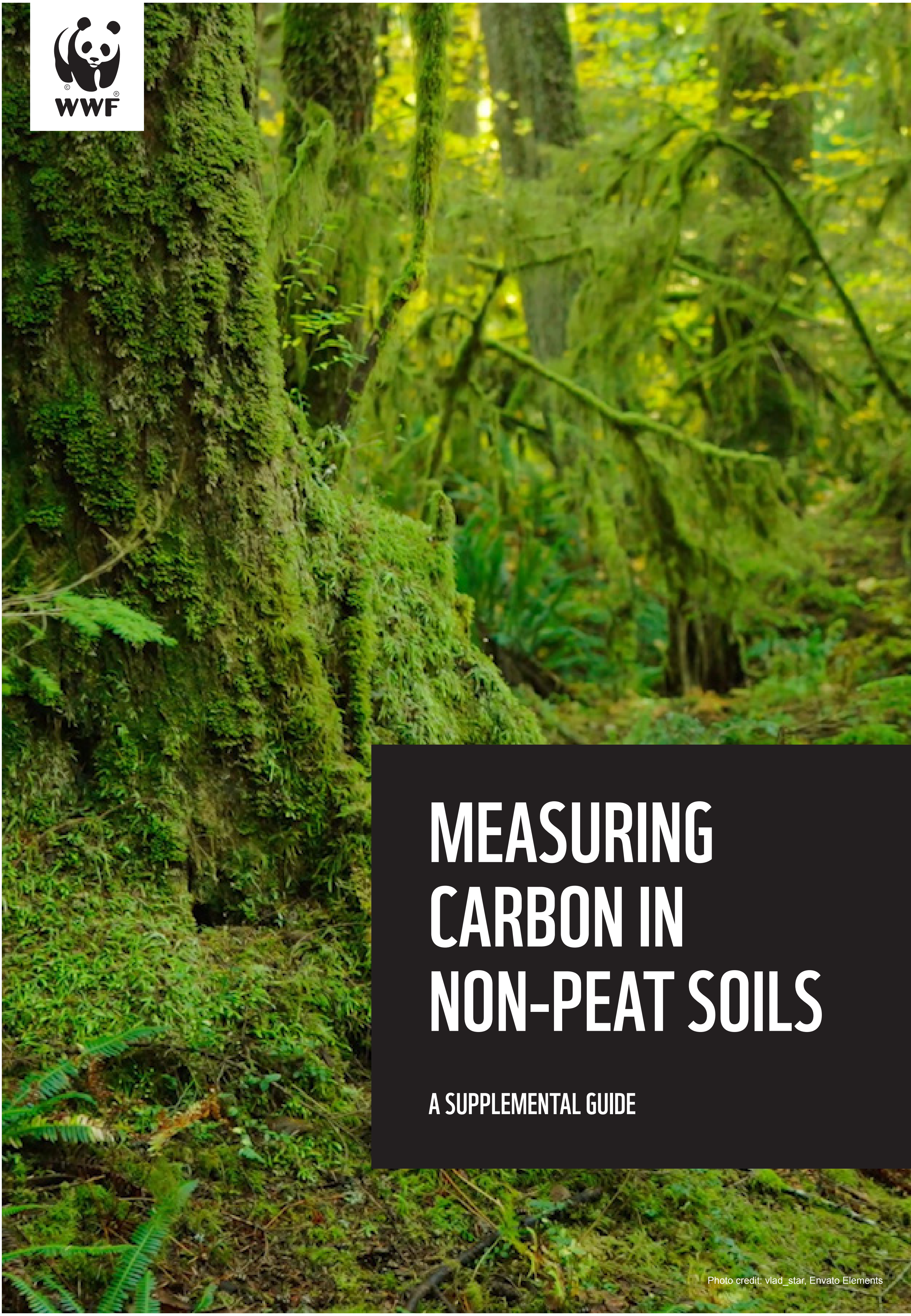


MEASURING CARBON IN NON-PEAT SOILS

A SUPPLEMENTAL GUIDE

Photo credit: vlad_star, Envato Elements


ISCO

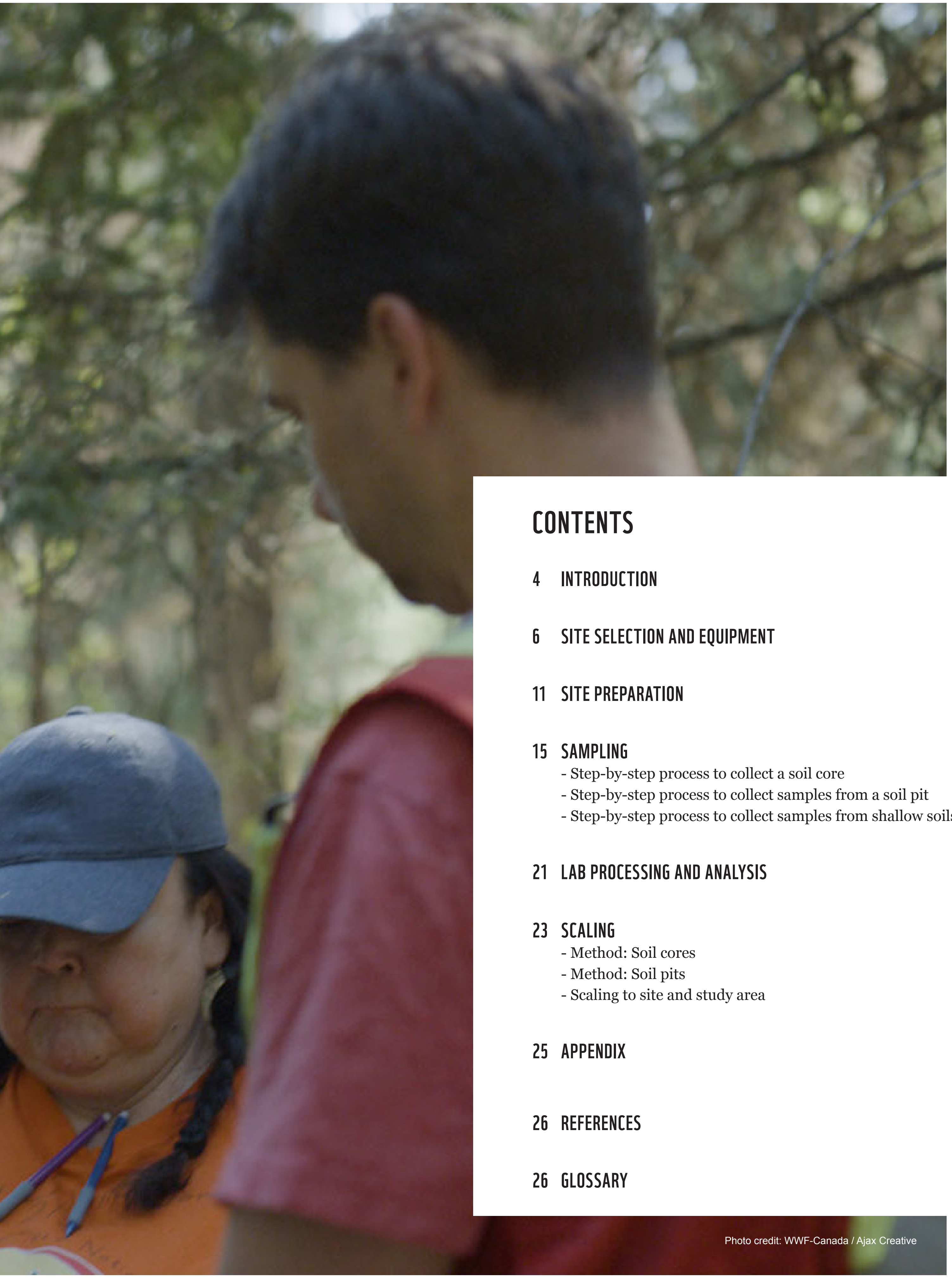
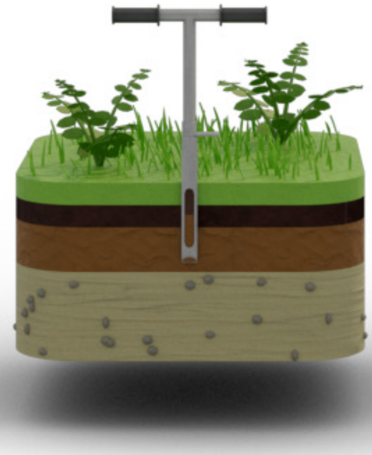


Photo credit: WWF-Canada / Ajax Creative

CONTENTS

MEASURING CARBON

IN NON-PEAT SOILS



INTRODUCTION

Soils occupy the largest terrestrial carbon pool in the terrestrial carbon cycle. In Canada alone, non-peat soils are estimated to hold over 208 billion tonnes of carbon within the top one metre. Soils sequester carbon through various processes, including photosynthesis and sedimentation. These processes are also responsible for cycling nutrients, purifying water and supporting biodiversity.

