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BOREAS TE-10 Leaf Chemistry Data

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BOREAS TE-10 Leaf Chemistry Data

Elizabeth M. Middleton,, Joe H. Sullivan

Summary

The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the reflectance, transmittance, gas exchange, chlorophyll content, carbon content, hydrogen content, and nitrogen content of boreal vegetation. This data set describes the relationship between sample location, age, chlorophyll content, and C-H-N concentrations at several sites in the SSA conducted during the growing seasons of 1994 and 1996. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-10 Leaf Chemistry Data

1.2 Data Set Introduction

This data set describes the relationship between sample location, age photosynthetic pigments (Chlorophyll A (chla), Chlorophyll B (chlb), and Carotenoid (carot)), and foliar Carbon-Hydrogen-Nitrogen (C-H-N) concentrations in canopies from the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) - Old Black Spruce (OBS), Old Jack Pine (OJP), Young Jack Pine (YJP), Old Aspen (OA), Old Aspen Auxiliary (OA-AUX), Young Aspen (YA), and Young Aspen Auxiliary (YA-AUX) sites. Chlorophyll pigments and foliar C-H-N concentrations were examined as part of an effort to characterize differences between species, seasons (spring, summer, and fall), stand age, leaf position, and age at the BOREAS SSA sites. Samples were taken at seven locations in the SSA: OBS, OJP, YJP, YA, YA-AUX, OA-AUX, and OA during each of the three Intensive Field Campaigns (IFCs) in 1994. Samples were taken at five locations in the

SSA: OBS, OJP, YJP, YA-AUX, and OA-AUX during each of the three seasons in 1996. This information will be useful for understanding variation in the gas exchange rates.

Measurements of chlorophyll and C-H-N concentration were made in the laboratory. A spectrophotometer was used to assess chlorophyll content and a Carbon-Hydrogen-Nitrogen-600 (CHN-600) Elemental Analyzer system was used to obtain foliar C-H-N concentrations.

1.3 Objective/Purpose

The purposes of this work were to:

- Obtain a canopy profile of chlorophyll absorptance and C-H-N concentrations.
- Examine interspecific and interseasonal differences in these parameters.
- Relate these differences to the photosynthetic measurements.

1.4 Summary of Parameters

Each data record includes the chla, chlb, carot, C/N ratio, C, N, and H.

1.5 Discussion

Chlorophyll pigment absorptances and C-H-N concentrations were measured in the laboratory on the dominant broadleaf and coniferous woody plant species growing at OBS (Picea mariana and Larix laricina), OJP (Pinus banksiana and Apocynum androsaemifolium), YJP (Pinus banksiana), YA (Populus tremuloides and Corylus cornuta Marsh), and YA-AUX (Populus tremuloides, Corylus cornuta Marsh, and Picea glauca), and the sites OA and OA-AUX (Populus tremuloides and Corylus cornuta Marsh) in the SSA of the boreal forest. Dogbane (Apocynum androsaemifolium) was an understory species at the OJP site. Tamarack (Larix laricina) was another species located at OBS, and hazelnut (Corylus cornuta Marsh) was an understory species at YA, YA-AUX, OA, and OA-AUX. Picea glauca was collected as a cospecies at the YA-AUX site.

1.6 Related Data Sets

BOREAS TE-09 NSA Leaf Chlorophyll Density
BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data
BOREAS TE-09 PAR and Leaf Nitrogen Data for NSA Species
BOREAS TE-10 Leaf Optical Properties

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Elizabeth Middleton, Project Scientist
Dr. Joseph Sullivan, Assistant Professor

2.2 Title of Investigation

CO_2 and Water Fluxes in the Boreal Forest Overstory: Relationship to fAPAR and Vegetation Indices for Needles/Leaves

2.3 Contact Information

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3. Theory of Measurements

Photosynthetic pigment concentrations were calculated using established equations that estimate concentration as a function of absorptance of foliar extracts at specific wavelengths. C and H were determined by infrared analysis of the combusted sample. N was determined by thermal conductivity.

4. Equipment

4.1 Sensor/Instrument Description

- CHN-600 Elemental Analyzer System 785-500 (LECO Corp., St. Joseph, MI).
- LI-COR Area Meter (LI-COR, Inc., Lincoln, Nebraska).
- In 1994, a Beckman DU-600 spectrophotometer was used in the laboratory at the University of Saskatchewan to determine chlorophyll absorptance.
- In 1994 and 1996, a Perkin-Elmer Lambda 3 Double Beam Spectrophotometer was used in the laboratory at the Beltsville Agricultural Research Center (BARC) to determine chlorophyll absorptance.

4.1.1 Collection Environment

The vertical profile of the canopy was divided into three layers: top, middle, and bottom. White spruce (Picea glauca) and tamarack (Larix laricina) had only one top layer measured. White spruce was located at YA-AUX. Tamarack was an understory species at the OBS. At OA and YA sites, there was a hazelnut (Corylus cornuta Marsh) understory that was measured during each IFC in 1994. At the OJP, the understory species dogbane (Apocynum androsaemifolium) was measured during IFC-2 in 1994.

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by BOREAS staff at the OBS, OA, OA-AUX, and OJP sites, and from the ground at the YJP, YA, and YA-AUX sites. Data were obtained during three discrete measurement periods (one to two measurement days each period) designated as the spring, summer, and fall seasons (IFC-1, -2, and -3).

