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BOREAS TE-9 PAR and Leaf Nitrogen Data for NSA Species

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BOREAS TE-9 PAR and Leaf Nitrogen Data for NSA Species

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Summary

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. This data set describes the relationship between PAR levels and foliage nitrogen in samples from six sites in the BOREAS NSA collected during the three 1994 IFCs. This information is useful for modeling the vertical distribution of carbon fixation for these different forest types in the boreal forest. The data were collected to quantify the relationship between PAR and leaf nitrogen of black spruce, jack pine, and aspen. The data are available in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification
BOREAS TE-09 PAR and Leaf Nitrogen Data for NSA Species

1.2 Data Set Introduction
The canopy profiles of nitrogen concentration and photosynthetic capacity were examined as part of an effort to characterize the spatial and temporal variations in photosynthetic capacity and nitrogen allocation in the boreal forest. This information will be useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest. Samples were taken from six forest types in the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA): NSA-Old Black Spruce (OBS), NSA-Upland Black Spruce (UBS), NSA-Old Jack Pine (OJP), NSA-Young Jack Pine (YJP), NSA-Young Aspen (YA), and NSA-Old Aspen (OA) during each of the three Intensive Field Campaigns (IFCs) in 1994.

1.3 Objective/Purpose

The purpose of this project was to quantify the relationship between percent Photosynthetically Active Radiation (PAR) levels and leaf nitrogen of three boreal forest tree species, black spruce, jack pine, and aspen, at the BOREAS NSA.

1.4 Summary of Parameters

Downwelling PAR, transmitted PAR, leaf nitrogen (N) concentration, specific leaf nitrogen (N) (i.e., N per unit leaf area).

1.5 Discussion

Functional convergence predicts that the investment into leaf nitrogen is limited by the amount of available light (PAR), which in turn determines photosynthetic capacity. This study tests this hypothesis through measurements of the relationship between fraction of absorbed PAR (FPAR), PAR, and N.

The downwelling radiation data from the BOREAS NSA were collected to characterize the FPAR levels at different canopy levels of six boreal canopy cover types: YJP (Pinus banksiana), OJP, YA (Populus tremuloides), OA, OBS (Picea mariana), and UBS. Leaf samples were harvested at each li8ght level in order to quantify specific leaf nitrogen content by leaf/needle age class. Radiation data were collected between 27-May-1994 and 17-Sep-1994.

1.6 Related Data Sets

BOREAS TE-09 NSA Photosynthetic Response Data
BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation

Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories

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3. Theory of Measurements

The PAR measurements were obtained by point quantum sensors. Data were relayed to a data acquisition system (CR10) for storage and data manipulation prior to downloading. The methodology for measuring leaf area is described in Appendix K of the BOREAS Experiment Plan, Version 3.0. Aspen foliage is expressed as hemisurface area leaf area, while conifer foliage is expressed as total surface area leaf area. Kjeldahl procedures were used to measure leaf nitrogen. See Section 5, Data Acquisition Methods, for further explanation.

4. Equipment

4.1 Sensor/Instrument Description
- Point quantum sensors, millivolt adaptors, extension cables, BNC connectors (LI-COR).
- Data acquisition system (CR10 measurement and control module with wiring panel and 12-volt power supply, CR10 keyboard and display, sc12 cable, datalogger support software, CR10 manual, screwdrivers, sc532 data transfer interface, data storage module (SM192), Campbell Scientific).
- Ladder, extendible pruning shears, two extendible support poles, polyethylene storage bags, freezer space, drying oven, optical image analysis system (AgVision, Decagon Inc.), top-loading weighing balance.
- Laboratory equipped for Kjeldahl N analysis.

4.1.1 Collection Environment
A quantum sensor was supported at the top of a pole that was extended to different levels in the canopy, following a vertical profile from the top of the canopy to the groundcover and understory shrubs. The particular weather conditions on each sampling day should be contained in the various BOREAS meteorological data.

4.1.2 Source/Platform

A quantum sensor was supported at the top of a pole that was extended to different levels in the canopy, following a vertical profile from the top of the canopy to the groundcover and understory shrubs. These levels were variable depending on the type of understory vegetation and the canopy profile. One point quantum sensor was used to obtain simultaneous incident light readings. This sensor was placed on a pole extended from a canopy access tower or a pole that was extended sufficiently above the tree canopy level to avoid any shading during the sampling period. The data acquisition system was kept at the sampling level while using canopy access towers, or on the ground.

