



CARA's Soil Health Sampling Protocol Guidelines (Updated)

Yamily Zavala, Ph.D

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When sampling for soil health, there is not much difference to sampling for standard soil nutrient analysis. However, you need to answer few questions to set up the proper approach for how to sample your soils:

Look at your soil constraints:

- a) Do your soils have issues with soil compaction, water infiltration, and/or aggregation stability?;
- b) Do you know if your soil microbes are active and in appropriate balance for doing their job to keep soil resilience?

If your answers are yes for a) and no for b), then you will be soil sampling for health assessment. You also need to define what your goals are:

Do you want to assess the current soil health status?

Compare two different managements

Identify problems in a particular area? or

Change management in some field? etc.

Properly sampled soils will provide accurate results for monitoring soil health management strategies.

Information presented in this protocol might help you to decide how you want to sample your soil. It is recommended to do a soil health baseline assessment for monitoring soil changes. This will include evaluations of three main soil health components: physical, chemical and biological status. CARA's Soil Health Lab (<https://www.carasoilhealthlab.ca/>) will be focusing on the physical and biological constraints. For the soil chemical properties (Nutrient Recommendation), a portion of the soil sample will be sent to the chosen commercial laboratory.

A complete assessment of soil health should be done every two to three years. The constraint indicators that are identified should be monitored at least once a year. Future samplings of the same field will contribute to monitoring the impact on soil health of implemented soil management practices. Soil samples for soil health can be taken at any time of the year when soil conditions are appropriate and before starting a new soil health management program. When monitoring a particular site, it is important to establish a regular sampling date (spring, summer and/or fall), as it should occur at the same time of year to reduce temporal variability of the results. Soil samples should not be taken when the soil is too wet or frozen or shortly after applying any soil amendments (organic matter, lime, fertilizer, etc).

Selecting your Field:

After you identify what your goals are, the first step is to determine the number of samples needed per field. This is dependent upon the amount of variability within the field. Looking at a map or aerial photos of your farm will help. (<https://www.lsdfinder.com/map> , <https://earth.google.com/web/> , Figure 1)

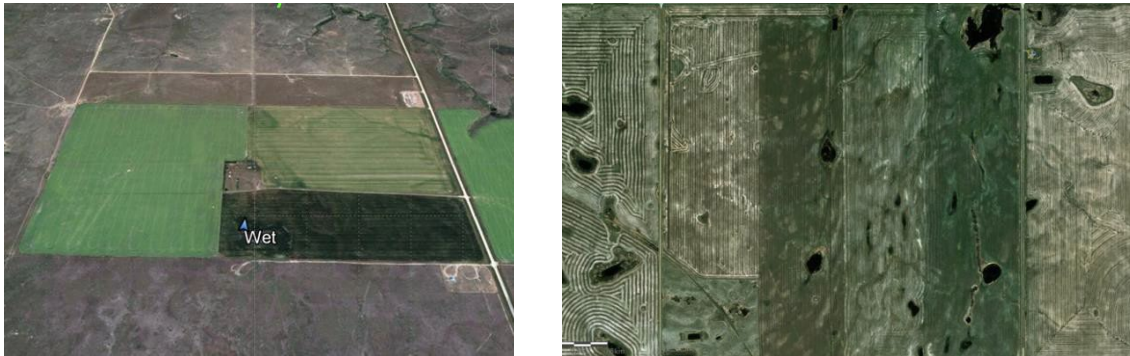


Figure 1.- Use aerial photos of fields for identifying sampling units

Select areas into sampling units with similar management, cropping system, yield response, similar soil type, slope, drainage, etc. Irregular areas should be avoided, unless a sample is specifically being collected from those areas to identify constraints (such as the dotted lines marked on Figure 2 and Figure 3, where there are uneven growth, low spots, eroded knolls, terraces and saline areas). Each sample should be representative of the target area.