Recently, there has been growing interest in the protection, sustainable management and restoration of soils as nature-based climate solutions, given their ability to capture and store atmospheric carbon. While carbon is stored temporarily in the above-ground plant material of these ecosystems, most carbon stored for longer periods is in the soils. So, in order to estimate carbon stocks, we must first “dig in” to the soils!

STEPS FOR ACCURATE MEASURES OF THE CARBON STOCK

There are two common methods for quantifying the amount of carbon stored in the soil of terrestrial ecosystems (e.g., forests, grasslands): taking soil cores and digging soil pits. A third method, for sampling in shallow soils, is also detailed in this guide. All three methods achieve similar goals—namely, sampling soil at different depths and analyzing their bulk density and carbon content. These methods are applicable to unsaturated soils (i.e., those above the water table).

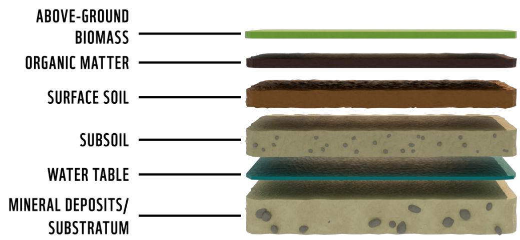
For each method, there are three steps to obtain accurate measures of the soil carbon stock:

1. Separate the soil into distinct layers.
2. Obtain the bulk density of samples from each layer.
3. Determine the carbon content of the samples.

In this guide and its corresponding video, we demonstrate how to take soil samples in the field and describe the subsequent laboratory analyses required to obtain carbon values. Be sure to plan for lab analysis in advance to ensure the data collected meets the end goals of the project. Detailed information about processing samples for lab analysis for carbon measurement can be found below. Contact the lab early on to see if they have any specific requirements.

Due to the large diversity of soil types found throughout Canada, the tools required for your specific site may vary. For a more comprehensive list of potential alternative techniques, refer to Bansal *et al.* (2023) and *The Blue Carbon Handbook* (2023).

SEPARATE SOIL

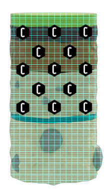


STEP 2

OBTAIN BULK DENSITY

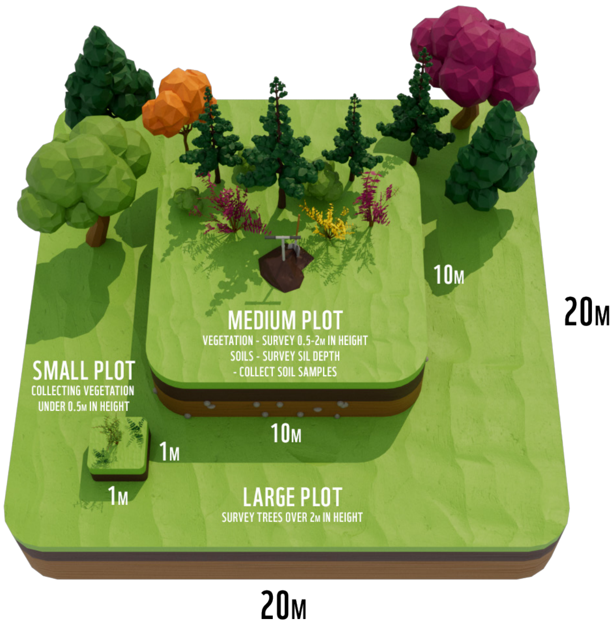
STEP 3

CALCULATE THE CARBON CONTENT



1

SITE SELECTION AND EQUIPMENT



Schematic diagram of a nested/integrated plot design, where soils are sampled alongside the three vegetation types, within their respective large, medium and small plots.

Before taking soil core samples, it is important to think about sampling locations and logistics for the coring sites. Consider the following:

- Where is the study region located?
- How large is the study area?
- How much variation is there across the study area?

This will help inform key aspects of the project design, including:

- How many sites are needed within the study area
- Where the sites should be located
- How many soil core samples should be collected at each site
- How deep the soil core samples should be

SAMPLING FROM MULTIPLE CARBON POOLS

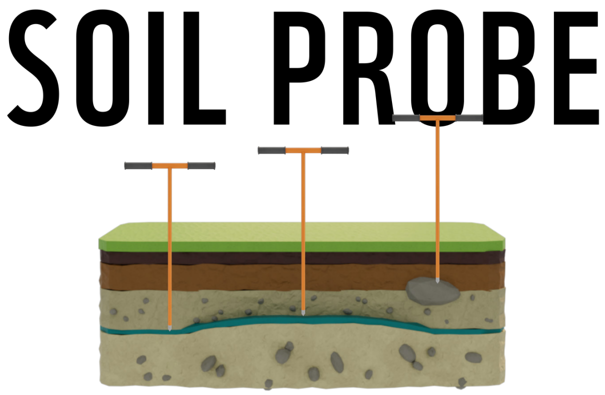
The team might be interested in sampling multiple carbon pools (e.g., sampling for trees, small vegetation and soils) from the same area. One method of accomplishing this is to use a nested plot design. This means setting up plots for each carbon pool that overlaps in a study area.

Nested plot design involves mapping out plots for large vegetation, medium vegetation, small vegetation and soil carbon before beginning sampling. In permanent plots, where carbon monitoring surveys are going to be repeated at the same location over multiple years, ensure that soil carbon samples and any other "destructive" sampling techniques are being completed outside of plot areas where non-destructive sampling takes place (e.g., vegetation plots; see the document "Supplemental Guide: Sampling Design," in the online Learning Library). Peat sampling is a destructive sampling technique; as a result, vegetation surveys must be completed **before** soil samples are collected in all plot types.

For smaller study areas (e.g., 50 hectares [ha] or less) **a systematic survey of soil depths** using a soil probe can help with identifying study sites and plot locations. Larger study areas (e.g., 10,000 ha or more) require using mapping software to select plot locations. For more details, please see the section "Supplemental Guide: Sampling Design," in the online Learning Library.

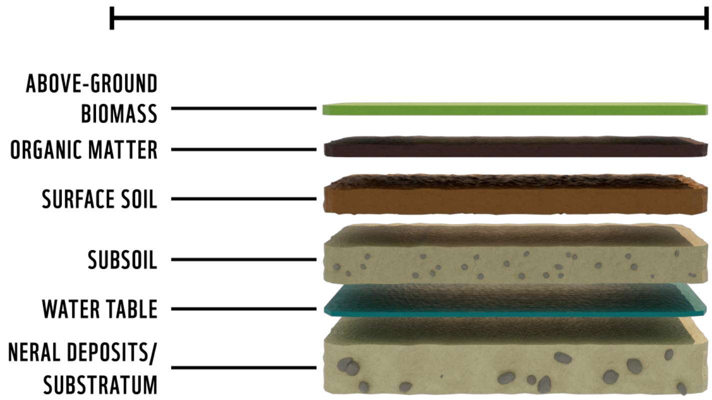
Note: *"Soil depths" refers to the depths from the ground surface to the "substratum," or hard clay, bedrock, or other parent materials underlying the soil.*

There are two ways to survey the site to determine variation in soil depths. Both methods are described in the following steps.



