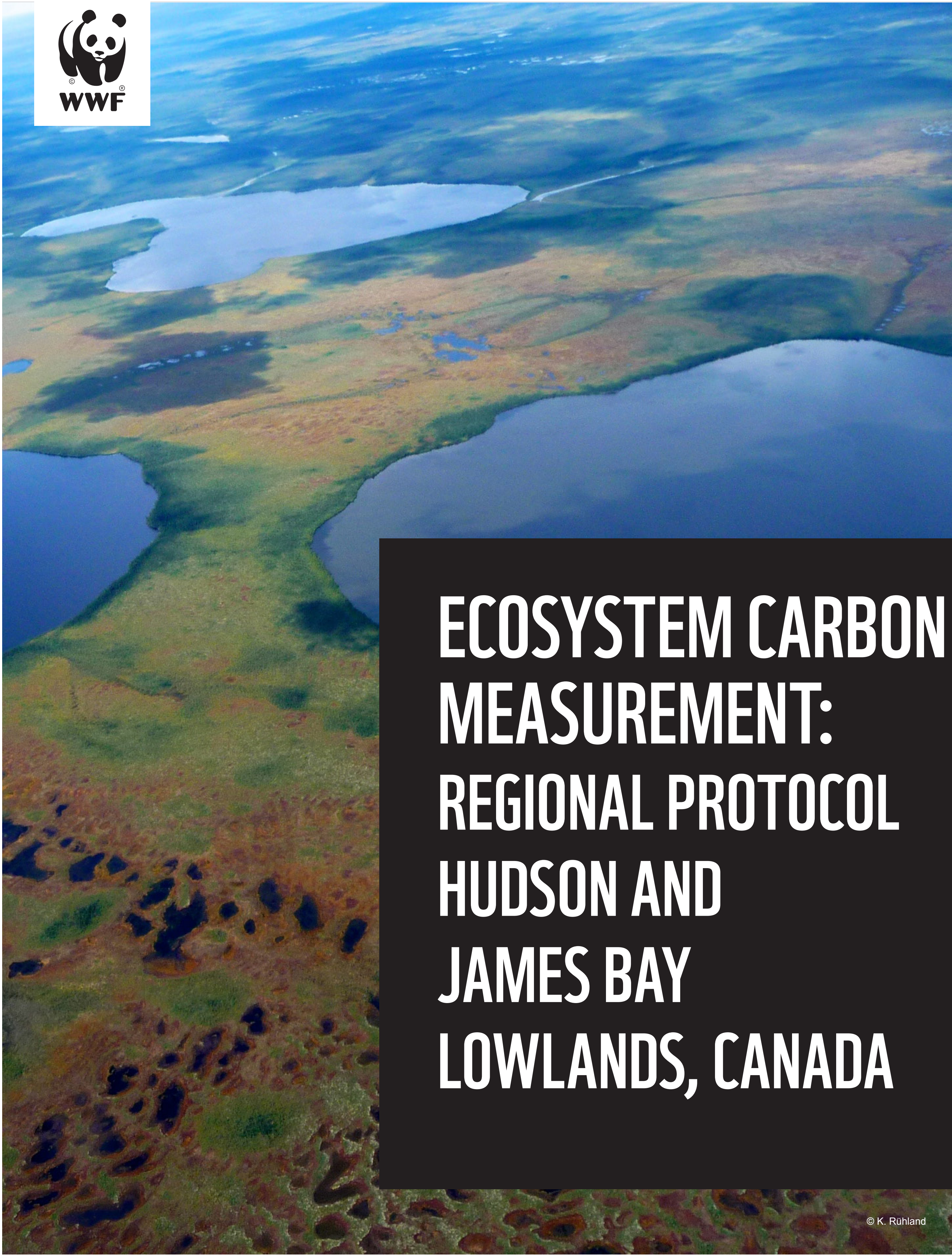
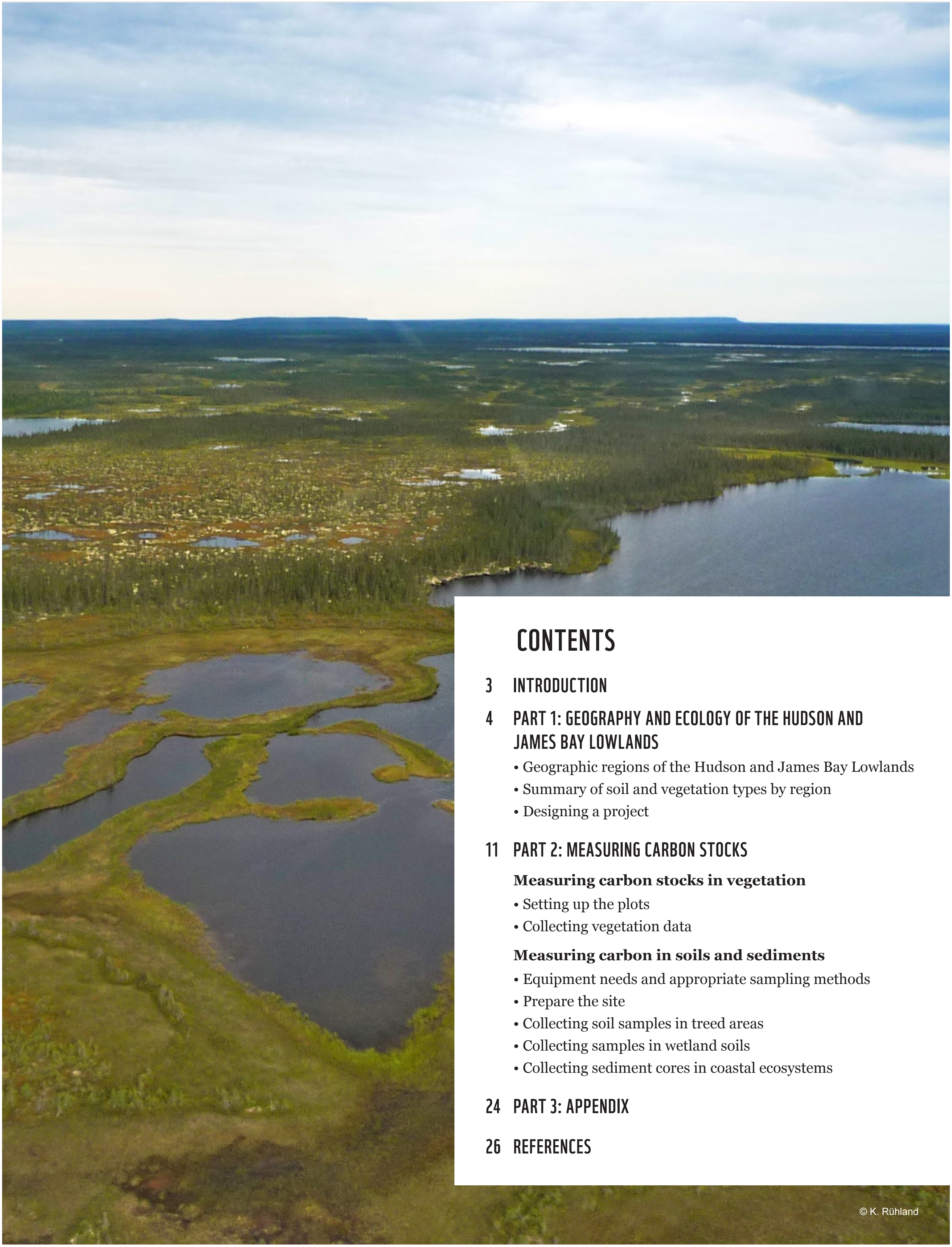


© K. Rühland

WWF

ECOSYSTEM CARBON MEASUREMENT: REGIONAL PROTOCOL HUDSON AND JAMES BAY LOWLANDS, CANADA



CONTENTS

© K. Rühland

INTRODUCTION

Field sampling is essential for estimating carbon stock, which is the amount of carbon stored in an ecosystem at a specific point in time. The carbon stock of an ecosystem is made up of two main carbon pools:

1) Vegetation or "biomass," including:

- trees
- shrubs
- herbaceous plants

2) Soils, including:

- peat soils (consisting of partially decomposed plant materials)
- non-peat soils (consisting of a mix of decomposed plant matter and other mineral sediments)

Ecosystems can vary in soil types, vegetation and geographic characteristics. Measuring their carbon pools therefore requires different methods and tools depending on the ecosystem being studied. Having background knowledge about your study area can help guide your project, anticipate conditions you might encounter and determine the specific equipment needed to accurately estimate carbon stocks.

