Methodology for GHG and Co-Benefits in Grazing Systems

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1. METHODOLOGY OVERVIEW

1.1. SCOPE

This *Methodology Protocol* is intended to provide a holistic assessment of multiple ecological state indicators for grasslands under the practice of prescribed grazing. It can be used by *Project Proponents* and other stakeholders to obtain estimates of Soil Organic Carbon (SOC) stocks within a project area, and measure additional ecological co-benefits such as animal welfare, ecosystem health, and soil health.

The general guidance is intended to assist *Project Proponents* in applying a measurement-based soil organic carbon approach focused on maximizing accuracy of SOC stock estimation, while minimizing sampling efforts and costs. Soil sampling coupled with Remote sensing data or more traditional spatial interpolation methods will be used to calculate SOC stocks. Soil samples will also be used to assess soil health while remote sensing data and peer reviewed literature will provide an assessment for ecosystem health.

The main ecological health indicator assessed in this methodology is:

- CARBON SEQUESTRATION
    - Soil Organic Carbon (SOC) stocks and CO_2 equivalents (CO_2e)

Additional Co-Benefits assessed are:

- SOIL HEALTH
    - pH
    - Macronutrients
        - Nitrogen, Phosphorus, Potassium
    - Cation Exchange Capacity - CEC
    - Minor nutrients:
        - Calcium, Magnesium, Potassium, Sodium, Aluminum
- ANIMAL WELFARE
    - Measured using standards aligned with the project area locale
- ECOSYSTEM HEALTH
    - Ecosystem Vigor
        - Normalized Difference Vegetation Index (NDVI)
    - Ecosystem Organization
        - Woody vegetation landscape metrics
        - Protected perimeter of wetlands and watercourses
    - Ecosystem Resilience
        - Bare Soil Estimation (BSI)

1.2. A MEASUREMENT-BASED SOIL ORGANIC CARBON METHODOLOGY

Several steps are required to estimate the long term changes in soil organic carbon stocks within a project area:

1. Develop a soil sampling plan for the project area according to Section 3.1.
2. Sample collection and preparation
3. Laboratory analysis of soil samples
4. Estimation of SOC stocks for the project area
5. Converting SOC stocks to CO_2 equivalent stocks
6. Calculating the change in CO_2e stocks between monitoring periods

A schema for the measurement-based approach to estimate changes in SOC stocks is presented in Figure 1. SOC stocks measured in the first sampling round (i.e. the Baseline), are compared to those calculated in subsequent sampling rounds to quantify changes in carbon stocks after project commencement. This methodology outlines two approaches for estimating carbon stocks. The first method is an innovative approach based on using remote sensing data to calibrate statistical models to estimate SOC stocks. This approach allows for a significant reduction in the number of soil samples that must be collected by the *Project Proponent* as compared to traditional sampling. The second method adopts a traditional extrapolation approach in which SOC stocks are calculated using soil samples extracted during an intensive sampling effort.