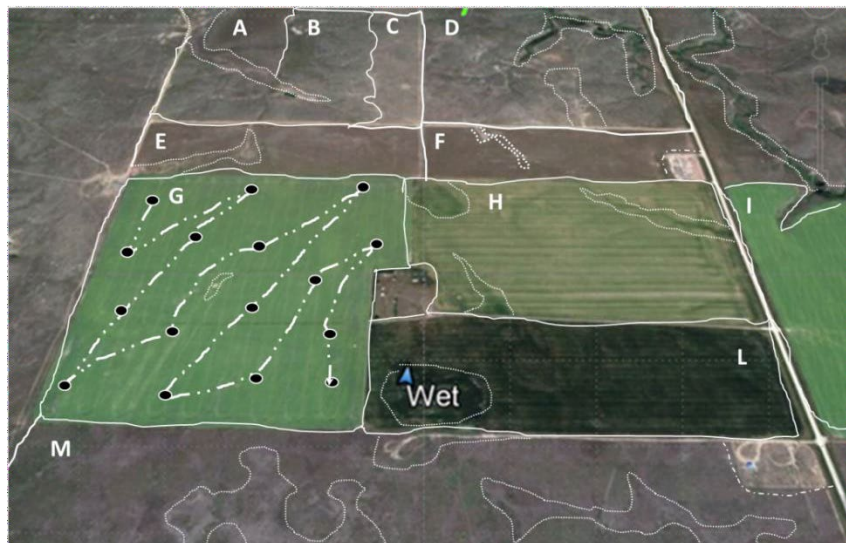


Figure 2.- Farmer field sampling units: Random composite (G) sampling

After the target areas have been defined, mark them on a map before sampling. Label them properly with a unique name or number (Figure 2 and 3) and use that identification for marking your soil sample bags.

Consideration for Sampling for Soil Health Assessment (SH-Assessment):

When starting a soil health management assessment, it is recommended to mark each soil sampling core site with a GPS. Sampling from the same area each time will reduce variability, and they will give a better evaluation of changes. Additional infield measurement information should be taken during sampling for complementing the soil health assessment such as soil bulk density (BD), soil water infiltration as well as soil compaction (more detailed information on infield measurements are annexed with this protocol). Collection of field history information is also important for better understanding soil health status (crop grown, chemical applications, tillage, etc.).

Soil Sampling Tools:

Sampling for soil health purposes may require special tools and different sampling procedures. Stainless steel soil sampling probes as well as vehicle-mounted hydraulic probes are very commonly used tools for collecting soil samples. The soil probe provides a continuous soil core with minimal disturbance to the soil and it can be readily divided into various sampling depths. However, for soil health sampling a small diameter soil probe may affect measurements on soil aggregates especially if the soil is high in moisture. Larger diameter probes are needed to avoid destruction of soil aggregates (physical assessment). When sampling for soil biology, a small core may be used (apple corer ~ 1 inch diameter, Picture 1). A spade might be also used but it will require more work to collect each sample. At each core (sub-sample), a small hole needs to be made deeper than the selected depth of each subsample; it is very important when using a spade to collect the same amount of soil at the selected depth. The collected soil should have the same thickness, depth and width to avoid different soil volume collected at each core. It is recommended to use a probe of at least 2 inches in diameter to avoid disturbance of soil aggregates. A 2-inch diameter by 3 inch depth or 2- inch diameter by 6 inch depth aluminum ring may be used for soil health sampling (Picture 2).



Picture 1. Apple corer 1" diameter, 3" depth



Picture 2. 2" Diameter rings: 3 and 6" depth

Picture 3 shows additional tools useful for soil health sampling: 3 large pails (or one for each selected depth), labeled 1-gallon freezer reusable (Ziploc) bags, markers, CARA's submission form, different size of ring cores, cooler, rubber hammer and a piece of wood (or a driver sampler), and field map (optional)



Picture 3. Other soil health sampling tools

Type of Sampling:

There are different procedures for soil sampling. You should choose the one most suited to your field condition ([http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/epw11920/\\$FILE/3-3.pdf](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw11920/$FILE/3-3.pdf) (Annex A)). It is important to utilize the same sampling strategies for the length of your soil health monitoring program. The two more common procedures used in the province of Alberta are described in this protocol.