These seasons were selected to measure parameters at bud break and leaf expansion (24-May-1994 to 12-Jun-1994 and 21-April-1996 to 24-June-1996), during midsummer or peak growing season (26-Jul-1994 to 08-Aug-1994 and 10-July-1996 to 17-July-1996), and at the onset of dormancy and

senescence in autumn (30-Aug-1994 to 15-Sept-1994 and 20-October-1996 to 31-October-1996). Measurements were made on leaves and needles from the upper, middle, and lower canopy sections of the trees adjacent to the canopy access towers at OJP, OA, OA-AUX, and OBS, and on the young trees present near the flux tower sites at YJP, YA, and YA-AUX. For Pinus banksiana, measurements were made on each needle class present. In the 1994 measurement year, needle age classes measured were 1994, 1993, and 1992. In the 1996 measurement year, needle age classes measured were 1996, 1995, and 1994. For Picea glauca, age classes 1 (1994) and 2 (1993) were measured in 1994. In 1996, age classes 1 (1996) and 2 (1995) were measured for Picea glauca. In 1994, for Picea mariana, the newest age class (1994 needles) was measured alone, while needles 2 and 3 years old (1993 and 1992 needles) were combined in one measurement, as were 4 and 5 year old needles (1991 and 1990 needles). In 1996, for Picea mariana, the newest age class (1996 needles) was measured alone, while needles 2 and 3 years old (1995 and 1994 needles) were combined in one measurement, as were 4 and 5 year old needles (1993 and 1992 needles).

At least eight replicate measurements and sample collection per season, canopy location, and age group were made for each species. These activities took place on trees that were accessible from the canopy access towers (approximately four trees, with two upper and lower branches measured per tree) at the OBS, OJP, OA_AUX, and OA sites and on the same number of trees each season at the YJP, YA, and YA-AUX sites.

Sample leaves and stems with needles were sealed in plastic bags with moist towels and placed on ice for transport to the laboratory for further analysis. The laboratory was provided by BOREAS staff in Paddockwood, Saskatchewan (SK), approximately 60 km from the research sites. Each sample was divided into two components, with one portion used for measurement of oxygen evolution (1994 only) and photosynthetic pigments, and the remaining material used for analysis of leaf optical properties and N content.

At the laboratory, samples were stored in the dark in the refrigerator until they were measured. Laboratory measurements included quantitative properties, oxygen evolution (1994 only), and optical properties. A foliar disk sample 2.73 cm in diameter was taken from each of the broadleaf samples for optical properties and then placed in a closed vial of dimethyl sulfoxide (DMSO) in the dark. A mass of needles, 10-20 count, chopped, was taken from the conifers for optical properties and then placed in a closed vial of DMSO in the dark. The sample pieces remained in DMSO until all of the photosynthetic pigments had been extracted. The rest of the samples were dried in an oven at 70 °F for three days. The samples in DMSO were of a known weight (grams) and/or hemisurface area (cm^2). The dried samples were weighed in grams using a balance and then transported to the Maryland Soils Laboratory. In 1994, after the chlorophyll was extracted in IFC-1, the chlorophyll absorptances were measured at the spectrophotometer lab at the University of Saskatchewan, Canada. The drained tissue samples were dried in an oven at 70 °F for three days and then weighed in grams. During IFCs-2 and -3 in 1994, and in 1996 , the DMSO sample vials were transported to the United States Department of Agriculture (USDA) lab in Beltsville, Maryland. The drained tissue samples were dried in an oven at 70 °F for three days and then weighed in grams.

In 1994:

Absorptance was measured at 470 nm, 640 nm, 648 nm, and 750 nm with a dual-beam spectrophotometer (Beckman DU-600 or Perkin-Elmer Lambda 3) for the calculation of chlorophyll and carotenoid concentrations by the equations of Lichtenthaler (1987) modified for DMSO by Chappelle and Kim (1992). Chemical analysis of tissue C-H-N was conducted at the University of Maryland by the Maryland Soil Testing Laboratory using a CHN-600 Elemental Analyzer System (LECO Corp., St. Joseph, MO).

chl formula:

$$chla = 12.15\ A664\ nm - 2.79\ A648\ nm \quad (1)$$

$$chlb = 21.5\ A648\ nm - 5.1\ A664\ nm \quad (2)$$

$$carot = (1000\ A470\ nm - 1.82\ chla - 85.02\ chlb)/198 \quad (3)$$

where A nm = absorptance at the specified wavelength

Refer to Lichtenthaler, 1987, and Chappelle and Kim, 1992, in the reference section.

Spectral absorptances were measured at several wavelengths (700, 664, 648, and 470 nm) and used in these equations (Lichtenthaler, 1987 and Chappelle and Kim, 1992) to calculate pigment content for chla, chlb, and carot. These formulae calculate pigment content as µg/ml, assuming 1 ml of solvent for the pigment extraction. Pigment content expressed as µg/cm^2 was determined by multiplying these values by a factor made up of the actual volume of the extraction divided by the one-sided projected leaf area of the sample (e.g., 4 ml/2.5 cm^2). When expressed on the basis of sample dry weight, the correction factor was the actual volume of the extraction divided by the sample dry weight (e.g., 4 ml/0.025 g). Values were reported to the BOREAS Information System (BORIS) as either µg/cm^2 (broadleaves, some conifers) or mg/g (conifers).