4.1.3 Source/Platform Mission Objectives

The objective of the hand-held or tower-supported pole was to hold the quantum sensor in place in order to make proper measurements.

4.1.4 Key Variables

Incoming PAR, FPAR, and foliar N concentration.

4.1.5 Principles of Operation

A quantum sensor under full sky exposure was set out under cloudy (diffuse) sky conditions in each stand type. A second quantum sensor was moved vertically throughout the canopy profile starting at ground level. Vegetation at each light harvesting level was removed in order to determine specific N content.

LI-COR quantum sensors measure PAR in the 400-700 nm wave band. The unit of measurement is micromoles per second per square meter ($\mu mol/sec/m^2$). The quantum sensor is designed to measure PAR received on a plane surface. The indicated sensor response corresponds to the expected photosynthetic response of plants for which data are available. A silicon photodiode with an enhanced response in the visible wavelengths is used as the sensor. A visible bandpass interference filter in combination with colored glass filters is mounted in a cosine-corrected head.

Quantum sensors were connected to a data acquisition system. This system (CR10) was programmed to convert a differential voltage measurement (rather than a single-ended measurement because of noise reduction) to a radiation value. Each quantum sensor has a different calibration constant provided by the manufacturing company that must be incorporated into the programming of the CR10.

The CR10 is a fully programmable datalogger/controller that permits a user to convert electronic responses of a sensor to comprehensible information about the physical environment (e.g., temperature, radiation). It allows the user to store data and program the retrieved data.

The AgVision System is an image analysis system that works by first looking at an object through a video camera, then processing the image into discrete numerical information with a digitizer and microcomputer, and finally displaying the image or other information on a monitor for examination. This system was used for leaf area measurements.

The Kjeldahl method, the most common method for nutrient analysis, was used for measuring total N.

4.1.6 Sensor/Instrument Measurement Geometry

Quantum sensors were pointed face up to the canopy (zenith angle) to obtain downwelling radiation.

4.1.7 Manufacturer of Sensor/Instrument

Point quantum sensors LI-190SA, millivolt adaptors, extension cables, BNC connectors:

LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, NE 68504
1 (800) 447-3576

CR10 data acquisition system, CR10 measurement and control module with wiring panel and 12-volt power supply, CR10 keyboard and display, sc12 cable, datalogger support software, CR10 manual, screwdrivers, sc532 data transfer gadget, data storage module (SM192):

Campbell Scientific Canada Corp.
11564 149 Street
Edmonton, Alberta
Canada T5M 1W7
(403) 454-2505

Leaf area measurement system/optical image analysis system (AgVision, Monochrome system, root and leaf analysis):

Decagon Devices, Inc.
P.O. Box 835
Pullman, WA 99163
1 (800) 755-2751

4.2 Calibration

4.2.1 Specifications
The quantum sensors had a resolution capability of 1 $\mu mol/sec/m^2$. The absolute calibration is +/- 5%, traceable to the U.S. National Institute of Standards and Technology (NIST). The weighing balance was accurate to within 0.0001 g. The leaf area system was accurate to within 1%.

The shape factor used for black spruce leaf area measurements was 4, in accordance with the BOREAS Experiment Plan, Appendix K, Version 3.0. Based on observations of two cross-sections of two needles per fascicle for five fascicles for six jack pine trees from Thompson, Manitoba, an average shape factor of 4.59 (+/- 0.07) was calculated.

Specifications of Kjeldahl instrumentation are unknown at this time.

4.2.1.1 Tolerance
The acceptable range for the radiation measurements is between 0 and 2 $\mu mol/sec/m^2$. According to the company, the quantum sensors are typically sensitive to 8 μA per 1,000 $\mu mol/sec/m^2$ with a maximum deviation of 1% up to 10,000 $\mu mol/sec/m^2$.

4.2.2 Frequency of Calibration
The quantum sensors used in the field were brand new. Calibration was completed by the manufacturing company, and recalibration of radiation sensors is normally recommended every 2 years. The calibration data are unique to each sensor and were incorporated into the programming when connected to a data acquisition system. Field checks of quantum sensor readings were made upon installation of the sensors and every time data were transferred.

