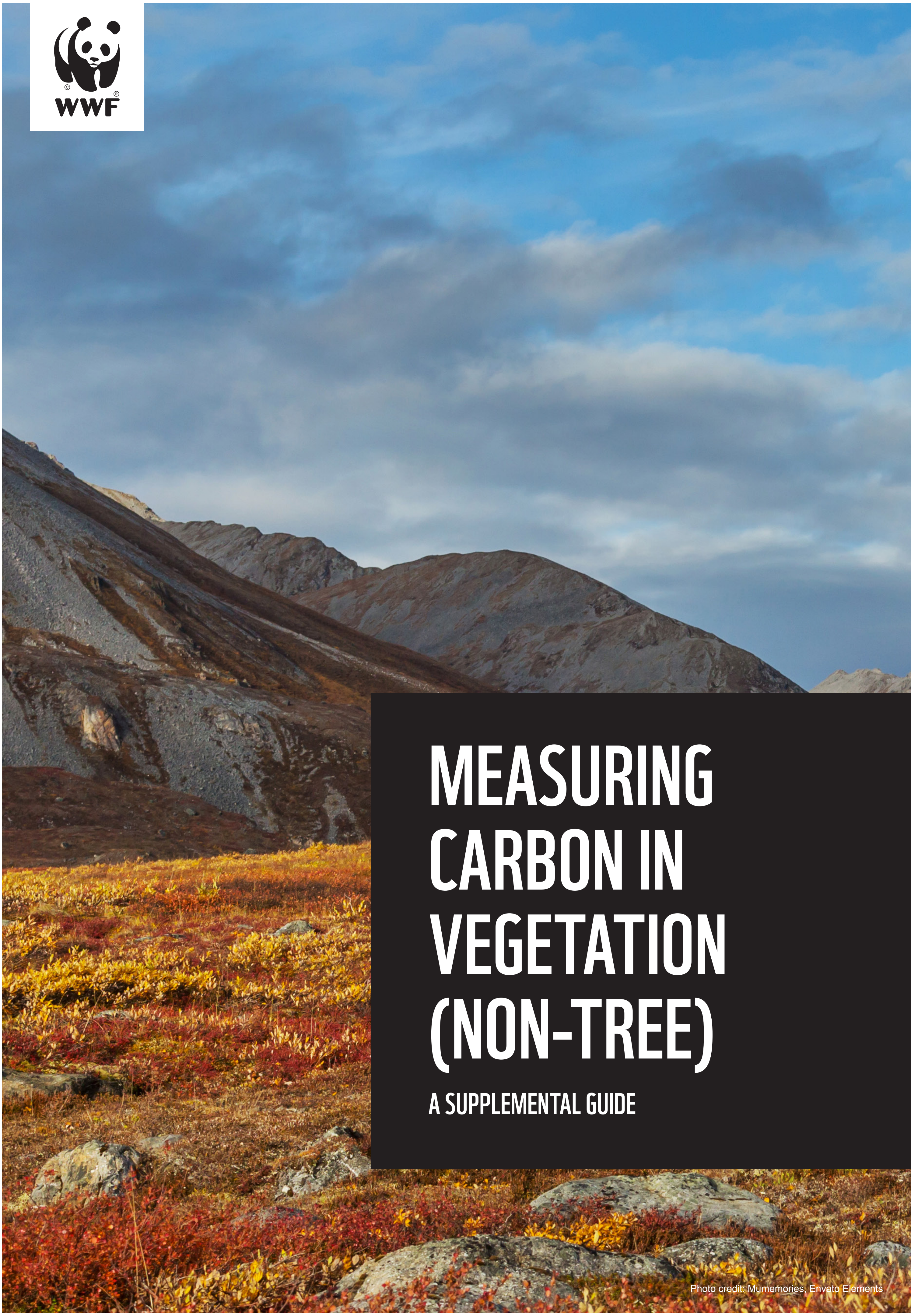


MEASURING CARBON IN VEGETATION (NON-TREE)

