VCS MODULE VMD0021

ESTIMATION OF STOCKS IN THE SOIL CARBON POOL

Version 1.0

16 November 2012

Sectoral Scope 14

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1 SOURCES

None

2 SUMMARY DESCRIPTION OF THE MODULE

This module provides the methods to be used to estimate the required number of soil plots in each stratum, design and establish the plots, determine the carbon stock in the soil carbon pool, and check the statistical rigor of the results.

3 DEFINITIONS

Carbon Project: See *VCS Program Definitions* for “project”.

Coarse Fragments: Pieces of rock or cemented soils > 2mm in diameter, and therefore too large to pass through the screen used in the laboratory prior to laboratory analyses.

Embedded Boulders: Rocks which are free of the bedrock, and at least partly embedded in the soil, but which are too large to move manually.

Ex-ante: Before the fact. Projection of values or conditions in the future.

Large Coarse Fragments: Coarse fragments greater than 10 mm in diameter, and therefore too large to be included in the bulk density sample.

Long Lived: Carbon which is in a form such that more than 80% of the carbon will remain in the soil for more than 10 years.

Monitoring Interval: The length of time between monitoring events.

Organic Soil Soils are organic if they:

1. Are saturated with water for less than 30 days (cumulative) per year in normal years and are not artificially drained, but contain more than 20 percent (by weight) organic carbon; or

2. Are saturated with water for 30 days or more cumulative in normal years (or are artificially drained) and, excluding live roots, have an organic carbon content (by weight) which is:

   a. 18 percent or more, if the mineral fraction contains 60 percent or more clay; or

   b. At least 12 percent, if the mineral fraction contains no clay; or

   c. Greater than 12 percent plus 0.1 multiplied by the clay percentage (12%+0.1*clay%), if the mineral fraction contains less than 60% clay.

Pedogenic:	Arising from processes occurring within the soil.
Pedogenic Carbonate:	Inorganic carbon derived from ongoing soil processes.
Project Area:	The area or areas of land on which the project proponent will undertake the project activities.
Reference Condition:	A condition of the ecosystem which is believed to have existed at some time, and which reasonably approximates the intended condition which will exist if the project is successful.
Small Coarse Fragments:	Coarse fragments between 2mm and 10 mm in diameter, and therefore small enough to be included in the bulk density sample.
Soil Types:	(Or Soil series) The lowest category of U.S. system of soil taxonomy; a conceptualized class of soil bodies (polypedons) that have limits and ranges more restrictive than all higher taxa. Each soil type has soil layers with similar soil color, texture, structure, Ph consistence as well as mineral and chemical composition. Standardized soil type/series classification systems must be used where available.
Soil Layer:	Layer of soil whose physical, chemical and/or biological characteristics distinctively differ from the layers below and/or above.
Stratification:	The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people.

4 APPLICABILITY CONDITIONS

This module is not applicable for sampling or estimation of soil carbon content in organic soils.

5 PROCEDURES

Introduction

The goal of soil sampling is to gather information on soil carbon concentrations with statistical rigor sufficient to permit estimation of the total soil carbon per unit area. Soil sampling must always be conducted on a stratified basis, using the stratification procedures laid out in the module *VMD0018 Methods to determine stratification*. During stratification, existing data such as soil maps, landforms classes, slopes steepness, slope aspects, land cover classifications, and data from previous soil surveys are gathered. The actual work of stratification and estimating soil carbon using this module is undertaken on an overlapping basis, as data from work undertaken in each module refines the work undertaken in the other module.

Stratification for soil carbon sampling must consider at minimum the following variables*:*

- Existing soil classifications and mapping
- Soil texture, mineralogy and parent material
- Soil profile depth
- Geomorphic position and related soil processes, including, but not limited to:
    - surface shape (concavity/convexity),
    - slope position,
    - rates of erosion and deposition,
    - drainage and water regime,
- Ecology, plant community, and related soil processes, including, but not limited to:
    - Factors which may influence nutrient cycling and inputs, such as nitrogen fixation, rooting intensity and depth, and biomass turnover,
    - Factors which may influence rates of plant mortality and forms of carbon input, such as differences in fire intensity/frequency associated with differences in ecology or plant community.
- Land use and management history and duration
- Fire history and landscape modifications

Soil sampling must be undertaken using a permanent sample plot technique, and a plot design which allows repeated sampling without bias resulting from disturbance caused by previous sampling. Sampling must be undertaken using the following 6 steps:

1. Land reconnaissance and presampling
2. Selection of sampling parameters
3. Identification of sampling requirements
4. Sampling
5. Laboratory procedures and quality assurance
6. Data verification and calculation

Conditions under which inorganic carbon is accounted

This method contains guidance for quantification of both organic and inorganic carbon in soils. However, in many cases changes in inorganic carbon content are slow and unlikely to be significant. Furthermore, accurate estimation of reductions in atmospheric GHGs due to accretion of inorganic carbon may be difficult, for several reasons:

- Carbonates may be transported from other locations in dust, or in solution, and increases in carbonates in the soil may therefore not represent the formation of new carbonates.
- Available calcium or magnesium for the formation of carbonates may be derived from the breakdown of carbonates at another location.

In general, therefore, it is recommended not to account inorganic carbon under most project scenarios, with the following exceptions:

1. Inorganic carbon must be accounted where project activities are likely to lead to changes in soil chemistry or processes (for instance, increased acidity in the soil), which may be expected to lead to the breakdown of carbonates and the release of carbon compounds to the atmosphere. For instance, under some management regimes ammonium sulfate fertilizer may be added to high pH

soils with the goal of reducing pH to a 6.5 to 7.5 range. This pH change will tend to result in the breakdown of inorganic soil carbon and the release of carbon compounds to the atmosphere.

2. Inorganic carbon may be accounted where it can be demonstrated that:
    a. Increases in inorganic carbon in the soil are not the result of the transport of carbonates from outside the project area, or from below the sampled depth, for instance through irrigation or percolation.
    b. Calcium and magnesium for the formation of carbonates are not sourced from breakdown of carbonates outside the project area or below the sampled depth.

    In either case, projection of a baseline for inorganic carbon must take into account the full range of carbonate formation, transport and breakdown processes and environmental conditions. If possible, and if suitable sites are available, strong consideration should be given to the use of a monitored baseline in addition to the ex-ante estimation, due to the complexity of inorganic carbon processes.

Step 1: Land reconnaissance and pre-sampling

Goal: Production of a qualitative assessment of soil carbon variation based on landscape processes and factors, and stratified sampling.

Product: Information on the expected values and distribution of soil carbon across the project area.

Method: In this step, the project area and, if used the reference region, are formally reconnoitered to understand the variability in site conditions in each major soil type (typically major soil types are derived from existing regional or national level soil classification systems, and associated mapping).

For the purpose of preparing an ex-ante estimation of soil carbon levels under the project scenario in Task 3, it may also be desirable to locate and presample reference areas during this step. Sampling of reference area locations where conditions reasonably resemble the soil conditions expected to occur under the project scenario may increase the accuracy of ex-ante projections.

Organize and implement field reconnaissance to observe site conditions, soil types, vegetation types and land uses in the project area, and reference region. During the field visit, mark areas on the aerial photographs (or other maps) that represent a conspicuous difference in the condition of vegetation and soils in each major proposed stratum, fence lines and agricultural field boundaries which may be management unit boundaries, and other conspicuous physical and ecological differences of the land. The reconnaissance must be systematic, and will begin to provide some understanding of changes in soil characteristics across the project area.