Prior to the season's field sampling, all quantum sensors were compared to confirm that no differences in measurements existed. This involved comparing radiation readings from the same light source. Following a comparison of electrical environmental conditions (outside a building versus inside the photosynthetic lab), a differential mode configuration rather than a single-ended voltage configuration was found to reduce response fluctuations (caused primarily by electrical noise). Therefore, the differential mode programming and wiring setup were used. In the field, a quick comparison among quantum sensors under similar light conditions was made.

The optical image analysis system was calibrated according to instrument specifications each time the system was opened or after it was left for a period of time. A fine ruler and flat disks of known area were used in the calibration.

Calibration of Kjeldahl instrumentation is unknown at this time.

4.2.3 Other Calibration Information
None.

5. Data Acquisition Methods

Downwelling radiation data for the BOREAS NSA were collected to characterize the vertical profile of FPAR of six boreal forest canopy cover types: YJP, OJP, YA, OA, OBS, and UBS. These data were collected during diffuse light conditions (overcast/cloudy days) during the three field campaigns between 27-May-1994 and 17-Sep-1994. For each stand, the following activities took place:

Vertical light profiles were established in each forest cover type based on five randomly chosen branches at five height levels (top, middle, and lower third of the crown; top of understory shrubs; and top of groundcover.) Where there were two levels of understory shrubs, another level was taken into account. Sampling took place from the bottom up. That is, samples were harvested starting from the groundcover level before moving up vertically in order to avoid any effect on subsequent light measurements.

Light readings on cloudy days (diffuse light conditions) were obtained for each stand using a quantum sensor connected to a CR10 data acquisition system. A BNC connector and a millivolt adaptor (604 ohms) were connected to each sensor that was connected to the CR10 data measurement system. Quantum sensors were suspended for a minimum period of 2 minutes at each level just above a branch level that was subsequently harvested (input readings = 5 seconds, output readings = 1 minute). One quantum sensor was extended to obtain simultaneous readings of incident PAR. This sensor was placed on a pole extended either from a canopy access tower or sufficiently above the tree canopy level to avoid any shading during the measurement period. This made it possible to calculate where 100% FPAR is complete interception, or darkness, and 0% is completely exposed and equal to the incident PAR.

For the radiation measurements in the canopy, one person leaned over the canopy access tower holding a pole with the quantum sensor attached at the end, while another person manipulated the CR10 at the same level. Following each measurement level, the light readings were transferred directly to a storage module.

FPAR was calculated for each measurement point.

The radiation measurements were based on a total of two point-quantum sensors (one taking the canopy profile and one at full light) that were relayed to the CR10. All quantum sensors were connected to the same CR10 for simultaneous measurements. Consequently, it was possible to calculate FPAR. Sensor readings were taken every 10 seconds, while output measurements were based on 5-minute intervals.

A branch at each light level was cut using a set of extendible pruning shears. These samples were used for N measurements. On conifer trees, these samples included the most recent year's needle growth and at least 2 years of previous needle growth. Branches for N analysis were stored in identified polyethylene bags for transport. These samples were stored in a freezer until time for further manipulation was available. A subsample of these branches was cut in order to determine specific leaf area (SLA). The remaining branches were oven-dried for 48 hours at 68 °C, after which the lignified material was separated from the foliage tissue. The foliage tissue was then ground to 1 mm and stored in sealed plastic containers until %N was quantified.

The material was oven-dried again and weighed 2 hours prior to N analysis. At least 200 mg of dried material was necessary for each N analysis. The Kjeldahl method was used to estimate nitrogen concentration. Nitrogen is expressed both on an SLA and a weight basis.

SLA was measured for each conifer leaf sample, by age class, using the volume displacement method to measure half the area of the surface of the leaf (HASL). An optical image analysis system (Decagon) was also used to measure shoot silhouette area and projected leaf area. For flat surfaces, such as aspen leaves, the hemisurface area is the same as both the projected area and the silhouette area. The silhouette area of conifer samples was measured by age class. (In the first IFC, however, there was only one age class.) A conifer shoot was first snipped and clipped into two age classes: (1)

1994 needles, and (2) anything produced in 1993 or before. Each shoot section was then randomly thrown under the camera lens and a silhouette measurement was taken. These samples were then processed under the normal procedures for measuring leaf area (volume displacement).

