soil clod remains on each mesh basket after an hour?

Sample A________________________Sample B____________________________________

Understanding Your Results

The living portion of the soil holds soil particles together using a range of exudates and fungal glues (glomalin). The resistance of soils of the same soil type to breaking apart in water can be compared as a relative measure of soil life. Soil disturbance breaks apart these biological connections and makes the soil more vulnerable to erosion events like heavy precipitation and flooding. By comparing how well your field / garden soil holds together over time underwater compared to how well a non-disturbed soil you can get a rough assessment of the potential vulnerability of your field soil to erosion in the event of extreme weather events.

6) Active Carbon

A NOFA/Mass Carbon Program Soil Test Protocol

based on work by Ohio State University

Purpose: Active or labile carbon is the portion of soil organic matter which can serve as a ready food source for soil microbes. In research, labile carbon levels are strongly correlated with total organic carbon levels in soil. In this test soil is mixed with a solution of potassium permanganate, which starts off a deep purple in color. As the permanganate oxidizes the active carbon it loses some of its color and changes toward pink. The amount of color change can be graded on a color chart.

Frequency: at least annually, at same time of year

Locations: Fields or garden areas where tester is interested in the results of management practices.

Duration: 30 minutes

Equipment:

- Soil Quality Test Kit (available from Soil1.com)
- Plastic bottle of reagent (0.2M potassium permanganate, $KmnO_4$, in 0.1M sodium hydroxide, pH 7.2)
- Black Plastic small tarp
- Glass vial with cap in which to perform the test
- Small pipette, 1 m; to measure and dispense reagent
- Laminated color chart to use to gauge color of test results
- Plastic case
- Distilled water (20 ml)
- Clipboard
- Pen or pencil
- Data sheet to fill out and record below data

Protocol:

- Choose and record location(s) to test
- Use air-dried soil. If too moist, take 20 g or about five teaspoons and spread thinly on the black plastic for 10 minutes in direct sunlight. Mix the soil a few times while drying.
- Add 2 droppers full (2 ml) of the reagent to the vial
- Add 5 grams of air-dried soil to the vial
- Fill the vial to the tape mark (20 ml) with water and swirl to mix
- Cap the vial and shake vigorously to 2 minutes (approximately 100 times per minute).
- Let it stand for 10 minutes out of direct sun to settle out the soil. Do not shake or disturb during this period.
- Compare the color of the liquid above the settled soil to the color chart included in the Active Carbon kit and record the result.

6. Active Carbon Data Sheet

Date of Test _______________ Name of Tester _____________________________________

Address of Test

____

Exact Location of Test

____

____

Other Notes about site

____

The color of the liquid after adding soil, shaking and settling corresponded to this on the chart:

____

Understanding Your Results

Active carbon is a good leading indicator of soil health because, according to research, active carbon can indicate a soil health response to management practices years sooner than total organic matter percent as indicated by traditional lab soil tests. Therefore, active carbon is particularly useful to monitor if the land manager / grower is trying out changes to soil health or crop management practices. Refer to color chart for specific AOM and N results.

Color comparison of $KMnO_4$ solution after shaking with soil

Poor soil quality	Fair soil quality	Good soil quality	Excellent soil quality
> 0 to 400 AOM lbs/A	> 400–800 AOM lbs/A	> 800–1600 AOM lbs/A	> 1600 AOM lbs/A
> 0–12 lbs available N/A	> 12–26 lbs available N/A	> 26–40 lbs available N/A	> 40 lbs available N/A

7) Soil Respiration

A NOFA/Mass Carbon Program Soil Test Protocol
based on work by Woods End Laboratory

Purpose: Soil microbial activity is a strong indicator of soil carbon. Carbon is a limiting factor in soil microbial populations – as carbon-based life forms microbes ingest carbon and oxidize it for metabolic function, exhaling the resulting carbon dioxide. In biologically active soil the amount of such CO_2 is quite large. Soil respiration tests measure the CO_2 emitted by a given amount of soil over time. The result, especially when compared year to year, is a good proxy for increasing levels of soil carbon.
Frequency: at least annually, taken at same time of year
Locations: fields or garden areas where building soil carbon is an important goal
Duration: 24 hours
Equipment:

- Solvita Field Test Kit
- Plastic jar with lid gasket
- Low CO_2 probe
- Color chart
- Manual
- Trowel
- Soil thermometer
- Sieve & cup to sieve into
- 1 gallon zip lock plastic bag
- Clipboard
- Pen or pencil
- Data sheet to fill out and record below data

Protocol:

- Choose and record location(s) to test (soil from several field locations should be mixed for each test)
- The soil should be under "natural field conditions" (2-3 days after a normal rain or irrigation event)
- For each location:
  - Take and record the soil temperature at a depth of about 3"
  - Using trowel, remove surface soil to the depth you wish to sample (4" to 6")
  - Cut down sides of soil to be sampled and lift into sieve, trying not to compress it
- Gently rub the soil through the sieve into a cup to remove stones and debris
- Mix the soil from the locations sampled together and place into plastic bag
- Place test jar on scale, set tare to zero, and add 90 grams of the fresh, moist soil to jar (to fill line)
- Open foil pouch and, without touching the gel surface (or letting anything else touch it) insert test probe into soil in jar
- Screw lid on tightly and record start time
- Keep jar at roughly 70˚ F
- After 24 - 25 hours, remove probe and compare color of gel to color chart to get color number
- Adjust color number by conversion factor in Table 2 of manual if soil temperature was not 70˚ F

- Using number resulting from temperature conversion, interpret test results by Table 1 in manual

Understanding Your Results

Measuring CO_2 output from soil provides a good indicator for biological functioning, since all soil organisms respire CO_2. Properly managed soils show strong rates of respiration under moist, warm conditions. It is worth noting that recently tilled soils may show high rates of CO_2 respiration even as microbial populations are declining, as stable (humic) carbon is released when aggregates are broken up. This test is best performed at least a week after a tillage event.

Table 1: Interpretation - Respiration in Test Jar at 20-25°C (70-75°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	**EMISSIONS (FLUX) OF CO_2-C as LBS / ACRE/ DAY**					
	0.5 - 1 lb/ acre/day	**1 - 5**	**5 - 15**	**15 - 25**	**25 - 60**	**60 - 160**
D	**INTERNATIONAL EMISSIONS (FLUX) OF CO_2 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 CO_2-C. Results depend on a variety of factors such as depth of sampling, soil temperature and field-moisture.

D: International Metric Units based on CO_2. For row C the units are CO_2-C. Use 3.7 to get to CO_2 from CO_2-C or 0.273 to go from CO_2 to CO_2-C.

7. Soil Respiration Data Sheet

Date of Test ________________ Name of Tester______________________________________

Address of Test

____

Exact Location of Test

____

____

Other Notes about site

____

Soil temperature at locations sampled: ____
Time probe inserted into soil in jar: __________ Number of hours probe in jar: ________

Color # of gel compared to color chart (A): ____

CO2- C lbs / acre/ day result (B): ____

Table 2 soil temperature conversion factor (C) _______________________________________

Final result, using color chart adjusted by Table 2 factor B/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 CO_2-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 CO_2 rates performed at non-standard results back to standard 70°F/20°C data.(*https://solvita.com/soil/basal-co2-guide*)