Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Sara K. Conrad, Editors

Volume 244

BOREAS TGB-12 Soil Carbon Data over the NSA

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000
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Summary

The BOREAS TGB-12 team made measurements of soil carbon inventories, carbon concentration in soil gases, and rates of soil respiration at several sites to estimate the rates of carbon accumulation and turnover in each of the major vegetation types. TGB-12 data sets include soil properties at tower and selected auxiliary sites in the BOREAS NSA and data on the seasonal variations in the radiocarbon content of CO₂ in the soil atmosphere at NSA tower sites. The sampling strategies for soils were designed to take advantage of local fire chronosequences, so that the accumulation of C in areas of moss regrowth could be determined. These data are used to calculate the inventory of C and N in moss and mineral soil layers at NSA sites and to determine the rates of input and turnover (using both accumulation since the last stand-killing fire and radiocarbon data). This data set includes physical parameters needed to determine carbon and nitrogen inventory in soils. The data were collected discontinuously from August 1993 to July 1996. The data are stored in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification
BOREAS TGB-12 Soil Carbon Data over the NSA

1.2 Data Set Introduction
The data presented here include physical parameters needed to determine carbon and nitrogen inventory in soils (bulk density, %C (both as organic C and CaCO₃), %N, C/N ratio in organic matter) as well as ^14C measurements of organic matter. Soil moisture data (good only for the day of collection) and brief descriptions of soil horizons are also included.
1.3 Objective/Purpose

The objectives of the research were:
- To estimate rates of carbon input, turnover, and accumulation in the soils of each of the major vegetation types at the BOREal Ecosystem-Atmosphere Study (BOREAS) study sites. The primary tool will be measures of $^{14}$C content in soils, litter, and soil atmospheres, and measurements of CO$_2$ emissions from the soil.
- To relate our estimates of dynamics of soil carbon to ecosystem models of the carbon cycle, to other measures of C cycling dynamics, to regional models of soil carbon accumulation, and to spatial and temporal models of soil moisture and drainage.

1.4 Summary of Parameters

The key parameters include brief description of the sample/horizon (e.g., brown decomposed moss, clay), soil pH, soil moisture, bulk density, organic carbon and nitrogen content, inorganic carbon content, and radiocarbon ($^{14}$C) content.

1.5 Discussion

Carbon inventories and $^{14}$C give information that is needed to determine C storage, as well as to determine the accumulation rate of C (in nonsteady-state systems) or the turnover rate of C (in systems where C turnover rate is less than soil or disturbance age). These data are checked using the isotopic composition of respired CO$_2$ (which will reflect the $^{14}$C content of root respiration and decomposing organic matter), and by a knowledge of soil C inputs and losses. See Section 3 (below) for details.

1.6 Related Data Sets

BOREAS TE-20 NSA Soil Lab Data
BOREAS TE-20 Soils Data over the NSA-MSA and Tower Sites in Raster Format
BOREAS TGB-01 Soil CH4 and CO2 Profile Data over the NSA
BOREAS TGB-03 Soil CO2 and CH4 Profile Data over the NSA
BOREAS TGB-12 222Rn Activity Data over the NSA
BOREAS TGB-12 222Rn Flux Data over the NSA
BOREAS TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format
BOREAS TGB-12 Isotopic Carbon Dioxide Data over the NSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation

Input, Accumulation and Turnover of Carbon in Boreal Forest Soils
2.3 Contact Information

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3. Theory of Measurements

Soil moisture and soil C and N inventory are relatively common and straightforward measurements to make and will not be discussed in detail here.

$^{14}$C is produced in the stratosphere by the $^{14}$N (n,p) $^{14}$C reaction. The $^{14}$C atom is oxidized rapidly to $^{14}$CO, which has a lifetime of months before it is oxidized to $^{14}$CO$_2$. Most $^{14}$C production occurs in the stratosphere, but the long lifetime of CO$_2$ enables $^{14}$CO$_2$ to become well mixed throughout the troposphere. The steady-state $^{14}$C content of the atmosphere is determined by the exchange of carbon in CO$_2$ with that in ocean and biospheric reservoirs. Because of the relatively rapid
cycling of carbon between the atmosphere and living biomass, most plants maintain a $^{14}$C specific activity (or $^{14}$C/$^{12}$C ratio corrected for mass-dependent isotope fractionation effects) that equals that of atmospheric CO$_2$. Similarly, animals reflect the $^{14}$C/$^{12}$C of the plants (or animals) they consume. Upon the death of an organism, the $^{14}$C in its tissues is no longer replenished, and decays with a half life of 5730 years. If the tissue remains intact and isolated from exchange, the $^{14}$C/$^{12}$C ratio may be used to indicate the time since the death of the organism. This is the basis for radiocarbon dating.

Calculation of a radiocarbon age requires the assumption that the $^{14}$C content of the carbon originally fixed in plant tissues equaled that of the atmospheric CO$_2$ in 1950 ($0.95$ times the activity of oxalic acid, or Modern). In fact, the $^{14}$C content of the atmosphere has varied with time because of changes in the production rate of $^{14}$C (cosmic ray flux and magnetic field variations) and because of changes in the distribution of carbon among ocean, biosphere, and atmospheric reservoirs. These variations, deduced from the $^{14}$C content of cellulose of known age taken from the annual growth rings of trees, are generally less than 10% over the past 7,000 years. More recent changes in the $^{14}$C content of atmospheric CO$_2$ have resulted from dilution by $^{14}$C-free fossil-fuel-derived carbon and by the production of $^{14}$C during atmospheric testing of thermonuclear weapons (bomb $^{14}$C). The latter effect dominates other natural and fossil fuel effects, as the atmospheric burden of $^{14}$C was approximately doubled in the few years preceding the implementation of the Nuclear Test Ban Treaty in 1964. This isotopic spike in the global carbon system provides a means for radiocarbon to be a useful tracer of carbon cycle processes on time scales of decades.

