ORNL/CDIAC-107
NDP-061A

Effects of CO_2 and Nitrogen Fertilization on Growth and Nutrient Content of Juvenile Ponderosa Pine

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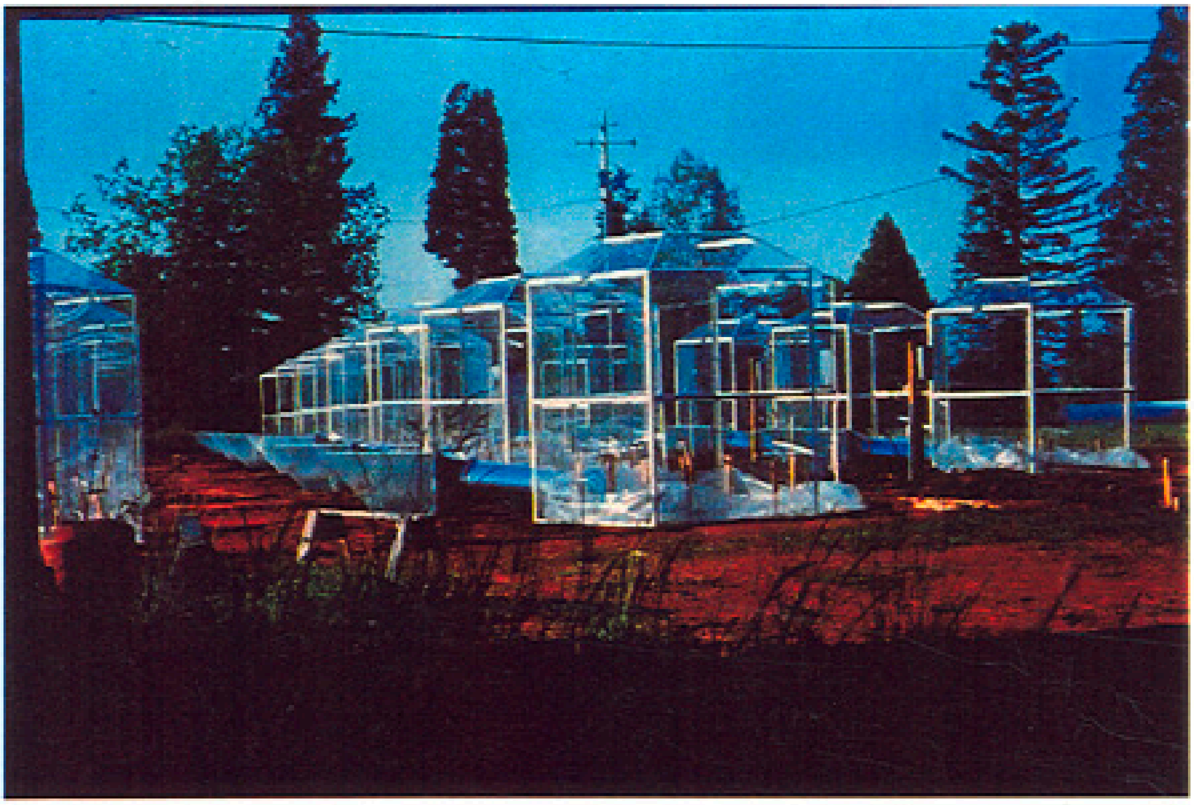

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EFFECTS OF CO_2 AND NITROGEN FERTILIZATION ON GROWTH AND NUTRIENT CONTENT OF JUVENILE PONDEROSA PINE

Contributed by

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ABSTRACT

JOHNSON, D. W., J. T. BALL, AND R. F. WALKER. 1998. *Effects of CO_2 and Nitrogen Fertilization on Growth and Nutrient Content of Juvenile Ponderosa Pine*. ORNL/CDIAC-107, NDP-061A, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, 78 pp.

This data set presents measured values of plant diameter and height, biomass of plant components, and nutrient (carbon, nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, boron, copper, iron, manganese, and zinc) concentrations from a study of the effects of carbon dioxide and nitrogen fertilization on ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) conducted in open-top chambers in Placerville, California, from 1991 through 1996. This data set contains values from 1991 through 1993.