In 1996:

Absorptance was measured at several wavelengths (750, 674, 646, 510, 490, and 470 nm) with a dual-beam spectrophotometer (Beckman DU-600 or Perkin-Elmer Lambda 3) for the calculation of chlorophyll (chl) and carotenoid concentrations by the equations of Lichtenthaler (1987) modified for DMSO by Chappelle and Kim (1992). Chemical analysis of tissue CHN was conducted at the University of Maryland by the Maryland Soil Testing Laboratory using a C-H-N-600 Elemental Analyzer System (LECO Corp., St. Joseph, MO).

chl formula:

$$chla = 22.9422\ A674\ nm \quad (4)$$

$$chlb = 25.30382\ A646\ nm - 16.1909\ A674\ nm \quad (5)$$

$$carot = (1000\ A470\ nm - 1.82\ chla - 85.02\ chlb)/198 \quad (6)$$

where A nm = absorptance at the specified wavelength

Refer to Lichtenthaler, 1987, and Chappelle and Kim, 1992, in the reference section.

Spectral absorptances were measured at several wavelengths (750, 674, 646, 510, 490, and 470 nm) and used in these equations (Lichtenthaler, 1987, and Chappelle and Kim, 1992) to calculate pigment content for chla, chlb, and carotenoid. These formulae calculate pigment content as µg/ml, assuming 1 ml of solvent for the pigment extraction. Pigment content expressed as µg/cm^2 was determined by multiplying these values by a factor made up of the actual volume of the extraction divided by the one-sided projected leaf area of the sample (e.g., 4 ml/2.5 cm^2). When expressed on the basis of sample dry weight, the correction factor was the actual volume of the extraction divided by the sample dry weight (e.g., 4 ml/0.025 g). Values were reported to BORIS as either µg/cm^2 (broadleaves, some conifers) or mg/g (conifers).

Chemical analysis of tissue C-H-N was conducted at the University of Maryland. by the Maryland Soil Testing Laboratory using a CHN-600 Elemental Analyzer System (LECO Corp., St. Joseph, MO). At the soils laboratory, the dried samples were ground. A coffee mill was used to grind the conifer samples. A mortar and pestle were used to grind the broadleaf samples. To have enough sample mass to perform the C-H-N measurements, some samples had to be combined with other samples from different trees, but of the same age class. These combined samples are shown in the data file. Samples were weighed using an analytical balance, and then processed in the Elemental Analyzer. C-H-N concentrations in each sample were expressed as a percentage of the sampled mass.

4.1.2 Source/Platform

Samples were taken from towers except at SSA-YJP, SSA-YA, and SSA-YA-AUX, and were cut using knives. Chlorophyll absorptances and C-H-N concentrations were measured in the laboratory.

4.1.3 Source/Platform Mission Objectives

The towers were constructed to supply a means of accessing the tree canopies.

4.1.4 Key Variables

- Chla, Chlb, and carot per gram dry weight
- Chla, Chlb, and carot per centimeter squared (cm^2) hemisurface area
- C/N ratio
- C, H, and N milligrams (mg) per gram (g) dry weight
- Pigment content was reported as either mg/g or $\mu g/cm^2$ unless both values were obtained.

4.1.5 Principles of Operation

Photosynthetic pigment concentrations were calculated using established equations (see Section 4.1.1, equations 1-6) that estimate concentration as a function of absorptance of foliar extracts at specific wavelengths. Carbon and hydrogen were determined by infrared analysis of the combusted sample. Nitrogen was determined by thermal conductivity.

4.1.6 Sensor/Instrument Geometry

All instrumentation took place under laboratory conditions.

4.1.7 Manufacturer of Sensor/Instrument

Beckman DU Series 600 Spectrophotometer
Beckman Instruments
Laboratory Automation Operations
90 Boroline Road
Allendale, NJ 07401
(201) 818-8900
(201) 818-9740 (fax)

CHN-600 Elemental Analyzer System 785-500
LECO Corporation
St. Joseph, MI
USA

LI-COR Area Meter
For 1994: Model Number 3100
For 1996: Model Number 3000A, Portable
LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, NE 68504-0425
USA
(402) 467-3576
(402) 467-2819 (fax)

Perkin Elmer Lambda 3 Double-Beam Spectrophotometer
Perkin-Elmer Corp.
761 Main Avenue
Norwalk, CT 06859
USA
1 (800) 762-4000

4.2 Calibration

The C-H-N analyzer was calibrated at the start of every day. The spectrophotometer was calibrated between each sample run against a blank standard, which was a quartz cuvette filled with the solvent (DMSO). The leaf area meter was calibrated before each use with a 10-cm disk. Measurements of weight (mass) were reset to zero before each sample reading.

4.2.1 Specifications

- The weighing balance was accurate to 0.01 g.
- The analytical balance was accurate to 0.0001 g.
- The leaf area meter was accurate to within 1.00 %.

4.2.1.1 Tolerance

No tolerance level was set.

4.2.2 Frequency of Calibration

The spectrophotometer was calibrated between each sample run. The leaf area and balances were calibrated every time they were turned on, two to four times a day. The CHN analyzer was calibrated at the start of every day of measurement.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

On the towers at OA, OA-AUX, OBS, YJP, and OJP, top samples were taken from the top tower level, middle samples from the middle level, and bottom samples from the bottom tower level. At YA-AUX and YA, top samples were taken from the upper 1/3, middle samples from the middle 1/3, and bottom samples from the lower 1/3 part of the trees. At white spruce, only a top layer was sampled. At OJP, there was a dogbane (Apocynum androsaemifolium) understory during IFC-2 in 1994. At OA and YA, there was a hazelnut (Corylus cornuta Marsh) understory. At OBS, there was a tamarack (Larix laricina) understory. Stems (with needles) and leaf samples were harvested from each layer and immediately placed within a plastic bag that also contained a moist towel. For transport to the laboratory, the bags were placed in a cooler. For black spruce, age classes 1, 2 and 3.were separated from ages 4 and 5, until analysis was performed at the laboratory. For jack pine, age classes 1, 2, and 3 were separated in the field before being brought to the laboratory. For white spruce, age class 1 was separated from age classes 2 and 3, which were separated from 4 and 5. Petioles were kept on all the broadleaves. At the laboratory, samples were stored in the dark in the refrigerator until they were measured.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