In order to conduct the volume displacement method for measuring conifer leaf area, a container large enough for an intact shoot to be submerged was filled with a solution of water and about 3-5% detergent. The detergent is necessary because it prevents small air bubbles and films from accumulating on the surface of the shoot. The container has to be large enough for the shoot to be submerged without touching the walls of the container. The container and liquid are placed on a top-loading electronic balance and tared to provide a zero reading. An intact shoot is submerged in the liquid without touching the walls of the container, and the weight is recorded. To push the shoot into the water, a force equal to the buoyant force must be applied. The buoyant force is related to the mass of the volume of water displaced by the shoot. Thus, the volume of the intact shoot in cubic centimeters is numerically equal to the weight increase in grams indicated on the balance. The length of these needles is determined. If measuring all the needles is too time-consuming, the number of needles on the shoot is counted, and a subsample of 10 to 20 needles spaced over the length of the shoot is used. The needles are then removed from the shoot, and the volume of the woody portion of the shoot is measured by submerging it in the liquid-filled container on the balance. The needle volume is the difference between the total volume and the woody volume.

The shape of the cross-sectional area is determined from observations under a microscope. This shape is usually fixed for all needles of a given species and so has to be determined only once for a given species. This shape determines the coefficients in an equation that relates the previous measurements to the surface area. The shape factor for black spruce is 4.00 (BOREAS Experiment Plan, Version 3.0, Appendix K). Based on observations of two cross-sections of two needles per fascicle for five fascicles for six jack pine trees from Thompson, Manitoba, an average shape factor of 1993 needles was calculated as 4.59 (+/- 0.07):

$$LA = SF \times sqrt(VL) \qquad (1)$$

where: LA = leaf area
        SF = shape factor
        V = volume of needles
        L = total length of needles

In the case where only a subsample of needles is used, the equation becomes:

$$LA = SF \times sqrt(Vnl)$$

where: LA = leaf area
        SF = shape factor
        V = volume of needles
        l = average length of needles (20 needles)
        n = total number of needles

6. Observations

6.1 Data Notes
None.

6.2 Field Notes
None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The data were collected from six principal sites in the NSA located in Manitoba. The NSA is approximately 100 km by 80 km, and is located 735 km north of Winnipeg. The North American Datum of 1983 (NAD83) coordinates for each of the principal sites in this study are:

- NSA-YA auxilliary site along Gillam Road (auxilliary site number W0Y5A, BOREAS Experiment Plan, Version 3.0): Lat/Long: 56.00339°N, 97.3355°W; UTM Zone 14, N: 6207706.6, E: 603796.6
- NSA-YJP flux tower site: Lat/Long: 55.89575°N, 98.28706°W; UTM Zone 14, N: 6194706.9 E: 544583.9;
- NSA-OJP flux tower site Lat/Long: 55.842°N, 98.62396°W; UTM Zone 14, N: 6198176.3, E: 523496.2
- NSA-OA canopy access tower site (auxilliary site number T2Q6A, BOREAS Experiment Plan, Version 3.0): Lat/Long 55.88691°N, 98.67479°W; UTM Zone 14, N: 6193540.7, E: 520342;
- NSA-OBS Flux tower site: Lat/Long: 55.88007°N, 98.48139°W; UTM Zone 14, N: 6192853.4, E: 532444.5
- NSA-UBS canopy access tower site (auxilliary site number T6R5S, BOREAS Experiment Plan, Version 3.0): Lat/Long: 55.90802°N, 98.51865°W; UTM Zone 14, N: 6195947, E: 530092

Quantum sensors (on poles) were used on the canopy access towers in the bottom, middle, and top canopy. In the case of the YJP site, where a canopy access tower did not exist, sensors were located within 1 km of the flux tower.

7.1.2 Spatial Coverage Map
None.

7.1.3 Spatial Resolution
These data are point source measurements at the indicated sites.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
Data acquisition at all six sites was repeated for each of the IFCs in 1994. The overall period extended from 24-May-1994 to 17-Sep-1994.