A SUPPLEMENTAL GUIDE

Photo credit: Mumemories, Envato Elements

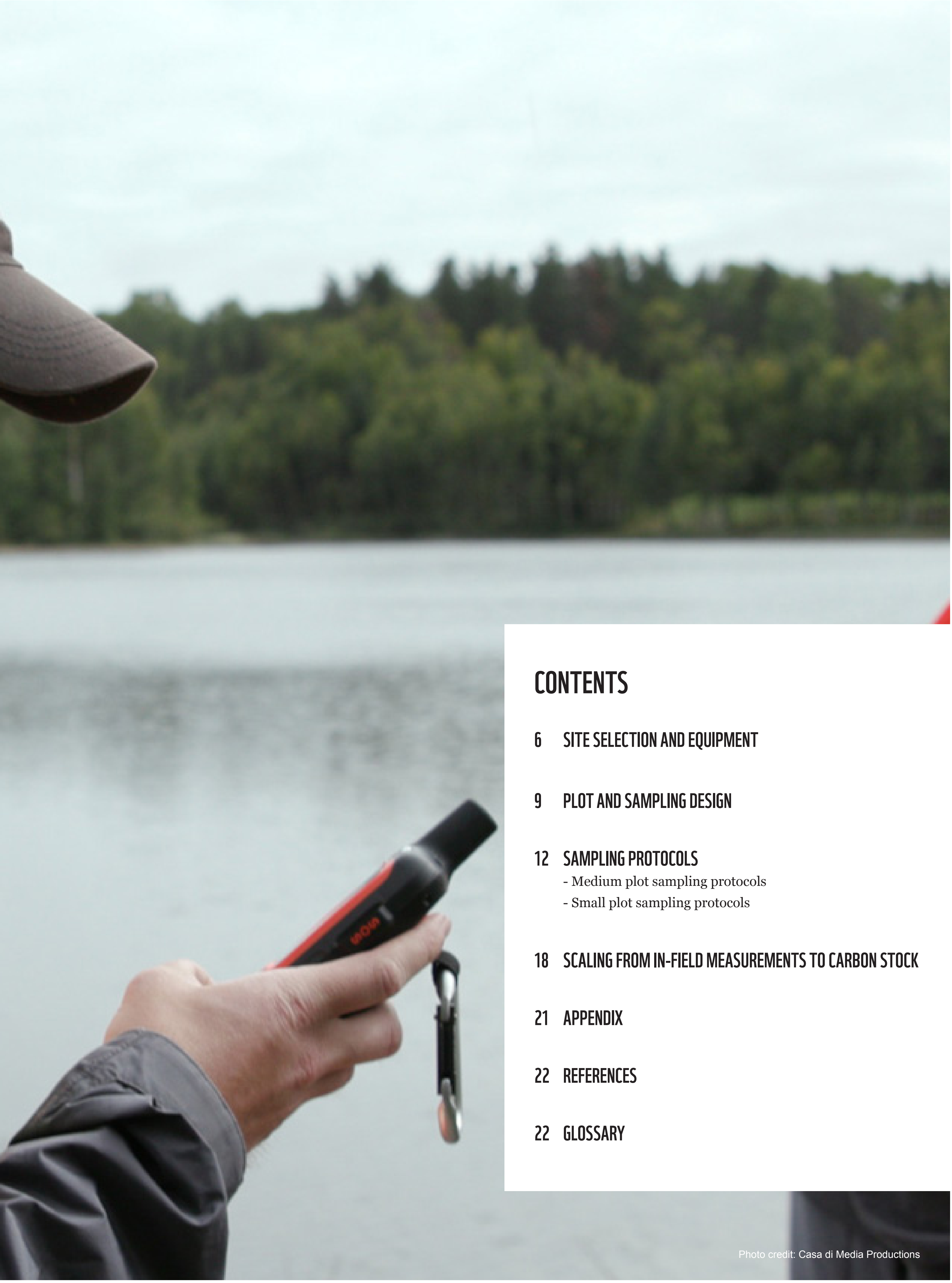


Photo credit: Casa di Media Productions

CONTENTS

MEASURING CARBON
IN VEGETATION
(NON-TREE)

INTRODUCTION

Canada's landscape is full of diverse ecosystems, from the vast forests of the Canadian Shield to the wetland complexes of the Hudson and James Bay Lowlands. Within these ecosystems, plants provide important ecological services—namely, climate regulation. Plants can capture carbon dioxide from the atmosphere and convert it into biomass through photosynthesis. This plant matter also supports the broader food chain, providing nutrients, energy and food to support the abundance of life we rely on. In addition, plant communities support air purification, nutrient cycling and sediment stabilization.

Across Canada, forests are estimated to store 18 billion tonnes of carbon in living biomass, primarily in the wood of trees. While the carbon stock of non-treed vegetation is much smaller, with estimates of 0.2 billion tonnes, it still contributes significantly to long-term carbon storage by producing materials that resist decomposition.

Plant communities—particularly mosses—insulate the soil and are able to alter soil chemistry. They help keep soil temperatures low and decrease the rate of soil organic matter decomposition, which increases carbon content.

In this guide and its corresponding video, we introduce a set of standardized field methods for determining the carbon stock of non-treed vegetation of different ecosystems throughout Canada, including shrublands, grasslands, tundra and wetlands. This guide can also supplement carbon measurements in mature forests for those teams who wish to conduct understory vegetation surveys. Please note that these guidelines are best suited to small projects (e.g., <50 hectares).

1

SITE SELECTION AND EQUIPMENT

Before sampling any vegetation, it is important to think about site selection, for example, where the plots are to be set up, how many plots are needed and what materials are required. It's also important to consider ahead of time the types of analyses that will be performed on the data. This will depend on the research questions, the logistical challenges and the available budget.

The **study area** encompasses the entire area to be investigated. Within this large area, specific, smaller **study sites** are identified to capture the variation of the area. Sites can be distinguished by changes in vegetation cover, elevation, ecosystem type or other geographical features that may vary across the study area.

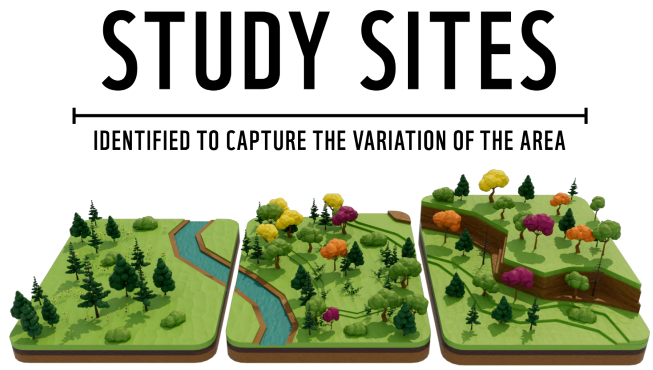
Once the study area, sites and plot locations are defined, vegetation data collection can begin.

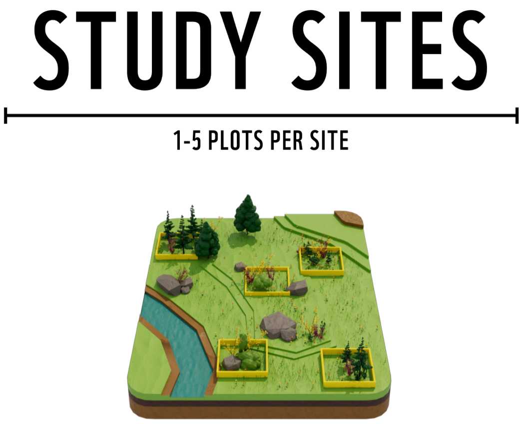
To sample within each site, plots are laid out to obtain a representative sample of the entire site. It is within these plots that vegetation will be surveyed. Within each site, one to five **plots** can be set up, depending on the nature of the site. For instance, larger projects (e.g., >10,000ha) may require 12-15 permanent plots per site, with five to ten sites per study area — though the exact number depends on the variability of the site. The more natural variation that exists across a site, the more plots are required. The layout of the plots might also differ. If the sites exist along a slope, a linear or stratified plot layout is recommended. Otherwise, a random or scattered plot layout is best.

