Soil sampling protocol for monitoring changes in soil carbon stocks in Amazonia

Objective

Estimate soil carbon stocks with a high precision up to a depth of 2 meter and detailed insight into the vertical and spatial distribution of the stocks.

Methods

Collect soil samples from 50 or more points spatially distributed in plots of one hectare up to a depth of 2 m. Each plot should also have a soil pit to collect bulk density samples and describe soil profiles.

Choosing the site for monitoring changes in soil carbon stocks

Monitoring small soil carbon changes requires some specific site conditions. In addition, site characteristics may make some sites more suitable compared to others. Some characteristics that should be considered for intensive soil sampling are:

1. The soil of the permanent sample plot should have a low coefficient of variation (CV) in soil carbon content. The smaller the CV, the greater the probability to (statistically) detect any changes in soil C stocks over time. Coefficient of variation greater than 50% should be avoided. Revision of previously obtained soil data is highly recommended.
2. Homogeneity. The area should be homogeneous to reduce spatial variability. For instance one should avoid plots with large variations in soil type.
3. Access and logistics. Intensive soil sampling involves heavy tools (approx. 150 kg), large teams and the collecting and transport of a large numbers of samples (400 per ha). Therefore, the sites should be of easy access and provide basic facilities.
4. It is important to choose areas where forest dynamics are being recorded over time. This will permit studying the link between above- and below-ground carbon fluxes.
5. Forests should be undisturbed by human intervention and not consists of a small, isolated fragment.
6. As the objective is to monitor carbon stocks over time, the site should be ideally situated within areas with long-term protection. This is a long-term study and involves a large investment of resources. The study areas should thus be protected for very long time (i.e. > 50 years)

Sampling details

Amount of sampling points:
At least 50 sampling points should be collected per hectare at the standardized depths of 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-50 cm, 50-100 cm, 100-150 cm and 150-200 cm.
The number of sampling points can be higher than 50, but should not be less. If a previous analysis of soil C is available (average, standard deviation and CV of soil C),

the ideal number of samples can be determined by Power Analysis supported in statistical packages.

Distribution of sampling points
The optimum distribution of sampling points may vary according to the shape of the plot. For square plots (100 x 100 m), a grid sampling system has proven to be quick and efficient. Nevertheless it is recommended to follow the internal divisions within the plot (i.e., subplots) to facilitate the recording of sampling point position. The sampling itself can be randomly selected around that area.
For "transect-plots" (e.g. 10 x 1000 m), it is recommended to sample at regular intervals (eg. every 20 m), but avoid sampling on the trails. Sampling points should then be randomly selected, covering the whole area of the plot.
For plots with other dimensions (e.g. 20 x 500 m) it is advised to sample in a "zigzag-pattern", following intervals of 10 m, again choosing the location of the sampling points randomly.
Totally randomized sampling systems can be used, but this will make the recording of the exact sample location more difficult.
GPS coordinates should be taken at the beginning and end of each sampling plot.

Independently of the applied sampling scheme, it is essential to record accurately the location of each sampling point to allow future soil sampling at the exact same location. It is thus of paramount importance to record x,y-coordinates of the sampling points (as in a Cartesian plan, see Figure).

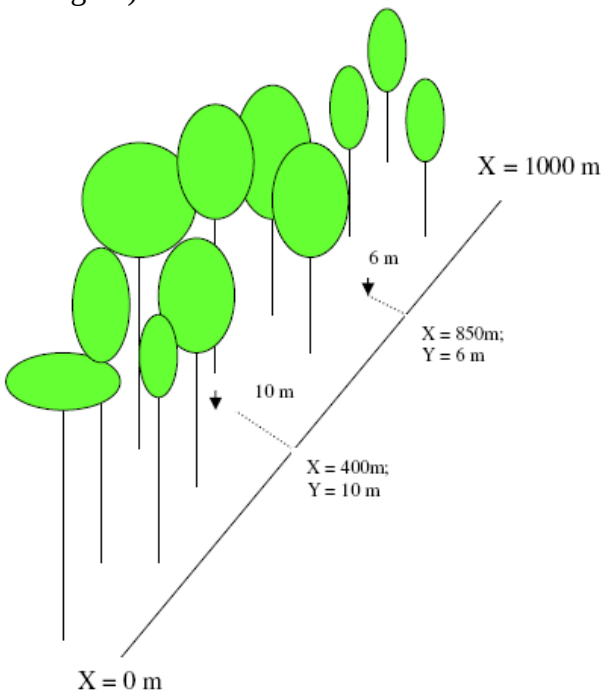

Figure 1. X,Y coordinates of Permanent Sample Plots. :

The long axis of a plot (eg. 10 x 1000 m plot) is defined as the x-axis, while the distance of the sampling point to the longest axis is defined as the y-axis. One should record the sampling point distance to the beginning of the plot (x-value), as well as the sampling point distance to the trail (y- value). For instance, a coordinate, x= 400m, y = 10 m,

means that your sampling point is at 400 m from the beginning of the plot, and 10 m aside (you should also define if it is to left or right).