At the OJP, OBS, OA, and OA-AUX tower sites, branch samples were taken from trees within reach from all sides of the towers. There were no towers at the other sites. At each site, at least five trees that had the required layers for that site. The SSA measurement sites and associated North American Datum of 1983 (NAD83) coordinates are:

- OA canopy access tower located 100 m up the path to the flux tower site, site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, Universal Transverse Mercator (UTM) Zone 13, N:5,942,899.9 E:420,790.5.
- OA-AUX canopy access tower located by the trailhead/parking area for the path leading to the flux tower at site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, UTM Zone 13, N:5,942,899.9 E:420,790.5 This OA-AUX site was farther up the path than OA from the flux tower site.
- OBS canopy access tower located at the flux tower site, site id G8I4T, Lat/Long: 53.98717° N, 105.11779° W, UTM Zone 13, N:5,982,100.5 E;492,276.5.
- OJP canopy access tower flux tower site, site id G2L3T, Lat/Long: 53.91634° N, 104.69203° W, UTM Zone 13, N:5,974,257.5 E:520,227.7.
- YA canopy access tower, site id D0H4T, Lat/Long: 53.65601° N, 105.32314° W, UTM Zone 13, N:5,945,298.9, E:478,644.1.
- YA-AUX, site id D6H4A, Lat/Long: 53.708° N, 105.315° W, UTM Zone 13, N:5,951,112.1, E:479,177.5.
- YJP near the flux tower site, site id F8L6T, Lat/Long: 53.87581° N, 104.64529° W, UTM Zone 13, N:5,969,762.5 E:523,320.2.

Please note that at SSA YA-AUX, black spruce, jack pine, aspen, balsam fir, balsam poplar, tamarack, hazelnut, were present and several other shrub and herbaceous species.

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

These data are point source measurements at the given locations.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Samples were collected from the field every day from 8 a.m. 3 p.m. An independent data set was taken at each of the field campaigns in 1994 and 1996. The specific dates for each collection of samples are given in the data table.

7.2.2 Temporal Coverage Map

		Sample Dates (1994)		
Site	Species	IFC-1	IFC-2	IFC-3
SSA-OBS	black spruce	01-JUN	28-JUL to 01-AUG	13-SEP
SSA-OA-AUX	aspen	-	03-AUG	02-SEP
SSA-OA-AUX	hazelnut	-	03-AUG	02-SEP
SSA-OJP	jack pine	31-MAY	25-JUL	06-SEP
SSA-OJP	dogbane	-	25-JUL	-
SSA-OA	aspen	30-MAY,11-JUN	21-JUL	15-SEP
SSA-OA	hazelnut	26-MAY,11-JUN	21-JUL	15-SEP
SSA-YA-AUX	aspen	25-MAY	-	-
SSA-YJP	jack pine	26-MAY,07-JUN	22-JUL to 23-JUL	08-SEP
SSA-YA-AUX	white spruce	-	31-JUL to 01-AUG	11-SEP
SSA-YA	aspen	04-JUN	30-JUL	02-SEP,12-SEP
SSA-YA	hazelnut	04-JUN	30-JUL	02-SEP,12-SEP

		Sample Dates (1996)		
Site	Species	Spring	Summer	Fall
SSA-OBS	black spruce	10-MAY	14-JUL	11-OCT
SSA-OBS	black spruce	19-JUN	-	-
SSA-OBS	black spruce	21-JUN	-	-
SSA-OBS	tamarack	-	17-JUL	10-OCT
SSA-OJP	jack pine	18-JUN	11-JUL	13-OCT
SSA-OJP	jack pine	23-JUN	-	-
SSA-OA-AUX	aspen	24-JUN	17-JUL	-
SSA-OA-AUX	hazelnut	24-JUN	17-JUL	-
SSA-YJP	jack pine	8-MAY TO 9-MAY	12-JUL	12-OCT
SSA-YJP	jack pine	23-JUN	15-JUL	-
SSA-YA-AUX	white spruce	8-MAY	10-JUL	10-OCT
SSA-YA-AUX	white spruce	20-JUN	-	-

7.2.3 Temporal Resolution

Not applicable.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

TE10_BIOCHEM_PER_AREA

Column Name
SITE_NAME
SUB_SITE
DATE_OBS
SPECIES
CANOPY_LOCATION
SAMPLE_GROWTH_YEAR
SAMPLE_ID
MEAN_FOLIAGE_HEMI_SURF_AREA
SDEV_FOLIAGE_HEMI_SURF_AREA

STD_ERR_FOLIAGE_HEMI_SURF_AREA
CHLOROPHYLL_A_DENSITY
CHLOROPHYLL_B_DENSITY
TOTAL_CHLOROPHYLL_DENSITY
CAROTENOID_DENSITY
CRTFCN_CODE
REVISION_DATE

