CONSERVATION EVALUATION AND MONITORING (CEMA) ACTIVITY

Soil Organic Carbon Stock Monitoring

CEMA 221

DEFINITION

- This activity outlines the tools and protocols to measure soil organic carbon stocks.
- Use to estimate carbon stocks and track trends when data are aggregated across many producers. Soil organic carbon storage should be measured before and after the implementation of a conservation practice, system, or activity. Evaluation and monitoring of change usually require several years (e.g., >5 years).

APPLICABLE LAND USES

All land uses where there is a change in management or vegetation.

REQUIREMENTS

Qualified Individual Requirements

Participants should know the following Qualified Individual (QI) Requirements to ensure that the person they hire is reputable, competent, and meets their needs and objectives.

A QI for this CEMA must meet one of the following:

- Individuals who hold current applicable credentials, such as: Certified Crop Advisor (CCA), Certified Professional Agronomist (CPAg) through the American Society of Agronomy or a Certified Professional Soil Scientist (CPSS) through the Soil Science Society of America.
- Individuals recognized through the NRCS Registry as a Technical Service Providers (TSP) are certified for one of the following: Conservation Practice Standard (CPS) Nutrient Management (Code 590) or Soil Health Management Design and Implementation Activity (162).
- Individuals who hold a Bachelor of Science degree or higher in agricultural or soil science with at least 2 years of experience collecting soil for laboratory analysis.

Individuals under the supervision of a QI are allowed to collect soil samples for this CEMA.

General Requirements

1) This CEMA includes the performance of work and documentation of the tasks, results, interpretations, and other activities described herein by a QI.
2) Prior to initiation of the CEMA, the QI shall arrange a pre-work conference to ensure all parties

understand the participant's objectives, required deliverables, purpose and requirements for data collection and entry, and characteristics of the CEMA tasks.

a) The parties in the pre-work conference must include the participant, the QI, and an NRCS field office staff.

b) If the participant will employ a TSP to implement a Conservation Planning Activity (CPA) or Design and Implementation Activity (DIA) that will be supported by results from this CEMA, it is recommended to invite them to the pre-work conference too.

3) A QI may use any reference information, resource concerns, conservation practice standards and related documents served in the NRCS Field Office Technical Guide (FOTG) for the state where this CEMA is performed. The FOTG home page hyperlink is: https://efotg.sc.egov.usda.gov/#/

Technical Requirements

This CEMA may be used concurrently or consecutively with a conservation plan designed to mitigate climate change by reducing greenhouse gas (GHG) emissions and sequestering atmospheric carbon in soils. The CEMA is intended to be used with NRCS conservation practices, systems, and activities which may sequester carbon in soils.

The CEMA provides the participant two options:

1) Option that supports a sampling protocol (Soil Carbon Stock Sampling) with fewer samples collected and no requirement to share historic, baseline, and conservation management and land use history done consecutively with implementation of a NRCS conservation practice; and

2) Option that supports a monitoring sampling protocol (Citizen Science) that requires the participant to share historic, baseline, and conservation management and land use history consecutively with implementation of a NRCS conservation practice.

Both options are required to be repeated at the same location 5 years or more after a conservation practice has been implemented. Each option will help inform participants of the effectiveness of their management activities in sequestering organic carbon.

Participants choosing the Citizen Science option are required to share data for the purpose of aggregating data across many producers, across regions and management systems. In the Citizen Science scenario, the following information will also be collected following guidelines in a separate document: historic, baseline, conservation management and land use history, crops that have been planted, relevant dates of planting and harvesting, tillage type and frequency, irrigation type and frequency, fertilizer, manure, liming applications, animal type and characteristics, grazing rotations, agroforestry and forestry type, number of trees, and forestry management prescription. Additional data elements may be required for identification of sites, sample points, samples, and other factors required for data management and quality assurance. Data provided by participants from completing the Citizen Science option is ancillary to those data collected as part of the NRCS-validated and statistically valid GHG quantification efforts conducted by USDA and its partners.

