Establishing field sites for studies using SAR data to analyze variations in permafrost, vegetation cover, and soil moisture during the ABoVE Airborne Campaign[1]

A Collective Vision for the ABoVE Science Team

There is considerable interest in using L- and P-band SAR data to monitor variations in aboveground woody biomass, soil moisture, and permafrost conditions (either surface deformation associated with seasonal permafrost thaw, or direct sensing of the thawed layer). To conduct these studies, it is highly desirable that the same set of data be collected at each site so that the data from multiple sites can be combined and used to analyze variations across different landscape geomorphologies and vegetation conditions. Thus, if researchers commit to collecting the same set of field data from 3 to 4 unique landscape units at their particular field site, if we focus on collecting data at 10 to 15 sites across the ABoVE Domain, we can produce a very rich data set that can be used by different sub-groups to focus on specific research questions that involve the use of SAR data.

While some field observations important to SAR studies can be collected in a relatively short period of time (e.g., surface soil moisture, thaw depth, organic layer thickness), other measurements, such as characterization of aboveground vegetation, are more time consuming. However, many of these measurements are of site characteristics that vary over longer time frames, and thus can be collected at a later date.

Optimum Plot Layout

The optimum plot size for SAR studies is one hectare or 100 by 100 m. Since a SAR is a coherent sensor, its imagery contains speckle that introduces variance into the image intensity or radar backscatter. To reduce this variance requires averaging of multiple pixels. Hence, a 100 by 100 m area will produce enough ground area for image averaging, for both airborne and spaceborne SAR data. Thus, the first step in setting up a field plot is to identify a one-hectare area that has a relatively homogeneous vegetation cover (Figure 1). Because ground conditions in boreal and Arctic ecosystems are highly variable at meter to sub-meter scales, it is necessary to develop a sampling scheme to capture this smaller scale variability.

For sampling of the variability in surface soil moisture, thaw depth, and thickness of the surface organic layer, it is recommended that two, 60 m long sample transects be established as outlined in Figure 2. Note that these sample transects can be used to systematically sample the site for soil moisture, thaw depth, and organic layer thickness (discussed below). In addition, the transects can be used to establish plots for measuring vegetation. For example, Figure 3 shows three 10 by 10 m plots for sampling vegetation located along each transect. However, the 100 by 100 m plot design allows for other vegetation sampling approach, such as a sampling of vegetation along randomly oriented transect lines.

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[1] This document includes content from *Establishing_field_sites_for_SAR_studies_R1* and *SoilMoistureSamplingProtocol_R2* documents supplied by the data provider. -- ORNL DAAC, 2022-08-31

For soil moisture, it is recommended that three sampling points be established along each 60 m transect, as illustrated in Figure 2.

Other Sample Designs

Some studies use a 30 by 30 m plot design for sampling of vegetation based on studies using Landsat data. In such studies, sampling of soil moisture for SAR studies could be based on establishing five sampling points as illustrated in Figure 4. Other studies where long transects are being established across a landscape could use a design similar to that presented in Figure 5.

Regardless of the sampling design, GPS locations of plot or transect locations are needed, along with field photos that document variations in vegetation cover and surface conditions.

Sampling Soil Moisture

Previous studies have shown that surface soil moisture in areas with organic soils are highly variable at sub-meter scales. In addition, because surface organic layers often dry out, we have found that the highest correlation with soil moisture occurs with measurements made at depths between 12 and up to 20 cm. Because of this, surface soil moisture measurements collected using the Campbell Scientific Hydrosense are collected at multiple depths. The Hydrosense comes with two probes with lengths of 12 and 20 cm. By inserting the 20 cm probe at an angle of 60 degrees from vertical, a depth of 6 cm is sampled. (Figure 6).

Previous studies have shown that sub-meter variations in soil moisture can be sampled using the Hydrosense by collecting 5 soil moisture samples at each sample point, as illustrated in Figure 6. At each sample point, 5 samples are collected for each depth (6, 12, and 20 cm). When using two, 60 m sample transects, this results in 30 soil moisture samples for each depth. Note that collection of the 15 soil moisture samples at each points, even with changing probes, will take 3 or 4 minutes. Thus, sampling of an entire plot rarely takes more than 30 minutes.

Finally, it is desirable to keep a hand written data sheet of the Hydrosense data in case there are problems with the data recorder. Note that the soil moisture and the time delay from the Hydrosense should both be recorded. For efficiency, tables can be set up in the field notebooks ahead of time.

Sampling Depth of Permafrost Thaw

Establishing transects within a specific sample area provides the basis for the systematic collection of the depth of permafrost thaw. As discussed in the Schaefer paper, it is desirable to collect a number of thaw depth measurements to establish an average thaw depth. Using the two 60 m transects, it is recommended that permafrost thaw depth measurements be collected every 5 m, beginning at 0 m, which would result in 13 samples per transect and 26 per plot. So as not to interfere with the soil moisture data, these data should be collected on the opposite side of the transect line where soil moisture data are being collected.

Organic Layer Thickness

The thickness of the organic layer and its various layers is an important site characteristic for understanding both permafrost conditions and soil moisture. Thus, collecting information on spatial variations in the organic layer is important. It is recommended that 26 organic layer thickness measurements be collected at each site, every 5 m along the two sample transects. For those familiar with the Canadian soil classification system, for each sample, the thickness of the live moss, dead moss, fibric, mesic, and humic soil horizons should be recorded. For those not familiar with this system, noting the thickness of live moss, dead moss and upper and lower duff layers will suffice (Figures 7 and 8). So as not to interfere with the soil moisture data, these data should be collected on the opposite side of the transect line where soil moisture data are being collected.

Sampling of Mineral Soils

While some field sites have established instrumentation to measure ground temperature and moisture profiles in areas with permafrost, it is desirable to obtain this information from a wide range of sites. Below is an efficient method to collect this information in terrains without significant near-surface ice or areas with rocky soils.

When digging soil pits, it is desirable to have a minimum impact on the site. Thus, one should have a heavy plastic ground tarp where the soil excavated from the pit can be placed and then returned after the measurements have been made.

Select 4 sites within the 100 by 100 m plot that span the range of surface organic layer thicknesses found at that site. Previous studies have shown that mineral soil temperature and moisture and thaw depth at a site are strongly correlated with organic layer thickness, thus it is important to have soil pits that capture the range in the organic layer thickness.

At each site, the goal is to excavate a soil pit that is approximate 25 by 50 cm in dimension to the depth of the frozen soil layer at the time of the SAR data collection. Using a flat-bladed garden shovel is usually the best way for digging this pit. In areas with rock soils, a depth of 30 to 40 cm is desirable, recognizing that excavating to frozen soil may not be possible. Even if it is not possible to reach the frozen soil layer, collection of data from the upper 30 to 40 cm of the soil layer will provide valuable information. See options on Figure 9.

When digging the soil pit, first remove the organic soil layer in one or two pieces and place on the tarp. Then dig out the mineral soil, keeping it separate from the organic layer.

The following measurements are made:

1. Beginning at the mineral soil/organic soil interface, measure soil temperature every 5 cm to permafrost on one face of the soil pit;
2. Beginning at the mineral soil/organic soil interface, measure soil moisture with the Hydrosense every 10 cm to permafrost on two opposite sides of the pit, noting the depth at which each measurement is made Two sets of soil moisture are needed because previous studies have shown that soil moisture is more variable than soil temperature.
3. At each pit, note the texture (e.g. sand, silt, clay, gravel) and thickness of the mineral soil horizons.

Probe Calibration

It is important to have organic soil calibration algorithms developed for each of the probes to the various soil types (Hydrosense-II (12 and 20 cm), Hydrosense (12 and 20 cm), etc). The default algorithms used by the Hydrosense and Hydrosense-II that converts probe period to volumetric moisture are based on a loam mineral soil. Therefore, any soil with high organic content or high clay content will result in an inaccurate estimation of soil moisture content. To develop a site specific or soil specific calibration of the probe, a methodology of harvesting a sample of appropriate size (using 2 gallon plastic buckets with lids) has been developed. The sample is carefully collected to minimize compaction and returned to a laboratory where it is saturated and then allowed to slowly air dry while daily probe periods are collected and gravimetric measurements taken, thus allowing a calibration algorithm to be developed. See Figure 9.

Note: Several of the ABoVE researchers are working to develop calibrations for their specific soils and a generic organic soil algorithm can be developed from these. However, the most appropriate algorithm can be chosen by measuring the depth of the horizons in a soil profile that the probe is crossing through and matching that to the existing algorithms or algorithms developed for your sites.

A series of calibration algorithms for a range of burned and unburned soils have been developed by MTRI for the ABoVE SAR soil moisture working group. We have calibration algorithms based on samples from arctic Alaska and boreal Alberta CA for unburned sites as well as a series of calibrations for primarily burned sites of Northwest Territories, CA. The Alaska unburned calibrations include a "tussock" calibration, thus probing of the tussocks can now be sampled in the field and calibrated. All calibrations are for organic soils. Also included are generalized algorithms as well as those broken down by soil profile groups or boreal ecotypes. Further differentiation for the unburned sites is conducted by sphagnum or feathermoss ground cover dominance. Feathermoss does not hold as much water as sphagnum and thus needs a different calibration.

Marking of Transects

It is highly desirable that soil moisture measurements and depth to permafrost be noted during the early and late summer SAR flights being made during the ABoVE Airborne Campaign. Because of this, it is recommended that for each transect: (a) the beginning and end of the transect be marked using a wooden stake; and (b) that the sample site locations along the transects be marked with pin flags.

Figure 1

SOIL MOISTURE SITES

Establishing a New 100 x 100 m Site

Procedure

- Locate potential site using aerial imagery, on site reconnaissance and receive permission (if necessary) to enter site (see example below of homogeneous peatland site in NWT accessed by boat)
- Identify an area that represents at least 100 m x 100 m of homogenous ecotype (note use 200 x 200 for 30 m resolution satellite, R-2 has 8 m resolution, UAVSAR 6 m, AirMoss 15 m – but multi-looked to 60 m)
- Collect a GPS location at the entrance to the site and GPS your car/boat or other transportation vehicle for return navigation
- Using a compass establish the bearing of the traverse line. Establish traverse line perpendicular to road/access path.

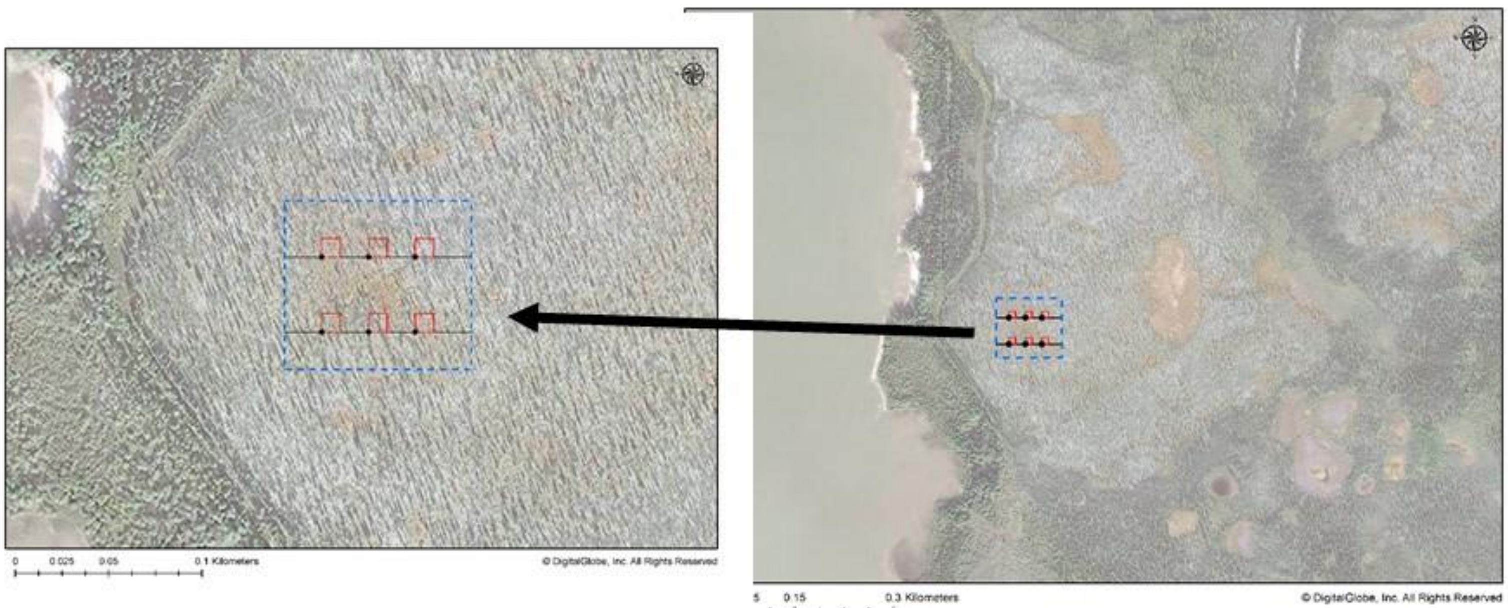


Figure 2

For each site within a study region, identify a 100 by 100 m (1 hectare) sample plot with relatively homogeneous surface conditions

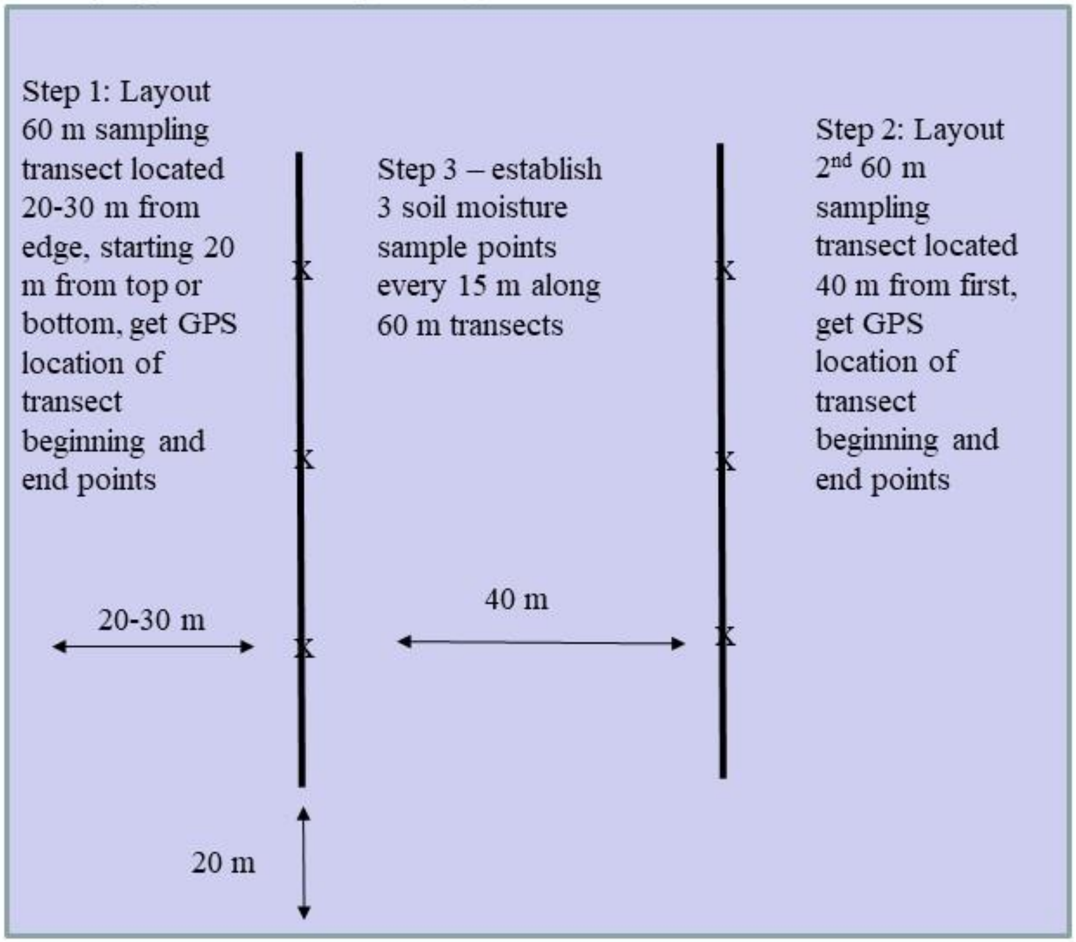


Figure 3

SAR (5-15 m res)
SOIL MOISTURE SITES

Establishing a New Site Overview

- Purpose: The study sites are established to represent the variety of conditions found in boreal/arctic ecosystems and to collect in-situ data to relate to a SAR image relevant to the resolution of the sensor and allowing for averaging of pixels due to speckle.
- Study sites should have the following characteristics:
  - At least (100 m x 100 m) of fairly homogenous ecosystem type
  - Fairly level topography (flat)
  - Public access or access granted by private owner
  - Easy access from road, river or trail

The distance between adjacent flags should be around 25 m, making plots 15 m apart

Traverse lines are at least 40 m apart and at least 20 m from the edge of the homogenous area.

- Traverse lines
  - 2 parallel lines are to be established
  - At least 20 m from edge of area
  - 40 m between traverse lines
- Flags
  - 3 Flags per traverse line
  - Flags are placed at a distance of 15 m from the outside of each plot
- Design allows data collection along traverse line 1 (plots 1-3), navigation to traverse line 2 (plot 4) and then collection along traverse line 2 to exit the site.

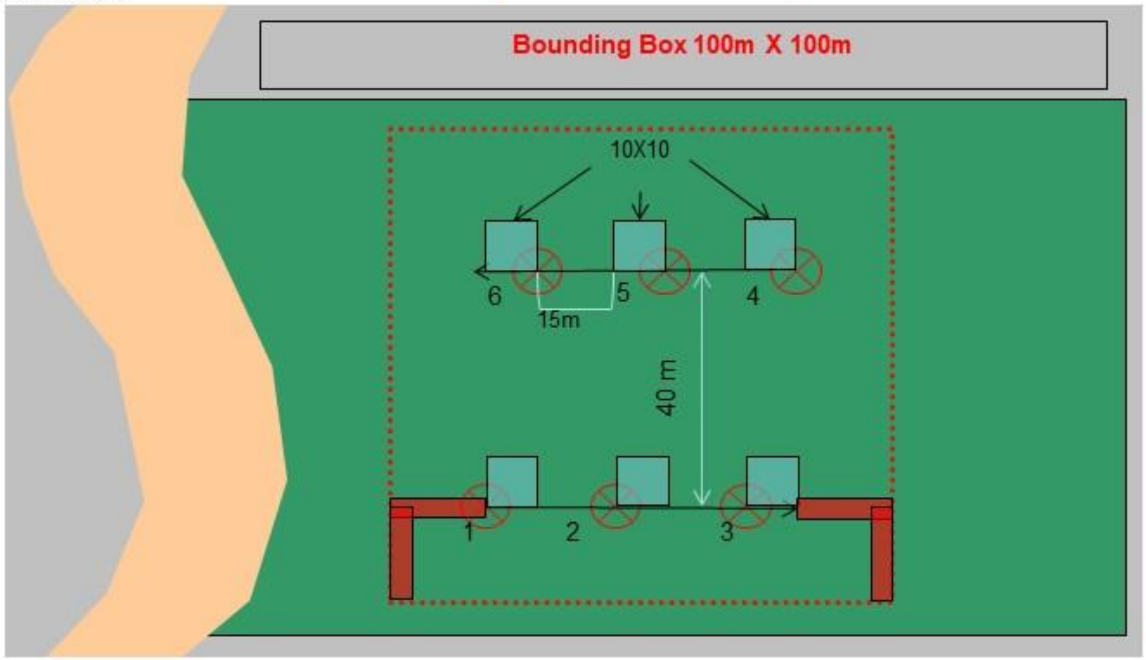


Figure 4

Alternate Site Set up for Sites sampled as 30 x 30 m plots (note this is too small for relating to AirMoss, but okay for UAVSAR and Radarsat-2)

- Sample moisture at the plot center and 4 corners (flags 1-5)
- Collect 5 samples at each flag (be sure that the ecotype does not change at plot edges and extends beyond sampled area by 10-15 m
- Use sampling protocol at each flag as described for 100 x 100 m site

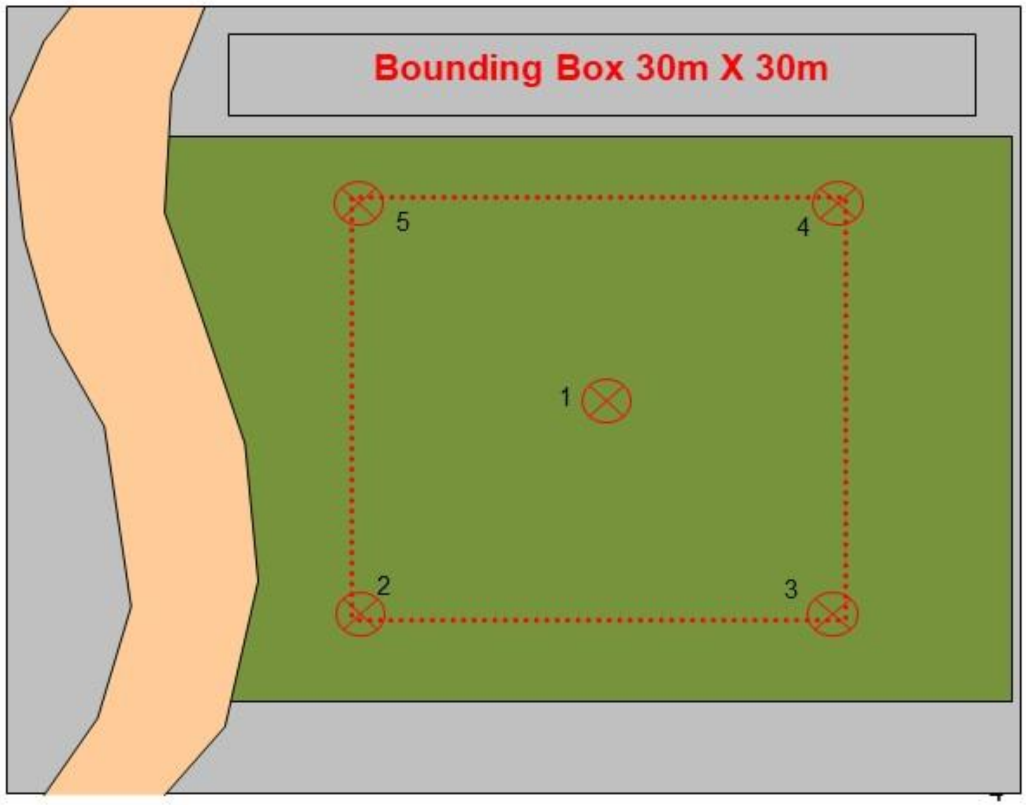


Figure 5

Alternate Site Set up for Sites sampled as Transects

(note this is not ideal and requires that the transect is representative of homogeneous area 20 m wide)

- For this to work, a photo, gps location and notation of ecotype will need to be collected along with transitions into new types. An idea of how wide of an area along the transect that the ecotype (somewhat homogeneous area) extends to is needed – with a minimum of 20 m (this will allow for 2 resolution cells to be averaged x X length). Need a minimum of 3 samples in each ecotype.

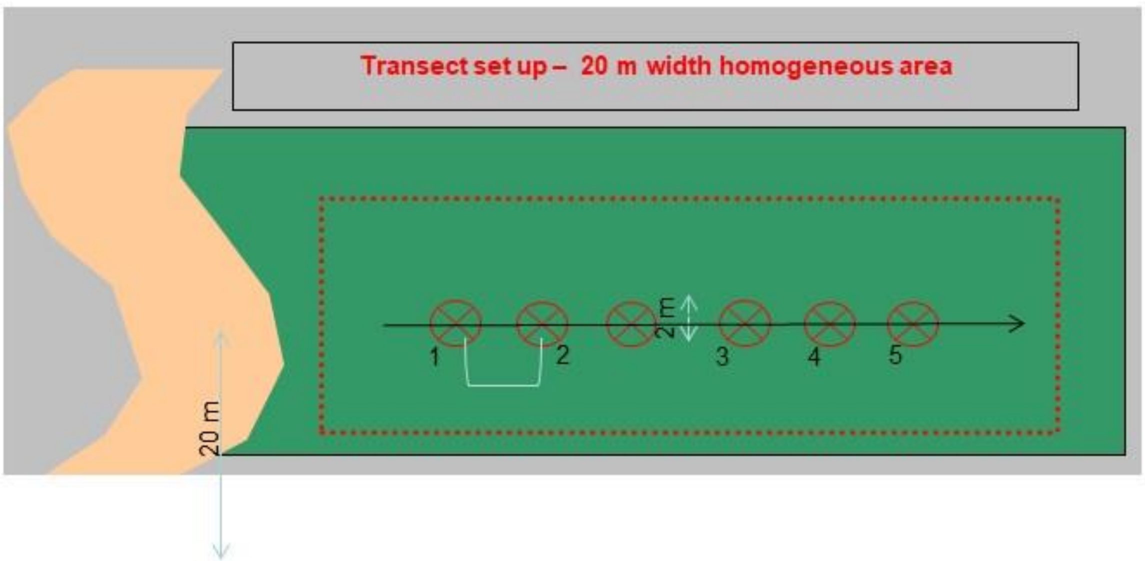


Figure 6

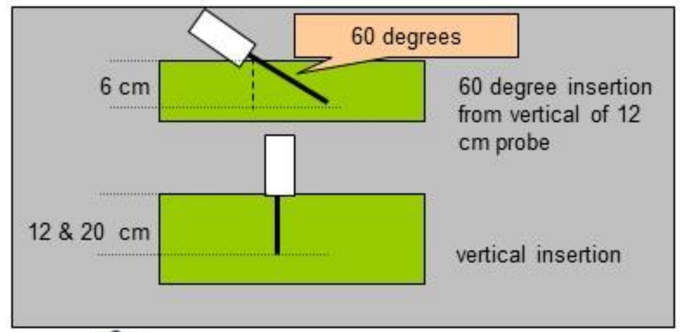
Soil Moisture Data Sampling

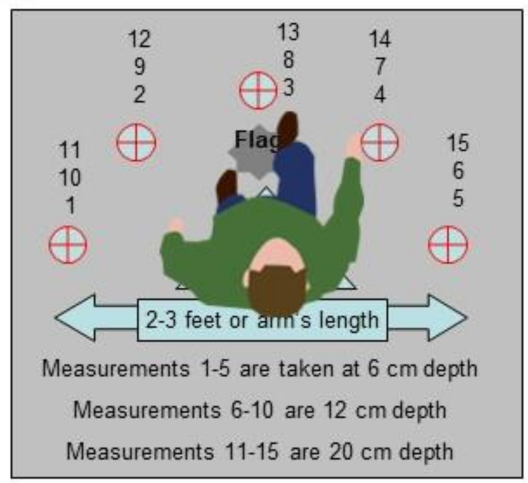
Data to be recorded includes

- Time/Date
- Location (site and GPS location)
- Current and recent past (day) weather (especially rain)

Brief description of site conditions

- General ecotype (e.g. tussock tundra, bog, upland black spruce, etc)
- Ground cover (moss, lichen, grass, etc)
- Dominant species
- If burn,
  - Year of Burn
  - Burn Conditions (canopy fire, ground fire, etc)
- Depth of organic soil (depth to mineral soil)
- Soil profile description (to 30 cm)
- ALT
- Photos of site
- Soil Moisture to be sampled with handheld Hydrosense probe or CS616, 615 or 625 and dataloggers or other instruments which have calibrations to organic soils
  - 5 Samples/flag at each depth to be sampled from surface down
    - 6 cm (angle probe)
    - 12 cm
    - 20 cm





Kneel down and use a semi-circle (0.5-1 m diameter – arms length) to provide a good sampling of the variation of the location. 5 measurements should be taken at 6, 12 cm and 20 cm depths.

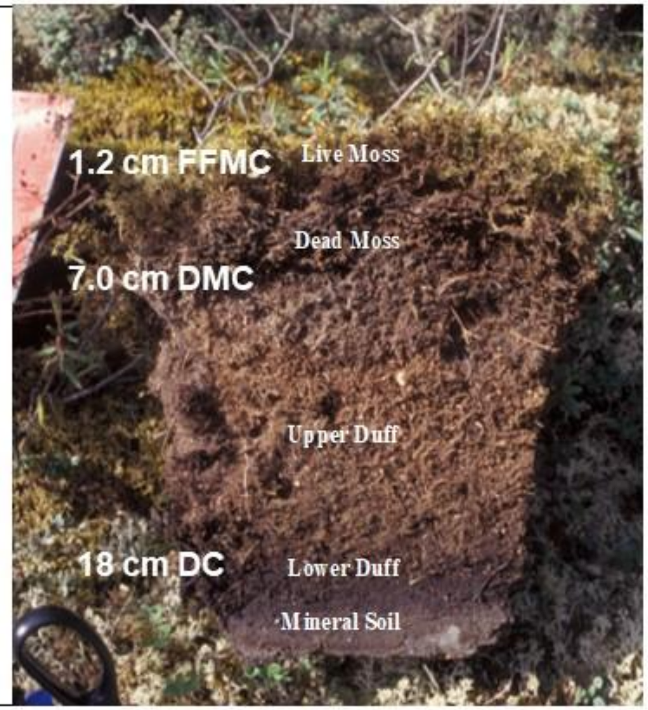
Figure 7

Required: Soil Profile Measurements 1/flag – (minimum 1/site) to nearest 1 cm

- Horizon naming convention is based on those used for fire danger assessment and can be easily translated to fibric and humic layers.

Top 30 cm soil profile	**Depth (cm)** to nearest 1 cm
Live Moss (LM)	______________
Dead Moss (DM)	______________
Upper Duff (UD)	______________
Lower Duff (LD)	________

- May adjust these for burned sites to include burned moss, singed moss, etc

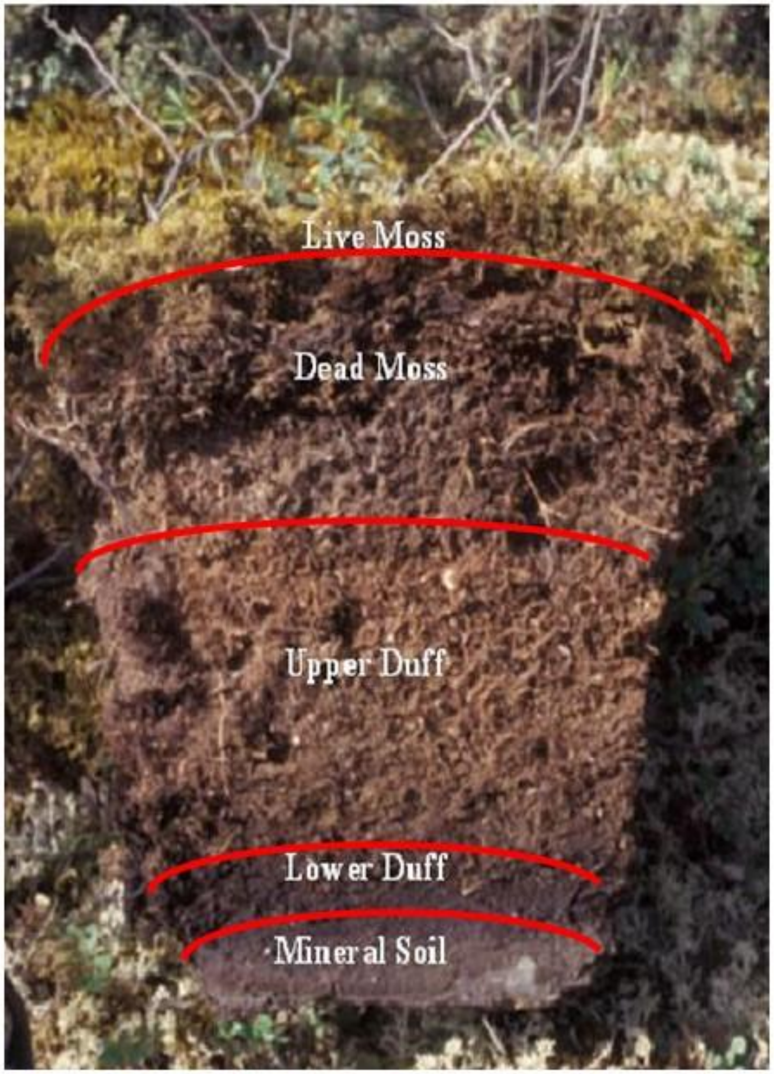


Use a trowel or small shovel (in the organic soils sometimes even just your hand will work), to get a view of the soil profile to 30 cm and record the depths in cm

Purpose: probe calibrations are dependent on what organic and mineral soil profile layers the probe is within and crossing over

Figure 8

Required: Soil Profile Measurements



- **Live moss: living moss layer**
- **Dead Moss: undecomposed moss and other plant parts**
- **Upper Duff: fibric layer, partially decomposed moss/organic plant parts still visible**
- **Lower Duff: humic layer, decomposition more advanced, denser than fibric layer and plant parts are no longer visible**

Note that if the site is burned, then the top layer may be any one of these, including singed or charred moss (in place of live or dead moss) – please note accordingly

Figure 9a

Optional: Extracting a Soil Core Sample for Calibration, Part 1

Required Equipment:

- Hydrosense CS620 probes with 12-cm and 20 cm prongs
- Folding Army Shovel
- Plastic Ruler
- **Sampling Device (2 gal bucket with bottom cut off)**
- Bread knife, scissors, pruning shears
- 2 gallon Plastic buckets with lids for transferring the sample to

Data to be Collected:

- Time/Date
- Location (site and GPS location)
- Current and recent past (day) weather
- Size of Sample (length, width, depth)
- Description of soil layers (strata)

Soil Sample Extraction Procedure:

- Insert the sampling device **(2 gal bucket with bottom cut off)** into the ground, being careful not to compact the surface layers
    - Lightly push the device onto the ground surface with a rotating motion
    - Using a saw/bread knife to carefully cut outside the device, gently creating an area for the sampling device to penetrate
    - Snip roots and wood material with pruners
    - Continue until the sampling devise hits mineral soil, ice, or is deeper than desired
- Using the shovel and bread knife/saw completely remove one side of soil/moss providing access to the bottom of the sample
- Cut across the bottom of the bucket with the bread knife
- Transfer sample to new bucket, attach lid and label




Completely remove the soil on one side to expose the bottom and facilitate removal

Figure 9b

Optional: Extracting a Soil Core Sample, Part 2

Labeling Containers

- Buckets should be sealed with duct tape and labeled with:
    - Location (Site and Lat/Long)
    - Date/Time
    - Weather
    - Observers
    - Horizons

Vertical Soil Moisture Profile

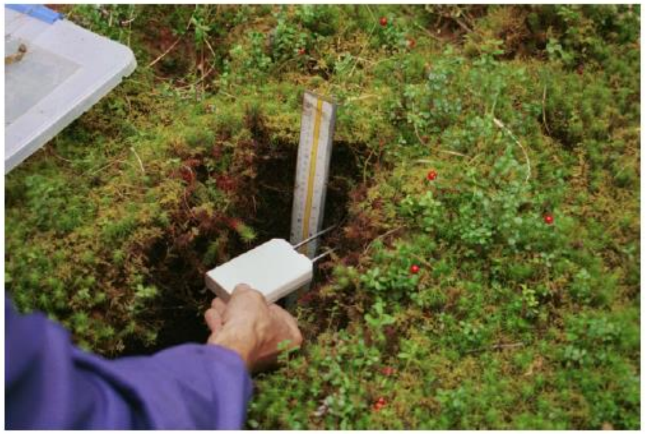
- Vertically place the plastic ruler into the hole left by the sample, record depth
- Establish the soil surface reference depth on ruler
- Horizontally insert the probe, record period and VWC reading on both sides of the ruler
- Repeat in every horizon of the sample.
- Record soil layers and their depths

Package the samples

- Place samples into a large tub, seal with duct tape, ship to lab for calibration

2 Gallon plastic tubs are available in cases of 10 from Home Depot. A set of 10 tubs and lids costs roughly $30. Pails: Lids are sold separately. These can also be purchased from Canadian Tire

The bottom of one pail can be removed with a fine toothed saw to serve as a sampling device.
The bottom edge should be thinned using a deburring tool.
Harvest with a saw or other serrated knife from the outside so that the sample will fit in the complete pail.



Try to minimize the amount of compaction and/or damage to the sample during extraction