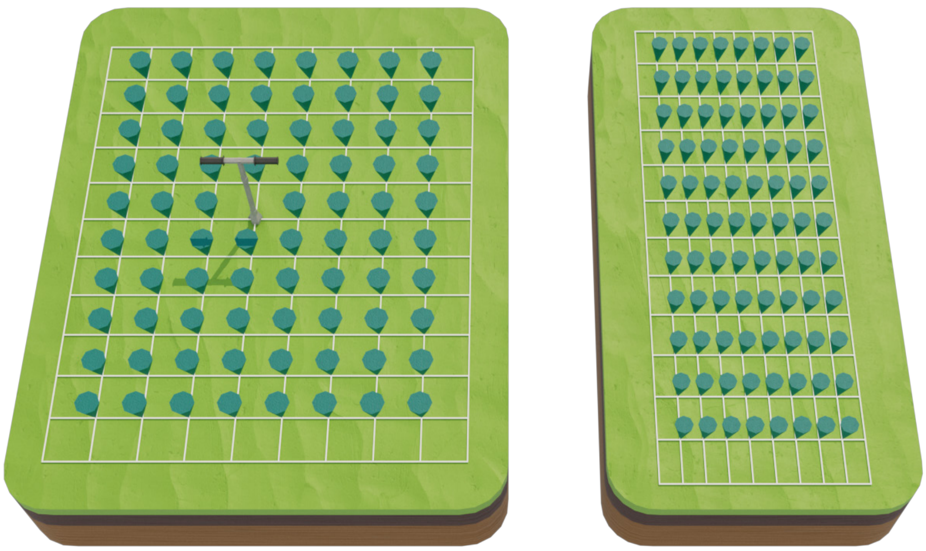
STEP 1

SEPARATE SOIL



STEP 1:
SYSTEMATIC SURVEY OF SITE

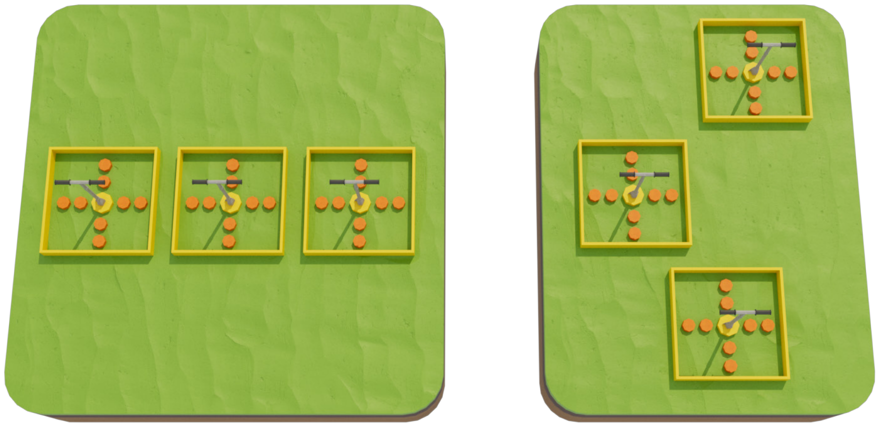
1. The first method, which is done before going into the field, involves digitally overlaying a grid on the site. In the field, this grid acts as a map, where depths can be measured with a soil probe at every line intersection of the grid. Generally, lines are 10–25 metres (m) apart.
2. The second method also involves sampling at 10–25m increments but relies on the use of a compass and measuring tape.
    - Beginning at one end of the site, use the compass to run a measuring tape 10–25m across the site. Record the soil depth at the start and end of the measuring tape. Then, from the end of the tape, lay out the measuring tape another 10–25m in the same direction, taking soil depth measurements at each end of the tape measure. When a boundary of the site is reached, turn perpendicular to the current line and measure 10–25m. Run the measuring tape in the opposite direction parallel to the first line, continuing to measure soil depths at each end of the tape measure. Repeat this for the entire site to result in a soil depth measurement at every 10–25m intersection of the site.



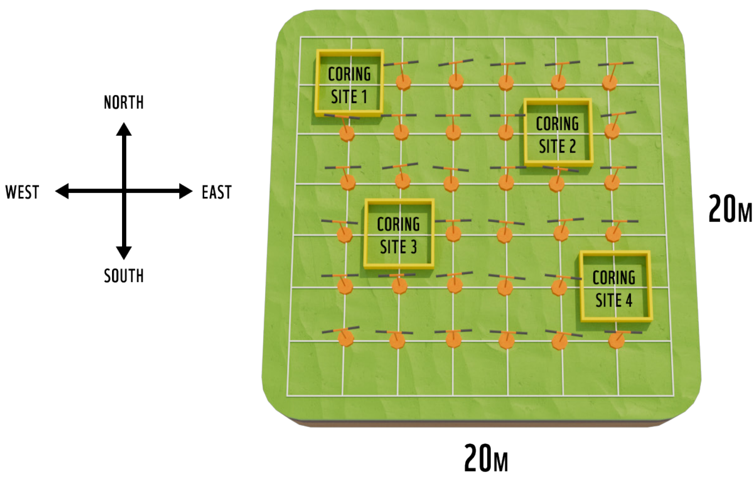
STEP 2:
PLOT IDENTIFICATION

Within the site, plots can be established across the varying soil depths to capture the variation across the site. Within each plot, soil depths are taken at every line intersection on the plot. The goal of surveying the soil depths within the plot is to take measurement of soil depths at every 1m intersection within a 10m-by-10m plot. There are two main ways to accomplish this.

1. The first method involves digitally overlaying a 1m-by-1m grid on the plot and recording the depth of the soil layer at every grid intersection.

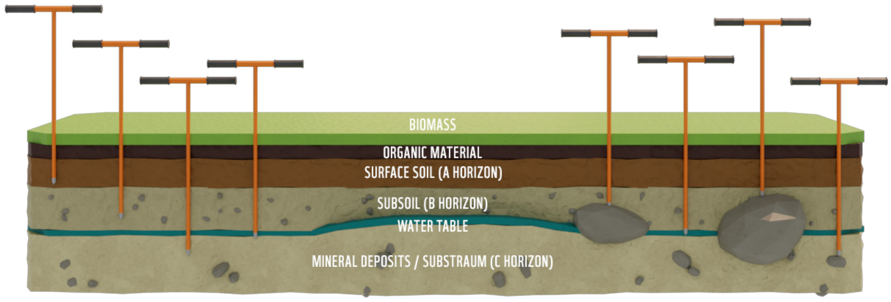


CORING SITE SELECTION SCHEMATIC



2. Alternatively, beginning at the plot edge, run a measuring tape vertically from end to end (10m). Run a second measuring tape perpendicular to the first, starting at one end of the first measuring tape. Take a measurement of soil depth at every metre along the second tape. Move the tape one metre at a time across the plot and continue this process, eventually measuring for each 1m intersection in the plot.

A soil probe can be a useful tool to survey the site before selecting a sampling location and may inform sampling depth. It is important to collect enough soil samples to represent the variation in soil depths across the plots. With cores less than 30 centimetres (cm), multiple samples can be taken across a plot or transect to capture variation across the plot and to better obtain a representative sample of the study site.



SECTION SUMMARY: SITE SELECTION

- **Within each site, use a soil auger or soil probe to survey the depths of soil to the substratum at every 10-25m grid intersection across the study site.**
- **Establish plots within the site to capture the variation in soil depth.**
- **Survey every 1m-by-1m within a 10m-by-10m plot to ensure the coring/sampling locations are representative of the plot area.**

REQUIRED FIELD EQUIPMENT

For setting up a plot:

- GPS
- Work gloves
- Soil probe
- Measuring tape
- Utility knife
- Camera
- Notebook
- Permanent markers
- Tarps
- Scissors
- Resealable bags

For taking a soil core:

- Soil corer
- Core extraction tool
- Cooler or storage box
- Tarps
- Plastic tubes
- Plastic tube end caps
- Notepad
- Permanent markers
- Measuring tape
- Duct tape
- Packing materials
- Cooler

For taking soil samples with a soil pit:

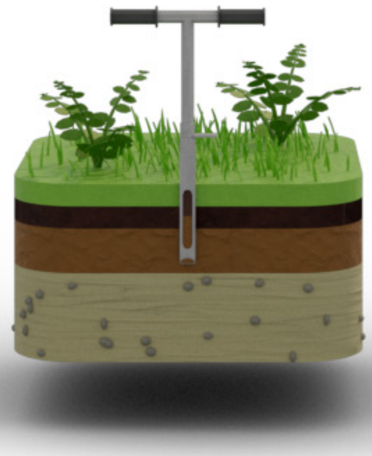
- Shovel
- Soil sampling ring/bulk density disk
- Resealable bags
- Permanent markers
- Cooler