Use the following sampling protocol to ensure accurate soil organic carbon (SOC), bulk density (BD), and coarse fragment measurements:

1) Site Selection

Select a representative planning land unit (PLU) to sample soil.

Use a geographic information system (GIS) or the Web Soil Survey to identify an area of interest (AOI). Other resources such as: recent aerial imagery, normalized difference vegetation index (NDVI), Landsat, soil adjusted vegetation index (SAVI), elevation data, slope, aspect, yield maps, and producer knowledge can also be used to determine if the soil and vegetation within the AOI is uniform, or if there are distinct variations that can be clustered together in the soil sampling strategy (stratification).

Identify and digitize an AOI of the footprint of the planned or applied conservation practice(s) where soil samples and critical associated data (such as management history) will be collected. Locate the AOI in a region that has been managed uniformly and is representative of the larger management unit.

Do not exceed 10 acres when creating the AOI.

Ensure the AOI is not on a histosol (muck or peat soil) since these are soils formed from mostly organic material.

Contact all applicable utilities in the project area, or a coordinated entity, such as 811, State One Call system, MISS UTILITY, DIG SAFE, etc., to check for any buried utilities. The landowner and the QI are responsible for locating all buried structural measures in the PLU, including drainage tiles and other structural measures. Contact the local soil and water conservation district for assistance in locating any buried conservation measures.

2) Soil Carbon Stock Sampling:

Identify locations within the PLU to collect soil. Sampling points should be selected prior to going to the field. This is important for repeatability of soil sampling. See Appendix for detailed sampling strategy. Use either of the following sampling strategies:

a) Uniform Sampling

If there is only one dominant soil type and no evidence that there is significant variability in factors affecting carbon amount or response to management in the AOI (<10ac), identify 6 random locations to collect soil.

b) Stratified Sampling

If there is evidence of spatial variability (such as more than one soil type) in the AOI, identify strata based on a combination of soil map units, soil series inclusions, landscape positions, past management, or other spatial features. If there are 2 strata, identify 3 random locations per strata. If there are 3 strata, identify 2 random locations per strata. If there are more than 3 strata, select another AOI. For either 2 or 3 strata, there will be a total of 6 sampling locations.

3) Citizen Science:

a) Stratified Sampling for Soil Carbon Monitoring

Identify 3 strata based on a combination of soil map units, soil series inclusions, landscape positions, past management, or other spatial features for a selected AOI (<10ac). Within each of the 3 individual strata, divide the strata into three equal sections. In each section,

select 1 random sampling location. Each of the 3 strata will have a total of 3 sampling locations for a total of 9 sampling locations.

4) Sample Collection

Navigate to each sampling location within the AOI using a GPS (WGS84). Record the actual location if it is different than the predetermined location.

Ensure equipment is relatively clean prior to collection. Remove all plant/organic matter (e.g., crop residue, moss) and ensure the surface of the mineral soil is bare.

When allowable, collect soil either before tillage/planting operations or after harvest operations. Ensure soil is not saturated or frozen, if soil is collected during other times of the year:

- Wait at least 8 weeks after tillage, additions of soil amendments or fertilizers, or other disturbances, or
- Collect soil at the same time of year under similar management conditions when production system or climate do not allow a waiting period of 8 weeks. Record time of year and management conditions.

Do not collect soil from:

- Wheel tracks or drive lanes, field borders, depressions, within 25 ft. of a gravel road, or any other odd areas within the field.
- Different landscape positions (i.e., summit, shoulder, backslope, foot-slope, or toe-slope) within a strata unless appropriately stratified.
- Areas where erosion is observed or obvious past occurrence.

Soil samples can be collected using either a soil probe (hydraulic or mechanized) or with a shovel (excavation). The probe must be free of rust, have a steel corer, and should be used without lubrication. In situations where lubrication is needed, use a sampling sleeve made of plastic or acrylic.

