

Soil Sampling Requirements

Soil Sampling for GHG Credits

The ESMC Protocol requires soil sampling to generate baseline results for soil organic carbon (SOC) and bulk density (BD) during the enrollment period for projects that generate GHG credits or assets.

Sampling and measurement for SOC and bulk density shall be repeated every 5 years. Values for pH shall be recorded every 5 years using soil sampling and measurement or by using an alternative ESMC approved approach (see Field Sampling section for details).

ESMC will work with project partners to conduct a field stratification, soil sampling, and soil analysis plan, which shall include:

- Field boundary cleanup, field or project level stratification, and sampling location generation; all currently part of ESMC's Stratification Process that uses SoilStack, a progressive web application (App). The standard requirements for this process are:
 - Field boundaries shall undergo a QA/QC process to confirm accuracy and eligibility that includes checking for:
 - overlap with other fields, protected areas, roads, and buildings
 - historical land use, e.g., recent (past 10 years) conversions to cropland from forest, grassland, prairie or native ecosystem
 - Relevant data sources shall be used to identify one of:
 - representative strata within each field
 - representative strata across all fields at the project scale
 - representative fields across all fields at the project scale
 - Power analysis or similar ESMC approved approach shall be used to determine the number of representative samples per strata or per field (i.e., the sampling density)
 - Sampling locations shall be georeferenced and linked to the producer's field and account in the Monitoring, Reporting and Verification (MRV) platform
- Identification and contact information of an ESMC approved soil sampling organization, and all contractors involved in sampling, along with confirmation of their review and agreement to the ESMC soil sampling procedures
- Identification and contact information of an accredited and ESMC approved laboratory used for conducting the soil analysis, and confirmation of laboratory accreditation and adherence to standard analysis methodology.

Soil sampling SOP requirements and guidance:

The ESMC stratification process generates and recommends approximately 1 sampling point per 3 acres of field. This translates to a minimum of 27 samples for each 80 acre field and 17 samples for a field that is 50 acres or less.

Methods for conducting stratification to determine sampling density and locations will continue to be developed through ESMRC Working Group research projects and pilots.

- Soil samples shall be taken within six months of the start (i.e., the Fall harvest date of the crop) of the first reporting year and prior to crop planting in the following spring.
- Sampling time shall account for the impacts of field management during this time that could influence estimates of SOC, bulk density, and pH. For example, sampling immediately after application of manures, tillage events, or residue incorporation should be avoided.
- Alternative measurement tools including handheld sensors and soil probes, and remote sensing technologies may also be used to generate a second set of estimates for SOC, bulk density, or pH. If these tools are deployed:
 - Their measurements shall be paired at least equally or to the greatest extent possible (along with justification to support any reduced pairing frequency) with ESMC's standard or an approved alternative sampling frequency and laboratory analysis measurements.
 - Locations shall use a random selection of fields or strata and shall be documented in the sampling plan.

ESMRC is currently developing more specific recommendations for employing these technologies, in particular to more cost effectively monitor SOC increase at ESMC enrolled sites.

Soil Sampling for Water Quality Credits

The ESMC Protocol requires reporting of available soil phosphorus (P) test results for quantifying Water Quality Credits. These test values are used for reporting each year but need not be sampled annually.

Sampling and measurement for available P should be repeated at least every 5 years unless prior test values are above State University Extension recommended thresholds, in which case annual data shall be required.

The ESMC soil sampling plan should be used to determine available P. An alternative ESMC approved approach may also be used to report available P. For example, prior soil testing (within 3 years of the project start date) in the same project field conducted as part of nutrient management planning may also be used.

Stratification, Soil Sampling, and Soil Analysis Procedures and Requirements

Stratification Procedures

- Stratification shall occur after the field boundary QA/QC process has been completed and any significant changes to the field boundary have been checked with and confirmed by the producer or his designee.

- Following QA/QC, field boundaries shall be transferred for Stratification that uses the ESMC SoilStack process or an alternative ESMC approved process.
- ESMC's SoilStack Stratification process:
 - collects remote sensing and digital soil mapping data clipped to target field
 - processes that data for use
 - implements a conditioned Latin Hypercube Sampling (cLHS) approach to determine sample coordinates
- Key inputs and sources for this stratification are:
 - Normalized differential vegetation index (NDVI) - Sentinel 2
 - Elevation, slope, aspect – USGS National Elevation Dataset
 - Soil type - SSURGO
 - Soil carbon stocks and clay content - POLARIS

Soil Sampling Procedures

Overview

- Soil sampling guidance, tracking, and data transfer shall be provided using the ESMC SoilStack Stratification App.
- Sampling in the project enrollment year and successive sampling events during the project period shall be collected within the same seasonal timeframe (preferably using phenological indicators) to provide consistency in capturing soil metrics.
- The timing of soil sampling shall account for recent field management that could impact estimates of SOC, bulk density, and pH. For example, sampling immediately after application of manures, tillage events, or residue incorporation should be avoided.
- Where samples cannot be collected from locations generated from the stratification, samplers shall sample within 10 meters of that location.
- Soil shall be sampled to a depth of 30 cm or to the limitation of sampling capability (whichever is shallowest). In locations where sampling to 30 cm is not possible, the soil sampling depth shall be recorded in the Stratification App and used in the bulk density and carbon stock calculation.
- Soil samples shall be shipped to the laboratory as soon as possible after being pulled from the ground and not stored at high temperatures.