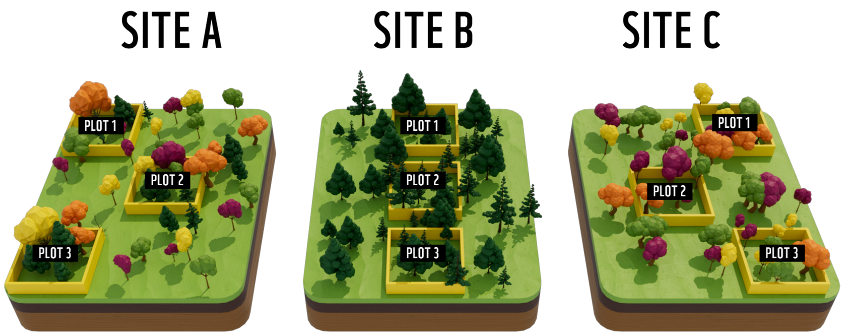
Once the study area, sites and plot locations have been defined, tree data collection can begin.

Sampling can be done at different times during the season to address different ecological questions.

Sampling dates should be flexible to accommodate the biological timing (i.e., phenological stage) of the plants. Biomass sampling must also be attuned to vegetation characteristics (e.g., herbaceous versus non-herbaceous, patchy versus non-patchy) and to the seasonality of the ecosystem. To quantify maximum biomass, above-ground biomass is often sampled in the peak growing season.

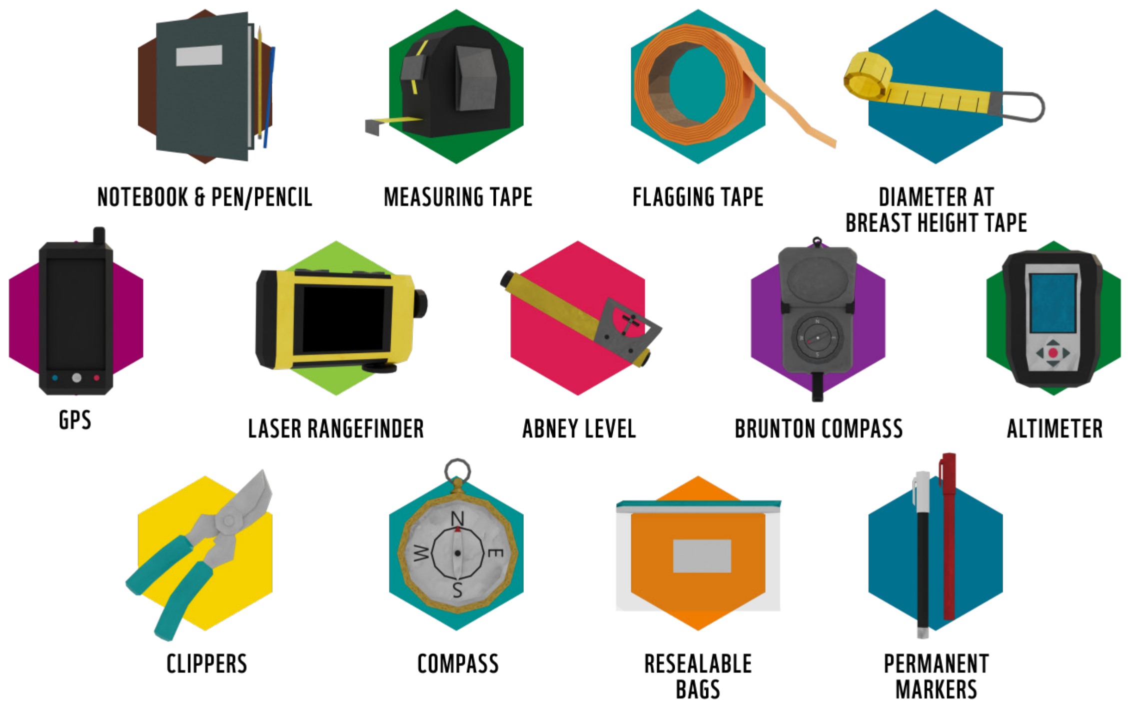






In the above example of a study area, Sites A and C show a scattered plot layout, while Site B shows a linear plot layout.

HERE'S WHAT YOU'LL NEED:



FOR SETTING UP PLOTS:

- **Notebook and pen/pencil**
- **Large measuring tapes**
- **String or flagging tape**
- **Plastic measuring tape**
- **GPS**
- **Rangefinder/clinometer/Abney level/ Brunton compass**
- **Altimeter**
- **Resealable bags**
- **Permanent marker**

FOR MEASURING MEDIUM VEGETATION:

- **Notebook and pen/pencil**
- **DBH tape**
- **Measuring tapes**

FOR MEASURING SMALL VEGETATION:

- **Notebook and pen/pencil**
- **Clippers**
- **1-by-1m quadrat**
- **0.5-by-0.5m quadrat**
- **Resealable bags**

2

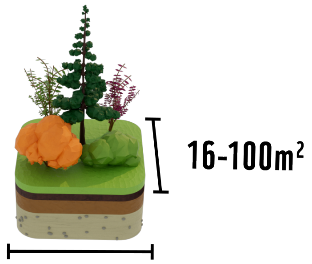
PLOT AND SAMPLING DESIGN

PLOT AND SAMPLING DESIGN

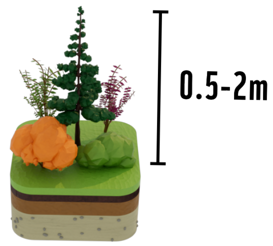
TWO PLOT TYPES ARE REQUIRED TO SAMPLE ALL NON-TREED VEGETATION WITHIN THE SITE. BOTH PLOT TYPES ARE SET UP IN A SIMILAR WAY.

1. **“Medium vegetation**” or “shrub” plots, which are typically 16–100 metres square (m²).

   All vegetation 0.5–2m in height will be sampled in this plot. This vegetation includes short-statured trees (i.e., most mature shrubs, some herbaceous plants and some grasses).

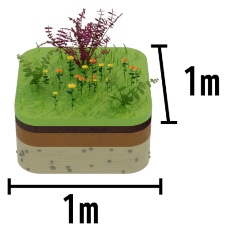


MEDIUM VEGETATION PLOT SAMPLING PROTOCOL



MEDIUM VEGETATION PLOT SAMPLING PROTOCOL

2. **“Small vegetation”** or “micro” plots. These plots are 1-by-1m in size. All vegetation below 0.5m in height — also known as ground vegetation — will be sampled in these plots.