If using a soil probe, ensure it has a minimum length of 100-cm and minimum diameter of 5-cm to collect soil for organic carbon and bulk density measurements from each of the following 4 depths:

Sampling Increments	**1**	**2**	**3**	**4**
Sampling Depth (cm)	0-15	15 to 30	30 to 60	60 to 100

If sample collection is not possible due to a restrictive layer or a municipal ordinance, collect soil from the maximum depth possible and record the depth. Reference the Web Soil Survey, depth to restrictive layer attribute prior to going to the field.

When coarse fragments prohibit the use of a hydraulic probe for sampling, use the excavation method to sample to depth.

When soil is collected by excavation:

- Measure bulk density at each depth using compliant cavity (water or polyurethane foam), clod paraffin, or coring. The same method must be applied for repeat sampling.
- See “Procedures and Protocols for Field Data and Sample Collection” located in the reference section for details.
- Calculate or visually estimate the coarse fragment content and record on the data sheet.

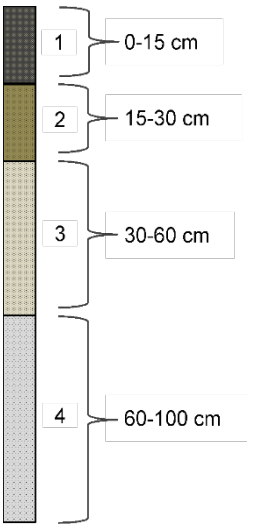

Figure 1. Soil Core Depth Increments

Take georeferenced digital images during soil collection. Images should include:

- 1 image of the entire AOI (landscape photo from sampling site).
- 1 image of each sampling location (include soil probe and bare soil surface).
- 1 of each core after extraction and prior to processing with a measuring tape.

5) Sample Processing

Create a sample ID, and label re-closable, plastic, freezer-grade bags prior to going to the field. Use a name system such as field name or Farm Name, Farm Number, or Tract number. Include type of sample (bulk density or carbon), depth of sampling, soil name, and date collected.

Record sample ID, GPS data and other required information.

Measure and remove soil (intact if using probe) from one depth increment and place in the appropriately labeled bag. Keep collected samples cool and out of sunlight while in the field.

After returning from the field, place samples in a cool dark place until shipping. Do not oven dry or freeze. Ship soils within 2 weeks of sampling. Follow all USDA-APHIS regulations for prohibited, regulated, or quarantined soils.

6) Soil Analysis

Soil samples will be shipped to laboratories that measure bulk density and soil carbon by dry combustion.

Ensure laboratories maintain current certification with one of the following:

- The Performance Assessment Program (PAP) from The North American Proficiency Testing Program (NAPT) under the auspices of the Soil Science Society of America, or
- The American National Standards Institute (ANSI) National Accreditation Board (ANAB), or
- The International Organization for Standardization (ISO/IEC 17043:2010) for ISO 10694:1995.

Record the sample volume of the intact core in the field before submitting to the laboratory for analysis. The laboratory will measure bulk density and organic carbon on each core increment without compositing.

Measure bulk density or measure the volume and oven-dry weight of fine earth soil material, and coarse fragments separately to calculate the bulk density.

7) Calculations and Reporting

Calculate the soil organic carbon stock for each layer using the corresponding bulk density results and the following formula:

SOC stock (milligrams C/square-cm) = Bulk Density (g/cubic-cm) x Soil Organic Carbon

(mg C/g soil) x Thickness (cm) x Volume of Whole Soil (1 – coarse fragment%).

Measure the internal diameter of the soil core cutting tip and record the height in cm on the data sheet. Calculate the volume of the bulk density sample in cubic-cm. Average the bulk density values obtained from each depth increment.

Calculate cylinder volume using $V = \pi r^2 h$. (π = Pi or 3.14, r = radius, h = height).

8) For the Citizen Science option, collect and report data that complements the soil carbon data using the guidance document.

9) Monitoring and Resampling

It is recommended to schedule this CEMA at least 2 times. Complete the first sampling prior to practice implementation and the second 4 years after the first.

Use the same georeferenced locations and sampling strategy under similar soil conditions, and the same time of year for the second sampling to monitor practice effects.