For taking shallow surface cores:

- Shovel/gardener shovel
- Resealable bags
- Permanent marker
- 0.25m-by-0.25m frame/mould
- Cooler

2

SITE PREPARATION

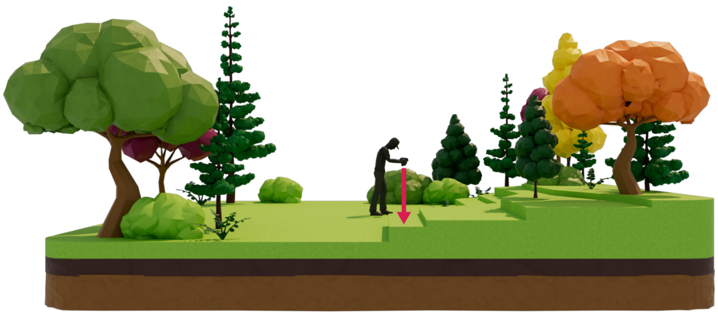


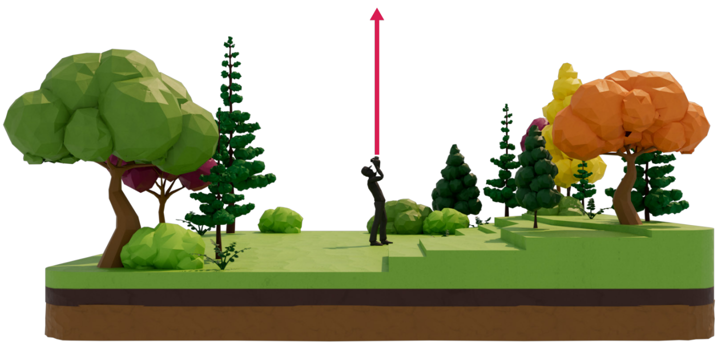
SITE PREPARATION

Once the team has arrived at the site, document the vegetation using a standardized photo series protocol.

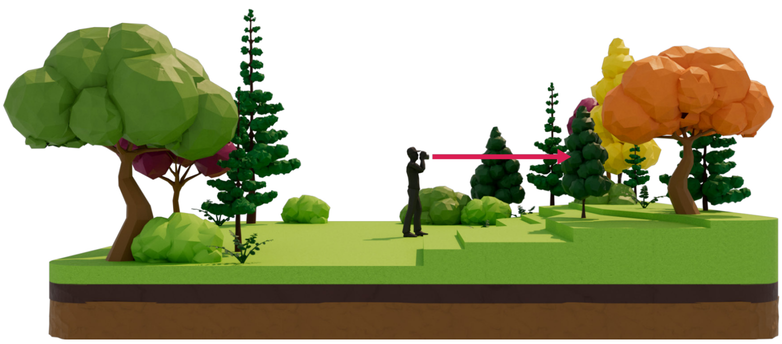
PHOTO SERIES PROTOCOL

1. Start by documenting vegetation and canopy cover (if any) by taking two photos of the site:
   a. One pointing straight down (vegetation)
   b. One pointing straight up (canopy)

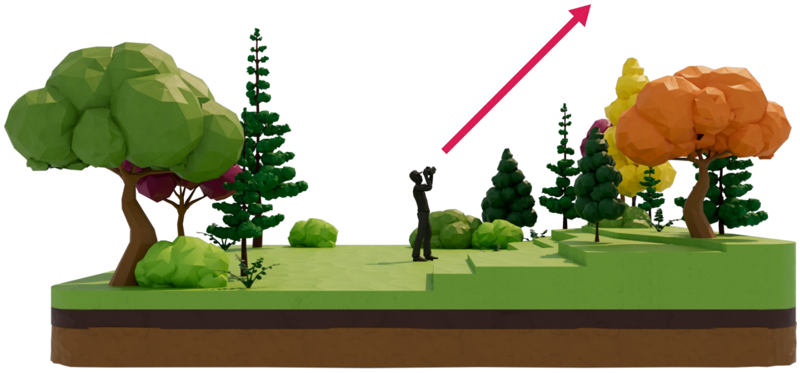




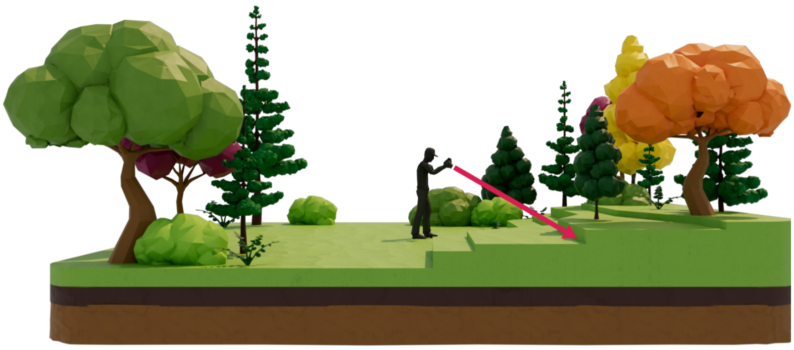
2. From the same spot, turn to each cardinal direction and take three photos:
   a. One parallel with the ground



SITE PREPARATION



b. One angled 45 degrees up



c. One angled 45 degrees down

14 PHOTOS

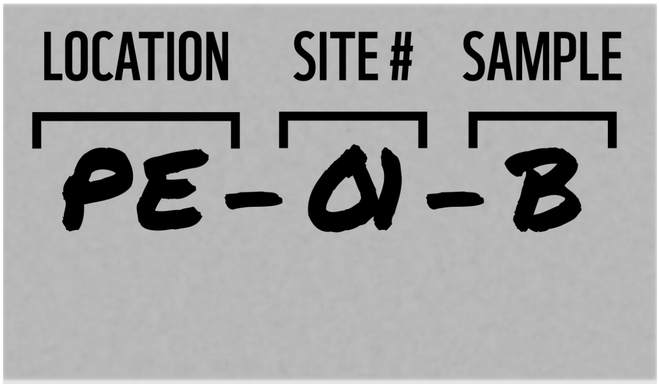
3 PHOTOS FOR EACH CARDINAL DIRECTION

1 DOCUMENTING VEGETATION

1 DOCUMENTING CANOPY COVER

3. Once finished, there will be 14 photos of the site (i.e., three photos for each cardinal direction, one documenting vegetation and one documenting canopy cover).

Be sure to record the site with a waypoint in a GPS and note the coordinates and site identifier in a notebook. Regardless of the number of samples being taken, we recommend using a systematic approach (i.e., using unique identifiers or CoreIDs) for labelling each core. The CoreID "PE-01-B," for example, identifies the location (PE refers to "Peawanuck"), the core number or sampling site (e.g., "01" refers to the first site) and the sample (e.g., the second sample is "B").

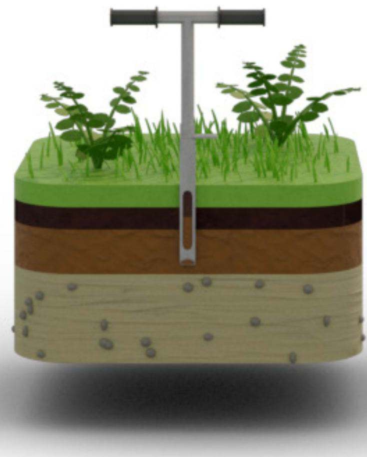


SECTION SUMMARY: SITE PREPARATION

- **Record the CoreID. For example, PE-01-B represents "location-site-sample number."**
- **Record the latitude, longitude and elevation of the coring site.**
- **Document the vegetation of the coring site using a 14-photo series protocol by taking photos from the coring site that capture views pointing:**
  - **straight up (canopy)**
  - **straight down (vegetation)**
  - **for all cardinal directions: one parallel with the ground; one 45 degrees up; and one 45 degrees down.**

3

SAMPLING



If a surface corer is available, we recommend using the coring method to obtain soil samples because it is the most effective way to sample an entire core. It is also simpler and faster than other methods, because multiple cores can be taken within the same plot.

Obtaining a surface core requires a **surface corer**. These can come in many shapes and sizes to meet your individual research needs and research objectives. All use the same basic steps.