TE10_BIOCHEM_PER_DRY_WT

Column Name

SITE_NAME
SUB_SITE
DATE_OBS
SPECIES
CANOPY_LOCATION
SAMPLE_GROWTH_YEAR
SAMPLE_ID
FOLIAGE_DRY_WEIGHT
CHLOROPHYLL_A_CONC
CHLOROPHYLL_B_CONC
TOTAL_CHLOROPHYLL_CONC
CAROTENOID_CONC
CRTFCN_CODE
REVISION_DATE

TE10_CARBON_HYDROGEN_NITROGEN

Column Name

SITE_NAME
SUB_SITE
DATE_OBS
SPECIES
CANOPY_LOCATION
SAMPLE_GROWTH_YEAR
SAMPLE_ID
FOLIAGE_DRY_WEIGHT
MEAN_FOLIAGE_HEMI_SURF_AREA
NITROGEN_CONTENT
HYDROGEN_CONTENT
CARBON_CONTENT
CARBON_NITROGEN_RATIO
NITROGEN_CONC
HYDROGEN_CONC
CARBON_CONC
NITROGEN_DENSITY
HYDROGEN_DENSITY
CARBON_DENSITY
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

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

TE10_BIOCHEM_PER_AREA

Column Name	Description
SITE_NAME	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.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
MEAN_FOLIAGE_HEMI_SURF_AREA	The mean foliage hemi-surface area of the sample used in the measurement.
SDEV_FOLIAGE_HEMI_SURF_AREA	The standard deviation of the mean foliage hemi-surface area of the sample used in the measurement.
STD_ERR_FOLIAGE_HEMI_SURF_AREA	Standard error of the mean foliage hemi-surface area of the sample used in the measurement.
CHLOROPHYLL_A_DENSITY	Chlorophyll A per unit hemi-surface area.
CHLOROPHYLL_B_DENSITY	Chlorophyll B per unit hemi-surface area.
TOTAL_CHLOROPHYLL_DENSITY	Total chlorophyll (chlorophyll A + chlorophyll B) per unit hemi-surface area.
CAROTENOID_DENSITY	Carotenoid per unit hemi-surface area.
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.

TE10_BIOCHEM_PER_DRY_WT

Column Name	Description
SITE_NAME	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.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
FOLIAGE_DRY_WEIGHT	The dry weight of the foliage sample measured.
CHLOROPHYLL_A_CONC	The chlorophyll A concentration in the foliage dry mass sample.
CHLOROPHYLL_B_CONC	The chlorophyll B concentration in the foliage dry mass sample.
TOTAL_CHLOROPHYLL_CONC	The total chlorophyll A + chlorophyll B concentration in the foliage dry mass sample.
CAROTENOID_CONC	The carotenoid concentration in the foliage dry mass sample.
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.

TE10_CARBON_HYDROGEN_NITROGEN

Column Name	Description
SITE_NAME	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.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site

	instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
FOLIAGE_DRY_WEIGHT	The dry weight of the foliage sample measured.
MEAN_FOLIAGE_HEMI_SURF_AREA	The mean foliage hemi-surface area of the sample used in the measurement.
NITROGEN_CONTENT	The nitrogen content of the sample based on dried sample weight.
HYDROGEN_CONTENT	The hydrogen content of the sample.
CARBON_CONTENT	The carbon content of the sample.
CARBON_NITROGEN_RATIO	Ratio of carbon content to the nitrogen content of the sample.
NITROGEN_CONC	The nitrogen concentration in the foliage dry mass sample.
HYDROGEN_CONC	The hydrogen concentration in the foliage dry mass sample.
CARBON_CONC	The carbon concentration in the foliage dry mass sample.
NITROGEN_DENSITY	Nitrogen per unit hemi-surface area.
HYDROGEN_DENSITY	Hydrogen per unit hemi-surface area.
CARBON_DENSITY	Carbon per unit hemi-surface area.
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:

TE10_BIOCHEM_PER_AREA

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]
MEAN_FOLIAGE_HEMI_SURF_AREA	[millimeters^2]
SDEV_FOLIAGE_HEMI_SURF_AREA	[millimeters^2]
STD_ERR_FOLIAGE_HEMI_SURF_AREA	[millimeters^2]
CHLOROPHYLL_A_DENSITY	[milligrams][meter^-2]

CHLOROPHYLL_B_DENSITY	[milligrams][meter^-2]
TOTAL_CHLOROPHYLL_DENSITY	[milligrams][meter^-2]
CAROTENOID_DENSITY	[milligrams][meter^-2]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

TE10_BIOCHEM_PER_DRY_WT

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]
FOLIAGE_DRY_WEIGHT	[grams]
CHLOROPHYLL_A_CONC	[milligrams][gram^-1]
CHLOROPHYLL_B_CONC	[milligrams][gram^-1]
TOTAL_CHLOROPHYLL_CONC	[milligrams][gram^-1]
CAROTENOID_CONC	[milligrams][gram^-1]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

TE10_CARBON_HYDROGEN_NITROGEN

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]
FOLIAGE_DRY_WEIGHT	[grams]
MEAN_FOLIAGE_HEMI_SURF_AREA	[millimeters^2]
NITROGEN_CONTENT	[percent]
HYDROGEN_CONTENT	[percent]
CARBON_CONTENT	[percent]
CARBON_NITROGEN_RATIO	[unitless]
NITROGEN_CONC	[milligrams][gram^-1]
HYDROGEN_CONC	[milligrams][gram^-1]
CARBON_CONC	[milligrams][gram^-1]
NITROGEN_DENSITY	[grams][meter^-2]
HYDROGEN_DENSITY	[grams][meter^-2]
CARBON_DENSITY	[grams][meter^-2]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