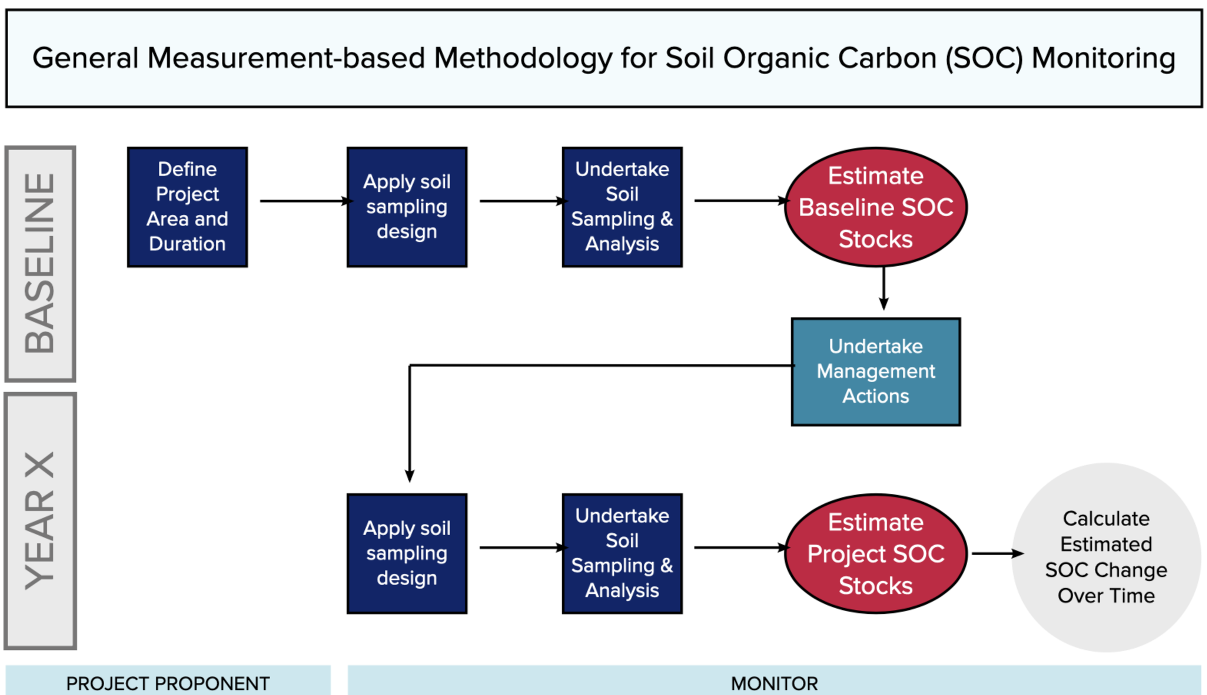

Figure 1: Main Steps for assessing changes in SOC stocks within a project area.

1.3. CO-BENEFITS

The co-benefits are intended to allow for a holistic assessment of the project area beyond carbon sequestration. The soil health, ecosystem health, and animal welfare metrics are chosen based on their widespread use as known, reliable indicators sensitive to the changes in ecological state.

1.3.1. SOIL HEALTH INDICATORS

Soil health indicators assess soil performance and functionality[1]. Chemical indicators such as pH, macronutrients, minor nutrients and Cation Exchange Capacity values can be used to assess changes in soil function and are sensitive to variations in management. Thus, chemical indicators will be ranked according to local benchmarks for the project region and project soils (see Section 4).

1.3.2. ECOSYSTEMS HEALTH

Ecosystem health is assessed holistically through the use of context-dependent indicators of ecosystem vigor, organization and resilience.

1.3.3. ANIMAL WELFARE

The American Veterinary Medical Association[2] defines Animal Welfare as the means by which "an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well-nourished, safe, able to express innate behavior, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling, and humane slaughter." Animal welfare evaluations are often locale specific. Regional guidelines and variations should be taken into account during the evaluation.

2. PROJECT BOUNDARY

2.1. SPATIAL BOUNDARIES

The spatial boundary encompasses all land on which the *Project Proponent* will undertake the *Proposed Activity*. Spatial boundaries defining the project area should be provided by the *Project Proponent* with any parcels or stratification schemes defined. Acceptable data formats include polygon shapefiles, geopackages, KML/KMZ files and GeoJSONs.

2.1.1. MASKING FOR GRASSLANDS AREA

To ensure proper estimation of soil organic carbon stocks, any man-made objects such as roads or buildings, woody vegetation, bodies of water and other land types not included within the bounds of the *Proposed Activity* must be excluded. A mask representing grasslands under the practice of prescribed grazing must be provided. This mask can be created using GIS and remote sensing tools, land cover algorithms, visual inspection or any other method chosen by the *Monitor* or *Project Proponent*.

[1] NRCS USDA Soil Health
[2] AVMA: Animal Welfare: What Is It?

2.2 TEMPORAL BOUNDARIES

The *Project Timeframe* is the period of time during which the *Project Proponent* will undertake the *Proposed Activity*. Current available data from scientific literature on sequestration rates from agricultural grasslands (e.g. Prescribed Grazing) is limited[3], but based on the available data and industry knowledge, it can take up to 10 years to build up enough carbon stock to warrant credit issuance. The monitoring period and frequency defining the temporal boundaries should adhere to the following guidelines:

- The minimum number of soil sampling rounds for a 10-year crediting period is five (5)
- Soil sampling rounds must be conducted on the first and last years of the project
- It is recommended that two (2) soil sample rounds occur consecutively during the first two years
- It is recommended that two (2) soil sample rounds occur consecutively during the last two years
- The minimum duration between monitoring periods is one (1) year
- The maximum time between soil sampling rounds is three (3) years

The example below outlines an acceptable soil sampling timeline during the 10-year crediting period.