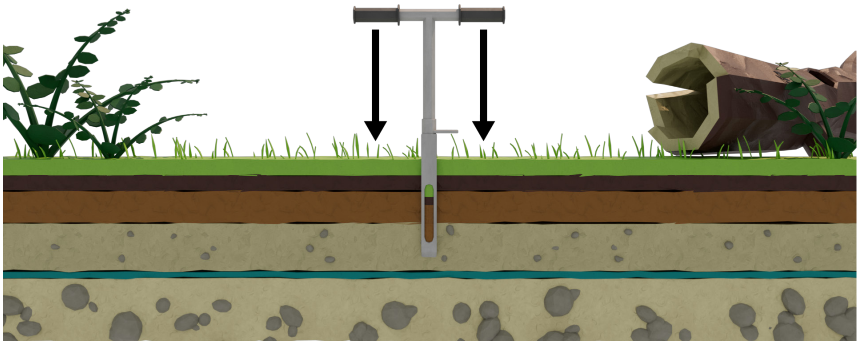
STEP-BY-STEP PROCESS TO COLLECT A SOIL CORE

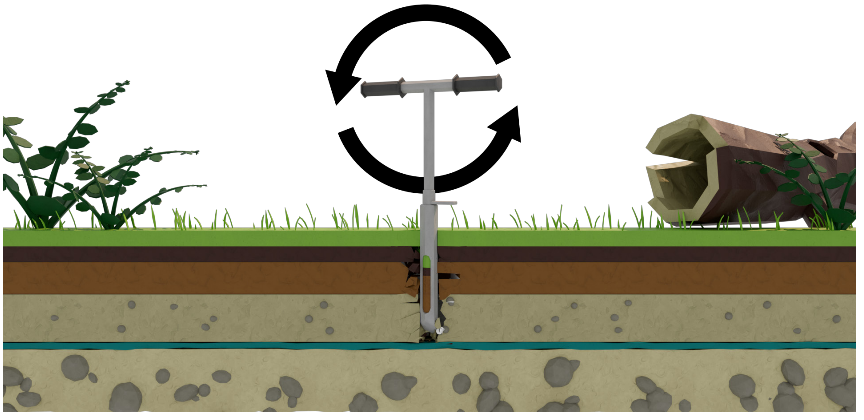
1) Before coring, find a flat area close to the coring spot, lay down a tarp and prepare all the required equipment.
2) Gently push the corer into the soil, keeping it as straight as possible.

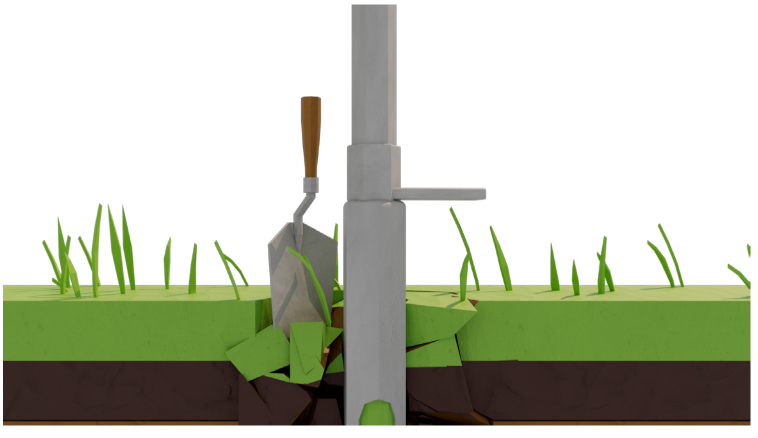
   a) Corers with serrated edges can be used to cut through coring spots with tough roots. When coring with this tool, it's also important to try and reduce compaction as much as possible.
3) The depth of each core depends on each site, but should first be estimated with a soil probe.

   a) Once a desired soil depth is decided, capture as much of the soil from the soil surface to the desired depth as possible to obtain the best bulk density and carbon measurements for each soil layer.
4) With the core fully inserted, twist and jiggle the corer to release the bottom part of the core sample from the base sediment.

   a) If the core is stuck, dig down from the outside of the core to give the corer more room, or cut with a trowel or knife.
5) Once the core is free, remove the corer with the sample inside.
6) Keep pressure on the bottom of the core sample to prevent the sample from falling out of the bottom of the corer.
7) Once fully removed, turn the corer horizontally and place a plastic core sleeve, cut lengthwise, around it.

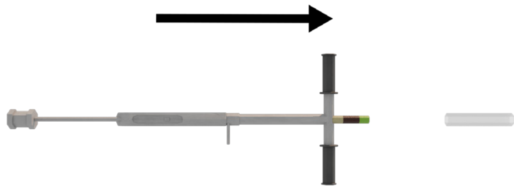






SAMPLING

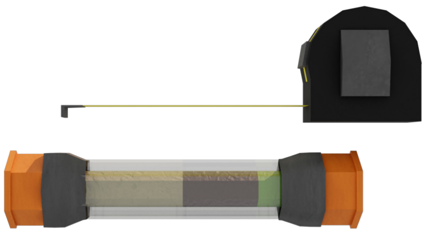
PUSH OUT THE SAMPLE FROM THE BOTTOM



8) Using the core extraction tool, push the sample from the bottom of the core to reveal the sample through the top of the corer. The plastic sleeve should be adjusted to catch the sample as it releases from the top of the core.

9) Once fully removed, place labelled end caps on the top and bottom end of the core. Secure it with tape. Apply a strip of duct tape along the cut edge of the tube.

10) Measure the length of the core and the depth of the hole that was just cored, and record these measurements in a notebook. The hole depth is the true depth of the core, whereas the core extracted length can be smaller due to compaction. It is important to correct for this compaction when measuring the bulk density of the core in a lab.



MEASURE THE LENGTH OF YOUR SAMPLE AND THE DEPTH OF THE HOLE

11) Label the sample and place it in a cooler for storage.

The cores can be transported to a lab for further processing, where they will be sectioned by soil layer type, measured to obtained volume, weighed to obtain bulk density and analyzed for carbon content.

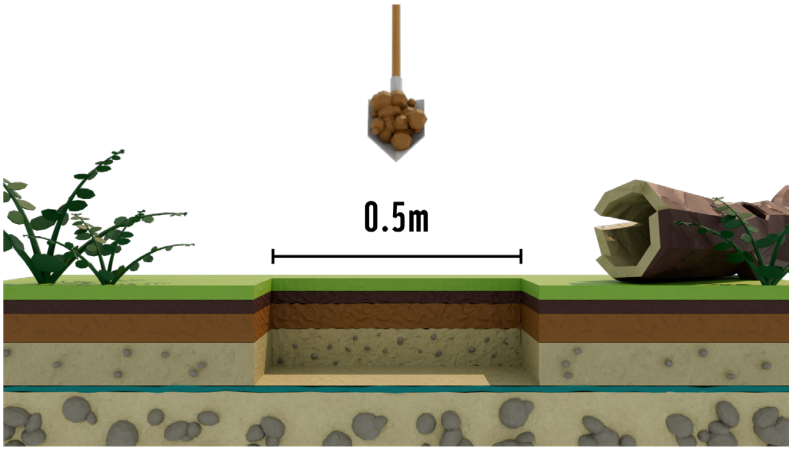
SECTION SUMMARY: COLLECTING A SOIL CORE

- **Find a flat area close to the coring spot, lay down a tarp and prepare the required equipment.**
- **Gently push the corer into the soil, keeping it as straight as possible.**
- **With the corer fully inserted, twist and jiggle the corer to release the bottom part of the core sample from the base sediment.**
- **Remove the corer with the sample inside. Keep pressure on the bottom of the core sample to prevent the sample from falling out of the bottom of the corer.**
- **Turn the corer horizontally and place a plastic core sleeve around the corer.**
- **Use a core extraction tool to push the core out of the corer into the sleeve. Place the appropriate end caps on the top and bottom of the core tube and secure it with tape.**
- **Measure and record the core length and the depth of the hole.**
- **Label the sample and place it in a cooler.**

STEP-BY-STEP PROCESS TO COLLECT SAMPLES FROM A SOIL PIT

The second method requires digging a soil pit and using a horizontal punch sampler. This method is designed to expose the soil horizons of the landscape and is the best method if other properties of the soil are also going to be measured. However, it takes more time and effort than soil coring.