Soil pit and bulk density

To obtain the necessary bulk density samples and profile description at least 1 soil pit should be dug per plot

The soil pit should be located 10 to 15 m outside the permanent plot, in order to reduce disturbance of the plot. However, it is important to choose a place that represents well the average conditions found within the plot.

To allow people to work on it comfortably, the soil pit should be at least 1.5 m long, 1 m. wide and 2 m. deep. Bulk density samples should be collected following the same depth intervals as for the standard sampling. Three bulk density samples should be collected per soil depth layer.

In addition one should use the soil pith to:

1. Describe the soil profile according to standard protocols (World Reference Base)
2. Collect samples for laboratory analysis
3. Sample soil to the depth of 4 m. from the bottom of the soil pit at depths of 200-250 cm, 250-300 cm, 300-350 cm and 350-400 cm.
4. Take profile pictures

Sampling equipment

The intensive sampling can be carried out with hand augers, but due to the large number of samples to be collected, this can be physically demanding and very time consuming. It is thus recommended to use mechanized auger systems consist of a percussion hammer (COBRA TT is our option) and a set of different core samplers (Figure 2). Eijkelkamp (www.eijkelkamp.com) has several soil core samplers which are specially adapted for use with percussion hammer.

Figure 2. Mechanized auger system - complete set

Among the several available systems, the most resistant system, allowing rapid and convenient sampling is the *Percussion Gauge with RD32 connection* (Figure 3). It is advisable to have spare parts on the system since these cores may break in the field.

Figure 3. Percussion Gauge Core sampler

Sampling procedure using COBRA TT and Percussion Gauge core samplers

1. Choose the sampling point.
2. Remove litter cover from soil.
3. Place the core sampler vertically over the soil (starting with the thickest corer)
4. Turn on the COBRA TT (engine) and place the engine while running, on the core sampler adaptor (striking pen).
5. Raise the engine "rpm" and gently push the engine downwards (this will start the hammering).
6. Let the core sampler go down until the 1 m. mark is reached
7. Assemble the extraction system (Rod puller, extension) and remove the core sampler from soil.
8. On the core sampler window, remove the soil that was in contact with the hole walls using a spatula. Then mark the desired depths with a ruler.
9. Retrieve the samples with a spatula and place the soil inside of a ziplock bag, which is properly labeled.
10. On the same hole, place the second core sampler (thinner than the one used before), this should be connected with a 1 m. extension to reach 2 m. deep. Proceed as described for the first core.
11. Record the XY coordinate of the sampling point.

Man power and time
On average it is possible to collect between 10 to 20 sampling points per day, depending on the soil conditions and on the team involved. Four people are needed to perform the sampling with the mechanized system, the sampling set is quite heavy and the work is physically demanding even working with a large team. It is advisable to hire an additional worker to dig the soil pits, which usually takes 1.5 day to dig.

Field notes
Attention should be paid to record all relevant data and other observations during sampling. Record the x,y-coordinates, sample number, date, maximum sampling depth, presence of stones and other coarse materials.

Limitations
1. Strong rain
2. Ground water level
3. Large surface roots
4. Open space (to turn equipment around)
5. Weight of equipment and samples

Preparation of samples for laboratory analysis
All samples should be air-dried, as soon as possible. Ideally the drying should start in the field-camp, opening the sample bags in a area protected from dust. Do not expose samples to sunlight. After drying, all samples must be cleaned, by removing roots, stones, plant remains and any detritus. After that, samples may be crushed if necessary and sieved through a 2 mm sieve. In case stones occur the % stones should be recorded. Once these preparations are finished, the samples should be well homogenized and two subsamples taken (about 10 g. each). One of these will be used to determine the moisture factor (%), once the samples are dried to a constant weight in an oven at 105 ˚C until (let it cool on a drying vessel). The other subsample should be milled till very fine powder is obtained (aprox. 8 µm) for analysis with an automated CN analyser.