<u>Example:</u> Years during which soil sampling occurred are shown in red. Two consecutive sampling rounds are set at the beginning of the crediting period: at the beginning (S1, 'baseline'), and at the end of first year (S2). The third sampling round (S3) is performed at the end of year 4, the fourth sampling round (S4) is performed at the end of year 7, and the last sampling round (S5) is set at the end of year 10.

<u>Note:</u> The schema described above can be modified if an extreme climatic event or disaster is declared for the area of the project.

3. CALCULATING THE CARBON SEQUESTRATION AND NET GHG REDUCTION

3.1. COLLECTION OF DATA

3.1.1. SAMPLE SIZE

The number of samples in the soil sampling plan is determined according to the approach selected for quantifying soil organic carbon. Traditional sampling methods (i.e intensive sampling) will require a much larger sample size than the remote sensing approach which uses the equation defined in Section 3.1.1.1. to stipulate a minimum number of samples needed to calibrate remote sensing data. If traditional sampling is used, please refer to one of the tools/resources listed in Section 3.1.1.3. to determine the appropriate level of samples required for the project area. The minimum number of samples required by either approach must be met to achieve a reliable and

[3] See for example NRCS data for Prescribed Grazing in Table 3 adapted from Swan et al [2015]

statistically valid level of rigor. Monitoring periods where the number of samples falls below the minimum could result in a deviation. In this case please contact the science@regen.network.

3.1.1.1. MINIMUM SAMPLE SIZE ESTIMATION FOR SATELLITE CALIBRATION

The soil sample size required **to calibrate satellite data** and estimate soil organic carbon stocks depends on the project size. The sample size should be determined according to Equations 1-3 listed below, which use the number of hectares of grassland area within the project area as the input metric. It is important to note the minimum number of samples is calculated using the grasslands area defined in Section 2.1.1, not the total property area. Figure 2 illustrates the relationship between grassland area and sample size per unit area.