TE10_BIOCHEM_PER_AREA

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
MEAN_FOLIAGE_HEMI_SURF_AREA	[Laboratory Equipment]
SDEV_FOLIAGE_HEMI_SURF_AREA	[Laboratory Equipment]
STD_ERR_FOLIAGE_HEMI_SURF_AREA	[Laboratory Equipment]
CHLOROPHYLL_A_DENSITY	[Laboratory Equipment]
CHLOROPHYLL_B_DENSITY	[Laboratory Equipment]
TOTAL_CHLOROPHYLL_DENSITY	[Laboratory Equipment]
CAROTENOID_DENSITY	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

TE10_BIOCHEM_PER_DRY_WT

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
FOLIAGE_DRY_WEIGHT	[Laboratory Equipment]
CHLOROPHYLL_A_CONC	[Laboratory Equipment]
CHLOROPHYLL_B_CONC	[Laboratory Equipment]
TOTAL_CHLOROPHYLL_CONC	[Laboratory Equipment]
CAROTENOID_CONC	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

TE10_CARBON_HYDROGEN_NITROGEN

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
FOLIAGE_DRY_WEIGHT	[Laboratory Equipment]
MEAN_FOLIAGE_HEMI_SURF_AREA	[Laboratory Equipment]
NITROGEN_CONTENT	[Laboratory Equipment]

HYDROGEN_CONTENT	[Laboratory Equipment]
CARBON_CONTENT	[Laboratory Equipment]
CARBON_NITROGEN_RATIO	[Laboratory Equipment]
NITROGEN_CONC	[Laboratory Equipment]
HYDROGEN_CONC	[Laboratory Equipment]
CARBON_CONC	[Laboratory Equipment]
NITROGEN_DENSITY	[Laboratory Equipment]
HYDROGEN_DENSITY	[Laboratory Equipment]
CARBON_DENSITY	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

7.3.5 Data Range

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

TE10_BIOCHEM_PER_AREA

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE10-LCH01	9TE10-LCH02	None	None	None	None
DATE_OBS	25-MAY-94	17-JUL-96	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	Bottom	Top	None	None	None	Blank
SAMPLE_GROWTH_YEAR	1989	1996	None	None	None	None
SAMPLE_ID	N/A	N/A	None	None	None	None
MEAN_FOLIAGE_HEMI_SURF_AREA	102	2932	None	None	None	Blank
SDEV_FOLIAGE_HEMI_SURF_AREA	.707	78.428	None	None	None	Blank
STD_ERR_FOLIAGE_HEMI_SURF_AREA	.5	45.281	None	None	None	Blank
CHLOROPHYLL_A_DENSITY	1.005	608.85	None	None	None	Blank
CHLOROPHYLL_B_DENSITY	-3.66	251.75	None	None	None	Blank
TOTAL_CHLOROPHYLL_DENSITY	1.773	860.6	None	None	None	Blank
CAROTENOID_DENSITY	3.16	259.31	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	04-SEP-98	05-JAN-99	None	None	None	None

TE10_BIOCHEM_PER_DRY_WT

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE10-LCH01	9TE10-LCH02	None	None	None	None
DATE_OBS	25-MAY-94	17-JUL-96	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None

CANOPY_LOCATION	Bottom	Top	None	None	None	Blank
SAMPLE_GROWTH_YEAR	1989	1996	None	None	None	None
SAMPLE_ID	N/A	N/A	None	None	None	None
FOLIAGE_DRY_WEIGHT	.0012	.958	None	None	None	Blank
CHLOROPHYLL_A_CONC	.0046	21.4051	None	None	None	Blank
CHLOROPHYLL_B_CONC	-.0183	9.4217	None	None	None	Blank
TOTAL_CHLOROPHYLL_CONC	.0081	30.8268	None	None	None	Blank
CAROTENOID_CONC	.0427	6.22	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	04-SEP-98	05-JAN-99	None	None	None	None

TE10_CARBON_HYDROGEN_NITROGEN

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE10-LCH01	9TE10-LCH02	None	None	None	None
DATE_OBS	26-MAY-94	13-OCT-96	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	Bottom	Top	None	None	None	None
SAMPLE_GROWTH_YEAR	1989	1996	None	None	None	None
SAMPLE_ID	N/A	N/A	None	None	None	None
FOLIAGE_DRY_WEIGHT	.0199	.21	None	None	None	None
MEAN_FOLIAGE_HEMI_SURF_AREA	113	2277	None	None	None	Blank
NITROGEN_CONTENT	.08	4.66	None	None	None	None
HYDROGEN_CONTENT	2.63	13.56	None	None	None	None
CARBON_CONTENT	21.74	57.7	None	None	None	None
CARBON_NITROGEN_RATIO	10.13072	658.72	None	None	None	None
NITROGEN_CONC	.78	46.6	None	None	None	None
HYDROGEN_CONC	26.3	135.6	None	None	None	None
CARBON_CONC	217.4	577	None	None	None	None
NITROGEN_DENSITY	.2	4.1	None	None	None	Blank
HYDROGEN_DENSITY	2.1	34.8	None	None	None	Blank
CARBON_DENSITY	15.7	267.4	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	08-SEP-98	09-SEP-98	None	None	None	None

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 unreliable by the analysis personnel.
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 Cllctd     -- 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.