We express $^{14}$C data in the geochemical D notation, the deviation in parts per thousand (per mil) from an absolute standard ($95$ times the activity of NBS oxalic acid measured in 1950). In this notation, zero equals the $^{14}$C content of 1895 wood, positive values indicate the presence of 'bomb' radiocarbon, and negative values indicate the predominance of C fixed from the atmosphere more than several hundred years ago.

One important correction made in calculating the D $^{14}$C value is the $^{13}$C concentration is needed to account for isotopic fractionation effects. For example, consider that the d $^{14}$C difference between atmospheric CO$_2$ and carbon fixed during photosynthesis by C3 plants is approximately 20. Since the mass difference between 12 and 14 is twice that between 12 and 13, the fractionation of $^{14}$C will be roughly twice that of $^{13}$C. The $^{14}$C contents of a tree and the CO$_2$ that it is fixing through photosynthesis will differ by approximately 40%. To account for fractionation effects, the sample (with d $^{13}$C of d) and standard are corrected to a constant $^{13}$C content. The standard oxalic acid is corrected in the same way, to -19 per mil (see references in Section 17 for more detail).

For seeds and deciduous leaves that represent a single year's growth, the $^{14}$C content of recent samples may be used to determine the age of a sample to within a year or two. The $^{14}$C content of the sample is compared to the $^{14}$C record of atmospheric C in the Northern Hemisphere (see Burcholadze reference in Section 17 for an example). Evergreen needles, that may average several years' growth, will be less easily interpreted.

For samples prior to 1960, radiocarbon ages in years may be calculated from the given Delta values as $-8033\times(\ln(Delta_{0.995/1000 +1}))$. The conventional radiocarbon age must be converted to a calibrated age using the tree-ring-based calibration curves that correct for known variations in atmospheric $^{14}$C over time. Both ages are usually rounded to the nearest decade or pentad.

One application of radiocarbon to soil science is the $^{14}$C dating of charcoal and plant macrofossils to determine the accumulation rate of C in vertically aggrading soils (peat or moss).

Unlike the closed systems represented by intact macrofossils, such as seeds or pollen, bulk Soil Organic Matter (SOM) is a heterogeneous reservoir with a variety of turnover times, to which carbon is continuously added (as new plant matter) and lost (as leached organic carbon or CO$_2$). The radiocarbon content of SOM can not be interpreted as a 'date,' but represents the average age of a carbon atom in this reservoir.

The breakdown of C into faster and slower cycling pools may be determined by combining several approaches (see the articles in the reference list for more information).

For soils that are accumulating organic matter, the Harden et al. (1992) approach is used. The
upward accumulation of carbon in feathermoss is modeled as a time sequence described by inputs and decomposition according to the following equation:

\[
\frac{dC}{dt} = I - kC \quad (1) \\
C_t = \frac{I}{k} \left(1 - e^{-k t}\right) \quad (2)
\]

where C is carbon mass in units of mass per area, t is time, I is input rate in mass per area per year, and k is a decomposition coefficient in units of time-1. This approach assumes that decomposition is proportional to total mass.

Two approaches were used:
- Measuring the \(\frac{dC}{dt}\) for mosses in stands of different ages of recovery since fire and fitting a curve of \(C\) and time with equation (2). At each identified postburn site, transects were conducted across a variety of soil drainage classes to collect samples for inventories of biomass (trees and understory), accumulating slash, moss, and soil.
- Using \(^{14}C\) to determine time to construct a curve of cumulative C inventory versus time at a single site (to which equation (2) is fit and I and k determined). In moss layers, we use the bomb- \(^{14}C\) signal recorded in growing mosses (particularly Sphagnum); in humic and mineral soil layers, we use standard radiocarbon ‘age’ calculations. This approach assumes that time information, derived from macrofossils picked from the soil or moss sample, is representative of C dynamics for the bulk sample (not particularly true for feather mosses).

4. Equipment

4.1 Sensor/Instrument Description

Shovel, eyes, and sample bags. Lab Equipment - Carlo Erba NA1500 carbon and nitrogen combustion analyzer; vacuum lines for purification of CO\(_2\) from combusted samples and graphite target preparation. Accelerator mass spectrometer (AMS) used for \(^{14}C\) measurement is described in Southon et al. (1992) and Trumbore (1993).

4.1.1 Collection Environment

Samples were collected under all environmental conditions.

4.1.2 Source/Platform

Ground.

4.1.3 Source/Platform Mission Objectives

None given.

4.1.4 Key Variables

Soil temperature, sample depth, air temperature, site descriptions, del \(^{13}C\), del \(^{14}C\), CO\(_2\) concentration, pH of the soil, volumetric and gravimetric soil, bulk density, and organic C and N.

4.1.5 Principles of Operation

None given.

4.1.6 Sensor/Instrument Measurement Geometry

None given.

4.1.7 Manufacturer of Sensor/Instrument

None given.