SMALL VEGETATION (MICRO) PLOT SAMPLING PROTOCOL

SMALL VEGETATION (MICRO) PLOT SAMPLING PROTOCOL

Step-by-step process to set up plots

1) Plot locations should be mapped out ahead of time based on a standardized sampling design.

2) Obtain GPS coordinates for the longitude, latitude and elevation of the plot centre.

3) Map out the border of the plots using a measuring tape.

   a) Once the border has been measured out, the measuring tape can be replaced by flagging markers or flagging tape.

4) If a compass is available, align the width of the plot along the east/west axis, and align the length of the plot along the north/south axis.
   - For medium vegetation plots only, use a laser rangefinder to measure and record the slope in the north-south and east-west directions.

5) For all vegetation over 2m in height, please refer to “Measuring Carbon in Trees” (large vegetation plots).

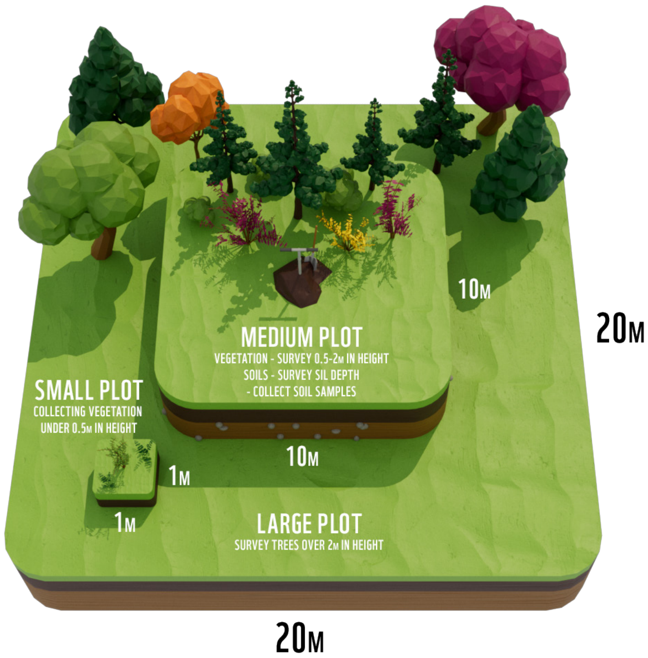
SECTION SUMMARY: PLOT AND SAMPLING DESIGN

- **Record the date, location, plot ID, latitude, longitude and elevation of the plot centre.**
- **Mark out the border of the plot using a compass, laser rangefinder and measuring tapes, and mark the plot border with flagging tape.**
- **Using a laser rangefinder, measure and record the slope in north-south and east-west directions (medium plots only).**
- **Map out any other plots planned for this area and repeat steps one to three for each plot.**

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/integrated plot design. This means setting up plots for each carbon pool that overlaps in a study area.

Nested/integrated 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.



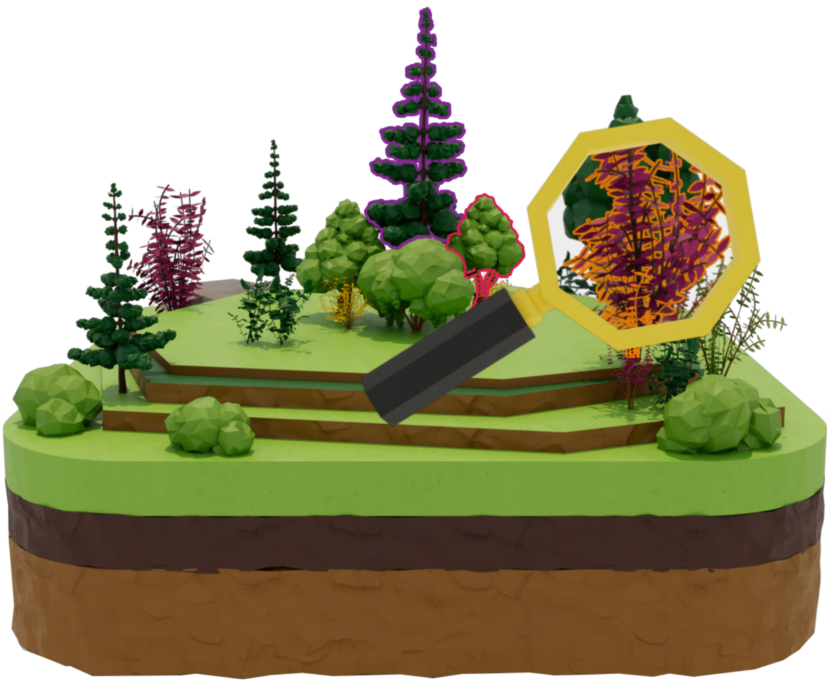
Schematic diagram of a nested/integrated plot design, where soils are sampled alongside the three vegetation types, within their respective large, medium and small plots.