1. At the selected site, dig a hole in the ground that is at least 0.5m wide.
    a. The hole should be deep enough to expose all the soil horizons and should be wide enough to easily collect samples from each horizon.



2. Identify each soil layer by its major soil horizon group using the Canadian System of Soil Classification, outlined in the Appendix. Distinctions are made using the colour, texture and depth of the soil horizon.
3. In a notebook, record the soil layer, depth increment, colour and texture for horizon classification.

4. Using a small mould with a known volume, often referred to as a “soil sampling ring” or a “bulk density disk,” collect a sample in the middle of each horizon for the purpose of determining bulk density.
5. Place the sample in a labelled resealable bag.
6. Additional samples from each layer can be collected in a separate bag for carbon content or other lab analyses.

COLLECT SAMPLES FROM THE MIDDLE OF EACH SOIL LAYER

SECTION SUMMARY: COLLECTING SOIL SAMPLES FROM A SOIL PIT

- **At the selected site, dig a hole 0.5m wide and to the desired sampling depth.**
- **For each soil layer, record the depth interval, colour and texture.**
- **Label resealable bags with a unique CoreID and sample depth interval for each layer.**
- **With a soil sampling ring/bulk density disk, obtain a sample from the middle of each of the soil layers and transfer each of the samples to its respective labelled bag.**
  Note: Additional samples from each layer can be collected and transferred to a separate bag.
- **Place samples in a cooler.**

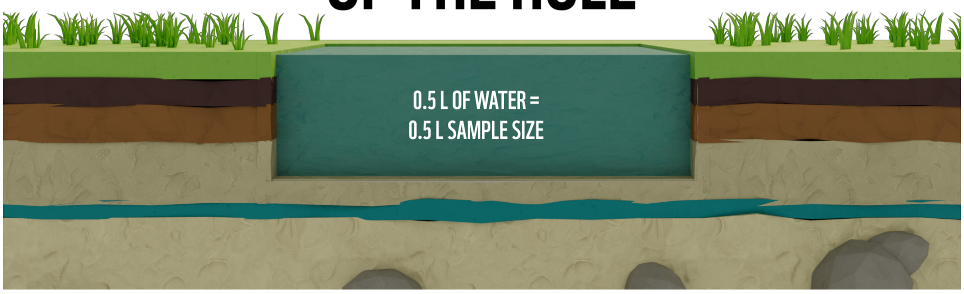
STEP-BY-STEP PROCESS TO COLLECT SAMPLES FROM SHALLOW SOILS

The last method is only applicable to very shallow soils, such as those found throughout the Canadian Shield. While this method is the least precise because it cannot sample distinct layers, it can be useful in the right conditions.

Steps for collecting samples from shallow soils:

1. Use a frame to dig a small pit.
2. Collect the entire sample in one go and transfer to a labelled resealable bag.
3. Fill the sample area with a material of known volume (such as water) to determine the sample volume, which will be used to determine the soil sample's bulk density.
4. **Record** the **unique sample name** and **volume** in your notebook.
5. Package, label and store your sample in a cooler until it can be transferred to a freezer for lab analysis.

USE WATER TO DETERMINE THE VOLUME OF THE HOLE

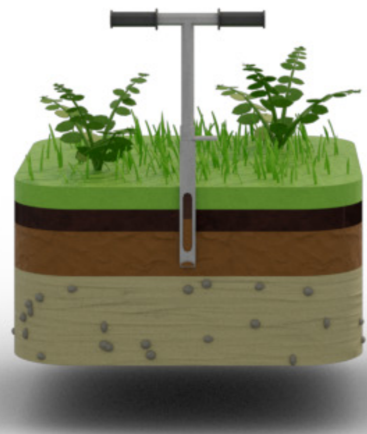


SECTION SUMMARY: COLLECTING SOIL SAMPLES FROM SHALLOW SOILS

- **At the selected site, dig a small pit following a mould with known dimensions.**
- **Collect the entire sample and transfer it to a resealable bag labelled with a sample number.**
- **Fill the area sampled with a material of known volume (such as water) to determine the volume of the soil sample.**
- **Record the unique sample name and volume in your notebook.**

4

LAB PROCESSING AND ANALYSIS



LAB PROCESSING AND ANALYSIS

If planning on doing the lab analysis independently, please see the document "Supplemental Guide: Laboratory Analysis."

Alternatively, soil cores can be sent to a lab for analysis, in which case it's important to contact the lab ahead of time for specific requirements regarding the handling, packaging and delivery of the samples.

There are multiple methods for determining the carbon content of the samples; the list below provides a brief overview of common methods and what they mean for calculating carbon stocks.

Dry bulk density – A key component of estimating the stock of an ecosystem is first determining how much material is in the ecosystem in the first place. Dry bulk density is a measurement of the weight and volume of a sample after it has been dried; this weight is then divided by the volume to obtain a value for the density of the sample (typically in grams per centimetres cubed; g/cm^3). Combining bulk density with other analyses, such as those for carbon, nitrogen, toxic metals or pollutants, can provide additional information that may be of value to the project.

Moisture content – Knowing the amount of water in a sample is important for determining the soil conditions. This is done by weighing the sample fresh from the ground, drying the sample in an oven to evaporate the water and then weighing the sample again. The difference between the fresh and dry sample is the moisture content of the sample.

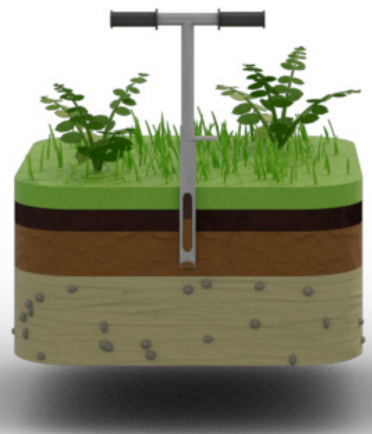
Loss-on-ignition at 550 degrees Celsius (LOI550) – Once dried, the samples are combusted in a muffle furnace set to 550 degrees Celsius (°C). Under these conditions, the organic matter (i.e., the dead plant material that has turned into peat or soil) is burnt off, converted to CO_2 and water vapour, and expelled from the sample. The remaining sample after four hours of burning is only the inorganic fraction of the peat or soil. The difference between the unburned weight of the sample and burned weight is called the LOI or organic matter fraction of the sample.

Carbon conversion factor – Organic matter is typically composed of 50 per cent carbon by weight. Using this value, we can convert the organic matter estimate from LOI to estimate the organic carbon fraction of the sample by multiplying the LOI550 value by 0.5.

Other methods might be more practical for estimating carbon content in ecosystems where the soil has a larger fraction of inorganic matter. In this case, methods such as infrared spectroscopy for organic carbon, acid dissolution of CO_2 for inorganic carbon and a CHN elemental analyzer for determining total carbon may be used. For further details on these methods, please see "Supplemental Guide: Laboratory Analysis."

5

SCALING



SCALING FROM SAMPLES TO CORES TO SITES TO STUDY AREA

The total soil carbon stock within a study area is determined by the amount of carbon within a defined area and soil depth. It is important to define the depth to which measurements will be collected and used to calculate soil carbon stock, typically expressed at either 30cm, 50cm, 1m, or 2m depths. Calculating the total soil carbon for the study area requires the following information:

- Dry bulk density (g/cm^3)
- Total carbon (%C) or organic carbon content (%C_{org})
- Cores: core subsection depth interval (cm) = bottom depth (cm) - top depth (cm)
- Soil pits: soil layer depth interval (cm) = bottom soil layer depth (cm) - top of soil layer depth (cm)

METHOD: SOIL CORES

The average carbon stock of soils cores can be determined as follows:

1. For each core subsection, calculate the soil organic carbon density:
    - **Eq 1: Soil carbon density (g/cm^3) = dry bulk density (g/cm^3) * (% C_{org}/100)**
    - ***Note:*** *Total carbon content (%) can be substituted with organic carbon content (%C_{org}) to determine the soil organic carbon density (g C_{org}/cm^3).*
2. To calculate the amount of carbon in a subsection, multiply each soil carbon density value obtained in Eq 1 by the subsection depth interval (cm):
    - **Eq 2: Average carbon stock of subsection (g/cm^2) = soil carbon density (g/cm^3) * depth interval (cm)**
    - ***Note:*** *The depth interval is for either the core subsection or soil layer depending on the sampling method used.*
3. To obtain the average carbon stock (g/cm^2) of the core, add up the values for each subsection calculated above:
    - **Eq 3: Average carbon stock of core (g/cm^2) = sum of average carbon stocks of subsections**
    - ***Note:*** *Subsections must add up to 100% of the core to obtain the average carbon stock.*
4. Convert the average carbon stock of the core (g/cm^2) from Eq 3 into units of kg/m^2 by multiplying by 10, *or more formally*:
    - **Eq 4: Average carbon stock of core (kg/m^2) = average carbon stock of core (g/cm+) * (1kg/1000g) * ($10000cm^2/m^2$)**
5. Repeat steps one to four for each core.

