



Soil Data from a Moderately Well and Somewhat Poorly Drained Fire Chronosequence near Thompson, Manitoba, Canada

By K.L. Manies, J.W. Harden, and Hugo Veldhuis

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Abstract

The U.S. Geological Survey project *Fate of Carbon in Alaskan Landscapes* (FOCAL) is studying the effect of fire and soil drainage on soil carbon storage in the boreal forest. As such this group was invited to be a part of a NSF-funded project (Fire, Ecosystem and Succession - Experiment Boreal or FIRES-ExB) to study the carbon balance of sites that varied in age (time since fire) and soil drainage in the Thompson, Manitoba, Canada region. This report describes the location of our FIRES-ExB sampling sites as well as the procedures used to describe, sample, and analyze the soils. This report also contains data tables with sample related information including, but not limited to, field descriptions, bulk density, particle size distribution, moisture content, carbon (C) concentration, nitrogen (N) concentration, isotopic data for C, and major, minor and trace elemental concentration.

Introduction

Background

This study, entitled Fire, Ecosystem and Succession - Experiment Boreal or FIRES-ExB, was designed to examine the impacts of fire and soil drainage on carbon inputs (e.g., net primary production) and losses (e.g., autotrophic and heterotrophic respiration) as well as the net accumulation of carbon within the soil and detritus pools. It was a follow up study to the Boreal Ecosystem-Atmosphere Study (BOREAS), an international effort to examine C balance in boreal forests (Sellers and others, 1997). Eight study sites in various stages of recovery (time since last fire) were established in northern Manitoba (Table 1; Figure 1). Where possible, paired moderately well and somewhat poorly drained areas were sampled within each stand age.

Burn year	Moderately well drained	Somewhat poorly drained
2003	X	X
1998	X	
1995	X	X
1989	X	
1981	X	
1964	X	X
1930	X	X
1850 (OBS)	X	X

Table 1. Distribution of stands within the chronosequence (time since last fire) studied. X's indicate a stand of that soil drainage type was studied. OBS is the name of the stand, as named during the BOREAS.

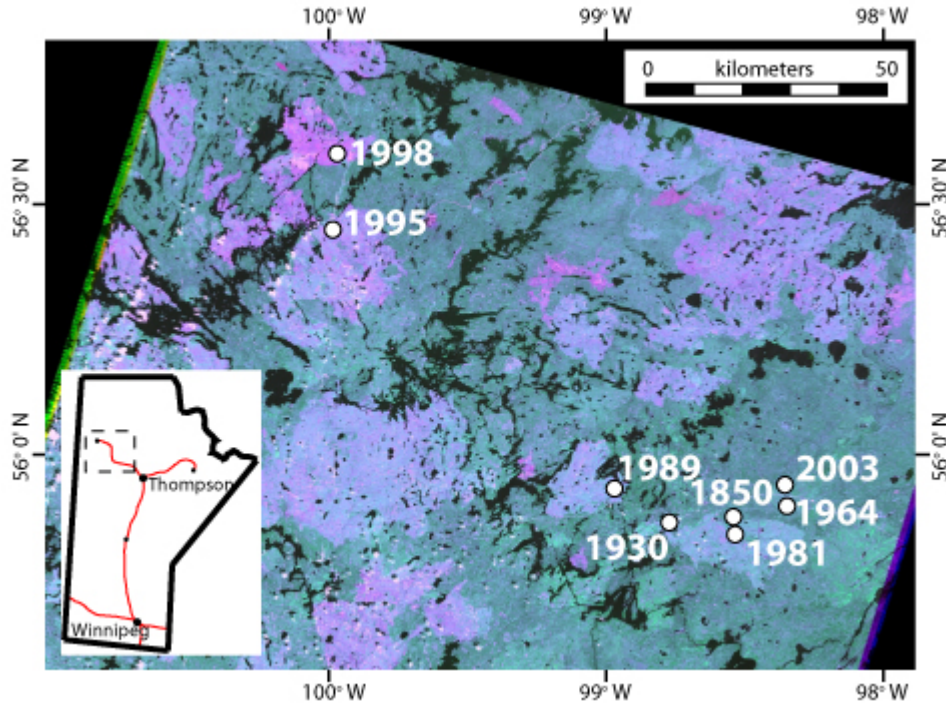


Figure 1. The location of the FIERES-ExB sites. Years listed represent when the stand last burned.

Landsat ETM image courtesy of B. Bond-Lamberty.