Random Composite Sampling:

If a random composite sampling is selected (Figure 2 and Figure 3a, 3b and 3d), the field should be sampled in a simple zig-zag pattern collecting cores from 15 to 20 sites. Separate cores by the selected depths. Avoid areas such as manure piles, fertilizer spills and wet or salty spots, etc. Do all the infield measurement as described. For more information, see annexed references.

Benchmark Sampling:

For benchmark sampling (Figure 3c, 3e and 3F) select areas which are similar to most of your field unit. To select potential benchmark sites, observe crop development patterns at the beginning of the growing

season where differences in growth are more noticeable. Select a small area of minimum 30m x 30m. Collect at least 6 - 8 cores in a random or grid pattern (GPS each core). Make composite soil samples for each soil depth selected. Do all the infield measurement as described (pages 8-11). For more information, see annexed references.

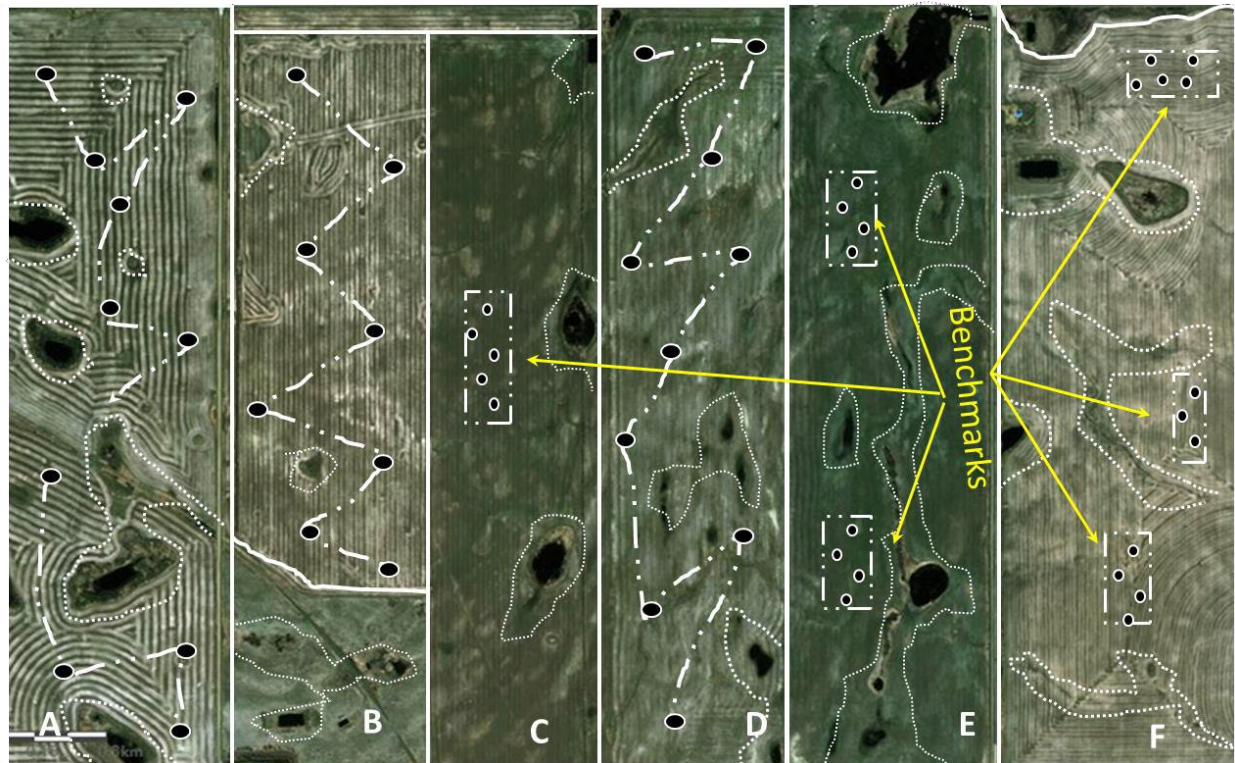


Figure 3.- Farmer Field Sampling Units. Random composite (A, B, D) and Benchmark (C, E, F) samplings

Sampling Depth Considerations

Conventional soil sampling depths are commonly based on laboratory calibrations developed for nutrient recommendations, generally using the upper 0–6 inches for surface fertility assessment and deeper increments, such as 6–18 inches, for mobile nutrients including nitrogen and sulfur. Soil-health sampling requires additional consideration because physical and biological conditions can vary substantially within the upper 6 inches of the soil profile.

