Soil Sampling Methodology: Project Shed Inventory Approach

December 2025

The following soil sampling methodology has been developed as a supplement to HabiTerre's Project Shed Inventory Approach, *published October 2025. As global standards continue to evolve, we are committed to updating our methodology and related strategies to align with new guidance as appropriate.*

Purpose of Soil Sampling for a Tier-3 "Measure and Model" Inventory Approach

HabiTerre's Project Shed Inventory Methodology[1] is based on a tier-3 "measure and model" approach to quantify net greenhouse gas emissions and net CO_2 removal with improved agricultural management practices[2-4]. The methodology uses soil sampling data for model initialization when the inventory accounting starts and for model reinitialization every 5 years. Through the model initialization and reinitialization, the methodology provides a recalibration of model estimated soil organic carbon (SOC) change every 5 years.

Planning Soil Sampling

Define the spatial boundary: Clearly delineate the land area subject to carbon inventory accounting, ensuring it aligns with the company's value chain control (Scope 3).

Define the temporal boundary: Clearly define the accounting starting year and the MRV period for quantifying net CO_2 removal.

Design the Stratification and Determine the Sampling Density

To capture spatial variability and management impacts accurately, we will first divide all the land involved in an inventory project into different sampling strata. This should be based on factors that significantly influence SOC stocks, including climate region/ecoregion, land use/land cover type, cropping systems, soil type, management practices, topography, and/or enrollment year. HabiTerre provides advanced geospatial analytics to define strata for each project.

After the strata is defined for a project, the next step is to use a statistically robust design within each stratum to ensure representativeness and minimize bias. Common designs include: (1) systematic sampling with a grid or transect pattern (e.g., sampling points at set intervals); (2) random or stratified random sampling to ensure every part of the stratum has an equal chance of being sampled. HabiTerre currently **uses a two-stage uniform random sampling** to determine selected fields for sampling and sampling locations within each selected field[5]. More

advanced stratification designs, such as multivariate stratification or balanced sampling[6], are available and can potentially be considered to further refine the sampling design depending on the specific project needs.

For the "measure-and-remeasure" approach, the number of samples must be statistically sufficient to estimate the mean SOC stock in each stratum with an acceptable level of precision and confidence (e.g., 90% confidence interval within +-10% of the mean). For the "measure and model" approach, the number of samples is determined by the uncertainty propagation into the final model-estimated SOC change. HabiTerre has developed a Monte-Carlo-based uncertainty propagation method to consider the impact of soil sampling density on the uncertainty of estimated SOC change. The final sampling density will be determined by customers considering the **tradeoffs between uncertainty reduction and increased costs from increased soil sampling**. HabiTerre will provide technical support and analysis to support customer decision making on sampling density.

The standard sampling depth for SOC reporting is 30 cm (as per the guideline from the protocols), or to the depth of the management practice change (e.g., tillage depth). Sampling to deeper layers (e.g., 1 m) is recommended to capture full stock changes and confirm stability below the root zone, if resources allow. Separate soil samples should be collected to measure soil bulk density (BD) at each sampling or re-sampling event, especially if management changes (like no-till) are expected to affect it. Composite samples should be collected by mixing multiple sub-samples taken randomly within a small area around each sampling point to account for micro-variability of SOC concentration and BD, if resource allows.

Field Sampling Procedures and Laboratory Analysis

A soil sampling service provider (SSSP) will be contracted to conduct field sampling and laboratory analysis. The SSSP should use a reliable tool to ensure a consistent core volume (e.g., soil core sampler or auger) for SOC concentration. The SSSP should also collect separate soil samples to measure soil bulk density (BD) using a core ring method at the same depth intervals as the SOC concentration samples. The SSSP should provide good record keeping for GPS coordinates for all sampling locations to ensure precise re-location for future monitoring and sampling logs.

Standard sample preparation should be conducted for lab analysis of SOC concentration, including drying (air-dry soil samples as soon as possible after collection), and grinding/sieving (grind the samples and pass them through a fine sieve, e.g., 2 mm for concentration analysis). Dry combustion with elemental analyzer method is preferred as it derives total organic carbon (TOC) through accurately measuring total carbon (TC) and total inorganic carbon (TIC) through a separate analysis (e.g., acidification and dry combustion). To measure BD, the soil samples should be oven-dried at 105 °C until it reaches a constant mass to remove all moisture. Coarse fragment content or rock fraction (RF) should also be measured and reported.

The SSSP should have a full Quality Assurance/Quality Control (QA/QC) plan, including (1) Chain of custody: Implement strict tracking for all samples from the field to the lab; (2) Laboratory QC:

The lab should use certified reference materials and run replicate analyses to ensure accuracy and precision. (3) Field QC: Include field duplicates and blanks to check for contamination and consistency. The SSSP should also provide laboratory measurement uncertainty levels (i.e. standard deviation) for SOC concentration, BD, and RF measurements.

Use of Soil Sampling in Calculation and Modeling

From soil sampling data, the carbon stock (SOC stock) for each depth layer in a stratum can be directly calculated using the following equation: SOC Stock (MgC/ha) = SOC Concentration (gC/kg) x BD (g/cm^3) x Depth (cm) x (1-RF) x 10. The total SOC stock for the stratum will be derived through summing the SOC stocks across all depth layers. The uncertainty of estimated mean SOC stock in each stratum is derived using the error propagation formula, which considers the standard deviations of its components: SOC Concentration, BD, and RF. With repeated soil sampling, the uncertainty of estimated mean SOC stock change in each stratum can also be determined following standard methods[5].

For the “measure and model” approach, the measured SOC concentration, BD, and RF will be used for initialization and reinitialization in process-based model simulations for quantifying annual SOC change over the sampled fields. The uncertainty of estimated mean SOC stock change in each stratum will be estimated through a Monte-Carlo-based error propagation, which considers the **uncertainty of model structure and imperfect soil input data**.

Documentation and Reporting

All data, methods, and calculations will be transparently documented and retained for verification. Key information includes (1) Rationale for stratification and boundary selection; (2) Detailed sampling protocol (design, number of samples, GPS coordinates, depth, tools); Laboratory methods for SOC concentration and BD; (3) Calculation of SOC stock changes, including all raw data; (4) Quantification and reporting of uncertainty.

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[1] https://www.habiterre.com/wp-content/uploads/2025/10/HabiTerre-Project-Shed-Approach-2.pdf.

[2] https://verra.org/documents/vm0042-improved-agricultural-land-management/

[3] https://climateactionreserve.org/how/protocols/ncs/soil-enrichment/

[4] https://ghgprotocol.org/land-sector-and-removals-guidance

[5] Potash, E., Bradford, M.A., Oldfield, E.E. and Guan, K., 2025. Measure-and-remeasure as an economically feasible approach to crediting soil organic carbon at scale. *Environmental Research Letters*, *20*(2), p.024025.

[6] Potash, E., Guan, K., Margenot, A.J., Lee, D., Boe, A., Douglass, M., Heaton, E., Jang, C., Jin, V., Li, N. and Mitchell, R., Namoi, N., Schmer, M., Wang, S., Zumpf, C., 2023. Multi-site evaluation of stratified and balanced sampling of soil organic carbon stocks in agricultural fields. Geoderma, 438, p.116587.