Site Descriptions

The study sites are located in the area surrounding Thompson, Manitoba (lat 55.7° N., long 97.9° W.; Fig. 1). This area is underlain by glaciated Precambrian bedrock, which results in hummocky local topography (Veldhuis, 1995). This bedrock is blanketed by thick glacio-fluvial deposits, the result of Lake Agassiz. Soils tend to be classified as cold Cryoboreal (Veldhuis, 1995).

Collaborations and Ancillary Data

The sampling sites described here are the focus of several investigations. These studies include, but are not limited to the following: leaf area index (LAI), net primary production (NPP), soil surface CO₂, stem sapflux – S.T. Gower (Univ. of Wisconsin – Madison); eddy flux measurements - M. Goulden (Univ. of California – Irvine); soil ¹⁴C and CO₂ measurements – S. Trumbore (Univ. of California – Irvine); soil classification and mapping – H. Veldhuis (Agriculture Canada); and leaf level gas exchange and soil CO₂ measurements – M. Litvak (Univ. of New Mexico – Albuquerque). More information about this study can be found at <http://carbon.wr.usgs.gov> and <http://forestecology.forest.wisc.edu/wildfire.html>.

Sample Collection

The following methodology applied to samples collected by the U.S. Geological Survey. The attached databases also include data regarding samples collected by H. Veldhuis of Agriculture Canada. While the general sampling strategy remained the same for all samples, Agriculture Canada (AgCanada) samples were sent to the U.S. Geological Survey (Menlo Park, CA) for chemical analysis only. Bulk density and volumetric moisture content data presented in these spreadsheets are values obtained by Agriculture Canada. For these samples, only the methodology for total Carbon, total Nitrogen, $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$ applies. It should also be noted that these samples were not oven-dried. Therefore, the chemistry values presented in this report are on an air-dried basis. Conversion of air-dried %C and %N values to an oven-dried basis can increase these values by up to 8% for organic layers and up to 3% for the mineral soil (calculations based on data found in Manies and others, 2004).

Soils described by the U.S. Geological Survey were excavated by shovel or auger to the depth of mineral soil. The profile was then divided into distinct soil horizons and described according to USDA-

NRCS (Staff, 1998) and Canadian (Canadian Agricultural Services Coordinating Committee, 1998) methodologies. We modified soil horizon codes according to the following scheme:

- L Live moss, which are green and generally contain some leaf and needle litter.
- D Dead moss, which is comprised of non- or slightly-decomposed dead moss. The dead moss layer is characterized by fibric organic horizons that contain more moss than roots.
- F Fibric (according to Canadian soil system) or fibrous organic layers, which vary in degree of decomposition but in which roots are more abundant than recognizable moss parts. In most cases these layers would be considered Oi layers (U.S. soil system) or upper duff (U.S.F.S. system).
- M Mesic (according to Canadian soil system) organic layers, which are moderately decomposed with few if any recognizable plant parts other than roots. M layers are generally Oe horizons (U.S. soil system) or lower duff layers (U.S.F.S. system).
- H Humic (Canadian soil system) or sapric organic layers, which are highly decomposed. This layer generally smears upon squeezing and has no recognizable plant parts. H layers are generally Oa horizons (U.S. soil system) or lower duff (U.S.F.S. soil system) layers.
- A Mineral soil that forms at the surface or below organic horizons (U.S. and Canadian soil system), with less than 20% organic matter, as judged in the field.
- B Mineral soil that has formed below an A horizon (U.S. and Canadian soil system), with little or none of its original rock structure.
- C Mineral soil that has been little affected by pedogenic processes (U.S. and Canadian soil system).
- LT Litter layer (dead leaves, twigs, etc.)
- LN Lichen

A lower case 'b' before any horizon codes indicated the horizon had been burned. This code could indicate anything from light scorching to deep charring.

A subset of the soil profiles described were also sampled by soil horizon. Samples were collected for bulk density, chemistry, and to determine moisture content using a variety of tools, including a mineral soil sampler (Model 0200 soil sampler from Soilmoisture Equipment Corporation, Goleta, CA) and rectangles or cylinders of known area (used for litter and organic horizons). After collection, samples were air-dried as much as possible and sent to U.S.G.S. for sample preparation.