This field guide is intended for use in the ecosystems found in the Hudson and James Bay Lowlands. It is divided into two parts:

Part 1 introduces the diverse landscapes in the Hudson and James Bay Lowlands, highlighting common vegetation communities and soil types in each region. This information will assist in developing a strategy for a carbon measurement project.

Part 2 contains abbreviated in-field carbon measurement instructions (full guides for each ecosystem type are available through WWF-Canada's Carbon Measurement Learning Library) as well as specific instructions for measuring in ecosystems in the Hudson and James Bay Lowlands.

1 GEOGRAPHY AND ECOLOGY

GEOGRAPHY AND ECOLOGY OF THE HUDSON AND JAMES BAY LOWLANDS

REGIONAL OVERVIEW

The Hudson and James Bay Lowlands extend from the top of the Canadian Shield to the southern edge of the Hudson Bay and James Bay waterbodies. The land here rose slowly from the prehistoric Hudson Bay seawater over the past 7,500 years in a process called "isostatic rebound," where land masses lift up after the weight of glaciers is removed or reduced. Due to the flatness of this area, the water drainage is poor, resulting in vast wetlands, often consisting of three or more metres (m) of peat. The area is divided into three distinct geographic regions for the purposes of this guide (Fig. 1).

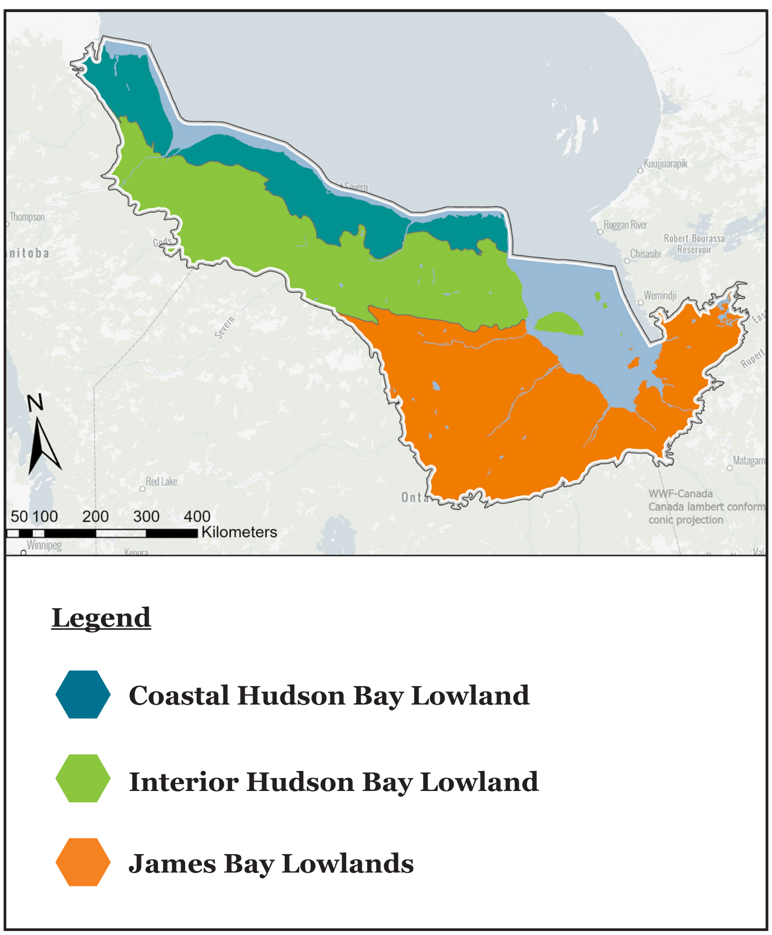


Figure 1: *Map of the geographic regions of the Hudson and James Bay Lowlands, highlighting the Coastal Hudson Bay Lowland, the Interior Hudson Bay Lowland, and the James Bay Lowlands (data from Agriculture and Agri-Food Canada, 2024).*

COASTAL HUDSON BAY LOWLAND

This region comprises mostly mudflats, coastal marshes and young wetlands on the shores of Hudson Bay. More than 70 per cent of the land is covered by wetlands: open fens, open bogs, treed bogs and marshes. Small ponds and lakes interspersed with fens occupy a small portion of the region. On drier sites near the coast, tundra ecosystems sit on top of permafrost or underlying bedrock.

A diagnostic feature of this region is the presence of continuous permafrost, which is frozen soil with the highest carbon stocks of any soil type in the area (Table 1). Permafrost significantly impacts the shape of the landscape and how water flows through the ecosystem. In abundance are also frozen wetlands, called palsas, which form frozen mounds of peat. Of concern is the susceptibility of permafrost melt to a warming climate and its potential effect on fish and wildlife habitat.

INTERIOR HUDSON BAY LOWLAND

Situated between the Coastal Hudson Bay Lowland region to the north and the Canadian Shield to the south, the Interior Hudson Bay Lowland contains some of the largest and deepest peat deposits in the world, and the highest average carbon stock in Canada. The predominant land cover types in this region are treed and open bogs, sparse forest, treed and open fens, and open water bodies.

Discontinuous permafrost—areas where permanently frozen soils are interspersed with patches of unfrozen soils (Fig. 2)—is distributed across this region. The thawing and freezing of the soils here significantly affect the structure of the ground, leading to diverse landscapes. As with the Coastal Hudson Bay Lowland, a significant portion of the Interior Hudson Bay Lowland is susceptible to climate change-fuelled melting of the frozen soil.

JAMES BAY LOWLANDS

Situated south-east of the Hudson Bay Lowlands, the James Bay Lowlands contain the most diverse landscapes of the three regions, including an abundance of treed and open fens, treed and open bogs and open water. Forests are also abundant, with coniferous forests as the predominant forest class, followed by sparse forest. This region notably includes the most extensive treed fens in the Hudson and James Bay Lowlands, particularly along the Moose River basin.

SOIL AND VEGETATION IN THE HUDSON AND JAMES BAY LOWLANDS

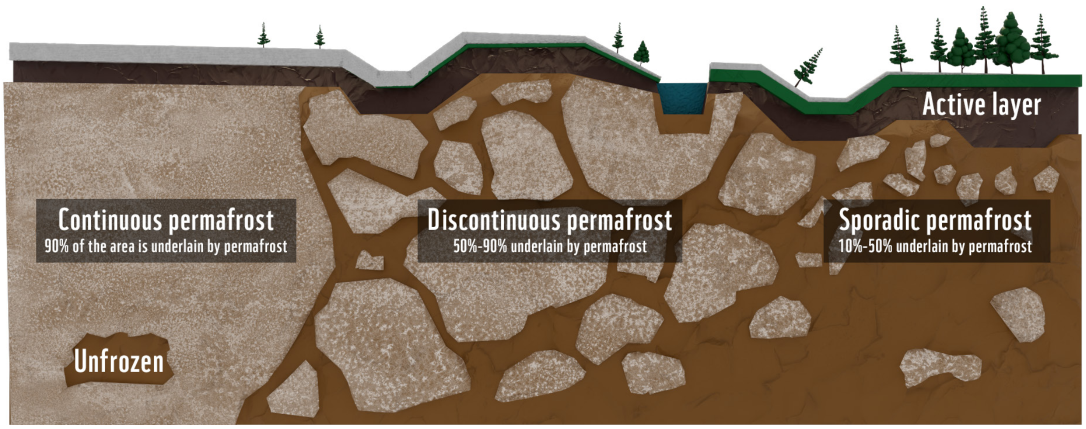


Figure 2: *Illustration showing the difference between continuous, discontinuous and sporadic permafrost.*

Understanding these different regions is crucial for carbon measuring and monitoring projects because each region supports different types of vegetation and soil. Ecosystems can also vary considerably within each region, largely as a result of differences in water flow, nutrients and local climatic conditions. Figure 3 summarizes the effects of these three factors on the soil and vegetation properties across the Hudson and James Bay Lowlands.