TE10_BIOCHEM_PER_AREA

```
SITE_NAME,SUB_SITE,DATE_OBS,SPECIES,CANOPY_LOCATION,SAMPLE_GROWTH_YEAR,SAMPLE_ID,
MEAN_FOLIAGE_HEMI_SURF_AREA,SDEV_FOLIAGE_HEMI_SURF_AREA,
STD_ERR_FOLIAGE_HEMI_SURF_AREA,CHLOROPHYLL_A_DENSITY,CHLOROPHYLL_B_DENSITY,
TOTAL_CHLOROPHYLL_DENSITY,CAROTENOID_DENSITY,CRTFCN_CODE,REVISION_DATE
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','17',
227.0,,,180.7,110.5,291.2,71.8,'CPI',05-JAN-99
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','18',,,,,,
,,'CPI',05-JAN-99
```

TE10_BIOCHEM_PER_DRY_WT

```
SITE_NAME,SUB_SITE,DATE_OBS,SPECIES,CANOPY_LOCATION,SAMPLE_GROWTH_YEAR,SAMPLE_ID,
FOLIAGE_DRY_WEIGHT,CHLOROPHYLL_A_CONC,CHLOROPHYLL_B_CONC,TOTAL_CHLOROPHYLL_CONC,
CAROTENOID_CONC,CRTFCN_CODE,REVISION_DATE
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','14',.01,
2.94,2.07,5.01,1.13,'CPI',05-JAN-99
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','15',,,,,,
'CPI',05-JAN-99
```