Sample Preparation and Drying

Field notes were used to inventory all samples entering the laboratory. Any discrepancy between field descriptions and laboratory observations was resolved before sample preparation began or the sample was discarded. All U.S.G.S. soil samples were immediately placed on open shelves in an isolated room and allowed to air dry to a constant weight. Temperature during air-drying ranged from 20 to 30 °C. Once air dried, samples were separated into two splits: one for archival purposes, the other for oven dry moisture/analytical purposes. (Archive fractions of most of the samples described here are available by contacting J. Harden at the Menlo Park, CA office of U.S.G.S.) Because bulk density calculations are made using the volume of the entire sample the oven dry moisture of the entire sample is also needed. Because samples were separated into splits bulk density calculations assumed that the air-to-oven dry moisture ratio in the entire sample was the same as for the moisture/analytical split. These splits were oven dried for 48 hours in a forced-draft oven. Moisture samples that appeared to contain greater than 20 % organic matter (e.g., moss, litter) were oven dried at 65 °C to avoid loss or alteration of organic matter by oxidation or decomposition. The remaining moisture samples were oven dried at 105 °C.

Following oven drying, samples were processed one of two ways, depending on horizon code. Mineral samples were gently crushed using a ceramic mallet and plate, being careful to break only aggregates. The crushed sample was mixed and split into subsamples for analysis and archiving. The chemical fraction was weighed and sieved using a 2 mm screen. Soil particles not passing the 2 mm screen were removed, weighed, and saved separately. Soil passing the 2 mm screen was ground by hand using a mortar and pestle or ceramic mallet and plate to pass through a 60 mesh (0.246 mm) screen. The ground material was mixed and placed in a labeled, glass sample bottle for subsequent analyses. Organic samples were weighed and roots greater than 1 cm in diameter were removed, weighed, and saved separately. The remaining sample was then milled in an Udy Corporation Cyclone mill (Ft. Collins, CO) to pass through a 0.5 mm screen. The milled sample was thoroughly mixed and a representative sample placed in a labeled, glass sample bottle for analytical chemistry.

Laboratory Methods

Total Carbon, Total Nitrogen, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$

A Carlo Erba NA1500 elemental analyzer (EA) was used to determine total C and total N. For initial measurements this EA was coupled to a Micromass Optima isotope ratio mass spectrometer (IRMS) in continuous flow mode, so we could also obtain $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. A subset of samples were run (or rerun) on a separate Carlo Erba NA 1500 elemental analyzer which was not associated with a IRMS. It should be noted that because carbonates exist in this region, thus total C values for mineral soil samples with pH values > 7.0 should be expected to include both organic and inorganic carbon (Soil Survey Staff, 1951). For mineral samples with a pH \leq 7.0 and all organic samples, all of the C can be assumed organic.

For reliable quantification of $\delta^{15}\text{N}$, 15 to 30 $\mu\text{g N}$ are generally needed and few samples met this criterion. Thus the $\delta^{15}\text{N}$ data are not reported here; these data are available from the authors by request.

The carbon and nitrogen concentration of all soil samples were compared to a main working standard, ethylene diamine tetra-acetic acid (EDTA), which has been calibrated to air nitrogen through a set of international standards. The chemical formula for this compound corresponds to a C concentration of 41.09 % and N concentration of 9.59 %. Additional working standards were analyzed as samples in all runs to check consistency and overall precision. Two to three working standards were included in all runs: a marine sediment (MESS-1), issued by the Chemistry Division of the Canadian National Research Council (Govindaraju (1989)); a river sediment (NBS 1645), issued by the National Bureau of Standards, now the National Institute of Standards and Technology (NIST) (Govindaraju

Standard	Carbon (%)	Nitrogen (%)	$\delta^{13}\text{C}$ (‰)
EDTA	41.11 (1.51) n = 673	9.53 (0.65) n = 674	-32.23 (0.22) n = 680
MESS-1	3.02 (0.15) n = 49	0.18 (0.01) n = 49	-25.64 (0.14) n = 49
NBS-1645	5.21 (0.39) n = 53	0.09 (0.01) n = 55	-22.29 (0.27) n = 53
NIST-1547	46.81 (0.98) n = 133	2.79 (0.09) n = 133	-26.11 (0.30) n = 134

Table 2. Statistical analyses for EA-IRMS standards run from mid-April 2001 through mid-January 2004.

The average value is followed by the standard deviation (in parentheses) and the number of samples run.

Certified values are as follows: MESS-1 = 2.99 %C; NBS-1645 = 0.0797 %N; NIST 1547 = 2.94 %N.

(1989); and NIST-1547, peach tree leaves (Becker, 1990). Certified values were obtained from

Govindaraju (1989). Our values were generally in good agreement with those for which the standard had been certified (Table 2).