Two primary objectives must be considered when selecting a soil-health sampling depth. The first is to determine whether soil compaction occurs within the upper 0–6 inches. Compaction must be assessed using a penetrometer, and the depths at which resistance reaches 200 and 300 PSI must be recorded. If 300 PSI is reached within the upper 6 inches, the compacted layer may restrict root development, pore space, water movement and biological activity. Under these conditions, separate samples must be collected from the 0–3-inch and 3–6-inch depth increments. Separating these depths allows the surface soil to be evaluated independently from the potentially compacted layer and supports monitoring of changes in soil physical and biological conditions over time.

The second objective is to monitor changes in soil biology following the application of biological

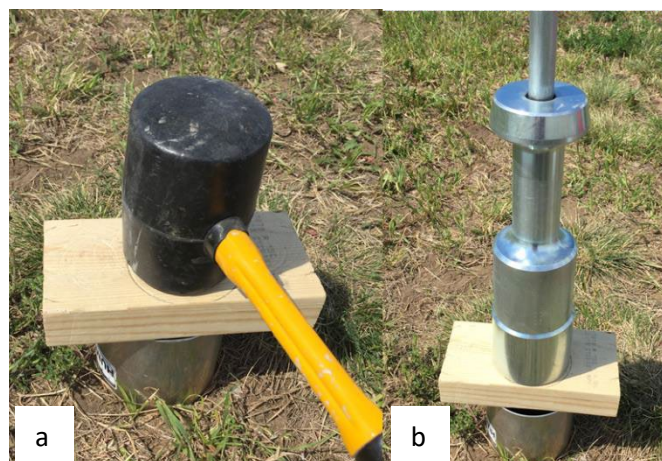
amendments, particularly when amendments are applied in or near the seeding zone. Biological responses may differ between the surface soil and the amendment-placement or rooting zone. Therefore, when the assessment is intended to evaluate the effects of a biological amendment, separate 0–3-inch and 3–6-inch samples should also be collected, even when severe compaction is not detected within the upper 6 inches. This sampling approach allows changes in microbial activity, microbial biomass and other biological indicators to be evaluated at the surface and within the seeding or amendment-placement zone rather than being diluted by combining the entire 0–6-inch profile.

When the purpose is a general surface soil-health assessment, no biological-amendment response is being monitored and 300 PSI is not reached within the upper 6 inches, one composite sample may be collected from the 0–6-inch depth. Deeper samples below 6 inches may also be collected when required to establish a profile baseline, investigate deeper compaction or monitor movement of management effects through the soil profile. Any additional depth must be recorded and sampled consistently during subsequent monitoring.

The same sampling depths must be used when comparing baseline and follow-up assessments. The selected depth, the reason for selecting it and all penetrometer measurements must be recorded on the CARA Soil Health Sampling and Bulk Density Infield Form. When carbon pools are calculated, a corresponding bulk-density sample must be collected for every reported depth according to the CARA Annex Soil Bulk Density Sampling for Composite Carbon Stock Calculations.

Soil sampling procedures:

Before starting to collect the soil samples, be sure to remove any crop residue or surface debris from the soil surface. If using the recommended ring, a 2(or 3)-inch diameter ring should be driven into the soil to the selected depth using a block of wood and a rubber hammer (Picture 4a) or the driver sampler (Picture 4b).



Picture 4.- collecting soil samples with a ring core.