3

SAMPLING PROTOCOLS

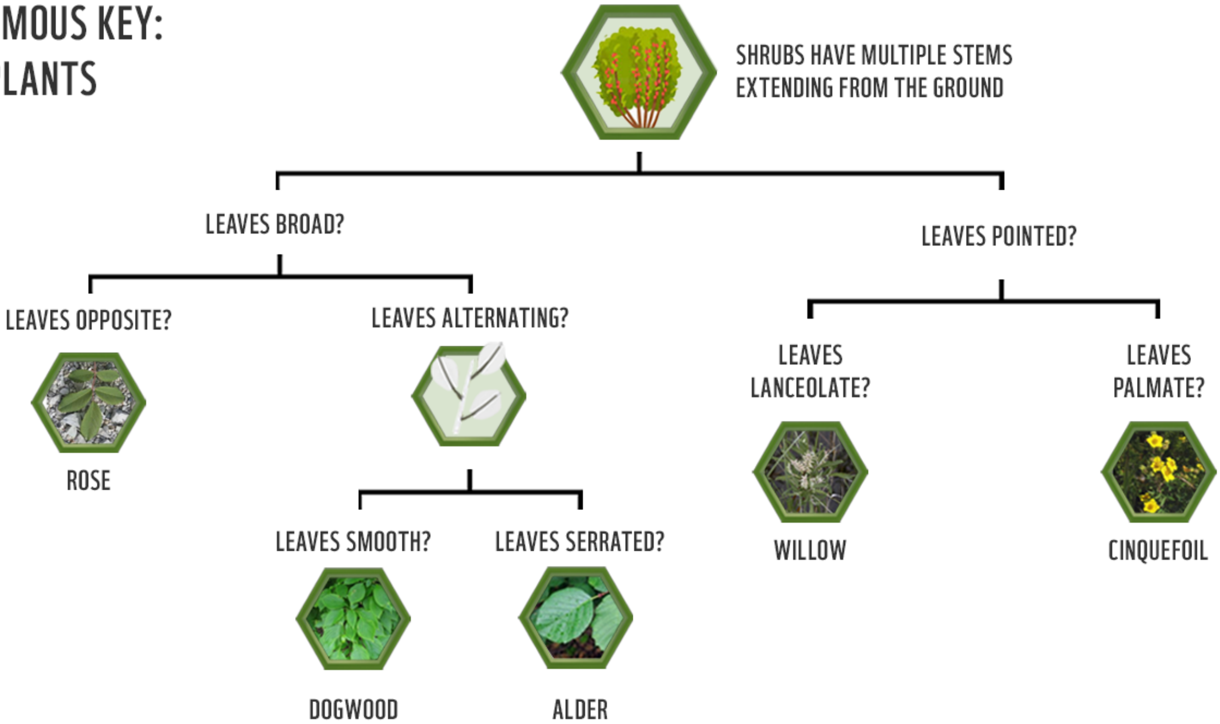
MEDIUM PLOT SAMPLING PROTOCOLS

With the plots mapped out, it is time to conduct surveys. For the medium plots, the goal is to systematically identify each individual plant species and obtain measurements for plant volume. This information will be used to estimate total biomass. Medium plots will primarily sample small trees, shrubs and occasionally some taller grasses.



1. Within the medium plot, systematically identify the species and measure all individuals between 0.5m (i.e., roughly knee-height) and 2m in height (i.e., roughly an arm's length above the head).
   a. Species identification can be done using a dichotomous key, or by using a mobile species identification application. A dichotomous key (meaning to "divide into parts") is a method of identifying an organism based on the species' observable traits. The method requires answering a series of statements with one of two options. Together, the statement answers lead to the correct species identification.
   b. It also helps to become familiar with the local plant communities before doing surveys, as species identification can initially be tedious.
   c. Some mobile applications are designed to recognize various tree attributes that can help with species identification. Some applications are Google Lens, LeafSnap, vTree and Seek by iNaturalist. There are several online resources available to find this information specific to the area of study.
   d. Instead of identifying species in the field, the field team may instead choose to take well-documented photos of each species (including the leaf, branching structure, bark and any buds, flowers or seeds) for later identification. Make sure to record in a notebook a unique photo identifier (such as photo number) alongside the measurements of each plant measured.

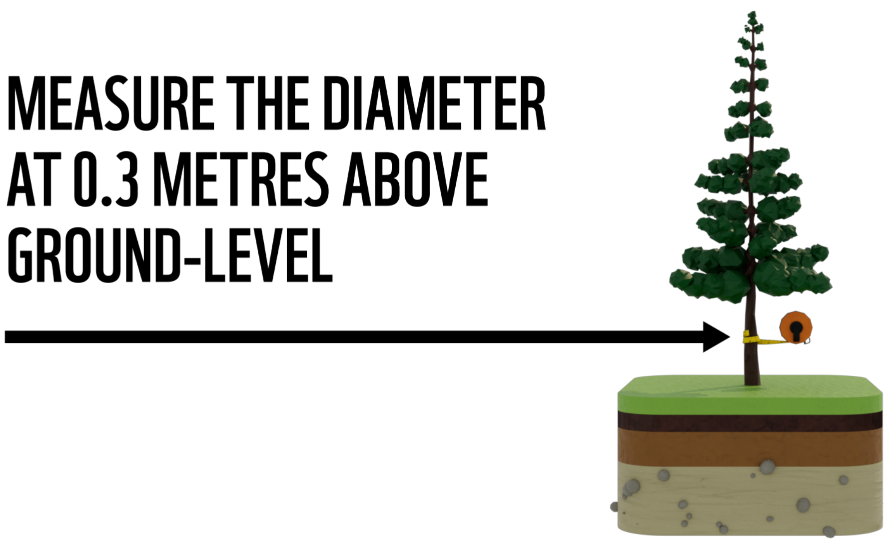
DICHOTOMOUS KEY: SMALL PLANTS



The above image depicts a dichotomous key for common small shrubs found throughout the Canadian Shield. Beginning at the top, a series of yes-or-no questions are followed in a "tree-like" manner, which lead to the next "branch" until we arrive at the species identification.

2. **Short-statured trees:** If the species in question is a small tree (i.e., single stem), measure the diameter of the tree stem in centimetres (cm) at 0.3m above ground level using a DBH (i.e., "diameter at breast height") tape.
   a. Record the species and diameter (cm) at 0.3 metres (m) height in a notebook.

MEASURE THE DIAMETER AT 0.3 METRES ABOVE GROUND-LEVEL



3. Shrubs and herbaceous plants: If the species in question does not have a single woody stem, but instead multiple branches emerging together from the earth, then it is a shrub. Instead of measuring the diameter of a shrub, measure its volume.
   a. Obtain the maximum height, length and width of the plant in metres (m).
      i. Maximum height is defined as the height of the tallest part of the plant measured from the ground.
      ii. Length, also called the line intercept cover, is a measure of the length between one end of the plant to the other, where the measurement is made parallel to the east-west plot lines.
      iii. Width runs perpendicular to length, measuring from one end of the plant to the other in the south-north direction.
   b. These measurements are best conducted with three field staff. Have two team members stand on either side of the plant, holding the measuring tape on either side of the plant while a third team member records the measurements in a notebook.
   c. Together, length and width provide the cross-sectional area (m^2) of the plant. Multiply length, width and height together to obtain the plant's volume (m^3).
4. To convert the measurements for volume to biomass and carbon stock for each individual plant, refer to the mathematical equations in the Appendix.