$\Delta^{14}\text{C}$ Analyses

A subset of soil samples was run for ^{14}C abundance. Most of these samples were chosen to aid in modeling soil turnover and/or partition carbon into more labile versus stable pools. The ^{14}C content of ground, untreated soil was measured by vacuum sealing a homogenized sample containing ~1 mg C with cupric oxide and elemental silver in a quartz tube. The sample was then combusted at 850 °C and the resulting CO_2 was purified cryogenically and reduced to graphite using a modified reduction method with titanium hydride, zinc, and cobalt catalyst (Vogel, 1992). The graphite target was measured directly for ^{14}C at Lawrence Livermore National Laboratory, Center for Accelerator Mass Spectrometry.

The ^{14}C data are expressed in Delta notation ($\Delta^{14}\text{C}$), which similar to $\delta^{13}\text{C}$, expresses the deviation in the $^{14}\text{C}/^{12}\text{C}$ in parts per thousand (‰) as compared to the standard NIST Oxalic Acid I ($\text{C}_2\text{H}_2\text{O}_4$), with additional correction for fractionation, based on generalized ^{13}C values (see Stuiver, 1980; Stuiver and Polach, 1977). $\Delta^{14}\text{C}$ values can also be converted to percent Modern (pM) values by dividing by 10 and adding 100. For example, $\Delta^{14}\text{C}$ of 0 ‰ would equal 100 pM. These values also approximately represent the $^{14}\text{C}/^{12}\text{C}$ of wood grown in 1890, a time at which the atmosphere was relatively free of CO_2 from fossil sources.

Elemental Analyses

Elemental concentrations within the samples were analyzed for forty major, minor, and trace elements using inductively coupled plasma-atomic emission spectrometry (ICP-AES). The sample was pretreated with nitric acid and hydrogen peroxide and brought to dryness at a low temperature to help reduce the organic content and reduce reactivity. The sample was then digested using a mixture of hydrochloric, nitric, perchloric, and hydrofluoric acids at low temperatures. This final solution was introduced into the ICP-AES, where the elemental emission signals were measured simultaneously for

the forty elements. More information regarding this procedure, calibration techniques, and its detection limits can be found in Briggs (2002).

Particle Size Analyses

A limited number of mineral soil samples were selected for particle size analyses by conventional pipette analyses (Walter and others, 1978). Due to the large amounts of organic matter in some of the samples, the 35% hydrogen peroxide treatment was repeated three times. Even after these treatments some organic matter persisted, skewing the results toward overestimation of the sand fraction. The samples for which particle size analysis may have been problematic due to abundant organic matter are indicated in the “Notes” column of the file called *Ttown_Physical*.

Sample Nomenclature

All samples are labeled with a code describing the site and location from which the samples were obtained. Almost all the sample names adhere to the following nomenclature: they begin with the letter T, indicating that these samples were taken from sites near Thompson, Manitoba, followed by the two digit year of the burn, followed by a D or W, depending on if the site is moderately-well drained (a.k.a. dry) or somewhat poorly drained (a.k.a. wet). The exception to this rule is the BOREAS site Old Black Spruce, which historically has used the acronym OBS. We continued the use of this acronym, followed by a W or D, depending on soil drainage. Samples are further labeled with two numbers representing the profile number and basal depth of the sample (in cm). A decimal point separates the profile number from the basal depth. For example, T64D 1.15 denotes a sample from the 1964 burn moderately well drained site, profile 1 with a basal depth of 15 cm. For organizational purposes, the data has been divided into the year in which it was sampled (represented by worksheets in the data files). There is also a separate worksheet representing Agriculture Canada data.

Data-set descriptions

There are seven separate downloadable files containing the soil data collected from the eight sites described in this report. The first file, *Ttown_Site_Descriptions*, is a Word (Microsoft, Inc.) file describing the location of each site as well as sample locations within a site. General information such as sampling date, investigators, and vegetative cover is also noted. The next file, *Ttown_File_Descriptions*, also a Word file, describes in detail the data within the following five Excel (Microsoft, Inc.) files. *Ttown_Field*, contains field descriptions, such as root abundance, color, and soil texture of the sampled soils. *Ttown_Physical* contains physical descriptions of the samples, such as volumetric field moisture and bulk density. It also contains particle size, where applicable. *Ttown_Chemistry* contains elemental C, N, and $\delta^{13}\text{C}$ values for all samples. *Ttown_Suppl_Chemistry* contains ^{14}C and ICP-AES values for samples on which these analyses were run. The last file, *Ttown_Transects*, contains sample locations and field descriptions for those profiles that were described, but not sampled. A dash within a field in any of these files indicates that the observations or analyses were not performed.

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