The goal of this step is to bring greater definition to the soil and vegetation conditions found in each proposed stratum. This information must be used to refine stratification and plan sampling strategy and intensity.

1. Pre-sampling Strategy: In each proposed stratum, during the reconnaissance period, complete a satisfactory number of soil sampling investigations (follow the procedures in Step 3 below) to determine whether or not the existing proposed stratification of the site is supported in the field, and to gather some information on the range of variation within the project area and stratum. The location of the plots during this step should be determined by deliberate selection of areas thought to be typical of a given proposed stratum, rather than by random or systematic sampling, and statistical assessment of the plot results need not be undertaken.

2. Pre-sampling Soils: In each area sampled, record the soil layers, textural characterization and associated depths of each sample. In each location, triplicate soil pits or probe samples will be required to affirm this characterization following the procedures as in Step 4.
3. Recording Vegetation: In each area sampled, record vegetation composition. The goal is to identify vegetation species and their corresponding percent cover values and communities which may be indicators of soil conditions. Recording vegetation during this phase is aimed at fine tuning soil classification, and not at developing a vegetation classification.

Following pre-sampling, revise the proposed stratification as required, following the techniques given in the module *VMD0018 Methods to determine stratification*. Note also that pre-sampling may be used to identify and eliminate areas containing organic soils, which may be sampled using the methods given below, but must not be accounted using this module.

Step 2: Selection of sampling parameters

Goal: Determination of the sampling parameters.

Product: Requirements for sampling intensity and depth, and calculated depth

Method:

Determining sampling intensity

The number of plots depends on the variation in soil carbon levels, the required level of accuracy and the length of the *monitoring interval*. Based on the pre-sampling work, select an initial number of plots for each stratum. The goal is to install enough plots to meet the required statistical rigor, as discussed in Step 6.4 below. The project proponent may use a number of statistical methods to estimate the expected number of plots required, including those given in Wenger (1984), and in the CDM A/R Methodological Tool *Calculation of the number of sample plots for measurements within A/R CDM project activities* (AR-AM Tool 03 Version 02 or later version).

It is possible to reasonably modify (e.g. increase or decrease) the sample size after the pre-sampling or first monitoring event based on the actual variation of the carbon stock changes determined from taking the initial samples. However, the goal is to install sufficient baseline sample plots such that repeated monitoring of these plots can also encompass anticipated increases in variation over time.

Determining calculated depth and sampling depth

Calculated Depth: For each stratum, determine the calculated depth. This is the depth which will be used in the calculation of total soil carbon. This depth must be determined based on the following criteria:

- The calculated depth must be set to a depth great enough to capture at least 90% of the expected change in soil carbon resulting from the project activity as compared with the projected soil carbon change under the baseline scenario within the project crediting period, or 2m, whichever is less. Identification of the depth above which 90% of the change is expected to occur must be based on current research which has examined changes at depth, since much of the older research limited sampling to 30 cm or less, and did not quantify soil carbon dynamics at depth. Project proponents must start from an expectation of a 1m calculated depth, and adjust to reflect the particular dynamics of the project area. Thus, for instance, if research shows that 90%

of the change in soil carbon resulting from the implementation of the project activity within the project crediting period is expected to occur in the upper 70 cm of the soil, the calculated depth might be set at 70 cm. Determination of the calculated depth must be undertaken based on the available literature, reference area measurements and knowledge of changes in soil carbon under the ecological and treatment conditions expected to apply. Note that some treatments may result in increases in soil carbon in some soil layers, and decreases in soil carbon in others. If this is the case, it is critical to capture both layers in the calculations.

- While bedrock or cemented layers may limit the total depth of the soil in some plots to less than the chosen calculated depth, soil depth in a majority of the plots must be expected to be greater than or equal to the calculated depth.
- The calculated depth must be less than the sampled depth, with the exception of individual plots in which the sampled depth is restricted by bedrock or a cemented layer, in which case the calculated depth may be equal to the sampled depth for that plot.

The calculated depth must be set for each stratum. However, note that within a stratum the actual depth used in the calculations may vary from plot to plot and from time to time due to one of the following conditions:

- Presence of bedrock or a cemented layer at a depth shallower than the calculated depth.
- Changes in soil depth or bulk density, as discussed in Steps 3.1 and 6 below.

Sampling Depth: The chosen sampling depth must be greater than the calculated depth, to allow for detection of change caused by the project in deeper layers, and to allow for changes in soil characteristics over time, as discussed in Step 6. Note that as with the calculated depth, the actual depth sampled may be less than the chosen sampling depth if bedrock or cemented layers are present which prevent deeper sampling. Sampling depth must be great enough to ensure that all soil layers where significant changes in soil carbon may occur are sampled. For instance:

- In sites where tillage has been or will be practiced, sampling depth must be great enough to sample both those layers where tillage is occurring, as well as at least one layer below the maximum depth of the tillage, or the crop rooting depth, whichever is greater, to capture effects of downward migration of soil carbon from the tillage and rooting layer.
- In untilled sites, sampling must be deep enough to capture the “C” layer – the soil layer consisting of un-weathered parent material with little organic input. However, where the “C” layer begins more than 2 meters below the soil surface, sampling depth may be limited to 2 meters.

In some cases the examples given above might lead to excessive sampling depths – for instance, in alluvial soils where repeated depositions of soil lead to very deep layers of organically modified soils. In such cases, sampling depth need not be greater than 2 meters. Typically sampling depth should be 10 – 20% greater than calculated depth, to allow for changes in soil density during subsequent sampling events.

Field reconnaissance and digging of a few test pits or probe samples may be required to determine the appropriate sampling depth. The goal of this reconnaissance is to identify the depth to which active and significant modification of the soil carbon is occurring due to both natural and anthropogenic processes. Identifying the depth will therefore require knowledge of the processes impacting the soil, and the reconnaissance will consist of identifying the depth at which these processes are occurring, and will require on expert judgment. Indicators may include process indicators such as active rooting, tillage disturbance, soil color changes indicating active carbon accumulation or leaching, textural changes resulting from mobilization of fine fractions, etc.

Step 3: Identification of sampling requirements where soil processes exist which may generate inaccuracies in the estimation of soil carbon

Goal: Determination of the sampling requirements where soil processes could result in inaccuracies in estimation of GHG effects.

Product: Sampling methods which will allow for the adjustments required to compensate for changes in soil density or depth.

Method:

Soils are dynamic systems whose properties, such as density, chemistry, depth, and other variables can change over time. The goal of this methodology is to allow accurate estimation of that total amount of carbon in the soils of a site, and changes in that total carbon. Amounts of carbon are determined based on the following 3 key variables:

- The amount of carbon in the soil as a percentage of the mass of the soil.
- The density of the soil (the amount of soil mass per unit volume).
- The volume of soil for which calculations are being done (the depth times the surface area).

The goal of the sampling and calculation methods given in this module is to allow the accurate estimation of changes in atmospheric carbon resulting from changes in soil carbon. For this reason, it is critical to ensure that calculations do not result in erroneous estimations of the amount of carbon removed from or emitted to the atmosphere from soil processes. Such errors may occur for a variety of reasons. The most common potential causes of errors are:

1. Changes in soil density (compaction, accrual of organic matter, tillage, etc.);
2. Apparent changes in soil depth resulting from sampling methods; or,
3. Actual changes in soil depth resulting from erosion or deposition of soils.

