



Soil data from *Picea mariana* stands near Delta

Junction, Alaska of different ages and soil drainage type

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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. This project has selected several sites to study within central Alaska of varying ages (time since fire) and soil drainage types. This report describes the location of these sampling sites, as well as the procedures used to describe, sample, and analyze the soils. This report also contains data tables with this 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

Boreal forests, which contain approximately 30% of all carbon (C) present in the terrestrial biome [Hom, 2003; Kasischke, 2000], play an important role in the global C cycle. Approximately 60% of the C within this ecosystem occurs within the organic and mineral soil horizons [McGuire *et al.*, 1997]. Therefore, to understand the boreal C cycle one must understand how C is gained and lost from the soil system. The main C input to soil is plant detritus, while C losses can result from decomposition, leaching, and the main disturbance of the boreal forest, fire.

Fire affects C storage of the boreal forest both directly (fire emissions) and indirectly. Indirect effects include altering the soil temperature regime through changes in albedo and the loss of organic layers, which play an important role in soil insulation [Viereck, 1981]. Changes in soil temperature in turn affects decomposition rates

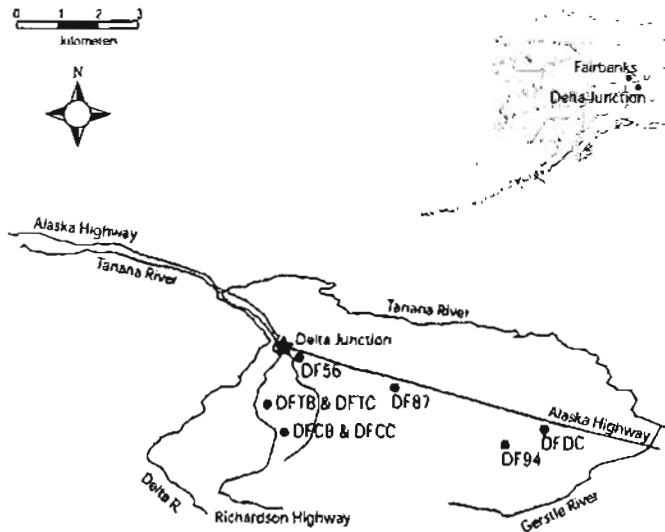


Figure 1. Location of sites in relation to Delta Junction, Alaska.

[Dioumaeva *et al.*, 2003; Hirsch *et al.*, 2003; Hobbie, 1996; Robinson, 2002] and vegetative regrowth [Chipman and Johnson, 2002]. The effects of fire differ depending on drainage type. Soil drainage affects factors such as fire frequency and severity [Harden *et al.*, 2000], vegetation recovery [Bond-Lamberty *et al.*, 2004; Viereck *et al.*, 1983], and rates of decomposition [Flanagan and Van Cleve, 1983].

The U.S. Geological Survey (U.S.G.S.) project *Fate of Carbon in Alaskan Landscapes* was created, in part, to examine in more detail how fire affects the C storage of boreal forests and how this response varies with soil drainage type. For this purpose we are studying several black spruce (*Picea mariana* (Mill.) BSP) dominated forests within central Alaska. These sites are at different stages of post-fire recovery and represent different soil moisture regimes.

Site Descriptions

The sites within this study are located in the Donnelly Flats area (lat 63° N., long 145° W.), which is ~95 mi (153 km) southeast of Fairbanks, near Delta Junction (Fig. 1). This area is

Drainage	Relative time since last burn		
	Recent	Recovering	Mature
well-drained	DFTB (1999)	DF87 (1987)	DFTC (<1950)
moderately well-drained	DFCB (1999)	DF94 (1994)	DFCC (<1860)
somewhat poorly drained			DFDC (<1860)

Table 1. Matrix of study areas by soil drainage class and relative time since last fire.

comprised of flood plains, alluvial plains, and low terraces dissected by glacier-fed streams. Soils within this area are mainly derived from the Donnelly moraine and wind blown loess [O'Neill, 2000]. Eight sites within this region were located within three different soil drainage types: well-, moderately well-, and somewhat poorly-drained. Soil drainage was based on depth to water table and hydraulic conductivity [Harden *et al.*, 2003]. Depth to water table was estimated using mineral soil characteristics, such as mottling, and depth to gravel. Hydraulic conductivity was estimated based on soil texture, where sand and soils with gravel were assumed to drain quickly and have higher hydraulic conductivity, while silt and clay dominated soils drain slower and were assumed to have lower hydraulic conductivities. Within soil drainage, sites also varied in their stage of recovery from fire (Table 1).