Collect as many cores (sub-samples) as you need for your field depending on the soil sampling procedure selected (Figure 2 or Figure 3). Place each portion of the sub-sample in clean labeled plastic

pail, separated by depth (Picture 3); continue collecting all the sub-samples for that field. Mix thoroughly to obtain an individual composite sample for each depth. After the composite sample is well mixed, transfer at least 3 cups of soil into a labeled re-closable freezer bag. Keep the samples in a cooler. Microorganisms in the soil are very sensitive to extreme conditions. Keep samples out of direct sunlight and keep them cool. DO NOT air dry the soil collected prior to shipping.

Infield SH-Assessment:

Special soil sampling techniques need to be used for evaluating infiltration, compaction (soil hardness) and/or bulk density

A.- Soil Water Infiltration Rate:

Infiltration rate measures how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface runoff on sloping fields.

Select 3 or 4 core sites representative of the field for measuring infiltration. Record on the data sheet the GPS information and the timing that it will take for 1 inch of water to infiltrate the soil. The USDA-NRCS protocol (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052494.pdf (Annex B)) is recommended for measuring infiltration. Pictures 6, 7 and 8 show a version of USDA-NRSC infiltration protocol. Depending on the diameter of the ring used, a different amount of water is needed for this test. Table 1 shows the volume of water needed for assessing infiltration rate of 1 inch of rain for different ring diameter sizes (calculations were done using the volume formula for a cylinder: $V = 7.98 \times R^2$) and the inside radius (R) for this measurements). However, it is recommended to use a ring with a wider diameter for easy monitoring of the water infiltration.

Table 1. Amount of water for infiltration rate measurements based on different ring diameters.

Ring* Diameter (inches)	Radius inside Ring (cm)	Amount of water (ml)
2	2.54	52
3	3.81	116
4	5.08	206
6	7.62 (7.45)	463 (444)

*Ring height at least 5"

Materials for measuring infiltration:

The following materials will be needed: a ring of known diameter (at least 5" height), plastic wrap, block of wood, rubber hammer or density driver, (Pictures 4a or 4b), distilled water or rain water (based on Table 1), data sheet and a timer.

Considerations:

If the soil is saturated, infiltration will not occur. Wait for one or two days following a rain event to allow for some drying. If soil is too dry, two infiltrations test are usually performed. The first inch of water wets the soil and the second inch gives a better estimate of the infiltration rate in the soil. If the first inch of water takes a lot of time to infiltrate, there is no need to do a second test, record this time.

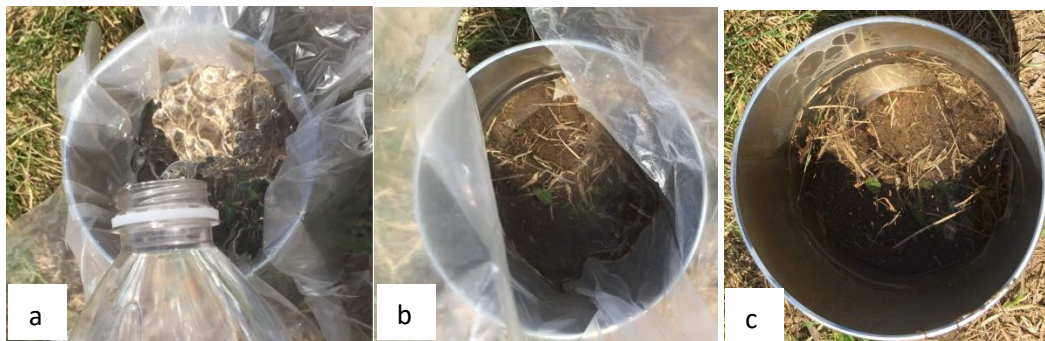
Procedure:

Clean the area of residue and weeds or trim the vegetation to the soil surface before inserting the ring. Insert the ring in place at least 2 inches deep, without disturbing the soil surface inside the ring. Gently firm the soil surface around the inside edges of the ring to prevent uneven water infiltration at the ring wall (Picture 6a). Using the plastic wrap, the ring should be covered allowing it to line inside the ring to hold the water as shown in picture 6b and 7a.