The calculation methods to be used are to ensure that false attributions of change in atmospheric carbon do not result from these potential causes of error given in Step 6. However, for changes in soil density and erosion or deposition, changes in sampling technique may need to be undertaken, as detailed below.

Step 3.1 Changes in soil density

Changes in soil density may occur when soils are subject to treatments such as compaction or tillage, or compositional changes such as that which can occur with increased organic matter. These processes may result in more or less soil being present to the calculated depth, and may thus result in incorrect estimation of the total amount of soil carbon present if not corrected. Where such events are identified as a possible process resulting from the project activity or existing soil processes, the calculated depth may increase over time, and thus the sampling depth must be set to a depth great enough to ensure that sampling captures the data required for the calculations after changes in soil density have occurred.

Step 3.2 Actual changes in soil depth resulting from erosion or deposition of soils

Where erosion or deposition is expected to occur under the project scenario, project proponents must monitor changes in soil depth arising from these causes, to be able to account for these processes when undertaking calculations. Several techniques may be used, including:

- Installation of pins: Using the plot layout given in Step 4.1 below, select a point which is not expected to be sampled. At this point, during the first sampling of the plot, install a metal rod surface just flush with the top of the mineral soil layer. The metal rod should be longer than the calculated depth, or equal to the depth to bedrock or a cemented layer, whichever is less.

  During each sampling, the metal rod must be relocated, and the amount of erosion or deposition (the length of the rod exposed, or the amount of soil above the top of the metal rod) measured. Care must be taken not to disturb the soil in the area of the rod during each sampling event. Where deposition or accrual has occurred, measurement of the depth of the soil on top of the rod should wherever possible be undertaken using a thin metal probe, to minimize the disturbance of the soil. Where disturbance occurs, the soil must be replaced after measurement.

  Note that this technique must not be used where frost heave is expected to occur, or in expansive clay soils, since these processes may change the vertical location of the metal rod, leading to false results.

- Use ground based surveying techniques from known elevation markers to determine changes in elevation to sub centimeter accuracy.

- Use GPS to determine changes in elevation to sub centimeter accuracy.

Along with these techniques, soil profile descriptions must be re-measured by soil layers using standard data forms and procedures given below to determine changes in soil profile and strata thicknesses.

At the same time the bulk density must be estimated using standard techniques given below to distinguish between erosion or deposition and changes soil depth caused by compaction or de-compaction, tillage, expanding clays, or other causes.

Step 4. Sampling

Goal: Collection of data which will allow the calculation of a quantitative estimate of soil carbon variation to the degree of statistical precision specified in Step 6.5.

Product: Plot data on total soil carbon, and organic and inorganic soil carbon separately.

Method:

Step 4.1 Locating plots

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more “convenient” positions), the permanent sample plots must be located randomly or systematically with a random start within each identified stratum. The geographical position (GPS coordinate); administrative location, and stratum of each plot must be recorded and archived. Also, the sampling plots are to be distributed proportionately. For example, if one stratum consists of three geographically separated sites, then the following steps should be undertaken:

- Divide the total stratum area by the number of expected necessary plots, resulting in the average area per plot.

- Divide the area of each site within the stratum by this average area per plot, and assign the integer part of the result to this site. e.g., if the division results in 6.3 plots, then 6 plots are assigned to this site and 0.3 plots are carried over to the next site, or strata and so on.

Random location of plots can be accomplished in one of two ways:

- Locate plots systematically with a random start. In this case the plots are located using a systematic method – usually on a grid, with the location of the first points on the grid determined randomly. This must be undertaken prior to field work, with the plot locations specified on a map or aerial photos, and locations specified either as distance and direction from a known point or as a GPS coordinate.
- Locate individual plots randomly, using a randomization procedure in a GIS to specify the coordinates of each plot.

Timing of sampling

In addition to random location of the plots, it is critical that plot sampling is undertaken at the same time of year each time repeat sampling at permanent sample plots is undertaken. The goal is to sample the plots under, to the greatest degree possible, the same ecological and treatment conditions with each repeat sampling. Thus the day and month of establishment of permanent sample plots, and the ecological conditions existing at that time, must be recorded. Future samples at these plots should be established within 15 days of the same day and month in the year in which the plots are resampled, unless significantly changed ecological or treatment conditions (for instance a very late spring, late tillage, etc.) mandate a greater gap between the initial sampling date and a specific later repeat sampling date.

Step 4.2 Soil Sampling Plot Design

The sampling plot is designed to allow for very efficient installation and permanent field marking to ensure it can be relocated and re-sampled in the future. The design is shaped in circular form, that typically fits natural patch sizes in the field better then square or rectangular or linear plot shapes. Figure 1 shows the dimensions and provides an example of how individual soil sampling locations within the plot could be randomly sampled using several different soil sampling methods, and resampled over time to accommodate resampling. The plot is designed to accommodate at least three soil sampling methods: the use of soil core sampling technologies and extraction; the use of dug soil pits where rocks, roots and unconsolidated substrate conditions do not allow core sampling to be effective; and, the use of newer in-situ methods that involve inserting direct reading probes into the soil without necessarily having to extract soil samples en-mass as the core and pits methods, and correlations between these methods.

The plot design physically separates these three intervention methods and by following the instruction below, no interaction, bias, or violation of statistical independence occurs.