All sites, except the DFDC site, had organic layer/soil-horizon thickness described every 10 to 20 m along two linear transects within the site. These transects were laid out perpendicular to each other to negate any possible directional influences due to slope or dominant wind direction. Samples were taken from a subset of transect sites and were analyzed for properties such as moisture content, bulk density, and C and nitrogen (N) elemental composition. No samples were taken for the 1994 burn (DF94) due to previous sampling efforts [O'Neill *et al.*, 2003]. The somewhat poorly-drained, or DFDC, site was primarily a U.S. Forest Service (U.S.F.S.) site.

Therefore, site setup was different than the other sites (no linear transects) and no soil descriptions were done other than for those locations which were sampled.

Collaborations and Ancillary Data

The sampling sites described here are the focus of several ongoing investigations. Therefore, many measurements, in addition to soil sampling, occurred at each site. These measurements may include percent coverage for different moss species and lichen, tree density, soil temperature and moisture, woody debris inventories, and ecosystem carbon exchange. Studies (and collaborators) include ecosystem recovery following fire (M. Mack¹), post-fire soil respiration (T. Schuur¹, J. Randerson²), soil moisture and temperature (J. Neff³, J. Randerson², K. Yoshikawa⁴), CO₂ fluxes using eddy covariance towers (J. Randerson²), remote sensing of stand characteristics and fire history (E. Kasischke⁵), and the influence of fire on N budgets (M. Mack¹).

Sample Collection

Soil was 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 [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.

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- 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

Horizon codes could be further described with one of three qualifiers placed before the main code. A lower case 'b' indicated the horizon had been burned. This code could indicate anything from light scorching to deep charring. A lower case 'f' indicated the horizon was frozen at the time of sampling. A lower case 'g' indicates gravel was noted within the layer.

A subset of the soil profiles was sampled by soil horizons. Samples were collected for bulk density, analytical purposes, and to determine moisture content. In most cases, one sample was collected for both bulk density and chemical analyses, while a second sample was collected for moisture content. Bulk density samples were collected with a variety of tools, including cores of known volume (mineral soil) and rectangles (litter and organic horizons) of known area. Cores used for mineral soil sampling include, in order of relative accuracy, a Soil Moisture Equipment Corporation Model 0200 core (Goleta, CA), an AMS Inc. regular soil auger (American Falls, ID), or a bevel-ended cylinder (individually manufactured, based on corers by Eijkelkamp Agrisearch Equipment, BV, Netherlands). After collection, all U.S.G.S. samples were weighed within 24 hours and air-dried. U.S.F.S. samples were immediately put into a 68 °C oven and dried for 48 hours. Samples were then 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. Samples that did not have separate moisture and analytical samples taken in the field were split at this point. Air dry moistures of both splits were recorded. Bulk density calculations for these samples assumed that the air-to-oven dry moisture ratio in the entire sample was the same as for the moisture split. After air-drying, moisture samples/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.

Air-dry analytical samples/splits were thoroughly mixed, then split into subsamples for analysis and archiving. (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.) These samples were then 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) coupled to a Micromass Optima isotope ratio mass spectrometer (IRMS) in continuous flow mode was used to determine total C, total N, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. Because carbonates tend not to exist in this region and all mineral soil pH values were ≤ 7.0 [Staff, 1951], all (or the vast majority) of this C can be considered organic. Samples

were combusted in the presence of excess oxygen. The resulting sample gasses were swept in a continuous flow of helium through an oxidation furnace, followed by a reduction furnace, to yield CO₂, N₂ and water vapor. Water was removed by a chemical trap and CO₂ and N₂ were chromatographically separated before entering the Micromass Optima IRMS for quantification of C, N, δ¹³C and δ¹⁵N. Carbon and N were determined by integrating the major ion peaks (mass 44 for CO₂, and mass 28 for N₂). For reliable quantification of δ¹⁵N, 15 to 30 µg N are generally needed and few samples met this criterion. Thus the δ¹⁵N data are not reported here; these data are available from the authors by special request. The δ¹³C data are reported as deviations in parts per thousand (‰) relative to a standard, here Vienna Pee Dee Belemnite (V-PDB). δ¹³C was calculated as:

$$\delta^{13}\text{C } \text{\textperthousand} = (((^{13}\text{C sample}/^{12}\text{C sample}) / (^{13}\text{C standard}/^{12}\text{C standard})) - 1) * 1000 \quad (1)$$