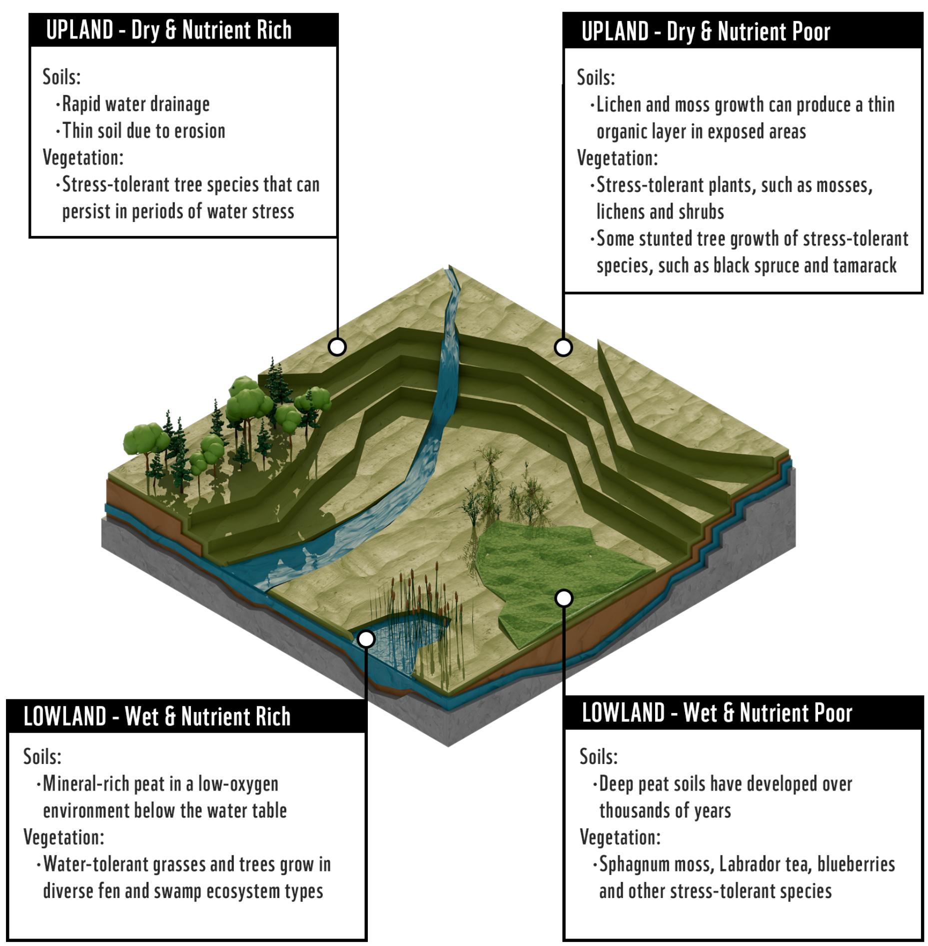


Figure 3: *Common soil properties and associated vegetation communities of the Hudson and James Bay Lowlands across gradients of nutrients, micro-climate and water content.*

Table 1: *Summary of carbon stocks (data from Sothe et al., 2022) for regions in the Hudson and James Bay Lowlands, separated into soil carbon, forest biomass carbon (including above-ground biomass, below-ground biomass and downed-woody biomass) and total carbon (soil + forest biomass). Maps for each component can be found in the Appendix (Fig. 7).*

Region	Total area of region (ha)	Area of terrestrial soil cover (ha)	Average soil carbon stock (kg/m²)	Total soil carbon stock *1 metre [m] depth;* (kilotonnes)	Area of forest cover (ha)	Average forest biomass carbon stock (kg/m²)	Total forest biomass carbon (kilotonnes)	Total carbon *soil carbon + forest biomass carbon* (kilotonnes)
COASTAL HUDSON BAY LOWLAND	8,695,723	5,899,995	111.7	6,590,294	3,205,639	2.3	73,729.70	6,664,023
INTERIOR HUDSON BAY LOWLAND	16,650,620	12,340,578	121.1	14,944,440	9,669,254	2.8	270,739.10	15,215,179
JAMES BAY LOWLANDS	19,496,750	16,756,018	97.4	16,320,362	13,930,570	3.5	487,570.00	16,807,932

ECOSYSTEM SPOTLIGHT

Hudson Bay bog peatlands

These peatlands are vast, waterlogged ecosystems formed over thousands of years as sphagnum moss and other plant materials accumulated vertically in oxygen-poor, nutrient-poor and acidic conditions.

Organic materials have built up in water-saturated areas, forming layers of peat several metres thick.

As the peat grows above the water table, it primarily receives water from precipitation, making it nutrient-poor compared to peat found in fens, which is fed by nutrient-rich groundwater.

This bog peat can store vast amounts of carbon because the release of carbon from decomposition is inhibited by the waterlogged, low-oxygen environment.

SUMMARY OF SOIL AND VEGETATION TYPES BY REGION

Knowing the types of soil and vegetation of a study area is crucial for choosing the appropriate method to collect samples and design a project effectively. The information below and Figures 4 and 5 provide detailed information about the soil and vegetation commonly found in each region. Use this information to answer some key questions that will guide your carbon measuring and monitoring work:

1. What kinds of soils and vegetation can I expect to find in my study area?
2. Based on the expected soils and vegetation, what equipment is most suitable for this specific ecosystem?
3. Which carbon pools am I focusing on?
4. How can I design a project that covers all these components effectively?

COASTAL HUDSON BAY LOWLAND

- **Soils:** Primarily undecomposed organic peats (48%), frozen cryosols (26%), brunisols and some regosols.
- **Vegetation:** Short, water-adapted species like willows, sedges and blueberries. Stunted conifers (spruce, tamarack) in sheltered spots.
- **Sampling:** Difficult due to marsh/mudflat mosaics and permafrost. Use surface cores with peatland techniques. Most vegetation <0.5m in height.

INTERIOR HUDSON BAY LOWLAND

- **Soils:** Thick peat layers over glacial sands/silts. Organic soils dominate; forest soils cover only 4%.
- **Vegetation:** Sedge fens, dwarf birch, willows; dry sites support tamarack and black spruce; taiga along ridges.
- **Sampling:** Peat depths 1–3m. Peat corers preferred. Tree heights need to be recorded for biomass estimates.

JAMES BAY LOWLANDS

- **Soils:** 89% organic, with mineral soils in high water areas. Sporadic permafrost and underdeveloped coastal flats.
- **Vegetation:** Black spruce, tamarack, open fens and bogs, and developed forests in protected, well-drained zones.
- **Sampling:** Use peat corers for deep soils and open-barrel for surface. Forests vary in stature; tree measurement required.

LAND COVER

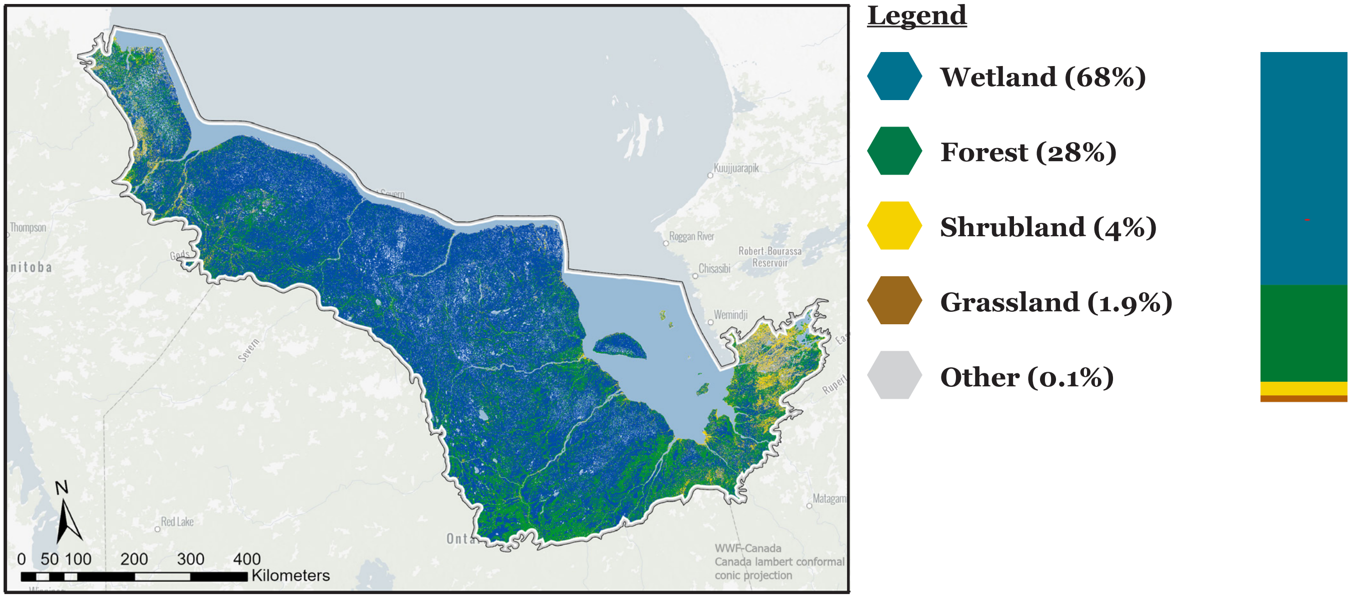


Figure 4: *(Left) Map of ecosystem and land cover class for the Hudson and James Bay Lowlands. (Right) Bar graph showing proportion of each class at a 30-by-30m resolution (data from Natural Resources Canada, 2020).*