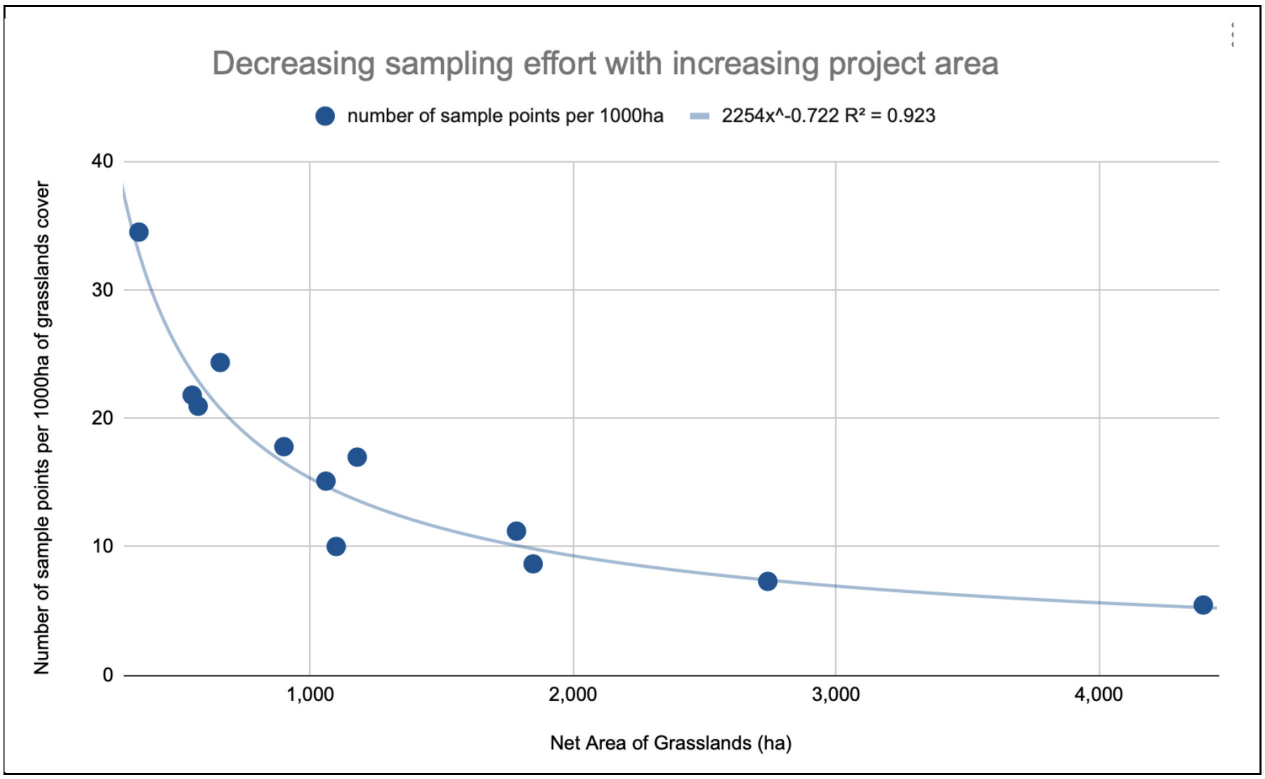

Figure 2. Relationship between the required number of sample points per 1000ha and the net project grasslands area.

The minimum number of sampling points for every 1,000 ha of grasslands (N_{1k}) needed to calibrate satellite data is estimated using Equation 1.

$$N_{1k} = 2254 * GrassArea^{(-0.72)} \qquad \text{(Eq. 1)}$$

where the net grassland area (GrassArea) of the project is in hectares.

The number of sampling points for the satellite calibration (N_{cal}) within the project area is then estimated as:

$$N_{cal} = (N_{1k} * GrassArea) / 1,000 \qquad \text{(Eq. 2)}$$

The total number of soil sampling points (N_{total}) for the project area must then be increased by 30% to account for any additional data needed to validate model performance when calculating soil organic carbon stocks:

$$N_{total}=N_{cal} + (0.3 * N_{cal}) \qquad \text{(Eq. 3)}$$

*It is highly recommended that three (3) soil subsamples cores are extracted at each sampling location and analyzed separately, in order to improve the total accuracy of the results and be able to discard outliers. Therefore, **the total number of samples** to be analyzed at a certified lab would be equal to [N_{total} **x 3**]. However, the absolute minimum number of samples required is* N_{total}*. If the project does not meet these minimum requirements you must contact science@regen.network.*

3.1.1.2. ANCILLARY SOIL SAMPLE DATA

Ancillary data from other farms can be used to increase the sample size for satellite calibration if the number of samples falls below the required minimum. Any ancillary data used must meet the following requirements:

I. The sample dates for the project area and the sample dates for the farm providing the ancillary data must fall within one month of each other.
II. The project area and the farm providing the ancillary data must be within the same climatic region according to the Köppen Climate Classification System[4].
III. The project area and the farm providing the ancillary data must have been under the same management practices for at least 3 years.
IV. The project area and the farm providing the ancillary data must have similar soils and vegetation cover.
V. The sample extraction methods and sample analysis methods at the ancillary farm must match the protocols used for the primary farm

3.1.1.3. SAMPLE SIZE ESTIMATION FOR TRADITIONAL SAMPLING

In contrast to the remote sensing approach which uses correlations between satellite imagery and ground truth data to estimate soil carbon at unsampled locations, the success of the traditional sampling approach to measure soil organic carbon revolves heavily around intensive sampling. Reliable results can only be achieved by collecting enough samples to account for the project size and spatial variability of the soil. Topographic variation, hydrology, vegetation cover, and soil composition, such as percent clay, are just a few variables which could affect the spatial variability. Large project areas are also more likely to have a high variability of soil properties, so establishing a sampling plan to cover the entire range of these variables is crucial to providing an accurate assessment.

[4] Beck et al. 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution

The traditional sampling plan may be determined by the *Monitor* or *Project Proponent*. The chosen approach for defining the sample size must be accompanied with a justification supported by peer reviewed literature or local guidelines detailing the sampling plan and the sample size calculations. The peer-reviewed resources below are examples of acceptable resources for developing a soil sampling plan.