MEASURE THE MAXIMUM HEIGHT, LENGTH AND WIDTH

SECTION SUMMARY: SAMPLING MEDIUM VEGETATION PLOTS

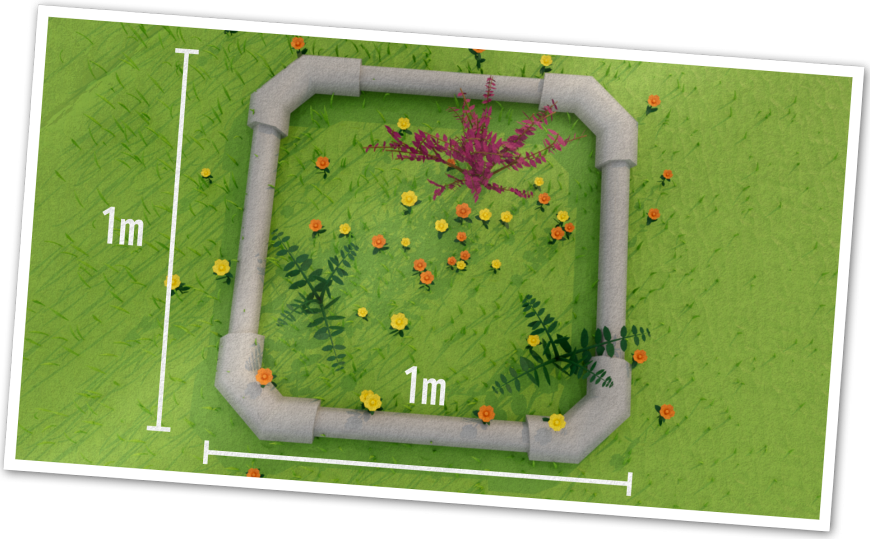
- **Using a systematic method (such as flagging all plants 0.5–2m in height before surveys), identify each plant. Record the unique species ID and species name. Another option is to take a photo of the plant components for later identification in the lab.**
- **If the species is a short-statured tree, measure the tree diameter (cm) of the stem at 0.3m in height and record this value in a notebook.**
- **If the species is a shrub or herbaceous plant, measure the plant's volume (m^3) instead of its diameter:**
  - **Measure the height (m) of the plant.**
  - **Measure the width (m) of the plant (east-west direction).**
  - **Measure the length (m) of the plant (north-south direction).**

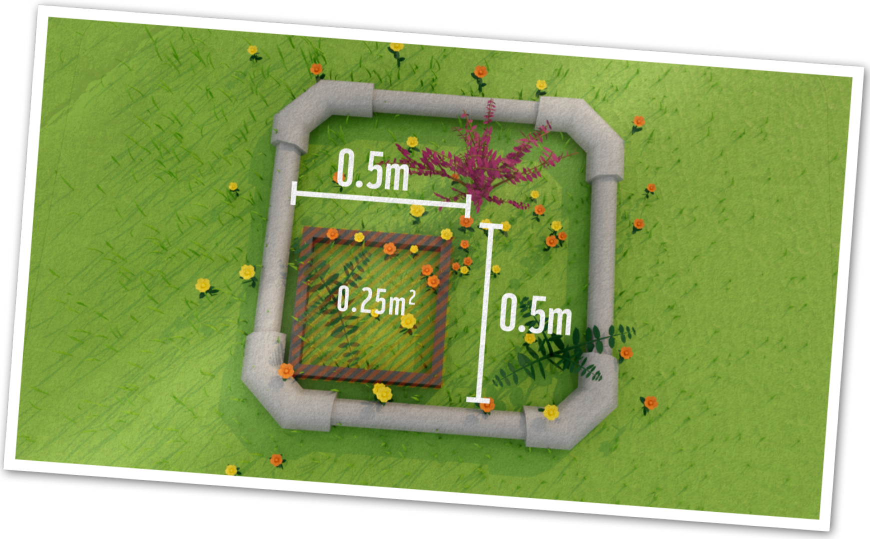
Record these values in a notebook.

Note: These measurements can be uploaded to the accompanying datasheets, which will automatically calculate the carbon stock value for each plant.

SMALL PLOT SAMPLING PROTOCOLS

There are multiple methods for estimating the carbon stock for vegetation below 0.5m in height. The most accurate method for determining the above-ground biomass of small plants is called the "clip-and-weigh" method. The "clip-and-weigh" method is a destructive sampling technique used to estimate the above-ground biomass of small vegetation. If non-destructive methods are desirable for future surveys, consult the other methods for estimating the ground cover of the species (see Appendix).





The "clip-and-weigh" steps are as follows:

1. Take photos of the plot directly above the plot centre. Make sure the boundary of the plot is visible in the photos. Using a 1-by-1m frame can help with this.
2. Within the 1-by-1m plots, section off a quarter of the plot, either by using a smaller, 0.5-by-0.5m square frame or a circle frame extending from the plot centre with a radius of 0.28m. Both the square and circle frames of these dimensions have an area of 0.25m^2.
3. Collect samples for all plants in the frame.
   a. Take a clipping of every single plant at 3cm above the ground level.
   b. Put these clippings into individual resealable bags labelled with the species, date and site identifier or coordinates before transferring them to a lab for analysis. See the section "Preparing samples in the lab" for lab protocols and the section "From in-field measurements to carbon stock" for instructions on carbon stock conversion.

TAKE A CLIPPING OF EVERY PLANT IN THE FRAME AT 3 CENTIMETRES ABOVE GROUND LEVEL

Sphagnum-rich bogs require their own sampling method (surface coring):

1. Using a mould or surface corer, retrieve the top 10–15cm of a sample of sphagnum moss.

2. Place the sample in a resealable bag labelled with the species, date and site identifier or coordinates to bring back to the lab.

3. In the lab, separate the living sphagnum from the non-living sphagnum. The living sphagnum will be prepared in the lab using the steps described in the section "Preparing samples in the lab."

Living sphagnum (colourful)

Non-living, actively decomposing peat (discoloured)


Photo credit: Cathal Doherty

SECTION SUMMARY: SAMPLING SMALL VEGETATION PLOTS

- **Lay out the 1-by-1m quadrat on the plot. Take a photo of the entire plot from directly above. Record the photo ID and plot ID.**
- **Section off one quarter of the plot by using a 0.25m² quadrat or a circle with a radius of 0.28m (0.25m²).**
- **Within this 0.25m² area, clip all vegetation under 0.5m at 3cm above the ground. Place each unique species clipping into its own resealable bag labelled with a unique plot ID, species name and date.**

Note: If the plot is within a sphagnum rich bog, taking a surface core sample is the best method for obtaining a live sample of sphagnum with a known area.