Picture 6.- a) Ring pushed 2 inches deep, b) plastic wrap lining inside the ring

Pour the correct amount of water (1" of water) depending on the ring diameter into the ring (Picture 7a). Have the timer ready to start at the same time that the plastic wrap is gently removed (Picture 7b) allowing the water to stay in the ring (Picture 7c)



Picture 7.- a) 1 inch of water, b) removing plastic wrap, c) water infiltrating the soil

Record the time in minutes it takes for the 1 inch of water to infiltrate the soil. Stop timing when the surface starts to glistening (picture 8). Record the amount of time on the infield data worksheet (Annex C).



Picture 8. Time to stop the timer, glistening surface

B.- Soil Compaction and selection of Soil Health Sampling Depth:

At every core sampling location, soil penetration resistance must be measured with a penetrometer or soil compaction tester. A penetrometer provides an estimate of the mechanical resistance encountered by plant roots and helps identify the depth and thickness of root-limiting compacted layers. As penetration resistance increases, root growth becomes progressively more restricted. At approximately 300 PSI, root penetration is severely limited and may practically stop, although roots may still grow through existing cracks, earthworm channels and other continuous macropores. Compaction can also reduce pore space, water infiltration, aeration and the quality of habitat available to soil microorganisms.

Penetrometer readings are influenced strongly by soil moisture. Measurements should therefore be taken when the soil profile is moist and near field capacity but not saturated or extremely dry. Wet soil can produce artificially low resistance readings, while dry soil can produce artificially high readings. Use the appropriate penetrometer cone and pressure scale and advance the penetrometer vertically at a steady rate of approximately 1 inch per second. CARA currently uses a Dickey-John penetrometer, as shown in Pictures 9a and 9b, but another properly calibrated soil compaction tester may be used when its operating instructions are followed consistently.

At every sampling point, record the depths at which the penetrometer first reaches 200 PSI and 300 PSI on the CARA Soil Health Sampling and Bulk Density Infield Form. The 200 PSI measurement identifies the depth at which root growth may begin to experience substantial mechanical restriction. The 300 PSI measurement identifies the depth at which root growth is expected to be severely restricted and is used by CARA to select the soil-health sampling depth.

If 300 PSI is reached within the upper 0–6 inches, collect separate composite samples from the 0–3-inch and 3–6-inch depth increments. Separating these depths allows the surface soil to be evaluated independently from the potentially compacted layer. This is important because compaction may affect root distribution, aeration, water movement and microbial habitat differently within each increment. Separate 0–3-inch and 3–6-inch samples should also be collected when the purpose of the assessment

is to monitor changes in soil biology following the application of biological amendments, particularly when the amendments are placed at or near seeding depth. Sampling the two increments separately allows biological responses near the soil surface and within the seeding or amendment-placement zone to be evaluated without being diluted by combining the entire 0–6-inch profile.

When 300 PSI is not reached within the upper 6 inches, and the assessment is not intended to monitor a depth-specific biological-amendment response, one composite sample may be collected from the 0–6-inch depth. Additional samples below 6 inches may be collected when required to establish a soil-profile baseline, investigate deeper compaction or monitor changes below the surface layer.

Penetrometer measurements must be interpreted together with the recorded soil-moisture condition (if available), sampling depth, management history and biological results. The same sampling depths, GPS locations and measurement procedures should be used during subsequent monitoring events.

When carbon pools are calculated, a corresponding bulk-density sample must be collected for every reported depth according to the CARA Soil Health Sampling and Bulk Density Infield Form and the CARA Annex Soil Bulk Density Sampling for Composite Carbon Stock Calculations.



Picture 9.- a) Soil Compaction Meter: Penetrometer, b) Penetrometer measurement

C.- Bulk Density Sampling for Carbon Pool Calculations

For all soil-health assessments that include bulk density or carbon-pool calculations, samplers must follow the instructions provided in the CARA Soil Health Sampling and Bulk Density Infield Form. One form must be completed for each sampling location and sampling depth. After determining the required depth or depths, the sampler must select either Method A, using the same known-volume cores collected for the analytical composite, or Method B, collecting a separate known-volume bulk-density core beside each analytical core.

