Demeter's Biodynamic Soil Monitoring Program

The Biodynamic Farm Standard requires implementation of numerous principles and practices that maintain and improve soil quality. Improvements may be manifold but include that the content of organic matter- and its main component, soil organic carbon- should maintain current levels or increase, as measured over a period of years. Soil organic matter is a dynamic feature which varies in a natural inbreathing (sequestration) and outbreathing (biodegradation) cycle. The strength and magnitude of this cycle varies seasonally, depending on the time of year, the type of rotation, the frequency and intensity of soil management and especially on the handling of crop residues together with the incorporation of green manures and composts; in all of these, therefore, the manner, timing and the choice of sampling locations has an overall influence.

The sampling protocol includes sensorial or semi-quantitative as well as measured, quantitative soil test procedures to be conducted at reasonable intervals over time in relation to crops and tillage. It is suggested that such evaluations and tests be performed at a similar time each year for consistency (such as spring, at or just before planting, or fall around or after the time of harvests.) Farmers who routinely soil sample for nutrient measurements may include these determinations in this cycle.

This special, composite soil test is to serve as a monitor over time. This would be in the same field each time- a field that reflects average properties of the farm – and this sample will be collected by farmers with a maximum periodicity of every three years. The origin of the composite test must be consistent for each submission (i.e., randomly taken within the same field by at least 12 – 15 individual cores or trowels of soil to the same topsoil depth, blended into one sample). This is so that the results can be compared from year to year. A map must be provided with the location of the sampled field, or optionally a smartphone with a mapping tool such as Google maps can be used to identify the lat./long. coordinates in the field being sampled and used for recording purposes. It is not recommended to try to sample the exact same locations using GPS since this is now considered to create bias over time.

This monitoring program aims to accommodate farmers financial and time constraints while addressing the needs for accountability with Demeter's certification program. The purpose of this program is to create snapshots over time to show the impact of Biodynamic farming practices on soil health.

Field Sampling to be Conducted by Farmers in Spring or Fall

Training videos are available for each sampling technique. Please record the GPS coordinates of the field of your sampling locations for Biodynamic certification.

The following table summarizes the field tests and there is a worksheet to complete for each sampling period. It is important to note that all on-farm, in-field tests are affected by both the person performing the test and the actual conditions around the time of making a sample. It is recommended to have 2 or more people perform the simple tests indicated to improve on its reliability.

Biodynamic Soil Monitoring Protocol (On-Farm Measurements + Soil Test)