PART 1: INFORMATION ABOUT THE DATA PACKAGE

1. NAME OF THE NUMERIC DATA PACKAGE

EFFECTS OF CO_2 AND NITROGEN FERTILIZATION ON GROWTH AND NUTRIENT CONTENT OF JUVENILE PONDEROSA PINE

2. PRINCIPAL INVESTIGATORS

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3. KEYWORDS

Boron, calcium, carbon, carbon dioxide fertilization, copper, growth, iron, magnesium, manganese, nitrogen, nitrogen fertilization, nutrients, phosphorus, ponderosa pine, potassium, sulfur, zinc

4. BACKGROUND INFORMATION

This data set presents measured values of plant diameter and height, biomass of plant components, and nutrients in vegetation from a study of the effects of carbon dioxide and nitrogen fertilization on ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.) conducted in open-top chambers in Placerville, California, from 1991 through 1996. This data set contains values from 1991 through 1993. Further background for the study, as well as the results and conclusions from the study, may be found in Johnson et al. (1997), which is the primary reference for this data set. Users who wish to use these data in specific model exercises or research exercises should first refer to Johnson et al. (1997).

5. EXPERIMENTAL SETUP AND METHODS

Detailed information concerning the site and experimental setup, treatments, and sampling and analytical methods is given in Johnson et al. (1997) and Walker et al. (1997); the methods are summarized below.

Twenty-four hexagonal open-top chambers, 3.6 m in diameter, were established in February–April 1991 at the Institute of Forest Genetics in Placerville, California, on a soil of Aiken clay loam, an andesite-derived Xeric Haplohumult. The studied pines were grown from seeds (21 locations per chamber) planted in May 1991.

Treatment began in May 1991. There were three treatment levels of nitrogen (N) fertilization (0, 10, and 20 g N per square meter per year applied as ammonium sulfate) and four CO_2 treatments (ambient, no chamber; ambient, chambered; 525 microliters CO_2 per liter air; and 700 microliters CO_2 per liter air). All combinations of the treatments were studied, except for the combination of 10 g N per square meter per year and 525 microliters CO_2 per liter air. Each of the unchambered treatments was replicated twice, each of the chambered treatments thrice. All plots were watered identically.

Three trees from each chamber were harvested in October 1991, 1992, and 1993 (including complete root systems for all three harvested trees per chamber in 1991 and 1992 and for one tree per chamber in 1993). Seedlings were dried, weighed by component (foliage, branch, stem, and roots; in 1991 and 1992, branches were sufficiently trivial that their weights were included with those of stems), and analyzed as follows:

N: analyzed on a Perkin-Elmer 2400 CHN Analyzer

Other nutrients (P, S, K, Ca, Mg, B, Cu, Fe, Mn, Zn): dry-ashed at 550ºC for 4 h, dissolved in 5% (v/v) nitric acid, and analyzed by inductively-coupled plasma (ICP) emission spectroscopy

In 1992, no elemental analyses were conducted for branches in the unchambered treatment.

Tree biomass for needles, stems (including branches), and roots was measured directly in 1991 for the trees analyzed for nutrient concentration. For 1992 and 1993, the following regression was established (based on measured diameters, heights, and biomass), relating biomass in grams for each component (Comp) to diameter (d), measured in mm at 10 cm, and height (h), measured in cm:

$\ln(\text{Comp}) = a + (b)\ln(d^2h)$, where a and b are regression constants given in the following table:

Component	a	b	r^2
		1992 Harvest	
Needles	-2.9797	0.65540	0.692
Stems + branches	-4.8812	0.86967	0.724
Roots	-4.9412	0.84429	0.615
		1993 Harvest	
Needles	-6.2504	1.0395	0.729
Branches	-12.173	1.4685	0.631
Stems	-9.4724	1.3200	0.819
Roots	-6.7686	1.038	0.868

Measurements in 1993 were based on one whole tree, plus two additional tree tops, harvested per chamber. The user should note that two sets of height and diameter data are reported for 1993 (in association with the measured nutrient concentration data, and in association with the biomass data used to generate the regressions); the height and diameter measurements used to generate the regressions were taken a short time after the measurements at harvest.

In the data files and this documentation, the terms “leaf” and “needle” are equivalents, as are “stem” and “trunk.”

6. APPLICATIONS OF THE DATA

These data may be used to study the effect of elevated levels of atmospheric carbon dioxide, in combination with various levels of nitrogen fertilization, on the growth and nutrient content of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), an important timber species of western North America. Johnson et al. (1997) used the data documented in this numeric data package to evaluate two hypotheses: (1) that elevated CO_2 would increase growth and yield of biomass per unit uptake of N even if N is limiting, and (2) that elevated CO_2 would increase biomass yield per unit uptake of other, nonlimiting nutrients only by growth dilution.