A. Sampling protocols published in the peer-reviewed literature (e.g. de Gruijter *et al*[5, 6] ; Viscarra Rossel et al., 2016b[7])
B. Generating spatially and statistically representative maps of environmental variables to test the efficiency of alternative sampling protocols (Cunningham et. al, 2017[8])
C. Soil carbon stock in the tropical rangelands of Australia: Effects of soil type and grazing pressure, and determination of sampling requirement (Pringle et. al, 2011[9])
D. A geostatistical method to account for the number of aliquots in composite samples for normal and lognormal random variables (Orton et. al, 2015[10])
E. CFI Equal area stratification soil sampling design guidelines[11]
F. CDM Guidelines[12]
G. FAO guidelines 2019[13]

Note: these recommendations were adopted from The Supplement for the CFI Methodology 2018[14].

<u>*Design considerations*</u>: *It is good practice to employ oversampling at the design stage, not only to compensate for any high variance or outliers, but also to prevent a situation at the analysis stage where the required reliability was not achieved and additional soil sampling efforts would be required. The need for additional soil sampling would be expensive, time-consuming, and inconvenient*[15].

3.1.2. STRATIFICATION

In statistics, stratified sampling is a technique used to partition the population into subgroups, or strata, based on similar characteristics. Stratified sampling can help reduce the number of samples needed to measure soil health by segregating the landscape into subregions which share similar

[5] De Gruijter et al. 2016. Farm-scale soil carbon auditing.
[6] de Gruijter et al. 2019. Using model predictions of soil carbon in farm-scale auditing - A software Tool.
[7] Viscarra Rossel, et al. 2010. Using data mining to model and interpret soil diffuse reflectance spectra.
[8] Cunningham et al. 2017. Generating spatially and statistically representative maps of environmental variables to test the efficiency of alternative sampling protocols.
[9] Pringle et al. 2011. Soil carbon stock in the tropical rangelands of Australia: Effects of soil type and grazing pressure, and determination of sampling requirement.
[10] Orton et al. 2015. A geostatistical method to account for the number of aliquots in composite samples for normal and lognormal random variables.
[11] Carbon Farming Initiative: Soil Sampling Design- Methods and Guidelines. 2014.
[12] Sampling and surveys for CDM project activities and programmes of activities (Version 3.0)
[13] FAO. 2019. Measuring and modeling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1)
[14] The Supplement- To the Carbon Credits (Carbon Farming Initiative—Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination 2018
[15] This is in accordance to Annex 4 Standard for Sampling and Surveys for CDM Project Activities and Programme of Activities

biophysical characteristics. Less samples are needed because the samples collected are representative of soil characteristics across the entire strata.

When to stratify?
Stratification should be applied if:

A. The spatial boundaries defined by the *Project Proponent* do not include pre-defined parcels or strata.
B. The spatial boundaries provided include a large number of parcels and there is a need to identify the most representative parcels to target.
C. The parcels provided by the *Project Proponent* are large and/or do not reflect the variability of soils, moisture, vegetation cover, hydrologic conditions, management history or other variables that might be affecting SOC in the topsoil. In this case, a stratification redefining parcels is recommended.

How to stratify?
Variables highly correlated to soil organic carbon can be used as proxies to divide the project area into strata encompassing the full range of SOC levels (low, medium and high). This approach will help establish a sampling plan which covers the full range of percent SOC values, thus providing more accurate stock estimates. Some variables found to be good proxies to spatial variability of SOC at the field scale include:

- Topographic: elevation, slope, aspect, erosion, terrain ruggedness Index (TRI) and the multi-resolution valley, bottom flatness index (MrVBF)
- Land Use / Land cover (LULC): Vegetation cover, above ground biomass, land management history
- Satellite Imagery: Multispectral satellite bands (e.g. Sentinel-2, Landsat TM), NDVI , BSI, NDWI, Tasseled Cap
- Hydrologic: topographic wetness index (TWI), catchment area and stream power index (SPI)
- Pedologic: soil types, clay content
- Other: pH

The project area can be restratified each soil sampling round as improved quality of information becomes available, however it is recommended sample locations remain consistent between monitoring rounds. If the stratification is used, any parcels defined in Section 2.1 should be replaced by or modified to match the stratified zones such that parcels fall within *only one* of the stratified zones. Any parcel which falls into two or more stratified zones should be broken down and redrawn such that new parcels are located within a single stratified zone.

The monitoring report must specify the methods and variables used to define strata and include a one-to-many relationship listing which parcels belong in each stratified zone. If parcels defined by the *Project Proponent* were re-drawn, the spatial boundary file created in Section 2.1 should be updated. A geospatial file defining stratified zones used for each monitoring round must be provided with each report.