Send soil for analysis to the same laboratory.

DEFINITIONS

1) *Soil Organic Carbon Stock* is the content or mass of organic carbon, analyzed by high-temperature and dry combustion of soil, in a sample of known bulk density. Soil organic carbon stock is expressed in Mg C per hectare.
2) *Strata* is an area that has been divided into a homogeneous subgroup as a result of the stratification process.
3) *Stratification* is a method of dividing an area into subgroups called strata based on characteristics they share for example, soil properties.

DELIVERABLES

The QI must provide documentation showing all the tasks indicated in the **General Requirements** section, the **Technical Requirements** section, and the following sections.

Cover Page

Cover page reporting the technical services provided by the QI. Cover page(s) must include the

following:

1) CEMA name and number.
2) Participant information: Name, farm bill program name, contract number (QI obtains contract number from participant), land identification (e.g., state, county, farm, and tract number).
3) QI name, address, phone number, email.
4) A statement by the QI explaining how they currently meet the QI requirements for this CEMA. Attach or enclose a copy of documentation for how the QI requirements are met and is encouraged. Examples include:
    - Certification Name and Number,
    - License Name and Number,
    - Agricultural Retailer Business Name, or
    - Other brief written statement indicating how the requirements of a QI for this CEMA are met.

    QI Signature: _____ *Date:* _____
5) A Participant's acceptance statement, such as:

    I accept the completed CEMA deliverables as thorough and satisfying my objectives.

    Participant Signature: _____ *Date:* _____
6) A space for an NRCS reviewer to certify the agency's acceptance of the completed CEMA and, such as:

    NRCS administrative review completion by:

    Signature: _____ *Title:* _____ *Date:* _____

Notes and Correspondence

1) Document sampling strategy including justification for uniform sampling or environmental variables used for stratification (such as soil map units, slope, equal area, etc.).
2) Document each site visit, its participants, the activity completed in the field, and results of each site visit.
3) Make copies of correspondence between the QI and the participant relating to decision-making and completion of this CEMA.
4) Make copies of observations, data, technology tool output, or test results prepared during completion of this CEMA.

Maps

1) Maps to include, but not limited to:
    a) General location map to locate the sampling area, such as geographic coordinates, public land survey coordinates, roads to access the site, etc.
    b) Soil Sampling map showing the PLU polygon data and GPS point data (WGS84 latitude and longitude) for sampling locations.
    c) Provide other maps as needed, with appropriate interpretations.

2) All maps developed for the CEMA will include:
   a) Map title.
   b) Participant's name (individual or business).
   c) Assisted By [QI name].
   d) Date prepared.
   e) Map scale.
   f) North arrow.
   g) Appropriate map unit symbols and a map symbol legend on the map or as an attachment.

Testing Results

At a minimum, prepare a report including the following is required:

1) Report describing the sampling strategy used for the test type.
2) Sample identification code(s).
3) Laboratory test results.
4) Schedule of additional testing or monitoring at recommended frequency, as determined by the conservation plan.
5) Additional required data on the conservation and management practices at the sample site location for participants of the Citizen Science option.

Deliver Completed Work

1) The QI must prepare and provide the participant two sets of all the items listed in the **General Requirements**, the **Technical Requirements,** and the **Deliverables** sections of this document.
2) One set is for the participant to keep.
3) The other set is for the local NRCS Office.
4) The QI may transmit a set of the completed work to the local NRCS Office, if their participant has authorized it.
5) It is recommended to provide the NRCS field office an opportunity to review the CEMA deliverables, prior to asking for their acceptance.

REFERENCES

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Nelson, D.W. and L.E. Sommers. 1996. Total Carbon, Organic Carbon, and Organic Matter. p 961-1010. In D.L. Sparks (ed). Methods of Soil Analysis, Part 3. Chemical Methods. Soil Science Society of America Book Series Number 5. American Society of Agronomy, Madison, WI.