METHOD: SOIL PITS

The average carbon stock of soil pits can be determined as follows:

6. For each subsample of the soil pit obtained for each soil layer, calculate the organic carbon density:
    - **Eq 1: Soil carbon density (g/cm^3) = dry bulk density (g/cm^3) * (% C_{org}/100)**
    - ***Note:*** *Total carbon content (%) can be substituted with organic carbon content (%C_{org}) to determine the soil organic carbon density (g C_{org}/cm^3).*
7. To calculate the amount of carbon in a soil layer, multiply each soil carbon density value obtained in Eq 1 by the thickness of the soil layers depth interval (cm):
    - **Eq 2: Average carbon stock of soil layer (g/cm2) = soil carbon density (g/cm^3) * thickness interval (cm)**
8. To obtain the average carbon stock (g/cm^2) of the soil profile, add up the values for each soil layer calculated above:
    - **Eq 3: Average carbon stock of soil profile (g/cm^2) = sum of average carbon stocks of soil layers**
    - ***Note:*** *Soil layer depths must add up to 100% of the total soil depth to obtain the average carbon stock.*
9. Convert the average carbon stock of the soil profile (g/cm^2) from Eq 3 into units of kg/m^2 by multiplying by 10, *or more formally*:
    - **Eq 4: Average carbon stock of soil profile (kg/m^2) = average carbon stock of soil profile (g/cm^2) * (1kg/1000g) * ($10000cm^2/m^2$)**

SCALING TO SITE AND STUDY AREA

The carbon stock of a study area can be determined as follows:

10. To obtain the average carbon stock of each study site (kg/m^2), add up the average carbon values from Eq 4 (kg/m^2) for each core obtained and divide it by the number of cores taken in each site.
    - **Eq 5: Average carbon stock of site (kg/m^2) = sum of average carbon stocks of cores (g/cm^2)/ number of cores**
11. Multiply the average carbon stock of the site by the size of the site (in metres square) to obtain the total carbon stock of each site (kg C).
    - **Eq 6: Total carbon stock of study site (kg C) = Average carbon stock of study site (kg C/m^2) * Study site size (m^2)**
12. Add up the total carbon stocks for the sites and divide by the sum of the site sizes. This gives the average carbon stock of the study area (kg C/m^2).
    - **Eq 7: Average carbon stock of study area (kg C/m^2) = sum of total carbon stocks of sites (kg C) / sum of site sizes (m^2)**
13. Finally, to calculate the total carbon stock of the study area (kg C), multiply the average carbon stock of the study area by the size of the study area (in metres square).
    - **Eq 8: Total carbon stock of study area (kg C) = Average carbon stock of study area (kg C/m^2) * Study area size (m^2)**

*The carbon values calculated here are in units of "C." If interested in units of "CO_2 equivalents," multiply by 3.67.

APPENDIX

The Canadian System of Soil Classification (CSSC), major horizon groups:

O – The "organic layer"; a plant litter layer that is relatively undecomposed and contains more than 17% organic carbon.

A – Surface soil or "bio-mantle"; a layer of mineral soil (i.e., less than 17% organic carbon) with the most organic matter compared to other mineral layers. This mineral horizon forms at or near the surface in the zone of leaching materials.

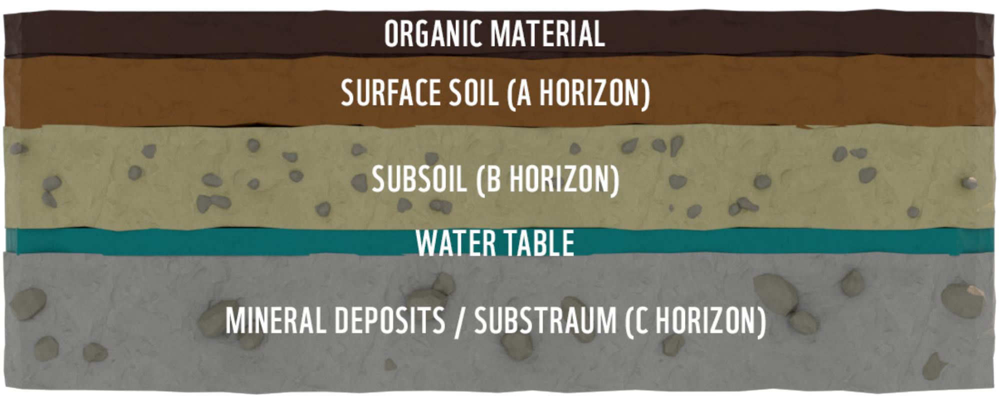
B – Subsoil; layer characterized by enrichment of other soil materials. Typically contains less organic matter when compared to the A horizon. In soil, where substances move down from the topsoil, this is the layer where they accumulate.

C – Substratum; layer not typically formed from soil processes and is the foundational layer the other soil layers build on. Made from unconsolidated sediments.

W – Water table; it is not unusual to find ground-water layers in some ecosystems.

R – Rock; this consolidated bedrock layer is too hard to break with the hands or shovel.

Schematic of major groups:



REFERENCES

Bansal, S., Creed, I.F., Tangen, B.A., Bridgham, S.D., Desai, A.R., Krauss, K.W., Neubauer, S.C. ... Zhu, X. (2023). Practical Guide to Measuring Wetland Carbon Pools and Fluxes. *Wetlands, 43*(8), 105. https://doi.org/10.1007/s13157-023-01722-2

Billings, S. A., Lajtha, K., Malhotra, A., Berhe, A. A., de Graaff, M.-A., Earl, S., Fraterrigo, J. ...Wieder, W. (2021). Soil organic carbon is not just for soil scientists: Measurement recommendations for diverse practitioners. *Ecological Applications*, 31(3), e02290. https://doi.org/10.1002/eap.2290

CSSC (2013). Agriculture and Agri-food Canada. "*Canadian System of Soil Classification, 3rd edition, Chapter 2: Soil, Pedon, Control Section, and Soil Horizons (continued)*." Accessed Jan 2024: https://sis.agr.gc.ca/cansis/taxa/cssc3/chpt02_a.html#tests

Jandl, R., Rodeghiero, M., Martinez, C., Cotrufo, M F., Bampa, F., van Wesemael, B., Harrison, R.B. ...Miglietta, F. (2014). Current status, uncertainty and future needs in soil organic carbon monitoring. *Science of The Total Environment, 468–469*, 376–383. https://doi.org/10.1016/j.scitotenv.2013.08.026

Kurz, W. A., Shaw, C. H., Boisvenue, C., Stinson, G., Metsaranta, J., Leckie, D., Dyk, A., Smyth, C. & Neilson, E.T. (2013). Carbon in Canada's boreal forest—A synthesis. *Environmental Reviews, 21*(4), 260–292. https://doi.org/10.1139/er-2013-0041

Murray, L.S., Milligan, B., Ashford, O.S., Bonotto, E., Cifuentes-Jara, M., Glass, L., Howard, J. ...von Unger M. (2023). The *blue carbon handbook: Blue carbon as a nature-based solution for climate action and sustainable development*. London: High Level Panel for a Sustainable Ocean Economy.

Petrokofsky, G., Kanamaru, H., Achard, F., Goetz, S. J., Joosten, H., Holmgren, P., Lehtonen, A. ...Wattenbach, M. (2012). Comparison of methods for measuring and assessing carbon stocks and carbon stock changes in terrestrial carbon pools. How do the accuracy and precision of current methods compare? A systematic review protocol. Environmental Evidence, 1(1), 6. https://doi.org/10.1186/2047-2382-1-6

GLOSSARY

Average carbon stock: A measure of the density of carbon in a carbon pool, expressed as carbon per square area, typically as kg/m^2 (kilograms per metre square) or t/ha (tons per hectare).