Indicator	Measures/Units	Rating (0 lowest – 4 highest)	Interpreting Results
Compaction	How easily penetrable the soil surface is by wire probe, T-bar penetrometer, or shovel	1. Difficult to penetrate to less than 8 in. (20 cm) 2. Moderately difficult to penetrate to less than 8 in (20 cm) 3. Moderate difficulty to penetrate to 8 in (20 cm) 4. Easy to penetrate to 8 in (20 cm)	A heavily compacted soil can restrict root growth and limit air and water movement in soil. This is a simple field measure of surface and sub-surface hardness. Description of soil conditions needed if excessively dry or wet.
Soil Texture	Percentage of Sand, Silt, Clay	No rating. This test can be done accurately by a soil lab or estimated by using a tall, narrow jar (pint sized). Fill jar 1/3 with soil, after removing all gravel and rough organic matter. Add water and a teaspoon of dish detergent or baking soda and fill to within ½ inch of the top. Cover jar. Shake jar intensely for 3-5 minutes until all particles appear suspended. Set down jar and leave undisturbed for 24 hours. Sand settles quickly within 1 minute, silt around 2 hrs. and clay from 24-48 hrs. The layers are often very visible, and you can mark the jar with a sharpie at each time point. Measure the depth of the layers and estimate the percentage of each layer. Describe soil texture using the USDA Soil Classification Triangle. The soil triangle enables one to derive a classification such as "sandy-loam", or "silty-clay" and so on. A soil lab will automatically report this. Home tests tend to overestimate clay since silt has a long separation time.	
Hardpan	Detection of a hardpan	1. Very dense or Impenetrable hardpan exists 2. Moderate hardpan exists 3. Possible hardpan forming 4. No hardpan detected	Hardpans diminish a soil's ability to support plant growth and a healthy soil carbon cycle. Detection of a hardpan must be followed up with determination if geological factors or farm management is the cause.
Diversity of Macro-life	Number of unique soil animals in 3 shovelfuls – suggested: 1 Qt of soil minimum per shovelful	1. No evident soil invertebrates after observing clod for several minutes 2. A small number of moving soil invertebrates 3. An obvious number and several kinds of soil invertebrates 4. Very active with number and kinds of soil invertebrates	"Soil animals include: earthworms, collembolas, mites, nematodes, and protozoa. The first 3 are relatively easy to spot but the latter are not. A higher diversity of soil animals indicates a healthy, diverse soil food web. Under dry conditions, soil animals may have burrowed deep to remain in moist soil, and therefore will not be observed. Describe soil conditions at the time of such an examination.
Ponding/ Infiltration	How readily water accumulates on the soil, particularly after heavy rains	1. Water ponds on the soil surface, remains for more than 24 hrs. 2. Some ponding on the surface but settling within a day 3. Soil ponds lightly heavy water rate but infiltrates withing hours 4. No ponding even with heavy rates of water addition	A field ponding test, or its inverse, the infiltration test, can provide valuable information of how easily water moves through the soil horizon; infiltration is often rated in inches per hour; less surface ponding means good infiltration where water can easily move through the horizon and provide available air to plants even under wet conditions. This field measurement is also related to tests for water holding capacity and aggregate stability tests.
Clod or aggregate strength	How easily a soil clod falls apart when placed gently into water; or when watered gently from above	1. Falls apart quickly or almost immediately 2. Resists dispersion and only gradually crumbles in 10 minutes 3. Does not disperse even after 30 minutes 4. Still retains clod integrity after 4 hrs.	Sandy soils even in good condition tend to fall apart more easily; clay soils tend to hold together even when not in good condition. The test works well conducted over time with the same soil and is related to soil texture and organic matter content.
Root Growth	Visual assessment of fine root growth in the surface soil (0-5 cm)	1. Few if any apparent fine root hairs, limited main roots 2. Somewhat restricted roots; some fine roots 3. Fairly dense, uninhibited roots, many fine roots 4. Soil is extremely densely explored by fine and main roots	Inspecting fine root growth provides an idea of how well the plants are able to put out roots and can indicate whether or not there are restrictions to root growth either physically (poor soil structure) or chemically (nutrient deficiencies or excess).
Soil Smell	Description of moist soil smell	1. Dull or dusty mineral smell 2. Weak soil odor 3. Moderate soil odor 4. Strong soil odor	Soil smell can indicate issues with soil or sour anaerobic conditions). Intensity of fresh soil smell (aka the actinomyces smell) can help indicate soil microbial activity. Soil moisture affects soil smell and conditions at time of test should be reported.
Ground Cover – Canopy Cover	Percentage of ground covered by plants, plant residues, or mulch per unit by field and by crop rotation	1. < 10% little or no ground cover 2. > 10- 30% ground cover 3. > 30 – 60 % ground cover 4. > 60 % or nearly completely covered	Observations should be made by tossing a hoop in various random locations and estimating the amount of bare, visible soil and its inverse, the ground cover. Note the type of crop being grown since row crops with weeding are inherently different than grassland or pastures. If significant areas are at the stage of planting, report the percentage when crops are fully established such as near time of harvest or cutting.

On- Farm Measurements Worksheet

GPS location:

Field Test	Results Key	Remarks on Method	Results for field ID/location	Notes about aspects that may affect the results
Compaction	1. Extremely difficult to penetrate to less than 8 in. (20 cm) 2. Difficult to penetrate to 8 in (20 cm) 3. Moderately difficult to penetrate to 8 in (20 cm) 4. Easy to penetrate to 8 in (20 cm)	Compaction relates to many factors such as soil density, texture (clay content) and humus content. May be affected by moisture. Often very difficult to repeatably or reliably measure.		
Soil Texture	Sand, Silt, Clay (no numerical score). Feel Test includes rubbing moist soil into a ribbon between the fingers.	Describe using the Soil Classification Triangle or the length of finger ribbon before it breaks		
Hardpan	1. Very dense or Impenetrable hardpan exists 2. Moderate hardpan exists 3. Possible hardpan forming indicated by resistance 4. No hardpan detected	Important to perform test with same moisture content and to indicate depth of apparent hardpan or resistance. Often very difficult to repeatably or reliably measure.		
Evidence of Macro-life	1. No evident invertebrates after observing clod for several minutes 2. A small number of moving soil invertebrates 3. An obvious number and several kinds of soil invertebrates 4. Very active with number and kinds of soil invertebrates	Difficult to determine without guidance on observational methods§. Dryness at sampling may adversely affect results. A Berlese Funnel is recommended for better measurement		
		DESCRIPTION OF SOIL CONDITIONS (wet, dry, hot, cool)		
Ponding/ Infiltration	1. Water ponds on the soil surface for more than 24 hrs. 2. Some ponding on the surface but settling within a day 3. Soil ponds lightly heavy water rate but infiltrates withing hours 4. No ponding even with heavy rates of water addition	Relates to infiltration; ability of soil to absorb water; alternate test for infiltration and measuring time required for water to pass into soil from a soil ring placed on surface.		
Clod or aggregate strength	1. Clod falls apart quickly or almost immediately 2. Clod resists dispersion and gradually crumbles in 10 minutes 3. Clod Does not disperse even after 30 minutes 4. Still retains clod integrity after 4 hrs.	Gentle handling of clod is needed; practice several times. Often very difficult to repeatably or reliably measure. High clay content may appear to indicate good aggregates.		
Root Growth	1. Few if any apparent fine root hairs, limited main roots 2. Somewhat restricted roots; some fine roots 3. Fairly dense, uninhibited roots, many fine roots 4. Soil is extremely densely explored by fine and main roots	Indicates plant health. Often difficult to assess in situ since many roots tear off; many plants differ in type of apparent rootlets.		
Soil Smell	1. Dull or dusty mineral smell 2. Weak soil odor 3. Moderate soil odor 4. Strong soil odor	Relates to soil origin, water content and amount and quality of organic matter. Dependent on soil depth and period of wetness or water-standing at time of sampling.		
Ground Cover - Canopy Cover *	1. < 10% little or no ground cover 2. > 10- 30% ground cover 3. > 30 – 60 % ground cover 4. > 60 % or nearly completely covered	This is best assessed for each crop type and time of year*. It is difficult to obtain a field average. An accurate canopy-test tool is available for some smart phones.		
Total Score	Add up the number rating from all the above tests which have a numerical value (i.e., all 8 categories x 4 highest score each means maximum score is 32)			
Average	Divide the Total Score by 8 (categories). For overall robustness, average up to 8 sample worksheets.			

*An App such as Canopeo at canopeoapp.com measures green ground cover. This smartphone tool was developed by Oklahoma State University Department of Plant and Soil Sciences and uses surface photos you make.

§ See J. Bockemühl's "In Partnership with Nature" published Bio-Dynamic Literature, 1981 which shows many sketches of the kinds of macrofauna that can be identified in healthy soil and compost. Berlese Funnel Method: https://www.youtube.com/watch?v=yWFyA2H9jos many other good instructional materials exist.

Sample Collection for Laboratory Testing

A soil test report must be submitted to Demeter USA at least once every three years from a soil laboratory qualified for farm soil testing. Such a lab would be listed as participating in the US Soil Sci Society "NAPT" soil proficiency program or in any quality assurance program in which soil testing is listed. A soil report must indicate at minimum soil organic matter (SOM) (with notation of which method) or at best total soil organic carbon (SOC), a specific carbon test by dry combustion. (The costs for SOC testing are coming down as more labs are entering the field) ‡. A SOC test is preferable to measuring soil organic matter (SOM), mainly because it is more accurate and specific to carbon; in contrast OM is considered a less accurate test since it is only measuring weight loss during hot ashing, which can include organic nitrogen and sulfur plus mineral-trapped water and therefore results vary more between sampling and between labs. Soil testing should ideally include other common soil quality data (e.g., need for nutrients, trace minerals and level of soil health). A proper soil sample is a composite (meaning a mixed, combined) sample taken at several random points within a reasonably uniform field area. To reduce sampling needs for varying fields, it is best to select an "indicator" field with soils typical of those on the farm. Note: For tracking total soil organic carbon (SOC) changes over time (i.e. every 3 – 5 years), a soil bulk-density test is recommended each time also (see below under additional criteria). Soil carbon (and soil organic matter) is influenced by the position of sample within the landscape, affected by slope, hydrology, and texture. Therefore, it is now generally urged by USDA to take more than one sample at a time to address variations within the farm, and individuals are encouraged to evaluate their farm's circumstances regarding potential variability, as underestimation may result in subsequent samplings failing to confirm gains or potentially overestimating soil carbon on the farm.