4.2 Calibration
4.2.1 Specifications
None given.

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibration
None given.

4.2.3 Other Calibration Information
None given.

5. Data Acquisition Methods

Special pits were equipped with thermistors (for monitoring soil temperature), Time Domain Reflectometry (TDR) probes (for monitoring soil water content), and soil gas probes (1/8" stainless steel tubing, perforated at one end and inserted 50 to 100 cm laterally into the soil pit wall, capped with 1/8" swagelock union fittings sealed with a septum). Further details are given in Winston et al. (1997), and in Section 4, below.

Gas samples were obtained using gas-tight syringes, <10 cc for soil CO₂ (made using a LI-COR and the method of Davidson and Trumbore (1995) and CH₄ measurements (made by flame ionization detector gas chromatography). Soil samples are sieved (to <2 mm) to remove rocks and large roots. We have quantified how much of this material was removed, and estimated the amount of C and N contained in the larger fractions. We report bulk density or carbon inventory data of the <2 mm fraction, then add the >2 mm portion back in to determine total bulk density and C inventory. In clay soils, this is a less important correction than in the sandy, gravelly soils (an example of where these data are needed is in the very gravelly soils found at the Northern Study Area (NSA) Young Jack Pine (YJP) site). The samples are then homogenized, split, and in some cases ground to <100 mesh for chemical analyses.

Laboratory measurements are described below:

Bulk density
Bulk density is measured by determining the oven dry weight of a specific volume of soil. Field sampling utilized a 'box' of known area for collection of organic samples in upper soil horizons (such as mosses and litter layers). The area sampled was generally 12 cm x 12 cm. Samples of generally less than 7 cm depth were taken. Note that the depths are not as well determined as the area, therefore areally expressed data (gC/cm²) should be used in these layers with more confidence than the bulk density data.

In deeper soil layers, the bulk density data were measured using several small cores (roughly 3.5 cm diameter by 5 cm in length) that were pushed into the pit wall.

%N, %C and %CaCO₃
These measurements were performed with a commercial combustion analyzer (Carlo Erba NA1500). This instrument flash-combusts organic matter, oxides all C to CO₂ and reduces all N to N₂, then separates these gases chromatographically, and detects them with a thermal conductivity detector. The detector response for C and N is determined by combusting known quantities of C and N-containing pure compounds. Combusting empty capsules determine blanks, due to the presence of small amounts of C in the tin boats used to hold the sample (for C) or to small amounts of residual air (for N₂). The combustion analyzer will oxidize both organic carbon and inorganic carbonates to CO₂. The Lake Agassiz clays underlying many of the soils in the NSA contain significant amounts of inorganic CaCO₃. To determine both CaCO₃ and organic C content, each sample is analyzed twice: once for total carbon and once after it has been acidified to remove calcium carbonate. The %CaCO₃ is
then the Total %C minus the %C due to organics. Uncertainties are still being investigated for this equipment in the Irvine laboratory, but in general %C values are reproducible to +/- 0.05% (organic) and %N.

$^{14}$C

Carbon-14 is measured by accelerator mass spectrometry of graphite targets prepared from CO$_2$ (see one of several references, including Trumbore, 1995). Samples (of 1-2 mg carbon equivalent) are combusted in vacuum in quartz tubes with cupric oxide wire at 900 °C. The resulting CO$_2$ is purified cryogenically, then reduced to graphite coating cobalt powder in a sealed Pyrex tube at 500-550 °C with zinc and titanium hydride powder. AMS measurements were made at the Lawrence Livermore National Laboratory Center for Accelerator Mass Spectrometry. One sigma precision is usually +/- 8-10 per mil (0.8-1.0 % Modern), and overall accuracy (based on repeated measurements of substandards prepared in the same way as samples) is 1.0-1.5% of Modern (10-15 per mil). We have noted what was measured for $^{14}$C, as specific fractions of the organic C are measured; these fractions include macrofossils (sphagnum leaves, fine root hairs, deciduous leaves, or charcoal), and chemically treated samples (residue after treatment with 0.5 N HCl).

6. Observations

6.1 Data Notes

The table below lists soil classification (by order, subgroup, and soil type) of soil pits in this study. This information enables the user to spatially link soils data from this study to the TE-20 Soils Data over the NSA-MSA and Tower Sites in Raster Format and TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format. See TE-20 soils data documentation, TE-20 Soils Report, and Soil Classification Working Group (1998) for detailed description of soil classification.

<table>
<thead>
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<th>Soil Pit</th>
<th>Order</th>
<th>Sub-group</th>
<th>Soil Type</th>
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<td>TYF</td>
<td>FCD</td>
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SOILDEV = Soil development (soil classification).

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Cryosolic
OSC  Orthic Static Cryosol
RSC  Regosolic Static Cryosol
OTC  Orthic Turbic Cryosol
RTC  Regosolic Turbic Cryosol
FIOC  Fibric Organic Cryosol
MEOC  Mesic Organic Cryosol
HUOC  Humic Organic Cryosol
TFIOC  Terric Fibric Organic Cryosol
TMEOC  Terric Mesic Organic Cryosol
THUOC  Terric Humic Organic Cryosol

VARIANT

Code  Class

c  Cryic
l  Lithic
p  Peaty

SOIL TYPE  (See TE-20 Soils Report for descriptions of soil types.)