SOIL GREAT GROUPS

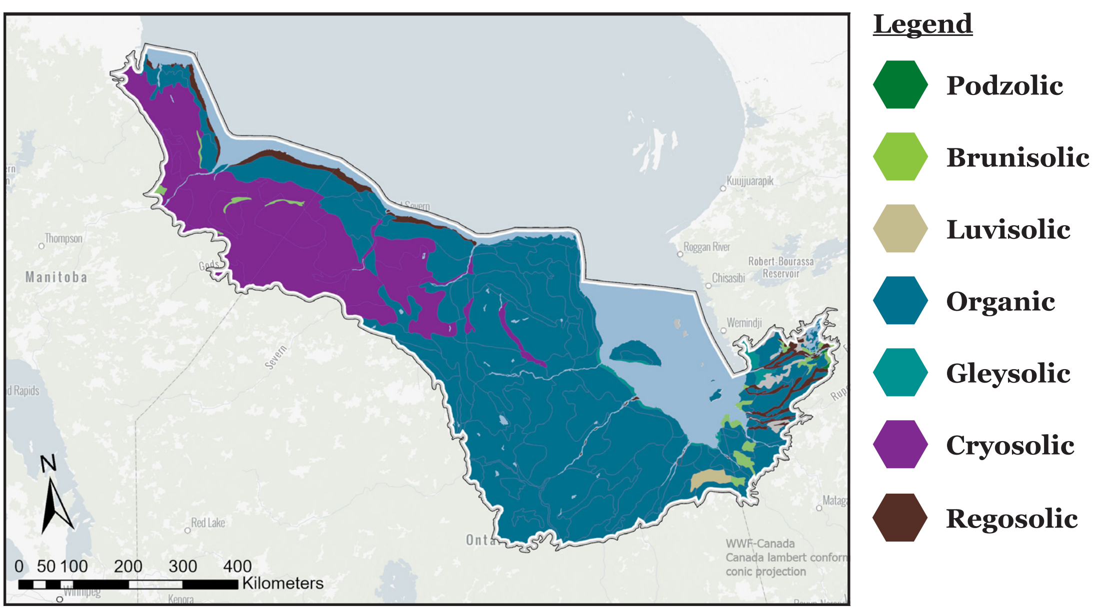


Figure 5: *Soil map of the Hudson and James Bay Lowlands, divided into ecosystem type and soil order (from Canadian System of Soil Classification) and the distribution of these soils in the Hudson and James Bay Lowlands (data from the Canadian National Soil Database, 2021).*

Table 2: *Summary of the soil carbon stocks (1m depth) for each soil component by ecosystem type (forest, wetland, frozen [cryosol] and undeveloped [egosol)] and soil order as shown in Figure 5 (data from Sothe et al., 2022).*

Soil type	Soil type coverage (ha)	Average soil carbon stock (1m depth; kg/m^2)	Total carbon stock (kilotonnes)
FOREST SOIL	748,951	66	494,308
Podzolic (sandy/loamy soils; compact and brittle)	39,163	43.5	17,036
Brunisolic (less developed forest soils; faint horizons)	544,383	75.8	412,642
Luvisolic (loamy forest soils; compact and consolidated)	165,405	39.0	64,508
WETLAND SOIL	23,711,378	102.4	24,280,541
Organic (deep, carbon-rich soil; heavily saturated with water)	23,373,761	102.4	23,934,731
Gleysolic (prolonged water saturation; lack mineral-organic surface soils; very low organic carbon)	337,618	100.8	340,319
UNDEVELOPED **Regosol** (no distinguishable soil layers; mineral-rich and highly varied)	980,945	76.1	746,499
FROZEN **Cryosol** (occur in cold environments where a layer of permanently frozen soil occurs within the soil profile; also called permafrost)	9,316,755	130.9	12,195,632

ECOSYSTEM SPOTLIGHT

Forested peatlands in James Bay

Forested peatlands are a dominant feature of the James Bay Lowlands. Like bog peatlands, these ecosystems accumulate peat over thousands of years in cool, waterlogged conditions, creating deep layers of peat. Unlike bogs, forested peatlands also support tree growth.

These ecosystems can receive water from both precipitation and ground water, which affects the amount of nutrients in the ecosystem.

Acidic, nutrient-poor areas have stunted tree growth in groundcover dominated by sphagnum mosses, whereas nutrient-rich ecosystems have water tables at about ground level.

DESIGNING A PROJECT

Designing your project depends on your goals. For more information on designing a project, please refer to the guide "Carbon Measurement: Sampling Design," in WWF-Canada's Carbon Measurement Learning Library, which includes information on:

A) **Sample allocation (how many samples are needed)**, which depends on how big the area of interest is and the degree of accuracy you wish to achieve in your estimates.

B) **Sample distribution (where to take your samples)**, which can be achieved using a statistically rigorous sampling approach (i.e., random, systematic or stratified-random), or by convenience, depending on your project goals. Be sure to consider the ecosystems and soil types where you are sampling (Fig. 5), as they may affect the anticipated carbon stock (Table 3).

In addition to the sampling design resources, Table 3 (in Appendix) summarizes relevant carbon measurement protocols for the Hudson and James Bay Lowlands region for communities interested in participating in larger-scale projects, and points to the federal and international standards associated with forest carbon monitoring projects.

2 MEASURING CARBON STOCKS

To estimate the carbon stock in ecosystems, you'll need to survey and collect samples from different carbon pools, including soils, biomass, or both. If you aim to measure multiple carbon pools in the same area, you can use an "integrated plot design." This means setting up overlapping plots.

Here's how it works:

A) **Create separate plots** for large vegetation, medium vegetation, small vegetation and soil carbon with the same centre mark, such that the plots are overlapping (Fig. 6).

B) **Collect data** for each carbon pool within their respective plots. Consider the order in which the carbon pools are sampled; to avoid damaging samples, the order is usually small vegetation ⟶ medium vegetation ⟶ large vegetation ⟶ soils. This ensures no samples are damaged from another sampling method.

C) **Extrapolate values to the study area and add them up to obtain** the total ecosystem carbon stock of a study area.

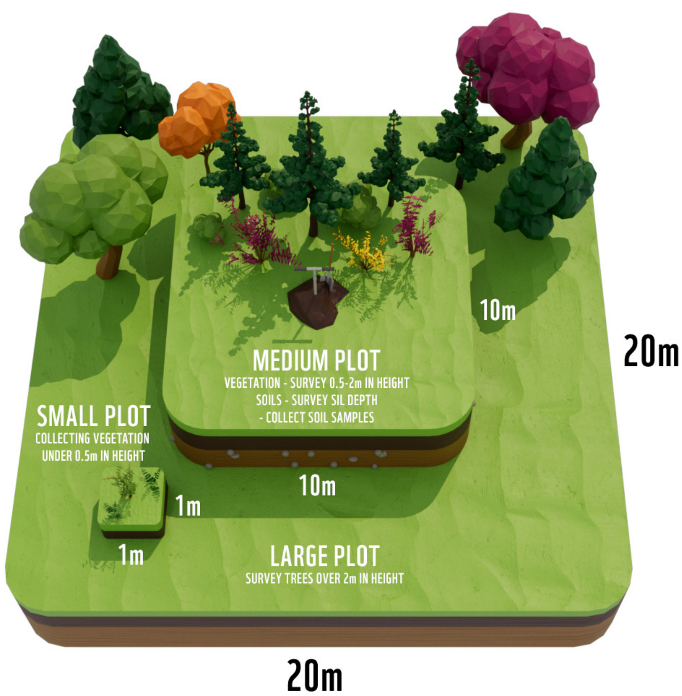


Figure 6: *Integrated plot design where soils are sampled alongside the three vegetation types, within their respective large, medium and small plots.*

MEASURING CARBON STOCKS IN VEGETATION

Carbon measurement of vegetation involves categorizing plants based on their heights in three groups:

A) **Large vegetation** (trees): plants over 2m in height.

B) **Medium vegetation** (shrubs and short-statured trees): plants that range from 0.5 to 2m in height.

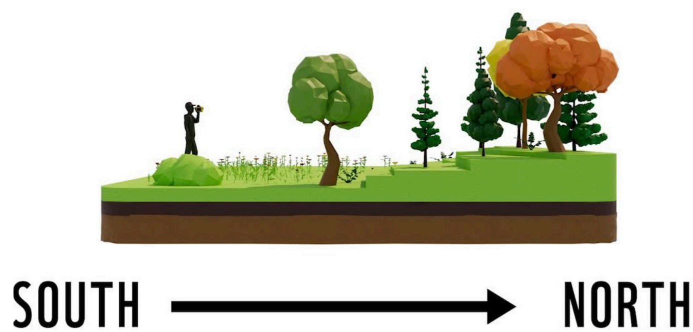
C) **Small vegetation** (ground vegetation): plants that are under 0.5m in height.