Preparing samples in the lab

For the plant samples clipped and bagged:

1) In a lab, dry samples in an oven between 50–80°C for 48–72 hours

2) Weigh the samples again to determine the weight of dry biomass. Record the weights in a notebook.

SECTION SUMMARY: PREPARING SAMPLES IN THE LAB

- **In a lab, dry samples in an oven between 50–80°C for 48–72 hours.**
- **Weigh sample again. Record this dry plant biomass in a notebook.**

5

SCALING FROM IN-FIELD MEASUREMENTS TO CARBON STOCK

FROM IN-FIELD MEASUREMENTS TO CARBON STOCK

Estimate total and average carbon stock of plots

Complete all calculations for all medium and small vegetation plots separately.

• Medium vegetation plots: Add together the individual carbon stocks of each plant to obtain the total carbon stock of the plot.

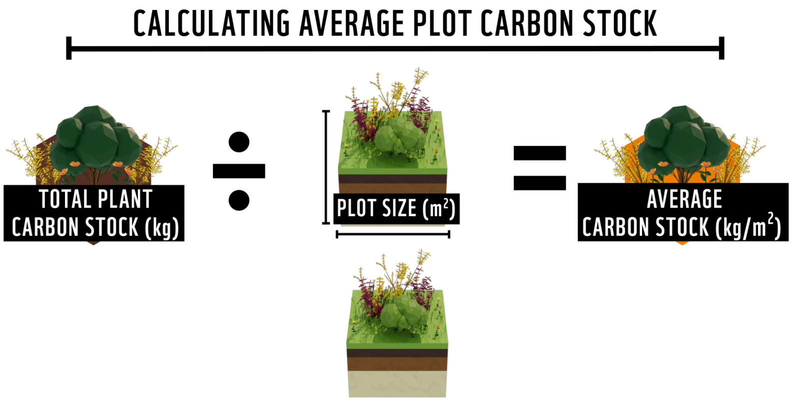
i. ***Equation 0.1*: Total carbon stock of medium vegetation plot (kg C) = sum of carbon stock of all plants (kg C)**

• Small vegetation plots: To estimate the total carbon stock of the plot, multiply the measured dry biomass of all the plants in the plot by the carbon conversion factor of 0.5.

i. ***Equation 0.2*: Total carbon stock of small vegetation plot (kg C) = sum of dry biomass of all plants (kg C) * 0.5**

To calculate average carbon stock (kg C/m^2) of the plot, add the total carbon stock (kg) of all individual plants measured and divide this value by the size of the plot (m^2).

• ***Equation 1:* Average carbon stock of plot (kg C/m2) = sum of carbon stock of plants (kg C) / plot size (m^2)**

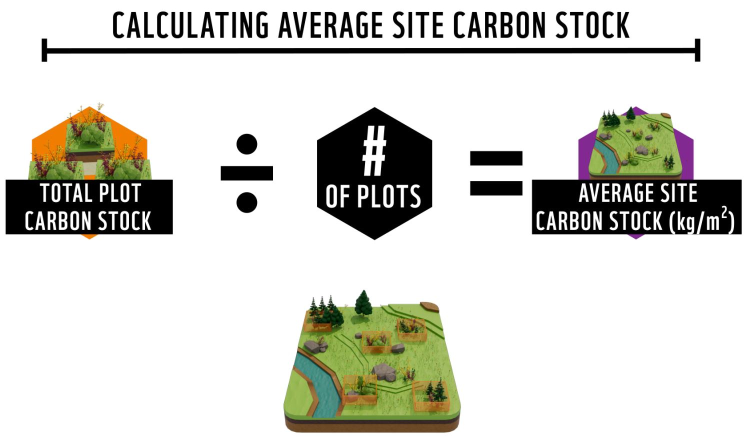


Scaling from plot to site to study area

Complete all calculations for all medium and small vegetation plots separately.

2) For each site, add all the plots' average carbon stocks and divide this value by the number of plots in the site (remember that all the plots are the same size). This is the <u>average</u> carbon stock of the study <u>site</u> (kg C/m^2).

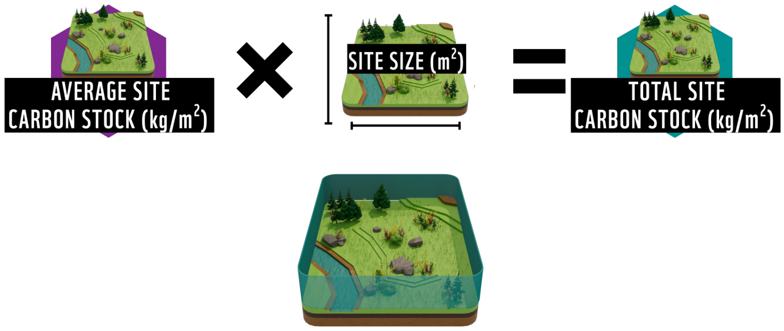
• ***Equation 2*: Average carbon stock of study site (kg C/m+) = sum of all the average carbon stocks of plots (kg C/m+) / number of plots**



3) 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).

- ***Equation 3*: Total carbon stock of study site (kg C) = average carbon stock of study site (kg C/m^2) * study site size (m^2).**

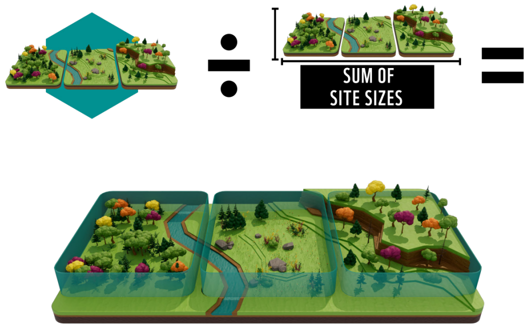
CALCULATING TOTAL SITE CARBON STOCK



4) 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).

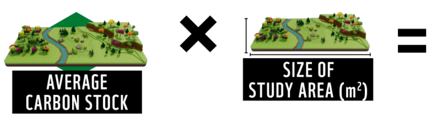
- ***Equation 4*: Average carbon stock of study area (kg C/m2) = sum of total carbon stocks of sites (kg C) / sum of site sizes (m^2)**

CALCULATING AVERAGE AREA CARBON STOCK



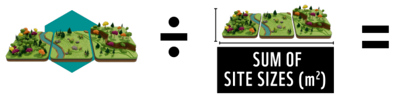
5) To obtain the total carbon stock of the study area (kg C), multiply the average carbon stock of the study area by the size of the study area (in metres square).