ATK  - Atik
BDY  - Baldy
BGC  - Bog Collapse
BRN  - Brannigan Creek
BTT  - Button
CLK  - Clarke
CMK  - Cormorant Lake
FCD  - Fen Collapse
FEN  - Fen
GRS  - Grass River
LPR  - La Perouse
LWP  - Low Pine
MDR  - Medard
NIC  - Nichols Lake
PAA  - Palsa
PCB  - Partridge Beak
PCH  - Partridge Head
PCP  - Partridge Crop
PKW  - Pakwa
PLH  - Palsa Hummock
PLT  - Plateau
PPU  - Pipun
ROK  - Roe Lake
SWK  - Sipiwesk
SYB  - Sandy Bog
TBL  - Turnbull
TFN  - Thaw Fen
TYL  - Tyrrell
WBT  - Wabowden
WRL  - Warren Landing
WTP  - Wet Pine
YGP  - Young Pine
SOIL PHASE

Code

d  Deep
h  Humus
s  Shallow
v  Very deep
w  Very shallow
x  Complex

Note: The TGB-12 and TE-20 raster data sets cover the same area of the NSA-MSA. Both data sets contain a raster image and an attribute file that describes each soil polygon. The TGB-12 raster data was modified to account for the 1981 burn. In this data set polygons with POLYNUM 238 - 248 are within the burn.

6.2 Field Notes
None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The coordinate information for the various sampled sites is incomplete in the following lists. Where latitude and longitude coordinates exist, they are expressed in degrees and in reference to the North American Datum of 1983 (NAD83).

Sites with Coordinate Information

<table>
<thead>
<tr>
<th>Site Name/Label</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR1, Gillam Road</td>
<td>55.9055° N</td>
<td>97.7087° W</td>
</tr>
<tr>
<td>GR2, Gillam Road</td>
<td>55.9082° N</td>
<td>97.7003° W</td>
</tr>
<tr>
<td>GR3, Gillam Road:</td>
<td>55.906° N</td>
<td>97.7098° W</td>
</tr>
<tr>
<td>GR4, Gillam Road:</td>
<td>55.9041° N</td>
<td>97.7063° W</td>
</tr>
<tr>
<td>GR5, Gillam Road:</td>
<td>55.9055° N</td>
<td>97.7087° W</td>
</tr>
<tr>
<td>Gillam Road Transect</td>
<td>55.9055° N</td>
<td>97.7087° W</td>
</tr>
</tbody>
</table>

(The transect starts 100m SW of so82715C, where GR5 was sampled in detail and continues SW parallel to road with sampling approximately every 100m.)

NSA-FEN: 55.91481° N 98.42072° W
NSA-OBS: 55.88007° N 98.48139° W
OJP1: 55.9287° N 98.6248° W
OJP2: 55.9287° N 98.6248° W
NSA-OJP: 55.92842° N 98.62396° W
YJP1: 55.8952° N 98.28686° W
NSA-YJP: 55.89575° N 98.28706° W
FF1: 55.906° N 98.949° W
SLJ1: 55.0667° N 98.5083° W
Sites with No Coordinate Information Available