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USDA Natural Resources Conservation Service. National Planning Procedures Handbook. https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=44407

USDA Natural Resources Conservation Service. National TSP Resources. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/technical/tsp/?cid=nrcseprd1417414

USDA Natural Resources Conservation Service. National TSP Website. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/tsp/

APPENDIX A - SOIL SAMPLING STRATEGY

Soil Carbon Stock Sampling

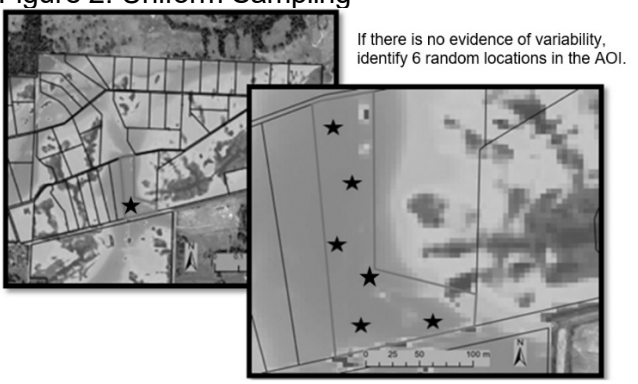
Identify locations within the AOI polygon (<10ac) to collect soil. Mark each sampling point on a map and record the coordinates. This is important for repeatability of soil sampling. Use either of the following sampling strategies:

★ Sampling Location ▭ PLU

Uniform Sampling

Generally, if there is only one dominant soil type and no evidence that there is significant variability in factors affecting carbon amount or response to management in the AOI, identify 6 random locations to collect soil.

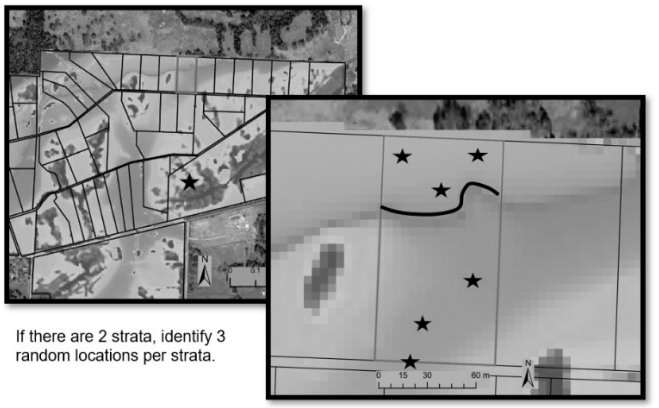
Figure 2: Uniform Sampling



Stratified Sampling

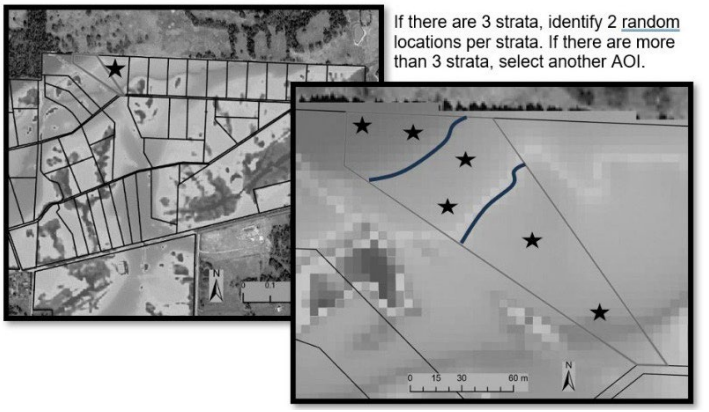
If there is evidence of spatial variability (such as more than one soil type) in the AOI (<10ac), identify strata based on a combination of soil map units, soil series inclusions, landscape positions, past management, or other spatial features. Within each individual strata, identify random sampling locations.

Figure 3: Stratified Sampling Map



Stratified Sampling (Continued)

Figure 4: Example of stratified unit



Citizen Science Option

Identify strata based on a combination of soil map units, soil series inclusions, landscape positions, past management, or other spatial features for a selected AOI (<10ac).

Figure 5: