Natural Resources
Canada

COLLECTING ANALYSING AND STORING

forest soil data and samples in the age of big data.

A Guide for Researchers and Field Practitioners.

Canada

This document is product of a reflection of the GOAL group (Groupe des laboratoires analytiques /Group of analytical Labs of Canadian Forest Service)

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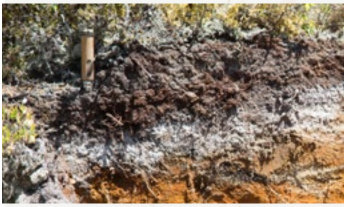

A short guide on how to collect, analyse and store forest soil data and samples in the age of big data.

Why such a guide?

Many people collect and analyse soils. Unfortunately, little of the data generated ends up in usable and accessible databases. One reason for this is that soil is a complex medium. It is composed of minerals, organic matter, gases, water, and organisms. It is also difficult to describe and to tell exactly where it starts, where it ends, and how to break it down in smaller units. For these reasons, soils are often sampled and analysed in different ways, making it difficult to combine the analytical results from different users to generate a broader understanding of their properties. This short guide is not intended to replace existing documents that deal in much greater detail with soil sampling and analysis methods. It is intended to provide basic information and guidance for collecting soil data that should facilitate the greater use of this information in forest ecosystem science and management.

Introduction

Soils support many ecosystem services. Specifically, they store huge amount of carbon, they are a habitat for numerous organisms, they purify water and regulate water flow and they provide support and nutrients for plant growth. Yet, apart from some surveys, soil data remain largely inaccessible and unusable for informing soil management and research. Soil data often lack the key information that would make them of use for more than the immediate project for which they were collected. The whole sequence from data collection –> sample preparation –> physical and chemical analysis –> to data curation and sample archiving would benefit from standardization which could make soil data accessible to researchers and practitioners for many different applications (e.g.: digital soil mapping, forest resource inventory, silvicultural planning, impact assessments, etc.).

Many people need to collect soil data, whether for a survey, a research project, or for various purposes regarding land management. Here we describe key elements that would help anyone collecting forest soil data in a standardized way to make them usable for the needs of science and of that of the management of ecosystems.

What to measure and report

Essential information is collected in the field. This information needs to be properly recorded and structured in a way that it can be linked to the data that will be generated upon lab analysis. It is good to think ahead about this linkage and to make sure that field information is accessible and can easily be merged with the upcoming lab data. **Sampling location** is a crucial parameter to record and linked to samples in the whole chain of data production. Many soil data are excluded from large soil databases because they simply lack basic information on location (Batjes 2019). Geolocation information on the soil pit or core should be taken as accurately as possible. A smart phone-based app or a hand-held GPS should be able to give location info to within 5-10 m. If possible, record how the location information was recorded (brand of GPS) and precision information if provided by the GPS. Note the coordinate system. Often having the GPS sit at the location of the sample collected for a longer period will increase the precision of location information. Additional site information (e.g.: dominant vegetation, evidence of disturbance or other notable characteristics such steep slope) could also be included.

How to sample?

Soil samples are best collected by either digging a small pit or by coring. Both approaches have their advantages and disadvantages, but ultimately the goal is to sample soil along the entire profile. The soil profile is the vertical cross-section of soil that captures the changes in soil from the top organic mineral interface to the deeper parent material – most often viewed as layers or horizons.

The organic layer, if present, should be sampled first (see method below) and its thickness recorded in the field. It is considered above the soil so that the reference elevation of 0 cm starts at the top mineral layer.

Fig. 1: Sampling by increment depth or by soil layer. Image from: https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/conservation-and-protection-canadas-forests/soil/13205

The organic layer ends where the more fibrous layer separates from the top of the A mineral horizon. Sampling can be conducted either by depth increment or by soil horizon **(Fig. 1)**.

GlobalSoilMap.net project specifications suggest the following depth (0–5, 5–15, 15–30, 30–60, 60–100 and 100–200 cm) with a maximum depth is 2m. However, in practice sampling is often stopped at shallower depths by rocks, water, or other obstacles. For Canada's National Forest Inventory (NFI 2008), sampling is done at 0-15 cm, 15-35 cm, 35-55 cm and 55-75 cm. If sampled by soil layer, the depth of each layer should be recorded in two columns of the database: (upper depth, lower depth). For either sampling method chosen, bulk density should be estimated. Bulk density (oven dried mass per unit volume) is a measurement of soil that captures the proportion of solid material to voids or air pockets within a given volume of soil and is necessary for determining soil carbon or nutrient contents. Other useful information to collect in the field are depth to bedrock, plant exploitable depth (depth where roots penetrate to), profile development depth and coarse fragments (visual estimate of volume of soil occupied by rock >20 mm). Common tools and sampling illustrations are presented in **Fig. 2**.

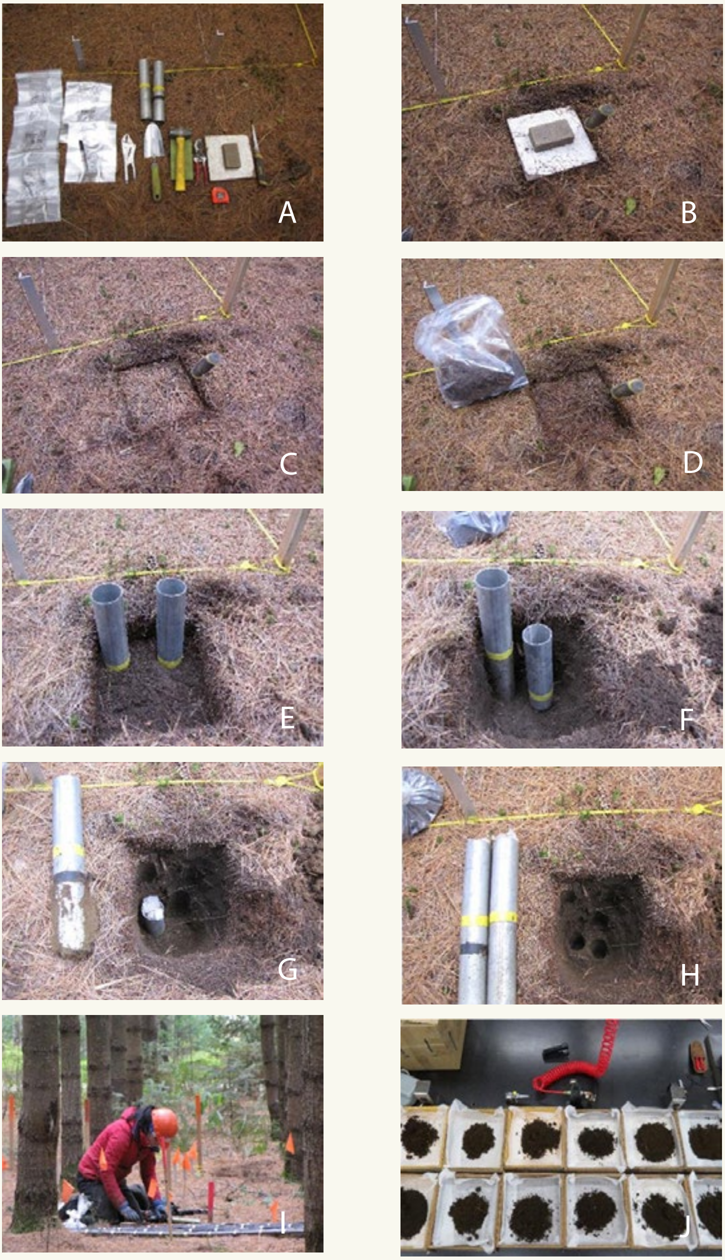

Figure 2: tools for sampling the soil by increment tubes.

Don’t forget to sample the organic layer

Forest soils often contain an organic layer (L, F, H or O). This layer is often overlooked in large soil surveys. When present, the organic layer can store large amount of water, carbon and nutrients. It is also the site of active biological activity including root growth, nutrient uptake, litter fragmentation by the soil fauna and decomposition but it is sometimes quite thin. If present, it needs to be sampled independently from the mineral soil even when sampling per depth. A square template of 20 cm by 20 cm is often used with a serrated bread knife to cut through the mat of organic material. The depth of the layer on all four sides is recorded in the field. Note that the subsequent measurement of soil depth starts below this organic layer – at the top of the mineral soil **(Fig. 2 B, C, D, E)**. Samples need to be kept cool until they are brought to the lab, especially the organic horizons that tend to rapidly get mouldy.