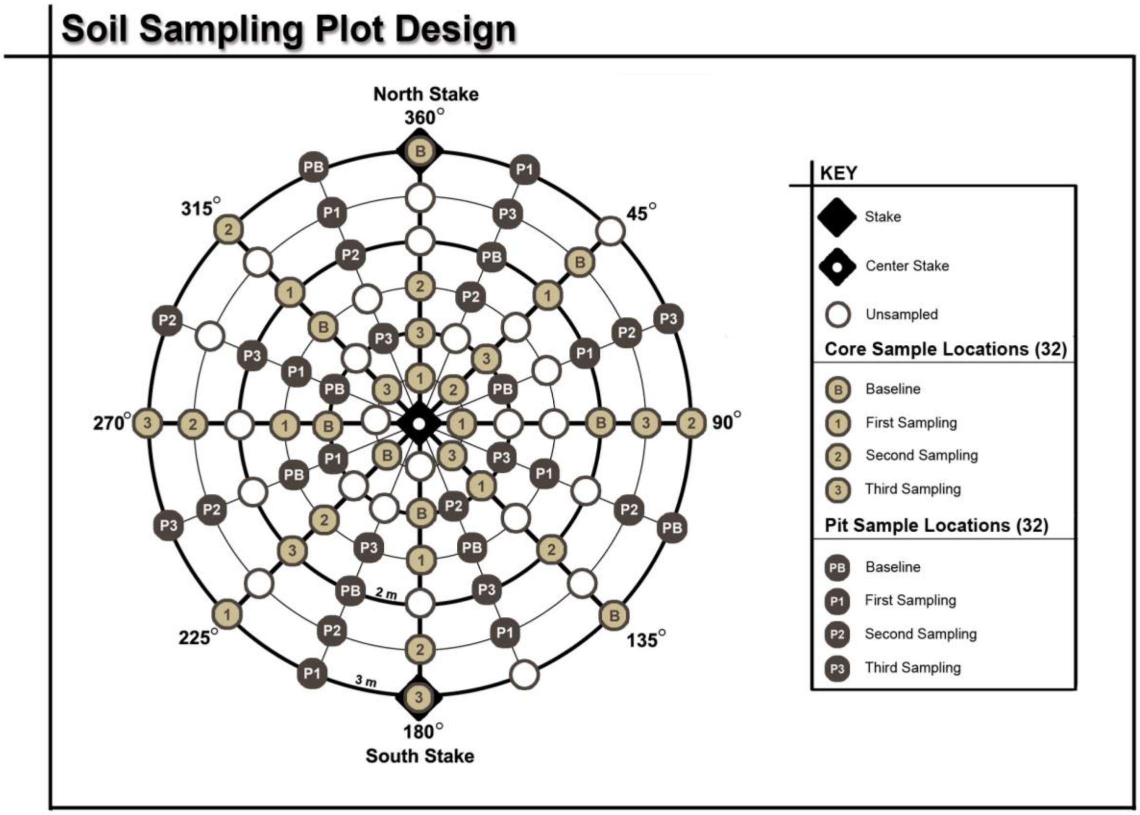

Figure 1. Layout of core and soil pit sampling site marking. Permanent plots centers and key radial end points allows easy metal detector relocation, re-measuring and gives statistical robustness and power.

Step 4.3 Initial Plot Establishment and Subsequent Relocations Steps

Step 4.3a Plot location: Using a handheld GPS with sub-meter accuracy, walk to the coordinates determined during Step 4.1, which locates the plot center. Achieving sub-meter accuracy may require use of control points (points with a known location). During initial plot establishment, install re-locatable marker. This marker may consist of:

- A 15-20 cm long by 0.25-0.50 cm diameter steel or iron rebar stake or 20-30 cm wire stake flag pins inserted into the soil at the plot center, and in the other locations as indicated in the sample plot figure. The rebar or wire stake pin must be completely buried by a minimum of 3-5 cm of soil to prevent discovery and damage to this marker, or injury to wildlife, livestock or humans, and vehicle tires in the future. This method should only be used where management does not include use of implements which could displace the center marker, or be damaged by the marker
- A power line marker or similar detectable marker buried 30 to 50 cm deep (at least 1.5 times the depth of expected disturbance) at the plot center where management disturbance (tillage or other activities) is possible.
- A surface marker outside the plot area along a fence line or other location where disturbance is unlikely. In this case the distance and direction from the marker to the plot center must be accurately determined and recorded.

If the sample plot location falls in an area of exposed bedrock or impermeable parent material (for instance compacted till) or an impermeable man made material (for instance a road surface), determine whether the area is representative (more than 5% of the stratum area is composed of areas of this type). If the area is representative, the sample plot must not be moved. On the other hand, if the area is anomalous (less than 5% of the stratum area is composed of areas of this type), the entire sample plot may be systematically relocated by moving the plot to a randomly located point, unless the project scenario includes activities which are expected to rebuild soil systems in locations of exposed bedrock or impermeable parent material.

When previously established plots are being re-sampled, a metal detector may be required to locate the exact location of the plot center and north stakes. Where an erosion measurement point has also been established, both the plot center stake and the erosion monitoring point must be found, to ensure that the correct stake is identified as the plot center.

Step 4.3b Plot layout: Laying out the plot in the field may be undertaken using the following steps:

> **Step 4.3b1** Mark the center point of the plot using the techniques described in Step 4.3a below.
>
> **Step 4.3b2** Secure one end of a precut and graduated tape or rope at the center stake and pull the tape or rope taught and strait on a magnetic north bearing (bearing of 360)
>
> **Step 4.3b3** Sight back over the tape or rope and ensure the back bearing registers a 180 degree magnetic north bearing. Adjust position as necessary to achieve this alignment of the tape/rope over the 180 degree back bearing.
>
> **Step 4.3b4** Establish the direct north stake point with another pounded rebar stake or buried marker, installed as in Step 4.3a. For relocating a formerly established north stake, use the same GPS and metal detector technique for relocating the metal center stakes.
>
> **Step 4.3b5** Establish the direct south point, located 3 meters south of the center point. Use the pre-measured tape or rope that is pulled to align the center of the length over the center stake and north end over the north stake. Flag the south end location with a temporary wire stake flag.
>
> **Step 4.3b6** Establish the 6 meter long radial that is magnetically aligned with the east (90 deg) to west (270 deg) compass bearings. Stretch the rope or tape taught between endpoint stake temporary flags and center the tape over the center plot stake.
>
> **Step 4.3b7** Establish the 6 meter long northeast (45 deg) to southwest (225 deg) tape or rope using the same method as in Step 4.2e.
>
> **Step 4.3b8** Establish the 6 meter long northwest (315 degrees) to southeast (135 deg) tape or rope using the same method as in Step 4.2e.

Step 4.3c Sampling point relocation The goal is to ensure that previous sampled points within a plot are not re-sampled on subsequent resampling events. Prior to commencing with plot installation, randomly select pit or core sample locations (an example is shown in Figure 1) for each planned sampling event. Five, to as many as eight, of the points within the plot should be sampled during each sampling event. If the planned number of sampling events requires more sample points than those shown in the diagram, the plot may be expanded or the number of sample points sampled per event can be reduced to a minimum of three. An additional point sampled at each sampling event will be a soil pit. If obstacles, such as large surficial rocks or trees, which have soil underneath them within the sampling depth, prevent collecting samples at designated points, it may be necessary to move sampling locations. For core samples, adjust by moving the center of the core sample in 5 centimeter increments north of prior designated point(s). For pits, randomly choose another of the pit sampling locations, shown on Figure 1. If, on the other hand, an outcrop of bedrock or compacted material, or an embedded boulder (a large rock extending down to below the sampling depth) prevents collecting samples, the sampling point should not be moved, and the soil depth should be recorded as zero. Note that results from such sampling points must only be used in determining the average soil depth used in the calculations, and must not be used in the determination of average soil carbon percentage within the stratum.

Step 4.3d Plot maintenance and records: To ensure independence among samples from the first and all subsequent soil sampling events, no extracted soil materials must be deposited on the surface of the sample plot. The soils removed from pits will be used to backfill the pits and backfill or cap the boreholes. During the sampling process the project proponent must ensure that even small amounts of soils or other materials are not accidently dropped from the core or shovel used during sampling onto other areas of the sampling plot.

Denote on the sample plot diagram and record which sampling points and pit locations have been sampled during each sampling period. Accurate recording of which sample points are actually sampled is necessary as points sampled in the field may be different than the a-priori randomly selected sample points. Also, record when adjustments are made to respond to rock, bedrock, tree roots, not being able to find a sample point, or where changes in the sample point justify it as atypical or modified from other representative conditions in the sample plot.

Sampling methods must remain constant from one measurement round to the next.