To allow comparison between tests, the same protocol needs to be done once SOM or TOC testing is chosen. A deliberate switch between testing options may be made with a commitment to long-term use of the new testing option.

A soil laboratory should follow the protocols recognized as acceptable for soil nutrients or soil health (USDA-NRCS 450-03* document). Nutrient methods should be in accordance with regionally optimal test methods**. It is recommended to request that the lab identify the actual test method (most do) and forward all results to Demeter USA.

Sampling protocol: take a handful of soil from a consistent depth of six to 12 inches (reflecting the natural topsoil or A-horizon) and identify the depth. For consistency in interpreting the results, keep the depth of sampling always the same. For best results collect at least 15 places randomly across the same area of a uniform field, avoiding unusual or extreme locations (water pockets, rocky outcrops, steep slopes). It is not necessary to record the location of each core or handful since the process of randomizing and compositing helps reduce location bias and distributes results in a manner representative of the changes over time.

Samples once taken should not remain wet inside a bag for more than a day but be shipped promptly to a lab, or if needed, refrigerated before shipment for several days, and if this is not available, air-dried indoors requiring 3 – 5 days). Drying will preserve traits if the soil cannot be shipped promptly. Note: Air drying soil (without added heat) does not significantly disturb the form of biological activity measured in labs, since microorganisms are naturally adaptive to typical drying/wetting cycles. As crops change and land use designation changes, continue to sample the same field (or fields, based on preference and budget) year after year. The objective is to

track changes that may occur over time which are due to farming practices with careful notation to the current crop rotation of the field when sampled.

Additional criteria to consider when requesting testing (optional): Common tests include pH, Electrical conductivity (a measure of salt or salinity), extractable P, exchangeable Ca, Mg and K, micronutrients, cation exchange capacity (CEC). Salinity of soil is not normally measured in northern, temperate-humid climates but is recommended for all greenhouse and high-tunnel situations and wherever irrigation is used. Soil health tests include soil microbial (CO_2) respiration, organic carbon, total and organic nitrogen, water stable aggregates, and water holding capacity, among others. For tracking carbon changes over time, it is necessary to also include a test for soil bulk-density. This is performed on a specific intact-core volume of soil removed undisturbed. Core sampling tools are available to purchase and soil sampling companies may be able to perform the test for 0-6" and 6-12" depth. Special instructions may be required to be able to provide the proper kind of sample for measuring bulk density (the fixed dry weight of a known volume of soil less stones) ‡‡. If soil bulk density is not evaluated, then one cannot know the tons/acre of carbon (C), and therefore it will not be possible to gauge increases (or decreases) in carbon (or other factors) that are really happening. Biodynamic soils have been shown by scientists to become more porous and less dense over time. When a soil becomes less dense due to improved crumb structure, then common lab tests repeated periodically are likely to underestimate improvements. A new, relatively simple correction method exists by which labs can compensate for this bias if bulk density tests are taken at the beginning and then at each sampling time point***.

* Soil Quality Test Kit Guide. USDA August 1999. A great, simply written booklet of individual tests and self-test methods to accurately indicate soil conditions. Available at: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health/soil-health-educators-guide

*ALSO: NRCS Soil Health Technical Note No. 450-03. Recommended Soil Health Indicators and Associated Laboratory Procedures; Also, NRCS Soil Health Technical Note No. 450-04. The Basics of Addressing Resource Concerns with Conservation Practices within Integrated Soil Health Management Systems on Cropland and
‡ Note: Soil carbon (and bulk density) sampling and analysis is now a recognized NRCS Practice, called "Soil Organic Carbon Stock Monitoring CEMA 221". This means it is eligible for cost sharing up to 90% for up to 6 samples each time. Contact a local TSP through your NRCS conservation office for details.