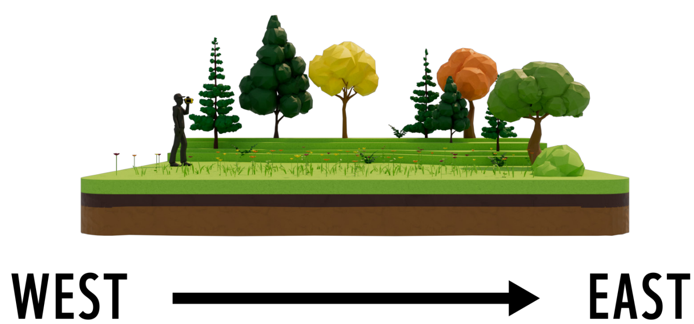
SETTING UP THE PLOTS

For each plot:

- **Record** the **date, location, plot ID, latitude, longitude** and **elevation** of the plot centre.
- For large and medium plots:
  - Mark out the border of your plots using a compass, laser rangefinder and measuring tapes, marking the trees on the border with flagging tape.
  - Using a laser rangefinder, **measure** and **record slope** in both the north-south and east-west directions.
- For small plots:
  - Mark out your plots using a compass and 1m-by-1m quadrat.

If additional sampling is being conducted within the same plot (e.g., measurements of soil carbon or other biomass), be sure to avoid disturbing these sample locations.

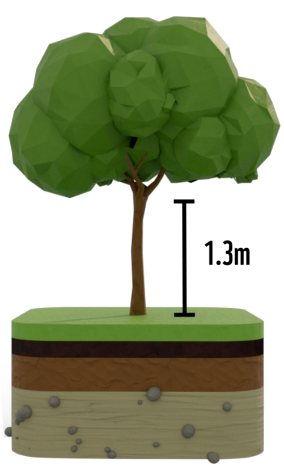




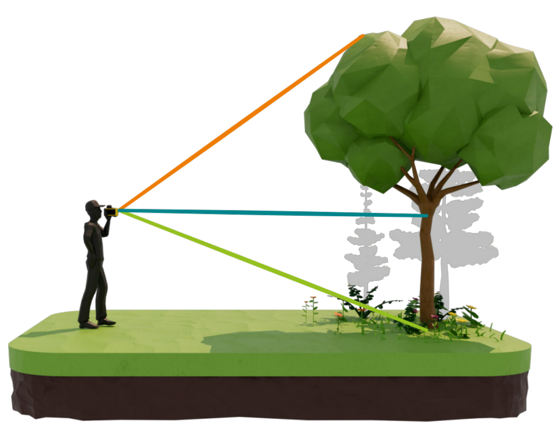
COLLECTING VEGETATION DATA

LARGE VEGETATION PLOTS (trees)

- In a systematic way (such as flagging each tree before surveys), choose a tree to measure and identify the species. **Record** the **tree ID** and **species name**.
- Measure the tree diameter at breast height (DBH). **Record** the **DBH (cm)** in a notebook or datasheet.
- Measure the tree height using a laser rangefinder. **Record** the **tree height (m)**.
- Repeat this for all trees in your plot.
- Input data into the accompanying datasheets found on WWF-Canada's Carbon Measurement Learning Library to calculate the carbon mass of each tree.

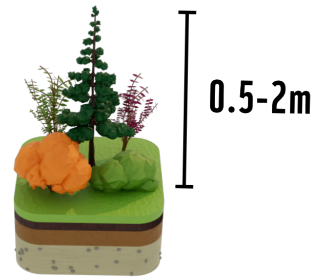


TREE HEIGHT REQUIRES THREE MEASUREMENTS

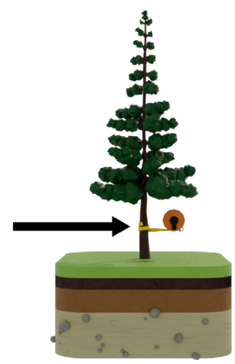


1. YOUR DISTANCE FROM THE TREE (IN METRES)
2. ANGLE TO THE TREE TOP
3. ANGLE TO THE TREE BASE

MEDIUM VEGETATION PLOTS (trees and vegetation)



- 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 (diameter at stem height, or DSH) and record this value in a notebook.

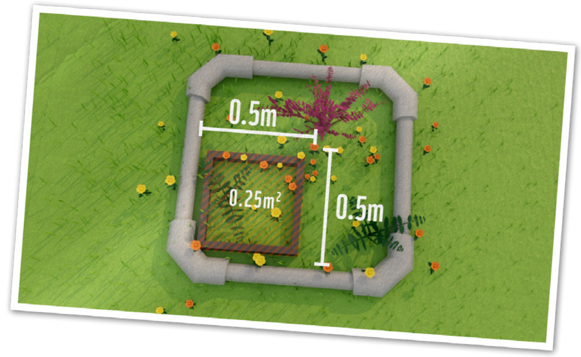


- If the species is a **shrub** or **herbaceous plant**, measure the plant's volume (m^3) instead of its diameter:
  - Measure the height (m) of the plant.
  - Measure the width (m) of the plant (east-west direction).
  - Measure the length (m) of the plant (north-south direction).
- **Record** these values in a notebook.

- **Upload** the data to the accompanying datasheets found on WWF-Canada's Carbon Measurement Learning Library, which will automatically calculate the carbon stock value for each plant.

SMALL VEGETATION PLOTS

- Take a photo of the entire plot from directly above the quadrat. **Record** the **photo ID** and **plot ID**.



- Section off one quarter of the plot by using a $0.25m^2$ quadrat or a circle with a radius of 0.28m ($0.25m^2$).

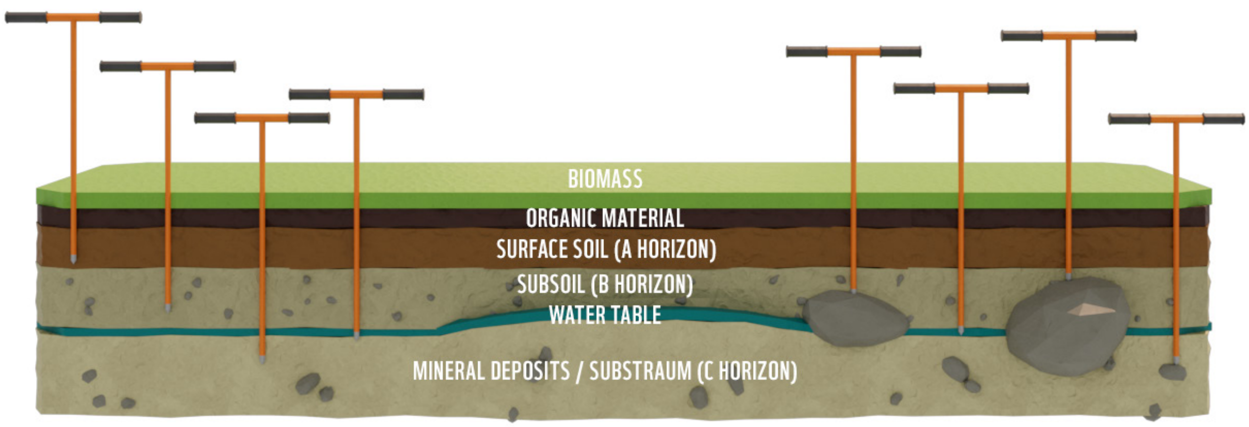
- Within this $0.25m^2$ area, clip all vegetation under 0.5m at 3cm above the ground. Place each unique species clipping into its own resealable bag labelled with a unique plot ID, species name and date.

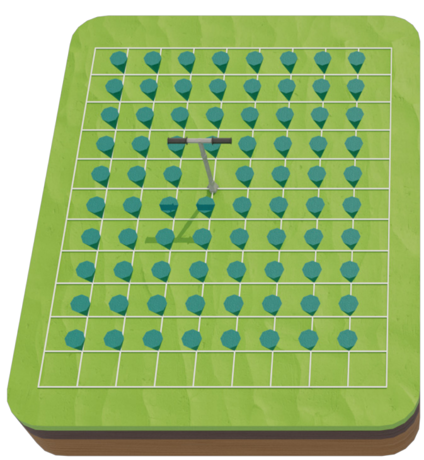
MEASURING CARBON IN SOILS AND SEDIMENTS

EQUIPMENT NEEDS AND APPROPRIATE SAMPLING METHODS

The equipment and methods for collecting soil samples depends on the water content and condition of the soil. Across the Hudson and James Bay Lowlands, soil conditions vary, from well-drained, dry soils with shallow layers of organic matter and topsoil in upland areas to poorly-drained, wet soils with more organic materials in lowland areas that may be saturated. The water table depth will often dictate the appropriate sampling equipment, as wet soils typically require closed-barrel corers, and dry soils are better taken with open-barrel corers.

Use a soil probing tool to measure the depth of the soil at regular intervals (every 10-100m) in a grid pattern across the study sites. The number of sample points depends on the size of the site, but there should be enough soil depth measurements to cover the variation across the study site.





Example survey grid, where at each dot a measurement of peat depth is taken and recorded. This information is used to understand the variation in peat depths across the site, which will help to ensure sampling is effective.

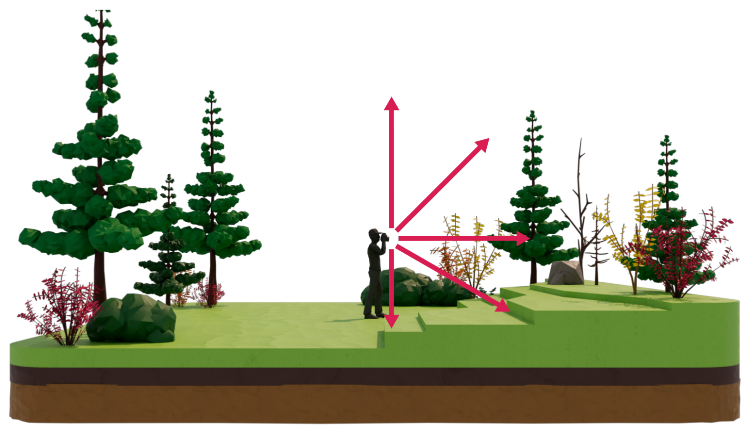
Based on your investigations, plots can be mapped out within each site to capture the variability in soil depths across the study site. The larger the site and the more variation in soil depth, the more plots you'll need. Here is a basic plot design for setting up study plots:

Step 1: Establish plots within the site to capture the variation in soil depth.

Step 2: Survey every 1m-by-1m within a 10m-by-10m plot to ensure the coring/sampling locations are representative of the plot area.

PREPARE THE SITE

- **Record** the **Core ID**. 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
- Find a flat area close to the coring spot, lay down a tarp and prepare the required equipment.

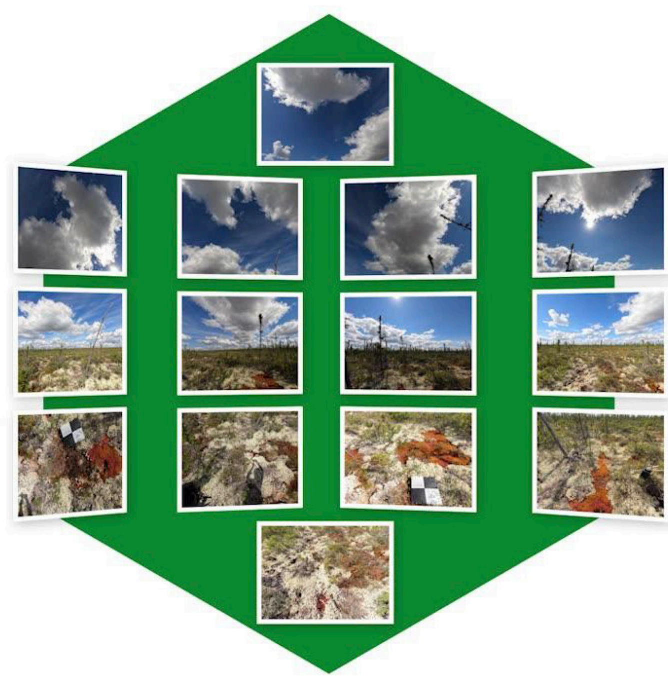


14 PHOTOS

3 PHOTOS FOR EACH CARDINAL DIRECTION

1 DOCUMENTING VEGETATION

1 DOCUMENTING CANOPY COVER



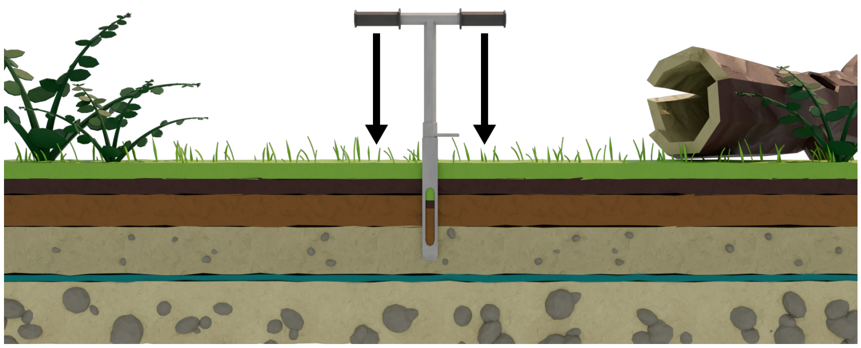
COLLECTING SOIL SAMPLES

COLLECTING SOIL SAMPLES IN FORESTS

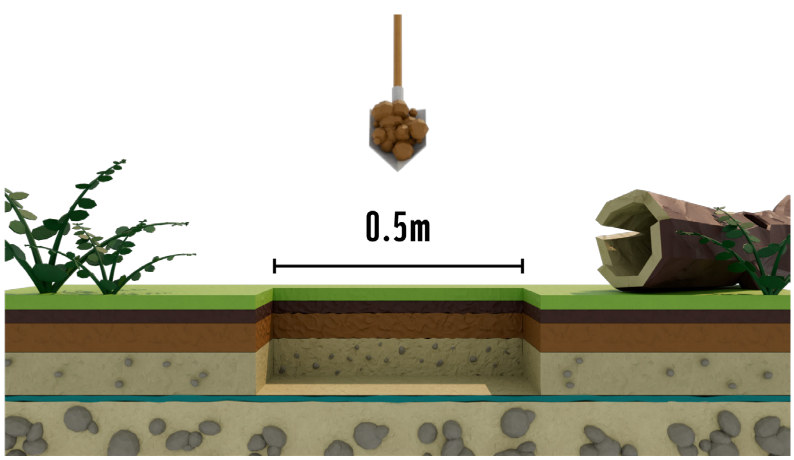
Forested ecosystems in the Hudson and James Bay Lowlands have diverse soil properties, ranging from upland areas with thinner soils to the forested swamps heavily saturated with water.

Here are two recommended methods for collecting soil samples in this region:

1. **Soil coring:** Use this method in areas where the soil is softer, holds together well, and has noticeable layers of organic matter or topsoil.



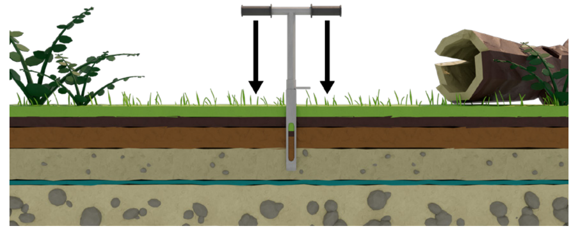
2. **Soil pit digging:** Use this method if the soil is too hard and/or too loosely packed (i.e., breaks apart easily) for soil coring.



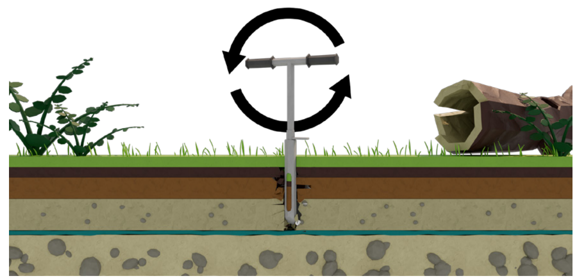
NOTE: In some situations, it may be practical to use both methods.

METHOD 1 – SOIL CORING

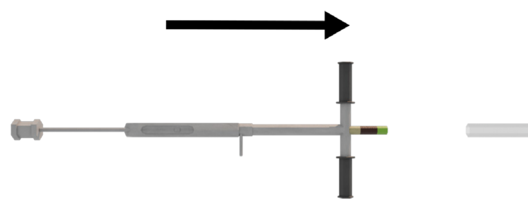
1. Gently push the corer into the soil, keeping it as straight as possible.



2. With the corer fully inserted, twist and jiggle the corer to release the bottom part of the core sample from the base sediment.



3. Remove the corer with the sample inside. Keep pressure on the bottom of the corer to prevent the sample from falling out.