Step 4.3e Recording of soil layers: At each sampling location, use either a sampling probe (a 1 to 8 cm diameter stainless steel probe with a functional length equal to or greater than the sampling depth) or a shovel to extract or expose soil layer samples for observations, recording the depth of each soil layer. At minimum these must include depths of surficial humus layers, “A” and “B” layers, interbedded layers, hydrological indicators such as mottling or gleying, and depth to the “C” layer. Additionally, any other soil information commonly used to determine soil types in national, regional or local soil classification systems should be collected. For each soil layer record the texture, colours (using a Munsel standard colour book), hydrological indicators (e.g. mottles, reduction indicators), and the thickness. The sequence of soil layers must be determined down to the sampling depth.

Soil sampling will be undertaken using either core probe samples (may include power auger and core samples, etc.), or soil pits. Use soil pits if roots, rock or unconsolidated substrates do not allow the sampling and collection of soil samples using core probe samples, as defined above.

Step 4.3f Sampling soil carbon and bulk density: From each sample point, collect a separate soil sample from each soil layer. Place each sample in a plastic bag which is labeled with sample plot sample point and layer identification code, to ensure identification for later processing and analysis.

Additionally, for each soil layer, collect a single composite soil sample that combines equal amounts of soil from each of the three sampling points within the plot. Alternatively, the composite sample for each plot can also be created by removing from each previously bagged core or pit substrates sample, a homogenized subsample which is then added to the composite sample bag and labeled as above to record the plot number, composited strata layer, and date. The composite and individual collected samples will be submitted to analytical laboratories for carbon and other analyses.

To allow determination of the bulk density of each layer of soil, collect a known volume of undisturbed soil from each sampled soil layer within the plot. Typically this can be achieved by pressing a soil can of known volume into an undisturbed section of soil from the intact sides of a pit, or cutting a section of known length out of a sufficiently large diameter core sample and bagging it. Where soils are cohesive, this may require carving a block of soil to precisely fit the sampling can. Bulk density canisters need to be of a size appropriate to capture inherent soil structure variance such as found where aggregated soil structures are found. Typically, a canister of 74-150 cubic centimeters is adequate for this purpose. Regardless of soil sampling method, the goal is to extract intact sections that have not been compressed or altered by the sampling methodology and equipment, that are representative of each of the soil strata present, and to ensure that bulk density sampling, used to determine carbon content by soil volume, is accurate.

Step 4.3g Sampling coarse fragment content: Where soils contain a significant component of *coarse fragments* (rock and cemented fragments larger than the screen size used in the laboratory prior to testing for soil carbon), the percentage of the soil composed of these fragments must be determined. One or both of the two methods given below should be used, depending on the size of the *coarse fragments* present:

Small coarse fragments (Coarse fragments between 2mm and 10 mm in diameter, and therefore small enough to be included in the bulk density sample)

Where soil contains significant amounts of coarse fragments small enough to be included in the bulk density sample, the mass of the bulk density sample without the coarse fragments must be determined. This is done either in an eligible laboratory, or in the field, by screening the bulk density samples. Determination must be done separately for each soil layer.

Large coarse fragments (Coarse fragments greater than 10 mm in diameter, and therefore too large to be included in the bulk density sample, but not too large to move)

Where soils contain significant amounts of coarse fragments too large to be contained in the bulk density sample, the percentage of the volume of the soil composed of these fragments must be determined. Typically this can be accomplished by excavating soil from a hole of known volume, containing a minimum of 25 kg of soil, screening out the coarse fragments meeting the specified size criteria, and determining the volume of these fragments using water displacement, conversion from weight to volume, or other techniques. This determination must be done separately for each soil layer. Note that these coarse fragments do not include large embedded boulders, which are accounted as described in Step 4.3b above.

Step 5 Soil Sample Preparation and Laboratory Procedures

Goal: Completion of laboratory tests on soil properties.

Product: Accurate soil test results for measured soil properties.

Method:

Step 5.1 Soil Sample Preparation

All samples need to be inventoried, labeled and packaged for shipping to ensure they are accurately recorded, and to ready the samples for laboratory analyses and archival preservation.

Sample preparation. If the nitrogen content of the soils is to be tested, freeze soil samples prior to delivery of the samples to a laboratory. Specimens need to be delivered to the testing laboratory immediately or at least as fast as possible once sample labeling is completed and the soil sample is recorded in a tracking system. Soil sample drying is done by the laboratory to which the samples are to be delivered, using repeated weighing to achieve and demonstrate constant dried weight is achieved which is required for bulk density precision. Note that for some soils (some clays and volcanic soils in particular) achieving a constant weight may be difficult without high heat drying. In that case, a subset of the soil sample should be weighed, dried at high heat, and weighed again, and a correction factor for the soil density derived from this subsample. Details of this procedure are found in the manual: *Soil Survey Laboratory Methods Manual* (USDA 2004).

Bulk Density. Measure the volume and initial wet and achieved final dry weight of the soils in the bulk density samples, and calculate the weight per unit volume based on these measurements. Screen the bulk density sample and determine the weight per unit volume of soil without the *coarse fragments*, as discussed in Step 4.3f above.

Chain of Custody. For fresh or dried samples, submit a chain of custody form to the soil testing laboratory and ensure that the laboratory maintains the chain of custody records.

QA/QC. The chosen soil testing laboratory must have a rigorous Quality Assurance program that meets or exceeds the US EPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detention limits for each constituent analyzed.

Sample Archiving. Samples must be large enough to permit future re-testing. To do so, make arrangements with the chosen laboratory to create archival quantity samples. Archived samples must be either completely dried or frozen, to prevent ongoing biological activity from changing soil carbon densities, or their chemistry. Archived samples of all soil samples submitted should be kept at minimum until completion of the next verification. Additionally, a sufficient number of samples from each sampling event to cover the range of conditions expected to be found in the project area under the project scenario should be stored for the life of the project to allow recalibration of results where future advances in soil testing methods may result in potential loss of comparability between results.

Step 5.2 Laboratory Procedures

All laboratory procedures must follow the methods given in the most current version of the following manual: *Soil Survey Laboratory Methods Manual,* Soil Survey Investigations Report No. 42, Version 4.0

by the USDA Natural Resources Conservation Service, dated November 2004, or a standard of equivalent rigor.

Precision Levels

Two forms of testing error may occur at the lab: systematic and specific. The laboratory must meet the following precision levels:

> ***Systematic Error.*** Systematic error occurs when instrument miscalibration or other problems result in consistent errors in results. Laboratories must demonstrate that in testing of standardized control samples the difference between the sample results and the known carbon content is not greater than +/- 2% of the known carbon content of the control sample.
>
> ***Specific Error.*** Specific error occurs when testing of a given sample results in incorrect results, even though no systematic error is present. In order to test for specific errors, split a homogenized sample and submit both split samples labeled differently. Compare test results between the two subsamples and determine the specific error. Differences between split samples must not be greater than 10% of the greater of the two reported results.

As a standard procedure, for projects with a small number of samples (≤50) at least 10% of the samples must be split and independently tested and compared. For projects with larger sample sets (>100), no less than 10 samples must be split and independently tested.

Step 6 Analytical Laboratory Data Checking and Calculation

Goal: Accurate calculation of soil parameters based on laboratory results.

Product: Laboratory results which are quality checked, and calculated soil parameters based on the laboratory results.

Method:

Step 6.1 Data checking

Evaluate if all reported values are within the expected data ranges based on prior analysis and reports. Identify any that appear aberrant. Review the quality of the variances from the split blind samples. If results do not indicate that the estimated soil carbon levels of the split samples are from the same population or soil setting (10% variance with a 90% confidence interval). Retesting of soil samples may be required. These tests must be undertaken for soils collected from the same soil type, slope, vegetation cover typing, based on the *stratification* described in the introduction and Step 1 of this module.