<table>
<thead>
<tr>
<th>Site Name/Label</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLJ2 Transect</td>
<td>approximately 500 m NNW of SLJ1</td>
</tr>
<tr>
<td>SLJ3 Transect</td>
<td>approximately 500 m NNW of SLJ2</td>
</tr>
<tr>
<td>SLJ4 Transect</td>
<td>approximately 500 m NNW of SLJ3</td>
</tr>
<tr>
<td>SLJ5 Transect</td>
<td>approximately 500 m NNW of SLJ4</td>
</tr>
<tr>
<td>SLJ6 Transect</td>
<td>approximately 500 m NNW of SLJ5</td>
</tr>
<tr>
<td>SLJ7 Transect</td>
<td>approximately 500 m NNW of SLJ6</td>
</tr>
<tr>
<td>SLJ8 Transect</td>
<td>approximately 500 m NNW of SLJ7</td>
</tr>
<tr>
<td>FFJ11</td>
<td>Footprint River, Footprint fire 1989 burn site, west side of Footprint River Bridge.</td>
</tr>
<tr>
<td>FFJ12</td>
<td>Footprint River, Footprint River, 1989 burn, west side of Footprint River bridge, poorly drained site.</td>
</tr>
<tr>
<td>SOBA0</td>
<td>Soab River 1956 burn, Site 0 on the transect; on the ridge of the SOAB 1956 burn.</td>
</tr>
<tr>
<td>SOBA1</td>
<td>Soab River, 1956 burn, South of Thompson on Hwy 391/6 just north of the Soab River on the west side of road.</td>
</tr>
<tr>
<td>SOBA2</td>
<td>Soab River, 1956 burn, 500m North of SOBA1</td>
</tr>
<tr>
<td>SOBA3</td>
<td>Soab River, 1956 burn, 500m North of SOBA2</td>
</tr>
<tr>
<td>SOBA4</td>
<td>Soab River, 1956 burn, 500m North of SOBA3</td>
</tr>
<tr>
<td>SOBA5</td>
<td>Soab River, 1956 burn, 500m North of SOBA4</td>
</tr>
<tr>
<td>SOBA6</td>
<td>Soab River, 1956 burn, 500m North of SOBA5</td>
</tr>
<tr>
<td>SOBA7</td>
<td>Soab River, 1956 burn, 500m North of SOBA6</td>
</tr>
<tr>
<td>SOBA8</td>
<td>Soab River, 1956 burn, 500m North of SOBA8</td>
</tr>
<tr>
<td>SOBA9</td>
<td>Soab River, 1956 burn, 500m North of SOBA9</td>
</tr>
<tr>
<td>SOBA10</td>
<td>Soab River, 1956 burn, 500m North of SOBA10</td>
</tr>
<tr>
<td>SOBA11</td>
<td>Soab River, 1956 burn, South of Thompson just north of the Soab River.</td>
</tr>
<tr>
<td>SOBA12</td>
<td>Soab River, 1956 burn, South of Thompson just north of the Soab River on Hwy 391.</td>
</tr>
<tr>
<td>SOBA13</td>
<td>Soab River, 1956 burn, South of Thompson just north of the Soab River on Hwy 391.</td>
</tr>
<tr>
<td>SOBA14</td>
<td>Soab River, 1956 burn, South of Thompson just north of the Soab River on Hwy 391.</td>
</tr>
<tr>
<td>SOBH1</td>
<td>Soab River</td>
</tr>
<tr>
<td>T3H</td>
<td>No location information is available.</td>
</tr>
<tr>
<td>FFJ1</td>
<td>Footprint fire 1989 burn site, far into Footprint burn, approximately 1Km north of FF1.</td>
</tr>
<tr>
<td>FFJ2</td>
<td>near the Footprint River along the FFJ transect between FFJ1 and 3.</td>
</tr>
<tr>
<td>YJPK1</td>
<td>Young Jack Pine, 1964 burn, Veldhuis Map name: Partridge soil; code pcp</td>
</tr>
<tr>
<td>YJPK2</td>
<td>Young Jack Pine, 1964 burn, Veldhuis Map name: Partridge soil; code pcp</td>
</tr>
<tr>
<td>BOG</td>
<td>No location information available.</td>
</tr>
<tr>
<td>OBS11</td>
<td>Old Black Spruce, Veldhuis Mapped name: Sipewisk.</td>
</tr>
<tr>
<td>OBSF3</td>
<td>Old Black Spruce, End of TGB spur, 2.5 m east of small corral.</td>
</tr>
<tr>
<td>OBSF4</td>
<td>Old Black Spruce, NW corner of boardwalk-TGB spur, 3m N and 3m W of intersection of spur and boardwalk.</td>
</tr>
<tr>
<td>OBSF9</td>
<td>Old Black Spruce, Veldhuis mapped name: Nicohols Lake (NIC)</td>
</tr>
</tbody>
</table>
Old Black Spruce, Site is very wet, seasonally if not perennially somewhat frozen. Bear east on catwalk, south on first spur, east about 5m

Old Black Spruce, Site is very wet, seasonally if not perennially somewhat frozen. Bear east on catwalk, south on first spur, east about 5m

Gillam Road: 1992 burn, near 89/90 km marker on Gillam Road

Gillam Road: 1994 burn.

Gillam Road: unburned control for 1992 burn, near 89/90 km marker on Gillam Road, North side of road, across from 1992 burn.

Gillam Road: unburned control for 1992 burn, near 89/90 km marker on Gillam Road, North side of road, across from 1992 burn.

Gillam Road: Cabin site, 1964 burn.

Gillam Road: Near 89/90 marker on Gillam Road.

Gillam Road: Near 89/90 marker on Gillam Road.

Gillam Road: 1992 burn, near 89/90 km marker on Gillam Road.

Gillam Road: 1992 burn, near 89/90 km marker on Gillam Road.

Gillam Road: Near 89/90 marker on Gillam Road.

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
None given.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
Soil carbon measurements were made from August 1993 to July 1996.

7.2.2 Temporal Coverage Map
Not applicable.

7.2.3 Temporal Resolution
The temporal resolution of the measurements was variable.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters contained in the data files on the CD-ROM are:

<table>
<thead>
<tr>
<th>Column Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
</tr>
<tr>
<td>SUB_SITE</td>
</tr>
<tr>
<td>DATE_OBS</td>
</tr>
<tr>
<td>SOIL_DEPTH</td>
</tr>
<tr>
<td>SOIL_TEMP</td>
</tr>
<tr>
<td>AIR_TEMP_1M</td>
</tr>
</tbody>
</table>

Page 12
The descriptions of the parameters contained in the data files on the CD-ROM are:

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
<td>The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.</td>
</tr>
<tr>
<td>SUB_SITE</td>
<td>The identifier assigned to the sub-site by BOREAS, in the format GGGGG-III, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIII is the identifier for sub-site, often this will refer to an instrument.</td>
</tr>
<tr>
<td>DATE_OBS</td>
<td>The date on which the data were collected.</td>
</tr>
<tr>
<td>SOIL_DEPTH</td>
<td>The depth below the soil surface at which the measurement was taken.</td>
</tr>
<tr>
<td>SOIL_TEMP</td>
<td>The temperature of the soil at the given depth/location.</td>
</tr>
<tr>
<td>AIR_TEMP_1M</td>
<td>The temperature of the air at 1 meter above ground level.</td>
</tr>
<tr>
<td>SNOW_DEPTH</td>
<td>The depth of snow on the ground.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>BASAL_DEPTH</td>
<td>Bottom depth of horizon/sample. Defined the top of the soil (0mm depth) as the top of the living moss layer. The top of each sample is the bottom depth of the sample above it.</td>
</tr>
<tr>
<td>SITE_COMMENTS</td>
<td>Descriptive information to clarify or enhance the site information.</td>
</tr>
<tr>
<td>COVER_TYPE</td>
<td>The dominant species, vegetation or type of land cover that exists at the location.</td>
</tr>
<tr>
<td>DEL_13C</td>
<td>The del 13C is a relative difference between the sample and the PeeDee Belemnite standard, relative to the PeeDee Belemnite standard.</td>
</tr>
<tr>
<td>DEL_14C</td>
<td>The del 14C is a relative difference between the sample and the 95% oxalic acid 1 standard, relative to the 95% oxalic acid 1 standard.</td>
</tr>
<tr>
<td>DEL_14C_DEPTH</td>
<td>The depth at which the DEL 14C measurements were taken.</td>
</tr>
<tr>
<td>CO2_CONC</td>
<td>CO2 concentration.</td>
</tr>
<tr>
<td>FLAG</td>
<td>1 means CO2 concentrations are from the amount of CO2 in the 500cc can-- 2 means 13C value given was assumed in correction of the 14C data and 0 means no comments.</td>
</tr>
<tr>
<td>SOIL_PH</td>
<td>The pH of the soil sample.</td>
</tr>
<tr>
<td>FLD_VOL_SOIL_MOISTURE</td>
<td>Grams of H2O in the field sample per cubic millimeter of volume in the soil horizon.</td>
</tr>
<tr>
<td>FLD_GRAV_SOIL_MOISTURE</td>
<td>Grams of water in the field sample per gram oven-dry total soil.</td>
</tr>
<tr>
<td>AIR_DRY_GRAV_SOIL_MOISTURE</td>
<td>Grams of water in an air-dried sample per gram of oven-dried soil whose particle size was less than 2mm. Calculation is used to express chemical data on an oven-dry basis.</td>
</tr>
<tr>
<td>OVEN_DRY_VOL_SOIL_MOISTURE</td>
<td>Volumetric moisture of oven dried samples.</td>
</tr>
<tr>
<td>OVEN_DRY_GRAV_SOIL_MOISTURE</td>
<td>Gravimetric moisture of oven dried samples.</td>
</tr>
<tr>
<td>TOT_BULK_DENSITY</td>
<td>The bulk density of all sizes of material, including rocks and coarse roots.</td>
</tr>
<tr>
<td>BULK_DENSITY_&lt;2MM</td>
<td>The bulk density of material less than 2mm in size, excluding all rocks and roots that were caught in a 2mm sieve.</td>
</tr>
<tr>
<td>ROCK_&gt;2MM</td>
<td>Percent by weight of the rock material greater than 2mm in size (i.e., did not pass through a 2mm sieve) calculated as (grams rock &gt; 2mm)/(total grams of sample).</td>
</tr>
<tr>
<td>ROOT_&gt;2MM</td>
<td>Percent by weight of the root material greater than 2mm in size (i.e., did not pass through a 2mm sieve) calculated as (grams root &gt; 2mm)/(total grams of sample).</td>
</tr>
<tr>
<td>INORG_C_CONTENT</td>
<td>Percentage of inorganic carbon contained in an oven-dried soil sample whose particles are less than 2mm in size (i.e., passed through a 2mm sieve) calculated as (grams inorganic carbon)/(total grams oven-dried sample).</td>
</tr>
<tr>
<td>ORG_C_CONTENT</td>
<td>Percentage of organic carbon contained in an oven-dried soil sample whose particles are less than 2mm in size (i.e., passed through a 2mm sieve) calculated as (grams organic</td>
</tr>
</tbody>
</table>
Carbon)/(total grams oven-dried sample).

**TOT_C_CONTENT**  Combustion analysis results, expressed as 100 * (grams C divided by grams air-dry soil) (this includes both organic and inorganic carbon). This analysis is presented on basis of <2mm air-dry soil because lab results can easily be checked but may be calculated as % of oven-dry soil using (%C air-dry basis) * (g oven-dry split)/(g air-dry basis).

**TOT_N_CONTENT**  Combustion analysis results, expressed as 100*.[g N]/[g air dry soil]. Presented on basis of <2mm oven-dry soil.

**C_N_RATIO**  Contains the ratio of grams of Carbon divided by grams of nitrogen in the soil sample, not expressed as atom ratio.

**SAMPLING_MEDIA**  What 14C was measured in (e.g. moss, bulk organics).

**CRTFCN_CODE**  The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).

**REVISION_DATE**  The most recent date when the information in the referenced data base table record was revised.

### 7.3.3 Unit of Measurement
The measurement units for the parameters contained in the data files on the CD-ROM are:

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
<td>[none]</td>
</tr>
<tr>
<td>SUB_SITE</td>
<td>[none]</td>
</tr>
<tr>
<td>DATE_OBS</td>
<td>[DD-MON-YY]</td>
</tr>
<tr>
<td>SOIL_DEPTH</td>
<td>[millimeters]</td>
</tr>
<tr>
<td>SOIL_TEMP</td>
<td>[degrees Celsius]</td>
</tr>
<tr>
<td>AIR_TEMP_1M</td>
<td>[degrees Celsius]</td>
</tr>
<tr>
<td>SNOW_DEPTH</td>
<td>[millimeters]</td>
</tr>
<tr>
<td>BASAL_DEPTH</td>
<td>[millimeters]</td>
</tr>
<tr>
<td>SITE_COMMENTS</td>
<td>[none]</td>
</tr>
<tr>
<td>COVER_TYPE</td>
<td>[none]</td>
</tr>
<tr>
<td>DEL_13C</td>
<td>[per mil]</td>
</tr>
<tr>
<td>DEL_14C</td>
<td>[per mil]</td>
</tr>
<tr>
<td>DEL_14C_DEPTH</td>
<td>[millimeters]</td>
</tr>
<tr>
<td>CO2_CONC</td>
<td>[parts per million]</td>
</tr>
<tr>
<td>FLAG</td>
<td>[unitless]</td>
</tr>
<tr>
<td>SOIL_PH</td>
<td>[pH]</td>
</tr>
<tr>
<td>FLD_VOL_SOIL_MOISTURE</td>
<td>[grams H2O][millimeter^-3 soil]</td>
</tr>
<tr>
<td>FLD_GRAV_SOIL_MOISTURE</td>
<td>[grams H2O][gram^-1 dry soil]</td>
</tr>
<tr>
<td>AIR_DRY_GRAV_SOIL_MOISTURE</td>
<td>[grams H2O][gram^-1 soil]</td>
</tr>
<tr>
<td>OVEN_DRY_VOL_SOIL_MOISTURE</td>
<td>[centimeters^3 H2O][centimeter^-3 soil]</td>
</tr>
<tr>
<td>OVEN_DRY_GRAV_SOIL_MOISTURE</td>
<td>[grams H2O][gram^-1 soil]</td>
</tr>
<tr>
<td>TOT_BULK_DENSITY</td>
<td>[grams][millimeter^-3]</td>
</tr>
<tr>
<td>BULK_DENSITY_&lt;2MM</td>
<td>[grams][millimeter^-3]</td>
</tr>
<tr>
<td>ROCK_&gt;2MM</td>
<td>[percent of total]</td>
</tr>
<tr>
<td>ROOT_&gt;2MM</td>
<td>[percent of total]</td>
</tr>
</tbody>
</table>
7.3.4 Data Source

The source of the parameter values contained in the data files on the CD-ROM are:

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
<td>Not applicable</td>
</tr>
<tr>
<td>SUB_SITE</td>
<td>Not applicable</td>
</tr>
<tr>
<td>DATE_OBS</td>
<td>Investigator</td>
</tr>
<tr>
<td>SOIL_DEPTH</td>
<td>investigator</td>
</tr>
<tr>
<td>SOIL_TEMP</td>
<td>thermistor</td>
</tr>
<tr>
<td>AIR_TEMP_1M</td>
<td>thermometer</td>
</tr>
<tr>
<td>SNOW_DEPTH</td>
<td>Investigator</td>
</tr>
<tr>
<td>BASAL_DEPTH</td>
<td>Investigator</td>
</tr>
<tr>
<td>SITE_COMMENTS</td>
<td>Investigator</td>
</tr>
<tr>
<td>COVER_TYPE</td>
<td>Investigator</td>
</tr>
<tr>
<td>DEL_13C</td>
<td>Mass spectrometry</td>
</tr>
<tr>
<td>DEL_14C</td>
<td>Accelerator mass spectrometry</td>
</tr>
<tr>
<td>DEL_14C_DEPTH</td>
<td>Investigator</td>
</tr>
<tr>
<td>CO2_CONC</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>FLAG</td>
<td>Investigator</td>
</tr>
<tr>
<td>SOIL_PH</td>
<td>Investigator</td>
</tr>
<tr>
<td>FLD_VOL_SOIL_MOISTURE</td>
<td>TDR</td>
</tr>
<tr>
<td>FLD_GRAV_SOIL_MOISTURE</td>
<td>Investigator</td>
</tr>
<tr>
<td>AIR_DRY_GRAV_SOIL_MOISTURE</td>
<td>Investigator</td>
</tr>
<tr>
<td>OVEN_DRY_VOL_SOIL_MOISTURE</td>
<td>TDR</td>
</tr>
<tr>
<td>OVEN_DRY_GRAV_SOIL_MOISTURE</td>
<td>Investigator</td>
</tr>
<tr>
<td>TOT_BULK_DENSITY</td>
<td>Calculated from BULK_DENSITY_&lt;2MM and BULK_DENSITY_&gt;2MM</td>
</tr>
<tr>
<td>BULK_DENSITY_&lt;=2MM</td>
<td>Scale</td>
</tr>
<tr>
<td>ROCK_&gt;=2MM</td>
<td>Investigator</td>
</tr>
<tr>
<td>ROOT_&gt;=2MM</td>
<td>Investigator</td>
</tr>
<tr>
<td>INORG_C_CONTENT</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>ORG_C_CONTENT</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>TOT_C_CONTENT</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>TOT_N_CONTENT</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>C_N_RATIO</td>
<td>Carlo Erba NA1500</td>
</tr>
<tr>
<td>SAMPLING_MEDIA</td>
<td>Investigator</td>
</tr>
<tr>
<td>CRTFCN_CODE</td>
<td>Not applicable</td>
</tr>
<tr>
<td>REVISION_DATE</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
### 7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Minimum Data Value</th>
<th>Maximum Data Value</th>
<th>Missng Data Value</th>
<th>Unrel Data Value</th>
<th>Below Data Limit</th>
<th>Not Cllctd</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
<td>NSA-999-999GR</td>
<td>REG-999-SOBH1</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>SUB_SITE</td>
<td>TGB03-FLXCB</td>
<td>TGB12-STM01</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>DATE_OBS</td>
<td>01-AUG-93</td>
<td>21-JUL-96</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>SOIL_DEPTH</td>
<td>0</td>
<td>920</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Blank</td>
</tr>
<tr>
<td>SOIL_TEMP</td>
<td>-9.6</td>
<td>1.12</td>
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<td>None</td>
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<td>229.5</td>
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<td>None</td>
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<td>TOT_N_CONTENT</td>
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<td>-888</td>
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<td>None</td>
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<td>C_N_RATIO</td>
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<td>448.08</td>
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<td>07-AUG-97</td>
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<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Minimum Data Value** -- The minimum value found in the column.

**Maximum Data Value** -- The maximum value found in the column.

**Missng Data Value** -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

**Unrel Data Value** -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be
Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.

Data Not Collected -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A -- Indicates that the value is not applicable to the respective column.
None -- Indicates that no values of that sort were found in the column.

7.4 Sample Data Record
The following are wrapped versions of data record from a sample data file on the CD-ROM.

<table>
<thead>
<tr>
<th>SITE_NAME</th>
<th>SUB_SITE</th>
<th>DATE_OBS</th>
<th>SOIL_DEPTH</th>
<th>SOIL_TEMP</th>
<th>AIR_TEMP_1M</th>
<th>SNOW_DEPTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSA-OJP-FLXTR</td>
<td>TGB12-IST01</td>
<td>14-JAN-95</td>
<td>240.0</td>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

8. Data Organization

8.1 Data Granularity
All of the TGB-12 NSA soil carbon data are contained in one data set.

8.2 Data Format(s)
The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data. Sample data records are shown in the companion data definition file (tgbl12scd.def).
9. Data Manipulations

9.1 Formulae

9.1.1 Derivation Techniques and Algorithms
None.

9.2 Data Processing Sequence

9.2.1 Processing Steps
None given.

9.2.2 Processing Changes
None given.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
None given.

9.3.2 Calculated Variables
None given.

9.4 Graphs and Plots
None given.

10. Errors

10.1 Sources of Error
None given.

10.2 Quality Assessment

10.2.1 Data Validation by Source
None given.

10.2.2 Confidence Level/Accuracy Judgment
None given.

10.2.3 Measurement Error for Parameters
None given.

10.2.4 Additional Quality Assessments
None given.

10.2.5 Data Verification by Data Center
The data were examined for general consistency and clarity.
11. Notes

11.1 Limitations of the Data
None given.

11.2 Known Problems with the Data
None given.

11.3 Usage Guidance
None given.

11.4 Other Relevant Information
None given.

12. Application of the Data Set

These data can be used to spatially extrapolate the storage of carbon in boreal soils. In addition, the data should prove useful to modelers who are looking at changing soil carbon amounts.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description
None given.

14.2 Software Access
None given.

15. Data Access

The TGB-12 soil carbon data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information
For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov
15.2 Data Center Identification
Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data
Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans
The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
None.

16.2 Film Products
None.

16.3 Other Products
These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation
None.

17.2 Journal Articles and Study Reports


17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms
None given.

19. List of Acronyms

AMS - Accelerator Mass Spectrometer
ASCII - American Standard Code for Information Interchange
BOREAS - BOREal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
CD-ROM - Compact Disk-Read-Only Memory
DAAC - Distributed Active Archive Center
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
GIS - Geographic Information System
GSFC - Goddard Space Flight Center
HTML - Hyper-Text Markup Language
MSA - Modeling Sub-Area
NAD\textsubscript{83} - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
OA - Old Aspen
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
SOM - Soil Organic Matter
SSA - Southern Study Area
TDR - Time Domain Reflectometry
TE - Terrestrial Ecology
TGB - Trace Gas Biogeochemistry
URL - Uniform Resource Locator
USGS - United States Geological Survey
YJP - Young Jack Pine
20. Document Information

20.1 Document Revision Date
Written: 24-Jul-1994
Last Updated: 16-Jul-1999

20.2 Document Review Date(s)
Science Review:

20.3 Document ID

20.4 Citation
When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:
The TGB-12 team published the data in two USGS open file reports (O'Neill et al., 1995a, 1995b). Please reference the reports or contact Susan Trumbore.

If using data from the BOREAS CD-ROM series, also reference the data as:

Also, cite the BOREAS CD-ROM set as:

20.5 Document Curator

20.6 Document URL
The BOREAS TGB-12 team made measurements of soil carbon inventories, carbon concentration in soil gases, and rates of soil respiration at several sites to estimate the rates of carbon accumulation and turnover in each of the major vegetation types. TGB-12 data sets include soil properties at tower and selected auxiliary sites in the BOREAS NSA and data on the seasonal variations in the radiocarbon content of CO₂ in the soil atmosphere at NSA tower sites. The sampling strategies for soils were designed to take advantage of local fire chronosequences, so that the accumulation of C in areas of moss regrowth could be determined. These data are used to calculate the inventory of C and N in moss and mineral soil layers at NSA sites and to determine the rates of input and turnover (using both accumulation since the last stand-killing fire and radiocarbon data). This data set includes physical parameters needed to determine carbon and nitrogen inventory in soils. The data were collected discontinuously from August 1993 to July 1996. The data are stored in tabular ASCII files.