For both methods, the internal diameter of the corer must be measured at the cutting edge. The selected sampling depth, number of accepted cores, GPS locations and any rejected, incomplete or relocated cores must be recorded on the in-field form. All soil, roots and coarse fragments recovered from each accepted core must be transferred to the correct sample bag. No soil from within the measured core volume may be discarded in the field. Samples must remain moist, cool, sealed and protected from direct sunlight until delivered to the laboratory.

The cylindrical-core method described in the USDA-NRCS Soil Quality Test Kit Guide, Section I, Chapter 4, Bulk Density Test is recommended as the technical basis for collecting and processing known-volume bulk-density cores. A copy of this USDA-NRCS reference is provided as Annex E of this protocol. The CARA Annex E1 Soil Bulk Density Sampling for Composite Carbon Stock Calculations provides the additional requirements for applying the known-volume core method to CARA composite samples and for matching the resulting bulk density with composite TC or TOC concentrations.

The bulk density used to calculate a soil carbon pool must represent the same sampling location, depth increment and sampling footprint represented by the composite carbon concentration. Field collection, laboratory handling, moisture correction, coarse-fragment measurement, bulk-density calculation and the matching of bulk density with TC or TOC results must follow the CARA bulk-density annex. Carbon-stock results should be reported only when the soil mass can be matched reliably with a documented sampled volume and accepted-core count. If these requirements are not met, the carbon concentration may still be reported, but a measured carbon stock must not be calculated without an appropriate corresponding bulk-density value.

Picture 10 illustrates the collection and handling of only one known-volume bulk-density core from the 0–3-inch depth. It demonstrates the correct procedure for inserting the ring, recovering the complete core without losing soil and transferring all recovered material into a labelled sealable bag. The picture does not indicate that one core is sufficient to represent a composite sample. The required number of accepted cores must be collected across the selected sampling locations according to Method A or Method B and recorded on the CARA Soil Health Sampling and Bulk Density Infield Form.



Picture 10. Soil core ring 3 by 3 inches soil surface (a), whole core (b), BD soil in sealable labeled bag (c).

The sampling depth must be selected according to the purpose of the assessment. For standard

soil-health assessment and carbon-pool monitoring, apply the 300 PSI compaction rule. If 300 PSI is reached within the upper 0–6 inches, collect separate samples from the 0–3-inch and 3–6-inch depth increments. If 300 PSI is not reached within the upper 0–6 inches, collect one sample from the 0–6-inch depth.

After determining the required sampling depth or depths, the sampler must select Method A or Method B for collecting the corresponding bulk-density sample. The number of accepted cores included in each composite sample, together with the selected depth, reason for the depth selection and bulk-density method, must be recorded on the CARA Soil Health Sampling and Bulk Density Infield Form. Any bulk density used for carbon-pool calculation must correspond to the same sampling location or SL and the same depth as the associated TC or TOC concentration.

Packing, Labeling and Shipping Recommendations:

Include the following information for labeling your samples in the submission form ([download submission form](#)):

Farmer name and/or submitter name, farm name, legal land location, E-mail address, phone, field ID unit (make sure your field ID is consistent with your maps and sampling bags), management history: cropland, pasture, range, etc., previous crop, crop to be grown and/or management strategy; what kind of tests are to be conducted, date of sampling and sampling depth; Also identify what kind of sampling procedure was used (randomized or benchmark). If infield measurements were done (BD, penetrometer readings and water infiltration), please submit the data sheet with the respective information. Save a copy of the information submitted to the lab for your records.

Each sample unit should be bagged individually in a 1-gallon plastic (Ziploc) bag. Make sure that each bag is properly labeling with the sampling field ID unit. Double bag your samples if it is necessary. Several samples bag can be placed in a larger plastic bag. Place your sample(s) in a cardboard box. Place the submission form inside a plastic bag and put it in the box. Make sure that the samples are well packed. Add packing material if it needed to minimize sample movement. Ship them immediately to the laboratory; ensure that the sample arrived at the lab during business hours. When temperatures are hot, you might use an ice pack(s) for sending the samples. All samples should be kept cool (4 °C) if they are not sent right away to the lab.