Conclude which points appear to be outlier data points with what appear to be significantly skewed or divergent reported data outside the range of similarity to other data point results. If these are present in the data set, reasons for the variance must be determined based on the plot characteristics. Based on this analysis, one of the following options must be followed:

- If no significant differences in plot characteristics are found, compared with other plots in the stratum, the results must be retained and used in calculations for the stratum.
- If significant differences in plot characteristics are found, and these characteristics resemble the characteristics of another stratum, the plot may be re-assigned to the other stratum.

- If significant and highly anomalous differences in plot characteristics are found, and it can be demonstrated that these anomalous characteristics are unique and do not exist elsewhere within the stratum, the plot may be deleted.

Request retesting by the laboratory of archived samples if some results appear to be aberrant and cannot be explained.

Step 6.2 Adjustment of variables

As discussed in Step 3, certain soil processes (compaction, accrual, erosion, deposition, etc.) have the potential to result in errors in estimation of the changes in atmospheric carbon resulting from soil carbon fluxes. The following methods must be used to reduce the risk of errors in estimation when using the equations given above. Note that in some cases more than one of these soil altering processes may be present, and more than one method may be needed to reduce the risk of errors in calculation of soil carbon. In such cases, the project proponent must justify the suite of methods used, and demonstrate that the methods will not to result in an overestimation of the reductions in atmospheric carbon resulting from the project.

Step 6.2a Changes in soil density

Changes in soil density may occur as a result of compaction or decompaction. For each sampling point where the sampling depth was not restricted by bedrock or a cemented layer, and for each sampling time after the initial sampling, if the soil density (bulk density) changes by more than 5% from the first sampling event to subsequent sampling events, the calculated depth for that plot must be adjusted such that the factor *ts* is the same for each sampling period, where *ts* is calculated as follows:

$$ts = \sum_{l} sdens_l \cdot sd_l \qquad (5.1)$$

Where

ts	=	The total mass of soil in a 1 cm^2 column, g/cm^3
l	=	The soil layers found in the plot
sd_l	=	The depth (thickness) of soil layer x above the calculated depth, cm
$sdens_l$	=	The bulk density of soil layer x, g/cm^3

Example:

For the project, a calculated depth is 30 cm has been chosen. During the first sampling the soil is found to consist of two layers, as shown in table 6.3.1 below

Sampling time 1

Soil layer	Thickness above the calculated depth, cm	Bulk Density, g/cm3
A	20	1.1
B	10	1.2
		ts=34

Table 6.2.1 T=1 sampling

During the second sampling, the soil is found to be as follows:

Sampling time 2

Soil layer	Thickness above the calculated depth, cm	Bulk Density, g/cm3
A	22	1
B	10	1.1
		ts =30.8

Table 6.2.2 T=2 sampling

Because the soil bulk density has changed, the total amount of soil above the calculated depth has changed – in this case it has gone down, due to decompaction. The calculated depth must therefore be adjusted, to ensure that calculations are based on the same amount of soil. In this case, the new calculated depth will be 32.9, as shown in the table 6.3.3.

Sampling time 2, adjusted

Soil layer	Thickness above the calculated depth, cm	Bulk Density, g/cm3
A	22	1
B	10.9	1.1
		ts =34.0

Table 6.2.3 T=2 sampling, with calculated depth adjusted, such that *ts* for time 2 = *ts* for time 1

Note that if the new calculated depth extends below the bottom of the lowest soil layer calculated at time T=1 (in this case stratum B), the thickness of that soil layer must be the thickness found in the field, and data from the next soil layer down must be used for the remaining depth. For this reason it is critical to ensure that sampling in the field includes a substantial depth below the expected calculated depth as decompaction could potentially occur.

Step 6.2b Changes in the amount of soil present

Changes in the amount of soil present may occur through processes of erosion or deposition, or through the planned addition of soil amendments such as char. Where such processes are predictable (for instance, where regular alluvial deposition of soils occurs within a floodplain), their amount and location must be projected when preparing the baseline carbon estimates for the project. Also, where such processes are predictable, project proponents must ensure that plots are distributed to be reasonably representative of the range of erosion and deposition processes within the site. For instance, if a rolling agricultural site sees regular movements of soil from steeper areas of the topography to valleys and benches during intense rainstorms, plots must be located to representatively capture both the steeper erosion areas and the flatter deposition zones. In some cases these two areas may be separate strata, in which case plots will automatically be representative. In other cases, however, the impact of other processes and factors on soil carbon may be so much greater than this movement of soil that both the steeper and flatter areas fall within a single stratum, and the plots within that stratum must to be representative of that diversity.

Soil Amendment: Where changes in the amount of soil result from the addition of amendments, no changes in sampling depths or calculation depths should be undertaken to adjust for the amendment. However, note that amendment may result in changes in bulk density which may result in adjustments to the calculated depth as described in Step 6.3a above.

Erosion**:** Erosion events occurring within the project area may consist of small specific events (for instance, a small slippage), or may consist of large areas of sheet erosion or other comparable processes. Where plots within a stratum fall in small, unrepresentative (<1/(number of plots times 2)% of the stratum area) erosion areas, the plots must be dropped. On the other hand, where erosion covers a larger portion of the stratum area, plots must be retained. Project proponents may choose either to continue to include the erosion area within the existing stratum, if the erosion impacts were relatively small, or to create a new stratum consisting of the eroded area, where the impacts of the erosion event were greater. Creation of a new stratum may lead to a requirement to install new permanent sample plots to ensure that the new strata meet statistical requirements.

Where changes in soil depth result from erosion, the amount and form of carbon released to the atmosphere as a result of the erosion process may vary widely, depending on the nature to the erosion event, the degree of separation of the carbon fraction of the soil from the mineral fraction of the soil during the erosion event, and the nature of the location where the carbon fraction of the eroded soil is eventually deposited. Due to these uncertainties, no changes to the calculated or sampled depths may be made after the erosion event, unless the event takes place in an area with a bedrock or cemented layer which restricts the sampling depth, in which case erosion may by default reduce the calculated and sampled depths.

The one exception to this rule will occur in the case that the sampling subsequent to the erosion event finds a new soil layer, high in carbonates, or consisting of a buried surface soil horizon, at the bottom of the sample. In such cases the actual carbon percentage of this layer must not be used, and the carbon content of the layer must be calculated using the carbon percentage found in the layer immediately above it.

Deposition: As with erosion, deposition may occur in small localized areas (for instance, at the tail of a slide) or across a broader area, as in the case of wide alluvial deposition zones. The same rules must be followed for elimination or retention of a plot falling into a deposition area, and restratification where necessary, as those given above for erosion.

Where changes in soil depth result from deposition, total sampling and calculation depths must not be changed. Where sampling and calculation depths were restricted by bedrock or cemented layers, subsequent sampling and calculations must only be undertaken to the depths previously used, even though more soil is now present.

Note that both deposition and erosion may result in changes in the nature and sequence of soil layers within the sample.