- ***Equation 5*: Total carbon stock of study area (kg C) = average carbon stock of study area (kg C/m^2) * study area size (m^2)**



TOTAL CARBON STOCK OF THE STUDY AREA

FROM IN-FIELD MEASUREMENTS TO CARBON STOCK



AVERAGE CARBON STOCK OF THE STUDY AREA

Add together the medium and small vegetation average carbon stock values to obtain the average carbon stock (kg C/m^2) of <u>all vegetation</u> below 2m in height. Similarly, add together the medium and small vegetation total carbon stock values to obtain the total carbon stock (kg C/m^2) of <u>all vegetation</u> below 2m in height.

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

For <u>both</u> the <u>medium</u> and <u>small</u> vegetation plots, <u>separately</u>:

SECTION SUMMARY:
ESTIMATE AVERAGE AND TOTAL CARBON STOCK FOR THE STUDY AREA

Calculate the average carbon stock (kg C/m^2) of each plot.

- **<u>Equation 1</u>: Average carbon stock of <u>plot</u> (kg C/m^2) = sum of carbon stock of plants (kg C) / plot size**

Calculate the average carbon stock of the site.

- **<u>Equation 2</u>: Average carbon stock of study <u>site</u> (kg C/m^2) = sum of all the average carbon stocks of plots (kg C/m^2) / number of plots**

Calculate the total carbon stock of all sites.

- **<u>Equation 3</u>: Total carbon stock of study <u>site</u> (kg C) = Average carbon stock of study site (kg C/m^2) * study site size (m^2)**

Calculate average carbon stock of the study area.

- **<u>Equation 4</u>: Average carbon stock of study <u>area</u> (kg C/m^2) = sum of total carbon stocks of sites (kg C) / sum of site sizes (m^2)**

Calculate total carbon stock of the study area.

- **<u>Equation 5</u>: Total carbon stock of study <u>area</u> (kg C) = average carbon stock of study area (kg C/m^2) * study area size (m^2)**

APPENDIX

A) Converting short-statured tree and shrub measurements to biomass with allometric equations: for all shrub species identified, the species and shrub volume will have already been measured from the field data. With this data it is possible to estimate the biomass for each individual shrub in the plot using the shrub-volume equation:

Shrub biomass (kg) = coefficient 1 *(volume (m^3))$^{\text{coefficient 2}}$

For short-statured trees, we can use the stem diameter at 0.3m above the ground inputted into the short-statured tree's stem diameter with the following biomass equation:

Short-statured tree biomass (kg) = coefficient 1 * (diameter (cm))$^{\text{coefficient 2}}$

Note: A table of values for coefficients 1 and 2 for shrubs and short-statured trees can be found in the accompanying data template.

B) Estimating per cent cover of ground vegetation in a 1-by-1m plot

There are many available methods for estimating the per cent cover of ground vegetation in a 1-by-1m microplot. A simple and common method is to divide the plot into smaller units (anywhere from 9–32 smaller squares) called **quadrats**. Below is a list of common techniques for estimating the per cent cover of ground vegetation, as well as a link to a helpful resource guide.

Links to resources for visually estimating per cent cover:

1. Visual cover estimation/Daubenmire method:
    a. LINK
    b. LINK
2. Point intercept method
3. Photo interpretation

REFERENCES

Flade, L., Hopkinson, C. & Chasmer, L. (2020). Allometric Equations for Shrub and Short-Stature Tree Aboveground Biomass within Boreal Ecosystems of Northwestern Canada. *Forests, 11*(11). https://doi.org/10.3390/f11111207

Muukkonen, P., Mäkipää, R., Laiho, R., Minkkinen, K., Vasander, H. & Finér, L. (2006). Relationship between biomass and percentage cover in understorey vegetation of boreal coniferous forests. *Silva Fennica, 40*(2). https://www.silvafennica.fi/article/340

Smith, W. B. & Brand, G. J. (1983). Allometric Biomass Equations for 98 Species of Herbs, Shrubs, and Small Trees. Research Note NC-299. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station. https://doi.org/10.2737/NC-RN-299

GLOSSARY

Average carbon stock: Measure of the amount of carbon per unit area, typically expressed in kg C/m^2 or tonnes per hectare (t/ha).

Daubenmire frame: A 20-by-50cm frame used for visually estimating the per cent cover of ground vegetation in a plot.

Diameter at breast height (DBH) tape: A tree-trunk measurement tool that automatically converts trunk circumference to diameter.

Destructive sampling: A sampling method where the objects of interest are fully removed from their environment.

Carbon stock: The amount of carbon in a carbon pool; can be expressed as an absolute value, such as in kilograms or tonnes, or as a relative value, such as kg/m^2 or t/ha.

Ecological services: The environmental benefits of the physical, chemical and biological functions of an ecosystem.

Ground vegetation: (For carbon measuring) all plants in a site that are below 0.5m in height.

Medium plot: A plot that is used to sample plants between 0.5–2m in height. Medium plots are typically between 16–10m^2 depending on the study area size, plant communities and variation across the site.

Microplot: A plot used to sample plants under 0.5m in height.

Non-destructive sampling: A sampling method where the objects (in this case, plants) of interest are not disturbed from their environment.

Per cent cover: The proportion a species or plant group covers relative to the amount of ground in a plot.

Plots: The specific areas within a site where sampling takes place.

Short-statured trees: Single stem trees below 2m in height.

Shrubs or herbaceous plants: Do not have a single woody stem, but instead multiple branches emerging together from the earth.

Study area: Distinct areas within a study region that differ in the types of ecosystems they include.

Study region: A large area that encompasses the ecosystems of interest for a study.

Sites: Specific areas within a study area used to set up and map plots.

Total carbon stock: A measure of the absolute value of the amount of carbon in a specific carbon pool, typically expressed in kilograms or tonnes.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WWF-Canada. 2024. Measuring Carbon in Vegetation (Non-Tree): A Supplemental Guide. World Wildlife Fund Canada. Toronto, Canada.