7.2.2 Temporal Coverage Map
During the first IFC, the following sites were measured:

```
NSA-YJP      29-May-94
NSA-OJP      31-May-94
NSA-YASP     14-Jun-94
NSA-OASP     12-Jun-94
NSA-OBS      12-Jun-94
NSA-TE-BS    03-Jun-94
```

During the second IFC, the following sites were measured:

```
NSA-YJP      24-Jul-94
NSA-OJP      19,20-Jul-94
NSA-YASP     26,30-Jul-94
NSA-OASP     21,24-Jul-94
NSA-OBS      25-Jul-94
NSA-TE-BS    22,23-Jul-94
```

During the third IFC, the following sites were measured:

```
NSA-YJP      08,11,12-Sep-94
NSA-OJP      05,06-Sep-94
NSA-YASP     08,11-Sep-94
NSA-OASP     02,05,06-Sep-94
NSA-OBS      13-Sep-94
NSA-TE-BS    12-Sep-94
```

7.2.3 Temporal Resolution

These data were collected during diffuse light conditions (overcast/cloudy days) during the three field campaigns between 27-May-1994 and 17-Sep-1994. Quantum sensors were suspended for a minimum period of 2 minutes at each level just above a branch level that was subsequently harvested (input readings = 5 seconds, output readings = 1 minute). All quantum sensors were connected to the same CR10 for simultaneous measurements.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

```
        Column Name
---------------------------------
SITE_NAME
SUB_SITE
START_DATE
END_DATE
SPECIES
CANOPY_SAMPLE_LVL
SAMPLE_ID
SAMPLE_GROWTH_YEAR
TRANS_PAR
LOG_TRANS_PAR
NITROGEN_CONC
NITROGEN_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:

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.
START_DATE	The date on which the collection of the reference data commenced.
END_DATE	The date on which the collection of the referenced data was terminated.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_SAMPLE_LVL	Identifies the canopy sampling level: 1=the top of overstory crown, 2=the middle of overstory crown, 3=the bottom of overstory crown, 4=the top of understory, 5=ground cover.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
TRANS_PAR	Photosynthetically active radiation in the canopy expressed as a percentage of a simultaneous measurement over the canopy.
LOG_TRANS_PAR	The natural log of PAR transmittance.
NITROGEN_CONC	The nitrogen concentration of the foliage dry mass sample.
NITROGEN_DENSITY	Nitrogen per unit hemisurface 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:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
START_DATE	[DD-MON-YY]

```
END_DATE                         [DD-MON-YY]
SPECIES                          [none]
CANOPY_SAMPLE_LVL                [none]
SAMPLE_ID                        [none]
SAMPLE_GROWTH_YEAR               [unitless]
TRANS_PAR                        [percent]
LOG_TRANS_PAR                    [natural log % PAR]
NITROGEN_CONC                    [milligrams][gram^-1]
NITROGEN_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:

```
        Column Name                            Data Source
-----------------------------    ------------------------------------------------
SITE_NAME                        BORIS Designation
SUB_SITE                         BORIS Designation
START_DATE                       BORIS Designation
END_DATE                         BORIS Designation
SPECIES                          Human Observer
CANOPY_SAMPLE_LVL                Human Observer
SAMPLE_ID                        Human Observer
SAMPLE_GROWTH_YEAR               Human Observer
TRANS_PAR                        Point Quantum Sensors
LOG_TRANS_PAR                    Point Quantum Sensors
NITROGEN_CONC                    Laboratory Equipment
NITROGEN_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.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-9TETR	NSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE09-PRN01	9TE09-PRN01	None	None	None	None
START_DATE	24-MAY-94	30-AUG-94	None	None	None	None
END_DATE	16-JUN-94	19-SEP-94	None	None	None	None
·SPECIES	N/A	N/A	None	None	None	None
CANOPY_SAMPLE_LVL	1	5	None	None	None	None
SAMPLE_ID	1	5	None	None	None	None
SAMPLE_GROWTH_YEAR	<=1993	1994	None	None	None	None
TRANS_PAR	1.489	4.605	-999	None	None	None
LOG_TRANS_PAR	3.5	40.97	-999	None	None	None
NITROGEN_CONC	4.43	100	-999	None	None	None
NITROGEN_DENSITY	.2	2.3	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	19-SEP-96	19-SEP-96	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 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 is a sample of the first few records from the data table on the CD-ROM:

```
SITE_NAME,SUB_SITE,START_DATE,END_DATE,SPECIES,CANOPY_SAMPLE_LVL,SAMPLE_ID,
SAMPLE_GROWTH_YEAR,TRANS_PAR,LOG_TRANS_PAR,NITROGEN_CONC,NITROGEN_DENSITY,
CRTFCN_CODE,REVISION_DATE
'NSA-9BS-9TETR','9TE09-PRN01',24-MAY-94,16-JUN-94,'Picea mariana',1,'1','<=1993',
4.377,6.85,79.57,1.9,'CPI',19-SEP-96
'NSA-9BS-9TETR','9TE09-PRN01',24-MAY-94,16-JUN-94,'Picea mariana',1,'2','<=1993',
4.238,5.96,69.25,1.3,'CPI',19-SEP-96
```

8. Data Organization

8.1 Data Granularity

The smallest unit of orderable data is the data on a given day at a given site.

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

FPAR (%)=((PAR at 100% exposure - PAR reading below canopy)/PAR at 100% exposure)*100.

For example, if the maximum PAR (no shading) was 890 and the PAR value underneath the canopy was 230, then FPAR under the canopy = 74.16% = ((890-230)/890) x 100

9.1.1 Derivation Techniques and Algorithms
None.

9.2 Data Processing Sequence

9.2.1 Processing Steps
Data from quantum sensors were first converted from electrical (voltage) data to a radiation value in a program (given by the user) for the CR10. This program is specific to this data acquisition system; see the Campbell Scientific manual for programming information. The CR10 was programmed to take the data each minute, which were being retrieved every second, and do the following:

- Identify the site location.
- Output the Julian day, hour, and minute.
- Output the minimum battery voltage. This was done to check for data errors caused by a low battery source (if the battery charge is below 9.6, errors can be expected in the data set).
- Output the maximum internal temperature of the module panel. This was done to be able to check for data errors if the temperature of the CR10 system was too high. Errors can be expected in the data set when the temperature is greater than 50 °C.
- Output the average, standard deviation, and maximum and minimum radiation values for each of the two quantum sensors.

Data were then transferred from the field site to a storage module that was brought back to a computer for data transfer and verification. All raw data were printed. Column headings were inserted and all lines that were not part of the sampling scheme were erased. A code that had been entered into the CR10 program in place of the site location enabled staff to identify when the relevant light data were not being taken. This code was normally 1.2 and has no other meaning other than to signify that the light values at that time are not useful. For example, the sensor may at that time have been between two different light levels.

Lines that contained zero readings for the quantum sensors were erased (using the autofilter function in Excel, Version 5.0). Where only 1 minute or less of data existed per level, these lines were not removed (to avoid blank data cells). Data were then sorted in order of the light profile. Light readings by minute for a level were then averaged together (using the subtotals function in Excel, Version 5.0) so that at each change in SITEID the function AVERAGE was used to subtotal all the columns of data.

%PAR and FPAR values were calculated. Year and calendar date (cdate) were inserted as columns.

Manitoba time data were converted from a numeric format to a time format (because original data were in numeric format). The following command was used in Excel, Version 5.0, to do this step: time(mid(a1;1;len(a1)-2);right(a1;2);0). where a1 refers to the data cell where the time data were found. Manitoba time was then converted to Greenwich Mean Time (GMT) = Thompson, Manitoba time + 6 hours.

Shoot silhouette data, SLA, and leaf area data were then transferred into the data files. (At this point there is only one line of data for each desired light level.) Data were then compared with the original data sheets.

Note that the SLA samples corresponding to the YJP stand in IFC-1 (29-May-1994) were misplaced, ground, or lost. In order to compensate for these lost SLA data, the SLA data from the photosynthesis data (27-May, group TE-9B) were substituted. The SLA data represent the same

sampling levels, but only four repetitions were available for this set. Photosynthesis was measured on three branches at each canopy level for five YJP trees. An average SLA (based on three branches for each canopy level) was used.

Data were recorded automatically by a computer and also printed on a printer. Subsequent calculations of different parameters were performed using MS Excel for Windows 5.0.

BOREAS Information System (BORIS) staff processed the data by:
- Reviewing the initial data files and loading them online for BOREAS team access.
- Designing relational data base tables to inventory and store the data.
- Loading the data into the relational data base tables.
- Working with the Hydrology (HYD)-06 team to document the data set.
- Extracting the standardized data into logical files.

9.2.2 Processing Changes