Step 6.2c Apparent changes in the amount of soil present where bedrock or cemented layers are present

Where soil sampling depths are restricted by bedrock or cemented layers, the sampling depth may change from point to point within a plot, even though no actual change in the amount of soil present, and no compaction or decompaction, has occurred. For instance, the depth to bedrock of the three sampling points at a given plot might be as follows:

	Total Sampling depths, cm		Changes in values between first and second sampling time	
Sample	First sampling time	Second sampling time	Erosion or deposition	Bulk density
1	28	29	No	No
2	24	26	No	No
3	27	30	No	No
Total	79	85		

Table 6.2.4 Changes in sampling depths between two sampling times, due to different depths to bedrock at different points within the plot**.**

If significant changes in bulk density have occurred, or significant deposition or erosion is found, adjustments to the calculated depth must be made using the methods given in Steps 6.3a or 6.3b, as applicable. However, if, as in the example given, no such significant changes are found, then the layer depths and total calculation depth used in the calculations for the first sampling time must also be used in the calculations for the second sampling time as well, in place of the actual measurements from the second sampling time, to eliminate false attributions of changes in total carbon resulting from different depths to bedrock or cemented layers across the plot.

Step 6.3 Accounting for soil carbon added as amendments

Some treatments, such as the addition of lime, char or manure to the soil, may directly add carbon to the soil. Adjustments to calculations of soil carbon may be required, depending on the source of the amendment.

Step 6.3a Amendments sourced within the project area

Amendments are considered to be sourced within the project area under the following conditions:

- For amendments other than manure, at least 95% of the biomass carbon must be sourced from within the project area, and must come from an accounted carbon pool. Thus for instance if char is derived from living biomass grown within the project area, and living biomass pools are accounted, the amendment is considered to be sourced within the project area. This will be the case even if the biomass is processed into char outside of the project area. On the other hand, if lime is sourced from within the physical boundaries of the project area, but comes from rock deposits or other sources which are not accounted pools, it cannot be considered to be sourced from the project area for the purposes of carbon accounting.
- For manure, the feedstock used for the animals must be at least 80% sourced within the project area. The percentage of feedstock sourced within the project area will be measured based on annual calorific value available to the animals. It is not required that the animals themselves be kept within the project area.

Where amendments meet the criteria given above, no adjustment to the soil carbon estimates is required. However, the following qualifications on emissions should be noted:

- If the processing of biomass into char, compost, or similar materials, or the processing of lime occurs within the project area, all emissions from the processing must be accounted as project emissions.
- If the processing of biomass into char, compost or similar materials, or the processing of lime occurs outside of the project area, the emissions must be accounted as leakage.
- If the animals from which the manure is sourced are kept within the project area, their emissions will be accounted as required in this methodology. If the animals from which the manure is sourced are kept outside of the project area, their emissions must be accounted as leakage. Where only a portion of the manure from these animals is used as soil amendment within the project area, the emissions may be prorated based on the percentage of the total manure used within the project area.

Step 6.3b Amendments sourced outside of the project area:

Where carboniferous amendments are sourced from biological or non-biological sources outside the project area, a deduction must be made from the calculated soil carbon as follows:

- Where amendments are long lived, meaning that at least 80% of the carbon in the amendment tends to remain in the soil for more than 10 years – for instance, where the amendment is char – 100% of the carbon content of the amendment must be deducted from the calculation of soil carbon in Step 6.6.
- Where amendments are not "long lived" – for instance, where the amendment is manure, 80% of the carbon in amendment must be deducted from the calculation of soil carbon in Step 6.6, unless the project proponent can show scientific evidence demonstrating that less than 80% of the carbon derived from the amendment will remain in the soil 10 years after application, in which case a percentage of the carbon contained in the amendment may be deducted. The percentage used must be conservative, based on the available scientific literature.

In either case the deduction need not be made if it can be shown that at least 95% of carbon in the amendment comes from a source within the project area of another carbon project, and the source biomass pool is being accounted in that project. In this case, if the emissions from processing the amendment are not being accounted within the other carbon project, they must be accounted as leakage within this project.

Step 6.4 Data Calculation: Total soil carbon:

Subject to the guidance given in step 6.3, the following equation is used to calculate soil carbon per unit area.

$$SC_y = \sum_{l}^{x}(sd_l \bullet (1-LCF\%_l) \bullet sdens_l \bullet \%osc_l \bullet 10^1) + \sum_{l}^{x}(sd_l \bullet (1-LCF\%_l) \bullet sdens_l \bullet iscg_l \bullet m_{iscl}{}^{-1} \bullet (12/44) \bullet 10^1) \quad (5.2)$$

Where

SC_y	=	Total measured soil carbon per square meter at plot y, kg/m^2
x	=	The number of soil layers measured
l	=	Soil layers

sd_l	=	The average depth (thickness) of soil layer x found in the sampling points within the plot, cm
LCF%	=	The % of soil volume composed of large coarse fragments, %
$sdens_l$	=	The average oven dry bulk density of soil layer x after removal of coarse fragments, found in the sampling points within the plot, g/cm^3
$\%osc_l$	=	The average mass of organic soil carbon in layer x, as a percentage of the total mass of the samples, as measured in the laboratory, %
$iscg_l$	=	The average mass of CO_2 emitted from the soil samples during acid testing, g
m_{iscl}	=	The average mass of the samples tested using acid testing , g.
12/44	=	Conversion from CO_2 to C

Note: The depth sd_x of the bottom-most measured soil layer is the thickness of that layer from the top of the layer to the calculated depth, or to bedrock or a cemented layer, whichever is less.

Note: The laboratory will often provide the term $iscg_l \cdot m_{iscl}^{-1}$ as a single value, percentage inorganic carbon.

Note: As discussed in the introduction, where changes in inorganic carbon are not expected to be significant, only organic carbon may be accounted.

Note: $\%osc_l$ and $iscg_l$ will be the average value determined from the samples submitted to the laboratory for that plot. If one or more sampling points within the plot have no soil (exposed bedrock, for instance), no sample will be submitted, and the sampling point will not be included when calculating $\%osc_l$ and $iscg_l$.

Step 6.5 Statistical Calculations

Calculate the standard deviation and the confidence interval for total carbon for each stratum. If soils contain significant amounts of inorganic soil carbon, and these amounts are not expected to change, statistical calculations must be undertaken based on the amount of organic soil carbon only, to avoid the masking effects of the large and static pool of inorganic soil carbon. In these cases only organic soil carbon may be accounted and reported, and the portion of the equation accounting inorganic carbon must be set to 0.