‡ Kellogg Soil Survey Laboratory Manual (KSSL) Version 6 (document available on-line).

** Example: RECOMMENDED SOIL TESTING PROCEDURES FOR THE NORTHEASTERN UNITED STATES. Northeastern Regional Publication No. 493 3rd Edition. NOTE: Manuals exist for each of four regions of the country: Southeast; Central and Northwest.

*** Fowler, A. F., Basso, B., Millar, N. & Brinton, W. F. (2023) A simple soil mass correction for a more accurate determination of soil carbon stock changes. Nature-Sci. Rep. 13.

Example of Laboratory Test Descriptions used for Soil Quality Assessment

Description	Units	Measures	Interpreting Results
Aggregate Stability or WSA-water table aggregates	Est %	Soil structural resistance to degradation under wetting pressure. Method include water dispersion.	An indicator of the strength of dynamic soil structure, higher aggregation indicates optimum air and water movement through soils; aggregation generally improves with plant cover and the addition of organic matter;
Water Holding Capacity	g H_2O per g soil	The amount of plant available water in the soil.	Chiefly affected by soil texture (clay content) and humus content; Generally, increases with the addition of organic matter in both the short and long-term; important to gauge a soil's resistance and resilience to drought conditions.
Salinity	dS/m or mmhos/cm	The accumulation of salts	Salinity tends to be a concern in low rainfall areas fed with irrigation water or harsh desert areas that have accumulated sodium ("sodic") soils. New problems have emerged with greenhouse and high-tunnel systems accumulating salts due to low loss rates from controlled watering.
Microbial Respiration	Ppm or mg CO_2-C per kg wet or dry soil in 24 hr	A measure of the total active microbial activity within a given, moist soil.	Generally, more respiration means more microbiological activity, improving nutrient flow and availability to plants. Generally, increases with plant presence and addition of organic materials and is sensitive to temporal and short-term effects as well as longer term change.
Soil Organic Carbon (SOC)	% or g / kg	The amount of total organic carbon not including limestone carbonates in soil	An actual carbon (TC) test is necessary to measure carbon stocks over time and is preferred over the OM test which is not accurate. Significant (and meaningful) changes in carbon stocks are very difficult to detect over short time scales (<5 years). SOC makes up one-half of soil organic matter.
Soil Organic Matter	% or g / kg	A measure of all once-living material that is combustible in a hot furnace. Usually this is twice the level of SOC	Confers beneficial physical and biological properties: (food source for microbes), (improves soil structure, holds onto water, improves aeration), and chemical (binds nutrients) properties. In the short-term (1-3 years), soil organic matter levels can increase with the addition of compost, manure, and crop residues, but to sustain and build levels over time, biodynamic practices are necessary.
Soil Texture	% sand, silt, clay	The percent sand, silt, and clay in the soil.	There is no ideal soil texture. Texture determines soil class such as "sandy-loam", "loam", "clay loam"; texture influences soil density, water retention capacity, crumb structure and has some influence on potential for accumulating carbon; an inherent soil physical characteristic, soil texture does not change in response to management.
Soil Total and Organic Nitrogen	ppm or % soil	The concentration of either total or fractions of organic nitrogen such as amino acids present in the soil.	Different forms of organic nitrogen (amino acids-N, protein-N, enzymes) are converted slowly to plant-available forms as a result of biological activity. Amino-N forms of soil nitrogen are usually higher in manure fed soils.
Cation Exchange Capacity (CEC)	meq per 100 g or cmol(+) per kg	The total capacity of a soil to hold exchangeable (positively charged) mineral cations.	CEC is an inherent soil characteristic that changes only slowly and is predominantly determined by clay and organic matter content; Sandy soils rely more heavily organic matter for the CEC to aid retention of nutrients. Sand added to heavy clay soils does not significantly reduce CEC while improving water infiltration and root health.