Biodiversity: The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Biogeochemistry: Scientific discipline that explores the physical, chemical, biological and geological processes and reactions that govern the composition of and changes to the natural environment.

Biological indicators: Biological proxies found in soil that are sensitive to paleoclimatic changes.

Bulk density: The weight of a volume unit of powder, usually expressed in g/cm^3 or kg/m^3.

Carbon accumulation rate: A measure of carbon sequestration calculated by dividing the carbon stock by the age of the sample interval, typically expressed in kilograms of carbon per metre square per year ($kg\ C/m^2$).

Carbon content: The proportion of carbon in a sample, typically expressed as a percentage or decimal.

Carbon pool: A system that has the capacity to store or release carbon.

Carbon stock: A measure of the amount of carbon in a carbon pool, typically presented in kilograms or tonnes.

CHN elemental analyzer: A device used for rapid, quantitative determination of carbon, hydrogen, nitrogen and sulfur in organic samples. Through a combustion process, these elements are converted to CO_2, H2O, N_2 and SO_2 gases and sent to the thermal conductivity detector to record the electrical signal proportional to the amount of each gas. This electrical signal then gives, for example, the percentage of elemental composition in proportion to the curve areas obtained in the spectrum.

Climate: The mean and variability of meteorological variables (i.e., weather) over a time spanning months to millions of years.

Climate change: The observed long-term shifts in meteorological variables, such as temperatures and weather patterns.

Coarse fragments: Soil particles or objects longer than two millimetres.

Compaction: The result of a core being smaller in volume than the volume it occupied in the soil due to the pressure exerted on the core while obtaining a soil core.

Crucible: A ceramic or metal container in which metals or other substances may be melted or subjected to very high temperatures.

Dry unit weight: Weight of soil solids (i.e., without any water content).

Dry bulk density: Dry unit weight of a sample divided by its volume, typically expressed as g/cm^3 (grams per centimetre cubed) or kg/m^3 (kilograms per metre cubed).

Isotope: Atoms with the same number of protons but different numbers of neutrons; can be used to infer the date of an object through the isotope's distinct half-life (i.e., rate of decay).

Lead-210 dating: A method for determining the rate of sediment accumulation within a 100- to 200-year time span using the decay of excess 210Pb activity.

Loss-on-ignition: Scientific method for determining the fraction of organic matter in a sample of soil by burning the sample between 450–950°C.

Mineral horizon: Soil horizons that have less than 17% organic carbon.

Muffle furnace: A laboratory instrument used to heat materials to extremely high temperatures while isolating them from fuel and the byproducts of combustion from the heat source.

Non-peat soil: All soils that are not composed of primarily peat.

Organic carbon: The amount of carbon found within the biomass of a thing (living or dead).

Organic horizon: Soil horizons that contain 17% or more organic carbon.

Plot: Designated area for collecting data and samples.

Radio-carbon dating: A method for estimating age of carbon-based materials that originated from living organisms through analyzing the ratio of carbon-13 to carbon-14 in a sample.

Sediment: Particle of soil created from erosional processes.

Sediment accumulation: The vertical buildup of sediment particles.

Site: The specific location from which data and samples are taken.

Soil core: Continuous length of soil.

Soil horizon: A layer parallel to the soil surface whose physical, chemical and biological characteristics differ from the layers above and beneath, defined in many cases by obvious physical features, mainly colour and texture.

Soil organic carbon: The carbon that remains in the soil after partial decomposition of any material produced by living organisms.

Soil organic matter: The fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition).

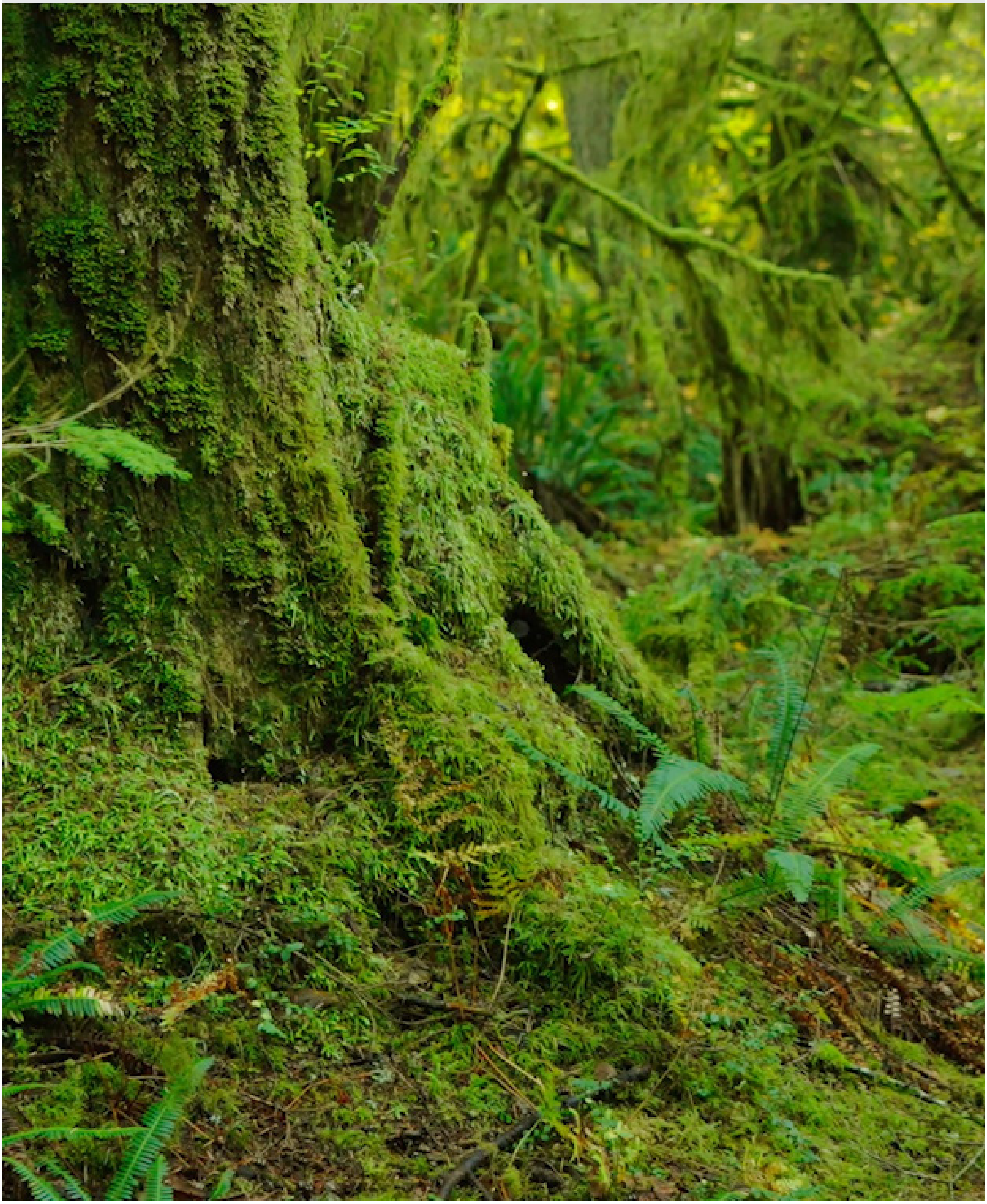
Soil texture: Refers to the proportion of sand, silt and clay-sized particles that make up the mineral fraction of the soil.

Swamp: A wetland with at least 25% tree cover; soil organic horizon depths can vary between shallow to very deep peat deposits.

Waypoint: Geographical position defined in terms of latitude/longitude coordinates.

Wetlands: Areas where water covers the soil or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season with the presence of aquatic adapted species.

Wet weight: Weight of soil sample before drying or losing any water content.



Working to sustain the natural world for the benefit of people and wildlife.

together possible™ panda.org

WWF-Canada. 2024. Measuring Carbon in Non-Peat Soils: A Supplemental Guide. World Wildlife Fund Canada. Toronto, Canada.