All 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 working standards were included in all runs: a marine sediment (MESS-1), issued by the Chemistry Division of the Canadian National Research Council, and a river sediment (NBS 1645), issued by the National Bureau of Standards, now the National Institute of Standards and Technology (NIST). Certified values were obtained from Govindaraju [1989]. These working standards are more representative of mineral soil samples. Over half the runs also included NIST-1547, N certified at 2.94 ± 0.12 % by weight [Becker, 1990].

Standard	Carbon (%)	Nitrogen (%)	$\delta^{13}\text{C}$ (‰)
EDTA	41.05 (1.05) n = 599	9.54 (0.60) n = 599	-32.24 (0.16) n = 599
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. Statistics 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.

NIST-1547 peach leaves are more similar to the highly organic surface soils. Our values were generally in good agreement with those for which the standard had been certified (Table 2).

¹⁴C Analyses

A subset of samples were run for ¹⁴C activity. Most of these samples were chosen to aid in modeling soil turnover and (or) partition carbon into more labile versus stable pools. The ¹⁴C 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 CO₂ 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 ¹⁴C at Lawrence Livermore National Laboratory, Center for Accelerator Mass Spectrometry.

The ¹⁴C data are expressed in Delta notation ($\delta^{14}\text{C}$), which similar to $\delta^{13}\text{C}$, expresses the deviation in the ¹⁴C/C in parts per thousand (‰) as compared to the standard NIST Oxalic Acid I (C₂H₂O₄),

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. A $\delta^{14}\text{C}$ of 0 ‰ or 100 pM or $^{14}\text{C/C}$ of 1.176×10^{-12} approximately represents the $^{14}\text{C/C}$ of atmospheric CO_2 in the year 1890.

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 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 et al.*, 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 organic matter may have been problematic in particle size analyses are indicated in the "Notes" column of the file called *Delta_Physical*.

Sample Nomenclature

All samples are labeled with a code describing the site and location from which the samples were obtained. All sample names begin with the same two letters (DF), representing Donnelly Flats, the region in which these sites are located. These two letters are followed by two characters indicating the site. For organizational sake, the eight sites have been subdivided into three sections (represented by worksheets in the data files). The first section (Tower) contains data from the two sites that have an eddy covariance tower: Tower Burn (DFTB), which burned in 1999, and Tower Control (DFTC), which is a mature site. Both of these sites have well-drained soils. The second section (Creek) is for another burn/control pair, located near Twelve-mile Creek: Creek Burn (DFCB), which burned in the same 1999 wildfire as Tower Burn, and Creek Control (DFCC), a mature site. Both of these sites are located on moderately-well drained soils. The last section (Misc.) contains data for stands that burned in 1994 (DF94; moderately well-drained soils), 1987 (DF87; well drained), 1956 (DF56; moderately well-drained), and DFDC, the mature somewhat poorly drained U.S.F.S. site.

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, DFTC 1.20 denotes a sample from Donnelly Flats Tower Control, profile 1 with a basal depth of 20 cm.

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, *Delta_Site_Descriptions*, is a Word (Microsoft, Inc.) file describing the location of each site and, within a site, where soils were sampled. General

information such as sampling date, investigators, and vegetative cover is also noted. The next file, *Delta_File_Descriptions*, also a Word file, describes in detail the data within the following five Excel (Microsoft, Inc.) files. *Delta_Field*, contains field descriptions, such as root abundance, color, and soil texture, of the sampled soils. *Delta_Physical* contains physical descriptions of the samples, such as volumetric field moisture and bulk density. It also contains particle size, where applicable. *Delta_Chemistry* contains elemental C, N, and $\delta^{13}\text{C}$ values for all samples. *Delta_Suppl_Chemistry* contains ^{14}C and ICP-AES values for samples on which these analyses were run. The last file, *Delta_Transects*, contains sample locations and field descriptions for those profiles that were described, but not sampled.

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