Useful Resources:

- cLHS - Conditioned Latin Hypercube Sampling[16] [17]
- QuickCarbon Stratifi[18]
- Equal-range stratification[19]
- k-means [20] [21]
- A thorough review of variations on these methodologies authored by Biswas and Zhang (2018)[22].

3.1.3. ASSIGNING SAMPLE LOCATIONS

- Soil sample locations must be determined prior to any soil sampling performed.
- If stratification was used, at least one sampling location must fall within each strata class to ensure underlying variations in soil organic carbon are represented. This is a requirement needed for later analysis.
- Geolocations for soil sampling units must be selected at random. GIS tools, such as the QGIS "random points inside polygons tool", can be useful for creating random sampling points.
- It is recommended that sample locations remain consistent between rounds, though if sample locations differ, it is crucial to record the GPS coordinates for the newly sampled locations
- There are various approaches to establishing sample locations using a traditional sampling framework. Please reference the resources provided above and select a sampling plan that is appropriate for the project location and variability. If traditional sampling is used, the approach used to determine the sampled locations within the project area must be provided and justified according to peer reviewed literature and/or local sampling protocols.

3.1.4. EXTRACTING SAMPLES

It is important that samples used for soil carbon quantification follow proper sample collection and preparation procedures. Improper collection or preparation of soil samples can result in substantial errors, which can render the results of expensive sampling rounds unusable and compromise the integrity of the results. Please refer to the Soil Sampling Guide for in depth recommendations for soil sampling instructructions.

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[16] White. 2019. cLHS - Conditioned Latin Hypercube Sampling
[17] Minasny and McBratney. 2006. A conditioned Latin hypercube method for sampling in the presence of ancillary information
[18] QuickCarbon Stratification Tool
[19] Hengl et al. 2003. Soil sampling strategies for spatial prediction by correlation with auxiliary maps
[20] Viscarra Rossel and Brus. 2018. The cost-efficiency and reliability of two methods for soil organic C accounting
[21] Brus et al. 1999. A sampling scheme for estimating the mean extractable phosphorus concentration of fields for environmental regulation
[22] Biswas and Zhang. 2018. Sampling Designs for Validating Digital Soil Maps: A Review

Regen Network recommends the following instructions to collect soil samples:

1) Prior to core extraction, clear the sample location of living plants, plant litter and surface rocks.
2) Recommended sampling depth of 15cm, unless otherwise specified by the lab or location specific recommendations (justification must be provided if sample depth differs from 15cm)
3) The sampling depth must be the same at all sample locations in all given carbon estimation areas. The only exception to this is where the nominated sampling depth cannot be reached due to bedrock or impenetrable layers. In this situation, the actual sampling depth must be recorded.
4) The sampling depth must be consistent between all sampling rounds (i.e if samples are collected at 15cm for the baseline, samples must be collected at 15cm for following monitoring rounds)
5) A GPS device with a minimum precision of 4 meters must be used to record the sampling point in the field
6) If subsamples are taken more than 4 meters apart, the sample location for each subsample should be recorded
7) Samples must be taken at least 10 meters away from any tree, structure, or body of water
8) Please refer to Section 2.1 in the [Soil Sampling Guide] for the recommended soil sample collection tools.
9) If the soil profile is altered (incorporating substances external to the profile, or vertically altering the profile – eg. tilling, clay delving, water ponding) the sampling depth must be at least 10 cm below the depth of profile alteration.
10) Report the day, month and year for each sample collected within the given sampling round.
11) It is a requirement that all sampling rounds occur at least 6 months after the application of non-synthetic fertilizer.

Each laboratory has specific soil sample collection instructions. Clients may choose a laboratory that is certified in their local area, or a part of a land-grant institution. Please refer to Table 1 in the Soil Sampling Resource Guide for a list of laboratory specific instructions, laboratory accreditation requirements, approved laboratories, soil tests offered, and estimated costs.

Report must include:

- Tools and methods used to estimate number of samples
- Sample stratification method and stratification map
- Tool used to extract soil cores
    - If core sampler used, include tool diameter in mm
- GPS coordinate for each sample location and sub-samples (if applicable)
- GPS device used to record sample locations

Additionally, the *Project Proponent* must provide the raw lab reports to the *Monitor*.