TE10_CARBON_HYDROGEN_NITROGEN

```
SITE_NAME,SUB_SITE,DATE_OBS,SPECIES,CANOPY_LOCATION,SAMPLE_GROWTH_YEAR,SAMPLE_ID,
FOLIAGE_DRY_WEIGHT,MEAN_FOLIAGE_HEMI_SURF_AREA,NITROGEN_CONTENT,HYDROGEN_CONTENT,
CARBON_CONTENT,CARBON_NITROGEN_RATIO,NITROGEN_CONC,HYDROGEN_CONC,CARBON_CONC,
NITROGEN_DENSITY,HYDROGEN_DENSITY,CARBON_DENSITY,CRTFCN_CODE,REVISION_DATE
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','1,2,3',
.0341,,4.33,5.84,47.21,10.903,43.3,58.4,472.1,,,,'CPI',08-SEP-98
'SSA-90A-FLXTR','9TE10-LCH01',26-MAY-94,'Corylus cornuta','Top','1994','6,7,10',
.0282,,4.47,6.02,46.44,10.38926,44.7,60.2,464.4,,,,'CPI',08-SEP-98
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BORIS was the data collected at a given site on a given date.

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.

9. Data Manipulations

9.1 Formulae

1994 chl formula:

chla = 12.15 A664 nm - 2.79 A648 nm
chlb = 21.5 A648 nm - 5.1 A664 nm
carot = (1000 A470 nm - 1.82 chla - 85.02 chlb)/198

where A nm = absorptance at the specified wavelength

Refer to Lichtenthaler, 1987, and Chappelle and Kim, 1992, in the reference section.

Spectral absorptances were measured at several wavelengths (700, 664, 648, and 470 nm) and used in these equations (Lichtenthaler, 1987, and Chappelle and Kim, 1992) to calculate pigment content for chla, chlb, and carot. These formulae calculate pigment content as µg/ml, assuming 1 ml of solvent for the pigment extraction. Pigment content expressed as µg/cm^2 was determined by multiplying these values by a factor made up of the actual volume of the extraction divided by the one-sided projected leaf area of the sample (e.g., 4 ml/2.5 cm^2). When expressed on the basis of sample dry weight, the correction factor was the actual volume of the extraction divided by the sample dry weight (e.g., 4-ml/0.025-g). Values were reported to BORIS as either µg/cm^2 (broadleaves, some conifers) or mg/g (conifers).

1996 chl formula:

chla = 22.9422 A674 nm
chlb = 25.30382 A646 nm - 16.1909 A674 nm
carot = (1000 A470 nm - 1.82 chla - 85.02 chlb)/198

where A nm = absorptance at the specified wavelength

Refer to Lichtenthaler, 1987, and Chappelle and Kim, 1992, in the reference section.

Spectral absorptances were measured at several wavelengths (750, 674, 646, 510, 490, and 470 nm) and used in these equations (Lichtenthaler, 1987, and Chappelle and Kim, 1992) to calculate pigment content for chla, chlb, and carotenoid. These formulae calculate pigment content as µg/ml, assuming 1 ml of solvent for the pigment extraction. Pigment content expressed as µg/cm^2 was

determined by multiplying these values by a factor made up of the actual volume of the extraction divided by the one-sided projected leaf area of the sample (e.g., 4 ml/2.5 cm^2). When expressed on the basis of sample dry weight, the correction factor was the actual volume of the extraction divided by the sample dry weight (e.g., 4 ml/0.025 g). Values were reported to BORIS as either $\mu g/cm^2$ (broadleaves, some conifers) or mg/g (conifers).

9.1.1 Derivation Techniques and Algorithms
See Section 9.1.

9.2 Data Processing Sequence

9.2.1 Processing Steps
Data were recorded automatically by a computer and printed or saved to a diskette. Subsequent calculations were performed using Quattro Pro 6.0 for Windows 3.1.

9.2.2 Processing Changes
None.

9.3 Calculations
See Section 9.1.

9.3.1 Special Corrections/Adjustments
None.

9.3.2 Calculated Variables
See Section 9.1.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
Errors are primarily caused by variation in researcher measurement techniques, the acquisition of measurements by multiple persons, and instrumentation variation. The data have received a quality review by Terrestrial Ecology (TE)-10 personnel, and all known sources of calculation errors have been corrected.

10.2 Quality Assessment
Data have received a quality review by TE-10 personnel.

10.2.1 Data Validation by Source
Comparisons were made with other BOREAS results and with published results.

10.2.2 Confidence Level/Accuracy Judgment
None available, but it is felt that these data are accurate.

10.2.3 Measurement Error for Parameters
Not available.

10.2.4 Additional Quality Assessments
Calculated results were plotted, and the plots were compared with those from published papers.

10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data

None.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

None.

11.4 Other Relevant Information

None.

12. Application of the Data Set

These data can be used to assess the relationship between sample location, sample age, chlorophyll content, and C-H-N concentrations.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Calculations were performed using Quattro Pro 6.0 for Windows 3.1. This document was prepared using Microsoft Word 5.1a and 6.0 for the Macintosh and Microsoft Word 6.0 for Windows.

14.2 Software Access

Contact the commercial vendors.

15. Data Access

The leaf chemistry 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

Located at the Soils Lab at the Department of Natural Resources Science at the University of Maryland, College Park, MD 20742: C-H-N-600 Elemental Analyzer System 785-500 Manual. LECO Corp., St. Joseph, MI.

Located at BARC: Perkin-Elmer Lambda 3 Double Beam Spectrophotometer Manual. 1988. Perkin-Elmer Corp.. 761 Main Avenue, Norwalk, CT 06859.

For 1994: LI-3100 LI-COR Area Meter Manual. Publication number 8805-0055, June 1988 LI-COR, Inc., 4421 Superior Street, P.O. Box 4425, Lincoln, NE 68504-0425.

For 1996: LI-3000A LI COR Portable Area Meter Manual., Publication number 8805-0055, June 1988. LI-COR, Inc., 4421 Superior Street, P.O. Box 4425, Lincoln, NE, 68504-0425.

17.2 Journal Article and Study Reports

Anderson, C.P., S.B. McLaughlin, and W.K. Roy. 1991. Foliar injury symptoms and pigment concentrations in red spruce saplings in the southern Appalachians. Can. J. For. Res. v21 n7: 1106-1110.

Chappelle, E.W. and M.S. Kim. 1992. Ratio analysis of reflectance spectra (RARS): an algorithm for the remote estimation of the concentration of chlorophyll a, chlorophyll b, and carotenoids in soybean leaves. Remote Sens. Environ. V39: 239-247.

Kharouk, V.I., E.M. Middleton, S.L. Spensor, B.N. Rock, and D.L. Williams. 1995. Aspen bark photosynthesis and its significance to remote sensing and carbon budget estimates in the boreal ecosystem. Water, Air and Soil Pollution. V82: 483-497.

Lichtenthaler, H.K. 1987. Chlorophylla and carotenoids: pigments of photosynthetic biomembranes. Methods in Enzymology, v148: 350-382.

Middleton, E.M., E.W. Chappelle, and A. DeLuca. 1995. Evaluating photosynthesis in Boreal forest species with fluorescence measurements. IGARSS 1995.

Middleton, E.M., J.H. Sullivan, B.D. Bovard, A.J. DeLuca, S.S. Chan, and T.A. Cannon. 1997. Seasonal variability in foliar characteristics and physiology for boreal forest species at the five Saskatchewan tower sites during the 1994 Boreal Ecosystem-Atmosphere Study. Journal of Geophysical Research 102(D24):28,831-28,844.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Schneckenburger, H. and W. Schmidt. 1995. Time-resolved chlorophyll fluorescence of spruce needles after different light exposure. Plant Physiol. V148: 593-598.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

A nm	- Absorptance at a Specified Wavelength (nm)
C	- Carbon
carot	- Carotenoid
chla	- Chlorophyll A
chlb	- Chlorophyll B
C-H-N	- Carbon-Hydrogen-Nitrogen
DMSO	- Dimethyl sulfoxide
H	- Hydrogen
N	- Nitrogen

19. List of Acronyms

ASCII	- American Standard Code for Information Interchange
BARC	- Beltsville Agricultural Research Center
BOREAS	- BOReal Ecosystem-Atmosphere Study
BORIS	- BOREAS Information System
CD-ROM	- Compact Disk-Read-Only Memory
DAAC	- Distributed Active Archive Center
DMSO	- Dimethyl Sulfoxide
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
GIS	- Geographic Information System
GSFC	- Goddard Space Flight Center
HTML	- HyperText Markup Language
IFC	- Intensive Field Campaign
NAD83	- North American Datum of 1983
NASA	- National Aeronautics and Space Administration
NOAA	- National Oceanic and Atmospheric Administration
NSA	- Northern Study Area
OA	- Old Aspen
OA-AUX	- Old Aspen-Auxiliary
OBS	- Old Black Spruce
OJP	- Old Jack Pine
ORNL	- Oak Ridge National Laboratory
PANP	- Prince Albert National Park
SSA	- Southern Study Area
TE	- Terrestrial Ecology
URL	- Uniform Resource Locator
USDA	- United States Department of Agriculture
UTM	- Universal Transverse Mercator
WS	- White Spruce
YA	- Young Aspen
YA-AUX	- Young Aspen-Auxiliary
YJP	- Young Jack Pine

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The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the reflectance, transmittance, gas exchange, chlorophyll content, carbon content, hydrogen content, and nitrogen content of boreal vegetation. This data set describes the relationship between sample location, age, chlorophyll content, and C-H-N concentrations at several sites in the SSA conducted during the growing seasons of 1994 and 1996. The data are stored in tabular ASCII files.

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