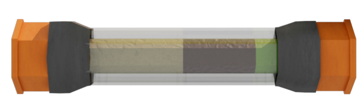


4. Turn the corer horizontally and place a plastic core sleeve around it.

5. 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.

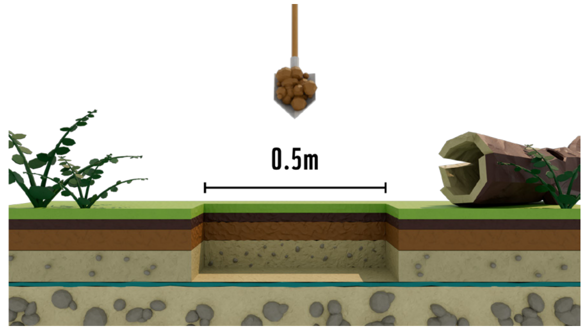
6. Measure and **record** the **core length** and the **depth of the hole**.

7. Label the sample and place it in a cooler.



METHOD 2 – DIGGING SOIL PITS

1. At the selected site, dig a hole 0.5m wide and to the desired sampling depth.
2. For each soil layer, **record** the **depth interval**, **colour** and **texture**.



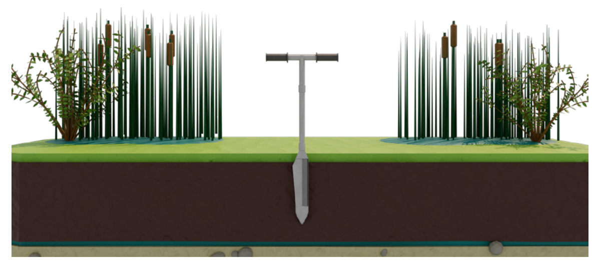
3. Label resealable bags with a unique Core ID and sample depth interval for each layer.
4. With a soil sampling ring/bulk density disk, obtain a sample from the middle of each of the soil layers and transfer each of the samples to its respective labelled bag.
5. **Note:** Additional samples from each layer can be collected and transferred to a separate bag.
6. Place samples in a cooler.

COLLECTING SAMPLES IN WETLAND SOILS

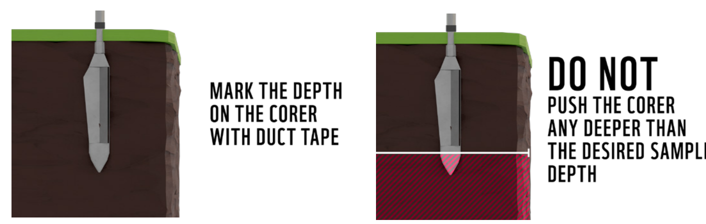
If the soil is heavily saturated by water, such as in a bog, fen or swamp ecosystem, then the soil will be too unconsolidated to use an open soil corer and the water level will be too high to dig a soil pit. Therefore, specialized sampling tools are required. A tool called a Macaulay peat corer is recommended to extract soil samples from wetlands.

STEP 1: EXTRACT A CORE SAMPLE

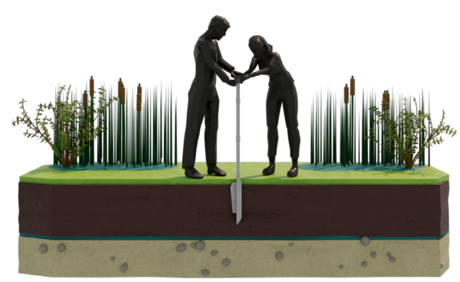
- With the corer in the “open” position, align the corer as straight as possible in the coring spot and push it into the ground.



- Continue pushing the corer into the ground to its desired depth, which can be marked with tape on the corer itself.

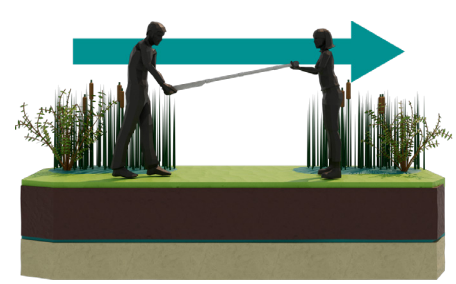


- Turn the corer handle 180 degrees into its “closed” position.



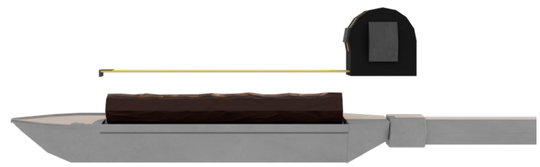
- Lift the corer out of the ground, clasping the barrel and the guard together as it is pulled from the ground.

- Turn the corer horizontally with the core barrel facing upwards and transport to the processing area.



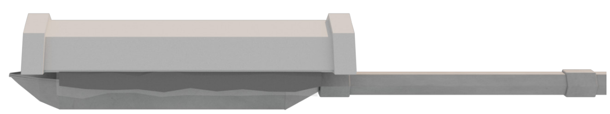
STEP 2:
REVEAL THE CORE

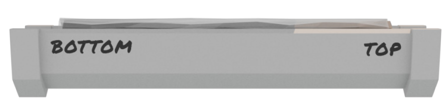
- Lay the corer flat on the tarp with the barrel facing upwards.
- Keeping the sample inside the corer facing upwards, reveal the core by opening the guard and turning the corer. Lay the corer back on the tarp with the sample exposed.
- Record the:
  - **core length (cm)**
  - any transitions in **soil colour** or **texture**
  - any visibly **large materials**
  - **gaps** in the sample
  - **water saturation** (mucky, semi-saturated, dry, etc.)
  - label poster board and PVC-pipe cutouts (see Step 3 below) "top" and "bottom"



STEP 3:
PACKAGE THE CORE

- Line the PVC pipe with aluminum foil and plastic wrap.
- Place the PVC pipe over the core, with the top (closest to the surface) and bottom label in the appropriate position.
- Flip the corer and PVC pipe over so that the core sample falls inside the PVC pipe. Use a knife to separate the sample from the corer if needed.
- Wrap the sample in plastic wrap and aluminum foil.
- Place a piece of poster board over the sample, ensuring the "top" and "bottom" labels are in the right position, and secure it with duct tape.
- Transport the sample to a cooler for short-term storage.
- Wash the corer and tools before taking another core sample.





COLLECTING SEDIMENT CORES IN COASTAL ECOSYSTEMS

Coastal ecosystems are unique landscapes characterized by tidal fluxes that periodically inundate the land. The coastlines of Hudson Bay and James Bay are vast, with continuous and discontinuous permafrost. A mix of coastal marshes and mudflats populate the region, typically containing large carbon stocks in the sediments relative to the vegetation found here. To measure the carbon in these ecosystems, consider the PVC-corer method outlined below.

STEP 1: PREPARE THE SITE

In a notebook or datasheet, **record**:

- date and time
- site conditions
- weather
- tidal conditions

STEP 2: INSERT THE CORER

- Align the corer in the coring spot and push it into the ground.
- Place a piece of lumber over the corer and hammer the PVC-tube into the ground to the desired depth.
- Measure core compaction by taking two measurements and **record them in a notebook**:
  - outside of the core from top of corer to the ground surface
  - inside of the core from the top of corer to the top of the core

STEP 3: EXTRACT THE CORE

- Release the core from the suction of surrounding sediment by digging around the core or gently rocking the PVC pipe.
- Once the bottom of the core is revealed, place an end cap on the bottom of the core.
- Keep the core in an upright position while transporting the core to the processing location.

STEP 4: SECTION AND PACKAGE THE CORE

- Place the core in position over the core-extruding device.
- Place the PVC collar in position at the top of the corer and push the PVC tube downward so that the sediment appears at the top. Keep pushing until the sediment is in line with the top of the PVC collar.
- Cut between the PVC collar and the top of the corer to slice off a subsection (i.e., the sample).
- Place the cut sample in a resealable bag, and **record the sample name and depth**.

* For field datasheets specific for each method, please find the accompanying materials in WWF-Canada's Carbon Measurement Learning Library.