Details on organic layers and how to collect and prepare them prior to analyses are often neglected in soil methodology textbooks. This material is different from mineral soil and needs to be treated differently. It is sieved carefully often on a coarser grid than mineral soil (we recommend 6 mm); it is advisable to sieve it before complete dryness to facilitate the separation of soil with fine roots, which could crack and fall in larger amount in the soil sample when the soil is fully dried. Also, a high temperature may cause losses of organic matter and nutrients as well as increase nutrient availability. We recommend a drying temperature of 50˚C.

Plot_ID	Sampling_yr	Latitude	Longitude	Coordinate system/ zone	Release_source	Availability	Add column for other ecological or terrain observations
22YKKR001	*2015*	*6991375068*	*1406978417*	*UTM/21*	*Name of person*	*Open*	

Table 1a: Example of a simple data entry sheet for site information.

Plot_ID	Sampling_yr	Sample_ID	Pit_num	Horizon	Org/MIn	Sample_ upper	Sample_ bottom	Hor_ thickness	Columns for any other variables from field or lab analysis
22YKKR001	*2006*	*2*	*2*	*B*	*Mineral*	*25*	*35*	*10*	

Table1b: Example of a simple data entry sheet for sample information.

How to report data?

Soil databases should contain a minimal set of information which should be coded in a way that is machine readable (i.e., text files, one line per sample, no special formatting, formulas or macros, a code for missing value). Soil database should be following FAIR principles: the data should be "findable, accessible, interoperable and reusable" (Wilkinson et al. 2016). A metadata file should accompany all data files. It should contain a definition of all variables and report on the units that are used. It is a good idea to add as much information as possible to the metadata file including, methods, analytical instruments and the name of the facility where the analyses were conducted.

In addition to the metadata file, it is useful to have a file with information about each of the sites within the database, and a separate file with soil pit/core and horizon information for each site within the database, that can be cross-referenced with a common plot ID. This is especially useful when there are replicate samples taken at location. Examples of a site and a soil data entry sheets are presented in **Table 1**; note that there is one soil sample (horizon or depth) per line.

What information is included in international soil initiatives?

Apart from the site information described in Table 1, international initiatives supported by FAO (WoSIS, ISRIC) have produced a description of a minimal datasets which contains information originating from both the lab and the field. GlobalSoilMap (Arrouays et al 2014) suggests to collect and record the following twelve variables with the following units:

1) Depth to rock (cm);
2) Plant exploitable (effective) depth (maximum rooting depth, cm);
3) Organic carbon (g kg^{-1});
4) pH;
5) Clay (g kg^{-1});
6) Silt (g kg^{-1});
7) Sand (g kg^{-1});
8) Coarse fragments (m^3 m^{-3});
9) Effective cation-exchange capacity ($mmol_c$ $kg-^{-1}$);
10) Bulk density (whole soil, Mg m^{-3});
11) Bulk density (fine earth, Mg m^{-3});
12) Available water capacity (cm), the later being generally predicted from other properties with pedotransfer functions.

However, many other physical, chemical, or biological properties can be assessed. The use of a simple, but unique sample ID is the best way to connect the information from the lab and the field.

Useful coding for a sample ID could include a project identifier, location code, number of the sample, and, if a multi-year project, an identifier of the year. For example, 22YKKR001 could be the structure used for the first sample (001) collected in the Yukon (YK) off the Klondike River (KR) in 2022 (22).

How to store soil samples

Dried soil samples stored in a clearly labelled plastic or glass container will keep for years. Barcoding or tracking system should include links between the sample ID and the metadata of site/plot information and analytical results.

Contributing to Big data

Efforts are underway to better track and archive soil sampling data within the Canadian Forest Service and enable its linkage with other soil data initiatives nationally and internationally. For more information on how to include your data in these initiatives please contact:

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References and additional reading

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Photo: Soil profile.