See Section 9.2.1.

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
If the wiring to the CR10 is not fixed securely, loose wires can lead to dubious data results. Likewise, if wires have been chewed up by rodents or by hungry canopy tower people, results may be questionable. There was no evidence of these activities during the field season.

If the battery charge is below 9.6 volts, errors can be expected in the data set. Although this was checked for in the data set, it is unlikely that a low battery charge ever occurred because at every data transfer in the field this value was checked.

Errors also can be expected in the data set when the CR10 module temperature exceeds 50 °C. This was checked for in the data set but, despite the warm and dry conditions during the summer of 1994, it is unlikely that the CR10 ever got too warm because it was placed in a shady understory location.

10.2 Quality Assessment

10.2.1 Data Validation by Source
All anticipated errors were checked and removed.

10.2.2 Confidence Level/Accuracy Judgment
The TE-09 team is confident that the values are correct.

10.2.3 Measurement Error for Parameters
Not available.

10.2.4 Additional Quality Assessments
None.

10.2.5 Data Verification by Data Center
Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data
Note that the SLA samples corresponding to the YJP stand in IFC-1 (29-May-1994) were misplaced, ground, or lost. In order to compensate for these lost SLA data, the SLA data from the photosynthesis data (27-May, group TE-9B) were substituted. These SLA data represent the same sampling levels, but only four repetitions were available for this set. Photosynthesis was measured on three branches at each canopy level for five YJP trees. An average SLA (based on three branches for each canopy level) was used.

11.2 Known Problems with the Data
Not available.

11.3 Usage Guidance
Not available.

11.4 Other Relevant Information
None.

12. Application of the Data Set

These data are useful for modeling photosynthesis at different levels in the canopy.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description
Microsoft Excel 5.0.

14.2 Software Access
Contact Microsoft.

15. Data Access

The NSA PAR and leaf nitrogen 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

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Decagon Devices, Inc. 199? AgVision monochrome system, root and leaf analysis, operator's manual. Pullman, WA.

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17.2 Journal Articles and Study Reports

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-total. pp. 595-624. In: Methods of Soil Analysis Ó Part 2. Chemical and microbiological properties (2e ed.). Page, A.L., R.H. Miller, and D.R. Keeney (eds.). Agron. No. 9. ASA-SSSA, Madison, WI.

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Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms

None.

19. List of Acronyms

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ASCII    - American Standard Code for Information Interchange
BOREAS   - BOReal Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
CD-ROM   - Compact Disk-Read-Only Memory
CGR      - Certified by Group
CPI      - Checked by Principal Investigator
DAAC     - Distributed Active Archive Center
EOS      - Earth Observing System
EOSDIS   - EOS Data and Information System
FPAR     - Fraction of Absorbed Photosynthetically Active Radiation
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GSFC     - Goddard Space Flight Center
HASL     - Half the Area of the Surface of the Leaf
HTML     - Hyper-Text Markup Language
HYD      - Hydrology
IFC      - Intensive Field Campaign
N        - nitrogen
NAD83    - North American Datum of 1983
NASA     - National Aeronautics and Space Administration
Net PS   - Net Photosynthetic
NIST     - National Institute of Standards and Technology
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
PAR      - Photosynthetically Active Radiation
PRE      - Preliminary
Ps       - Photosynthesis
SLA      - Specific Leaf Area
SSA      - Southern Study Area
TE       - Terrestrial Ecology
UBS      - Upland Black Spruce
URL      - Uniform Resource Locator
UTM      - Universal Transverse Mercator
YA       - Young Aspen
YJP      - Young Jack Pine
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13. ABSTRACT (Maximum 200 words)

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. This data set describes the relationship between PAR levels and foliage nitrogen in samples from six sites in the BOREAS NSA collected during the three 1994 IFCs. This information is useful for modeling the vertical distribution of carbon fixation for these different forest types in the boreal forest. The data were collected to quantify the relationship between PAR and leaf nitrogen of black spruce, jack pine, and aspen. The data are available in tabular ASCII files.

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