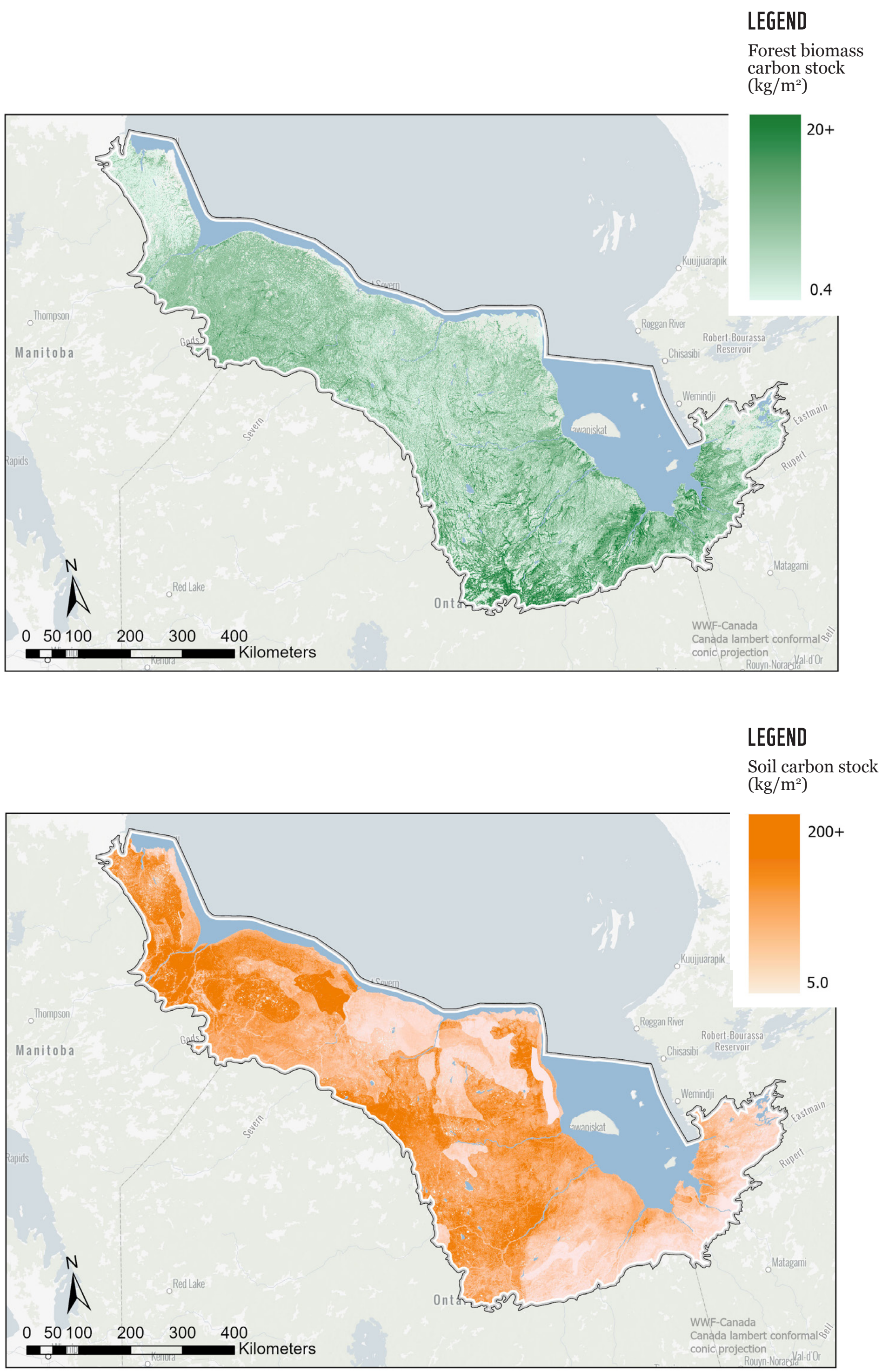


Figure 7: *(Top) Forest biomass (above-ground biomass, below-ground biomass and downed-woody biomass) carbon stock (kg/m²) and (bottom) soil carbon (to 1m depth) stock (kg/m²) for the Hudson and James Bay Lowlands (data from Sothe et al., 2022).*

Table 3: *Examples of protocols, programs and plans that may be relevant to carbon measurement and monitoring in forests and managed lands of the Hudson and James Bay Lowlands. These systems involve a mix of government and non-governmental organizations, with projects ranging from local community land management projects to global climate agreements. They work together to ensure consistency and reliability in carbon measurements across different scales.*

LEVEL OF GOVERNANCE	NAME OF ORGANIZATION	RELEVANT PROJECTS	SUMMARY
International (global)	Intergovernmental Panel on Climate Change (IPCC) Verra (verified carbon standard, MRV)	Sixth Assessment Report (Agriculture, Forestry, and Other Land Uses (AFOLU)) Methodology for Improved Forest Management Using Dynamic Matched Baselines from National Forest Inventories, v1.1	International guidelines of managed lands for the benefit of biodiversity and climate mitigation Carbon crediting system with published carbon monitoring protocols in conformity with monitoring, reporting and verification (MRV) systems
National (Canada)	Canadian Council of Forest Ministers (CCFM) Environment and Climate Change Canada (ECCC)	National Forest Information System (NFIS) National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) ECCC reports NFCMARS to IPCC under Agriculture, Forest, and Other Lands Uses (AFOLU) within the Greenhouse gas national inventory report	Ground observations, aerial surveys and carbon budget models to estimate carbon in Canada's forests (soils and vegetation) Reports greenhouse fluxes in Canada's managed forests and utilizes field observations and carbon budget modelling tools Values are incorporated in the AFOLU report which the ECCC compiles and reports yearly to the IPCC
Provincial (Manitoba, Ontario and Quebec)	Government of Manitoba, Manitoba Sustainable Development Government of Ontario, Ministry of the Environment and Climate Change Government of Quebec Department of Agriculture, Environment and Natural Resources Mushkegowuk Council, Lands & Resources Department	Manitoba Climate and Green Plan Ontario Climate Change Action Plan 2030 Plan for a Green Economy Draft Omushkego Wahkohtowin Conservation Plan March 2024 Tawich is Where I Belong, 2023	Strategic framework developed in 2017, with four underlying pillars: climate, jobs, water and nature. These are backed by keystones and specific tools for implementation Provincial legislation under Bill 198 "Ontario Climate Change Adaptation and Resilience Act, 2024" to address greenhouse gas balance of the province Provincial framework to reduce the province's net greenhouse gas balance and adapt to climate change through the management of forests and other land-use areas Draft conservation plan developed to highlight the beliefs and commitments of the Omushkego people and identify calls to action related to conservation Draft Feasibility Assessment for the Proposed Mushkegowuk National Marine Conservation Area, which includes a coastal buffer area

REFERENCES

Agriculture and Agri-Food Canada. (2024). *Soils of Canada*. Retrieved June 2024 from:
https://open.canada.ca/data/en/dataset/5ad5e20c-f2bb-497d-a2a2-440eec6e10cd

Agriculture and Agri-Food Canada. (2013). *Terrestrial Ecoregions of Canada*. Retrieved Dec 2024 from:
https://open.canada.ca/data/en/dataset/ade80d26-61f5-439e-8966-73b352811fe6

Bansal, S., Creed, I.F., Tangen, B.A., Bridgham, S.D., Desai, A.R., Krauss, K.W. ... 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

Ecozones Canada. (2014). *The Ecological Framework of Canada*. Retrieved Dec 2024 from:
http://www.ecozones.ca/english/

Government of Ontario. (2012). *The ecosystems of Ontario – Part 1: ecozones and ecoregions*. Retrieved Dec 2024 from:
https://www.ontario.ca/page/ecosystems-ontario-part-1-ecozones-and-ecoregions

Natural Resources Canada and the Canada Centre for Remote Sensing. (2020). *Land Cover Map*. Retrieved Dec 2024 from:
https://open.canada.ca/data/en/dataset/ee1580ab-a23d-4f86-a09b-79763677eb47

Martini, I.P. (2006). “The cold-climate peatlands of the Hudson Bay Lowland, Canada: Brief overview of recent work.” In I.P. Martini, A. Martínez Cortizas & W. Chesworth (Eds.), *Developments in Earth Surface Processes* (Vol. 9, pp. 53–84). Elsevier.
https://doi.org/10.1016/S0928-2025(06)09003-1

Sothe, C., Gonsamo, A., Arabian, J., Kurz, W.A., Finkelstein, S.A., & Snider, J. (2022). Large Soil Carbon Storage in Terrestrial Ecosystems of Canada. *Global Biogeochemical Cycles*, 36(2), e2021GB007213.
https://doi.org/10.1029/2021GB007213

WWF-Canada. 2025. Ecosystem Carbon Measurement: Regional Protocol for Regional Protocol for the Hudson and James Bay Lowlands, Canada. World Wildlife Fund Canada. Toronto, Canada.

A Canada with abundant wildlife, where nature and people thrive.

wwf.ca

WWF-Canada is a federally registered charity (No. 11930 4954 RR0001), and an official national organization of World Wildlife Fund for Nature, headquartered in Gland, Switzerland. WWF is known as World Wildlife Fund in Canada and the U.S.