Field sampling details

- Mechanized sampling should be used. For example, double cylinder, drop hammers with inner cores.
- For (any) separate cores taken for a composite sample (i.e., an alternate approach that may be used for analysis of SOC, pH and available P; see below), manual sampling may

be used. In either case, sampling equipment details shall be made available to ESMC and approved prior to sampling.

- The same core collected for bulk density measurement should be used for SOC analysis, and any pH or available P analysis. Alternatively, for SOC, pH, and P
 - a separate single core (same depth and diameter requirements as for bulk density) may be used, or
 - multiple (minimum 4) cores (no less than ¾ inch external diameter; 30 cm depth) may be sampled and composited into one sample, all shall be collected within 1m (e.g., in a concentric circle) of the single core for bulk density.

Bulk Density

- Bulk density shall be measured using the core method (e.g., Grossman and Reinsch, 2002)
- Sample cores shall be taken to a depth of 30 cm or 12" (30.5 cm) depending on equipment and units used.
 - In locations where sampling to this depth is not possible due to impediments in the soil, sampling attempts shall be relocated to within 10 meters of the original location. If this is not feasible, the greatest sampling depth attainable (less than 30 cm) shall be recorded in the App as accurately as equipment allows (e.g., to within 0.5 cm) and used in the volume calculation of the core.
 - A soil corer with a minimum *external* diameter of 2" (5.08 cm) shall be used. The *internal* diameter or *cutting tip* diameter (less than the external diameter) of the sampling device shall be recorded and used to determine the core volume.
 - If core sleeves are used, they shall not be lubricated with organic material
 - Sample cores may be kept intact or broken up in the field for transport. If samples are broken up sampling depths shall be recorded on the App prior to any break up.

pH

- Soil pH should be measured from ≥ 20% of the total number of sampling points generated by the stratification (NB 20% of the sampling locations will be randomly pre-selected for pH analysis by the App)
- Soil pH values may be sourced using an alternative ESMC approved approach*. For example
 - prior (last 3 years) fertility sampling in the same field
 - geospatial data layers

*Note that an alternative approach shall be approved in writing and the number of pH values generated from an approved alternative approach shall be $\geq 20\%$ of the total number of samples generated by stratification for that same field.

Available Phosphorus (P)

- Soil P should be measured from $\geq 20\%$ of the total number of sampling points generated by the stratification (NB 20% of the sampling locations will be randomly pre-selected for P analysis by the App)
- Soil P values may be sourced using an alternative ESMC approved approach*. For example
 - prior (last 3 years) fertility sampling in the same field

*Note that an alternative approach shall be approved in writing and the number of P values generated from an approved alternative approach shall be $\geq 20\%$ of the total number of samples generated by stratification for that same field.

Soil Analysis Procedures

- All samples shall be analyzed for SOC and bulk density.
- Bulk density and SOC shall be measured on the fine (<2 mm) soil fraction.
- $\geq 20\%$ of the samples should be analyzed for pH (automatically and randomly pre-selected during the ESMC stratification process). See also alternative approaches for sampling for pH determination above.
- Where water quality assets are being sought, $\geq 20\%$ of the samples should be analyzed for available P (automatically and randomly pre-selected during the ESMC stratification process). See also alternative approaches for sampling for available P determination above.
- Dry combustion shall be used for SOC analysis (e.g., Nelson and Summers 1996). Samples shall be oven dried and finely ground.
- Inorganic C (carbonates) shall be removed using either a qualitative acid pretreatment prior to dry combustion or a quantification technique using either a pressure calcimeter (e.g., Sherrod et al., 2002) or infra-red (IR) spectroscopy. Note that soil pH shall not be used as a determinant to decide whether to measure inorganic C.
 - Testing for inorganic C (carbonates) may be omitted if they can be shown to be a negligible component of the soil being analyzed.
 - ESMC shall approve in writing this approach for excluding inorganic C testing prior to soil sampling.
- Correction for coarse (> 2mm) fraction content shall be made for bulk density.
 - Sieving to separate the coarse (>2 mm) fraction may be omitted if the coarse fraction can be shown to be a negligible component of the soil being analyzed.

- ESMC shall approve in writing this approach for excluding this sieving prior to sampling.
- Where water quality assets are being sought, an appropriate test or tests for available soil P shall be used. Methods include Bray P1, Bray P2, Olsen, and Mehlich-3 (e.g., Mallarino, 1995).

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