Where the confidence interval exceeds +/- 10% with 90% confidence, project proponents may undertake one of three actions:

a. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-stratification should be considered, as discussed in module *VMD0018 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals must be re-calculated for the new strata. Re-stratification will require the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards, unless the project proponent elects to use option c for that stratum.
b. Increase the number of plots: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further plots. An estimate of the required number of further plots must be calculated, using the equation below (3), and further plots installed, located systematically or randomly.

$$N = t^2 \cdot s^2 \cdot (0.1 \cdot m)^{-2} \qquad (5.3)$$

Where

N	=	Total number of plots expected to be required
t	=	Student t-test 0.90 value for n-1, n being the number of plots already established
s	=	Standard deviation for the existing plot values
m	=	Mean value of the variable from the existing plots

c. Recalculate $SoilC_s$
In some cases, due to project size or other factors, installing enough plots to meet the required confidence interval may not be economically viable. In these cases, and provided that project proponents install a minimum of 10 plots per stratum, project proponents may proceed with data gathered to a lower confidence interval. However, project proponents must recalculate $SoilC_s$ (from Step 6.6 below) as follows:

1. Where sampling is undertaken prior to project start date to determine the baseline.

$$SoilC_s = SoilC_s \bullet (1 + (ci - 0.1)) \qquad (5.4)$$

Where:

$SoilC_s$	=	Total soil carbon in stratum s, t
ci	=	The calculated confidence interval at 90% confidence

2. Where sampling is undertaken after project commencement to determine soil carbon under the project scenario.

$$SoilC_s = SoilC_s \bullet (1 - (ci - 0.1)) \qquad (5.5)$$

Where

$SoilC_s$	=	Total soil carbon in stratum s, t
ci	=	The calculated confidence interval at 90% confidence

Step 6.6 Calculating the total accounted soil carbon for the stratum

The total accounted soil carbon for the stratum will be calculated using the following equation.

$$SoilC_s = (\sum_{y_s} (SC_y) \cdot \# y_s^{-1} \cdot A_s \cdot 10^{-3}) - AC_{s,t} \qquad (5.6)$$

Where

$SoilC_s$ = Total soil carbon in stratum s, t

y_s	=	The plots in stratum s
$\#y_s$	=	The number of plots in stratum s, dimensionless
SC_y	=	The average soil C per m^2 in plot y, kg/m^2
A_s	=	The area of stratum s, m^2
10^{-3}	=	Conversion from kg to t
$AC_{s,t}$	=	Carbon added to the soil as accounted amendments in stratum s to time t, t

Note: See Step 6.3 to determine the value of the variable AC_y. The carbon in all accounted amendments applied from the start of the project to the time of the calculation must be deducted.

6 PARAMETERS

Data Unit / Parameter:	*ts*
Data unit:	g/cm^3
Description:	Mass of soil
Source of data:	Calculated from sampling
Justification of choice of data or description of measurement methods and procedures applied:	The total mass of soil in a 1 cm^2 column to the calculated depth
Any comment:	

Data Unit / Parameter:	*l*
Data unit:	#
Description:	The soil layers found in the plot
Source of data:	Plot data
Justification of choice of data or description of measurement methods and procedures applied:	The various soil layers found in the plot, distinguished on the basis of texture, density, soil organic carbon content, or other features
Any comment:	

Data Unit / Parameter:	sd_x
Data unit:	*cm*
Description:	Thickness of the soil layer
Source of data:	Plot measurement
Justification of choice of data or description of measurement methods and procedures applied:	The depth (thickness) of soil layer x above the calculated depth,
Any comment:	

Data Unit / Parameter:	$sdens_x$
Data unit:	g/cm^3
Description:	Soil bulk density
Source of data:	Measured from field samples
Justification of choice of data or description of measurement methods and procedures applied:	The bulk density of soil layer x,
Any comment:	

Data Unit / Parameter:	*E*
Data unit:	% of the mean
Description:	Allowable error
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	e.g. ±10% of the mean
Any comment:	

Data Unit / Parameter:	*t*
Data unit:	Dimensionless
Description:	t value
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Student's t-test value for the confidence level (e.g. 90%)
Any comment:	

Data Unit / Parameter:	*L*
Data unit:	#
Description:	Amount of strata
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Total of number of strata types in the area to be sampled
Any comment:	

Data Unit / Parameter:	*sh*
Data unit:	Depending on estimated variable
Description:	Estimated standard deviation
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	estimated standard deviation of stratum h
Any comment:	

Data Unit / Parameter:	*Ch*
Data unit:	$
Description:	Cost to select and sample a plot in the stratum
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Cost to select and sample a plot in the stratum
Any comment:	

Data Unit / Parameter:	*N*
Data unit:	#
Description:	Total Number of samples
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Number of sample units (all strata) $N=\sum Nh$
Any comment:	

Data Unit / Parameter:	*Nh*
Data unit:	#
Description:	Number of samples per stratum
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Number of sample units for stratum h calculated by dividing the area of stratum h by area of each plot.
Any comment:	

Data Unit / Parameter:	*Wh*
Data unit:	Dimensionless
Description:	Proportion of samples in stratum of total amount of samples
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Nh/N
Any comment:	

Data Unit / Parameter:	*SCy*
Data unit:	kg/m2
Description:	Amount of carbon per m2
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Total measured soil carbon per square meter at plot y to a specified depth
Any comment:	

Data Unit / Parameter:	*x*
Data unit:	#
Description:	Number of soil layers
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Tthe number of soil layers measured
Any comment:	

Data Unit / Parameter:	***l***
Data unit:	#
Description:	Soil layers
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	Soil layer(s)
Any comment:	

Data Unit / Parameter:	sd_l
Data unit:	cm
Description:	Thickness of soil layer
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	The depth (thickness) of soil layer l
Any comment:	

Data Unit / Parameter:	*LCF%*
Data unit:	%
Description:	% of large coarse fragments
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	The percentage of the soil volume composed of large coarse fragments
Any comment:	

Data Unit / Parameter:	$sdens_l$
Data unit:	g/cm^3
Description:	The average bulk density of soil layer l
Source of data:	
Justification of choice of data or description of measurement methods and procedures applied:	The bulk density of soil layer l,
Any comment:	

Data Unit / Parameter:	$\%osc_l$
Data unit:	%
Description:	Percentage of organic soil carbon in layer l
Source of data:	Laboratory testing of field samples
Justification of choice of data or description of measurement methods and procedures applied:	The percentage of organic soil carbon in layer l, as measured in the laboratory from soil samples collected at the plots
Any comment:	

Data Unit / Parameter:	*$iscg_l$*
Data unit:	Tonnes
Description:	Mass of inorganic soil carbon emitted as CO2
Source of data:	Laboratory testing of field samples
Justification of choice of data or description of measurement methods and procedures applied:	The mass of inorganic soil carbon emitted as CO2 during acid testing in the laboratory
Any comment:	

Data Unit / Parameter:	*m_{iscl}*
Data unit:	Kg
Description:	Mass of the sample tested using acid testing
Source of data:	Laboratory measurement of tested sample
Justification of choice of data or description of measurement methods and procedures applied:	The mass of the sample tested using acid testing in layer l
Any comment:	

Data Unit / Parameter:	*12/44*
Data unit:	Dimensionless
Description:	Conversion from CO2 to C
Source of data:	Periodic table
Justification of choice of data or description of measurement methods and procedures applied:	Conversion from CO2 to C
Any comment:	

Data Unit / Parameter:	*$AC_{s,t}$*
Data unit:	Tonnes
Description:	Carbon in soil amendments
Source of data:	Accounting of carbon containing soil amendments applied
Justification of choice of data or description of measurement methods and procedures applied:	Carbon added to the soil as accounted amendments to time t
Any comment:	

Data Unit / Parameter:	$\#y_s$
Data unit:	#
Description:	Number of plots
Source of data:	Field data
Justification of choice of data or description of measurement methods and procedures applied:	The number of plots in stratum s
Any comment:	

Data Unit / Parameter:	A_s
Data unit:	m^2
Description:	Stratum area
Source of data:	Measured using GPS or other means of similar accuracy
Justification of choice of data or description of measurement methods and procedures applied:	The area of stratum s,
Any comment:	

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	16 Nov 2012	Initial version released