For several years, research has been conducted on the effects of elevated carbon dioxide, alone or in combination with other factors such as the availability of water and nutrients, on many different wild and cultivated plant species. There has been a trend towards more realistic conditions: from flowerpot studies in growth chambers to open-top chamber studies (the experiment whose data are documented in this numeric data package is one such study), in which the plants are exposed to the atmosphere and in which the roots are not necessarily confined to pots. A further step towards realism was taken in the 1990s with the development of the FACE (Free Air CO_2 Enrichment) studies (Ellsworth et al. 1995), in which plants are grown without confinement in chambers and carbon dioxide is typically released around the perimeter of the circular study area (with attention paid to wind speed and direction) in sufficient quantity to maintain desired concentrations of carbon dioxide within the study area.

An early review of the literature on the effects of elevated carbon dioxide on vegetation may be found in Strain and Cure (1985), while a recent review may be found in Amthor (1995). Two bibliographies that include much of the pertinent literature are Strain and Cure (1986) and Strain and Cure (1994). Curtis (1997) is an on-line data base that summarizes many studies of the effects of elevated carbon dioxide on woody vegetation**.**

7. DATA LIMITATIONS AND RESTRICTIONS

Users should appreciate that the study whose data are documented in this numeric data package suffers from the inherent limitation common to all open-top chambers studies: the plants are confined in chambers and therefore are not growing in completely natural conditions. For a critique of open-top chamber studies, and descriptions of other experimental approaches for measuring the responses of plants to elevated carbon dioxide, the user is referred to Allen et al. (1992) and Ceulemans and Mousseau (1994).

Johnson et al. (1997) have noted that observed declines in soil carbon and nitrogen during the study probably resulted from plowing that occurred before planting, rather than from the experimental treatment. It is possible that some observed changes in plant growth and nutrient content may also have been responses to plowing, rather than to the experimental treatment. That is, preplanting plowing may be considered a potential artifact of the experiment.

Users are cautioned against using sample tree averages to estimate treatment effects because that would yield a biased result; that is, the sample trees did not reflect the average dimensions of all trees in the chambers. An unbiased estimate of biomass and nutrient content can be obtained by applying regressions to the diameter and height measurements of all trees in the chambers.

8. REFERENCES

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Walker, R.F., D.R. Geisinger, D.W. Johnson, and J.T. Ball, 1997. Elevated atmospheric CO2 and soil N fertility effects on growth, mycorrhizal colonization, and xylem water potential of juvenile ponderosa pine in a field soil. *Plant and Soil* 195:25-36.

9. QUALITY-ASSURANCE CHECKS AND DATA-PROCESSING ACTIVITIES PERFORMED BY CDIAC

An important part of the data-packaging process at the Carbon Dioxide Information Analysis Center (CDIAC) is the quality assurance (QA) of the data before their distribution. The QA process is an important component in the value-added concept of ensuring accurate, usable information. The complete QA of a data set can be a time-consuming process, since data received by CDIAC are rarely in condition for immediate distribution, regardless of source. The following summarizes the QA checks and data-processing performed on the data sets presented in this document:

1. The EXCEL (registered trademark of the Microsoft Corporation, Redmond, Washington) spreadsheet files were provided by the principal investigators.

2. Cell formulas contained in the spreadsheets received by CDIAC were checked for correctness using EXCEL and QUATTRO PRO (registered trademark of the Corel Corporation, Ottawa, Ontario, Canada).

3. Values entered directly into the spreadsheets were verified wherever possible by values calculated from data already in the spreadsheets.

4. The files were simplified and reduced to include only direct measurements (of diameter, height, biomass, and nutrient concentrations); estimated values (e.g., biomass calculated from regressions, nutrient content derived from estimated biomass and measured concentration) and statistics were removed.

5. The files for the 1992 and 1993 data were compared with respect to carbon dioxide and nitrogen treatment levels, chamber label, and replicate number, to ensure correctness and consistency of nomenclature.

6. Variables were renamed for internal consistency, with the new names ranging from one to six characters each.

7. Spreadsheet files were reformatted into 1-2-3 (registered trademark of the Lotus Development Corporation, Cambridge, Massachusetts) *.wk1 spreadsheet files and converted into flat ASCII files, in which -9, -9.9, or -9.99 represent missing values.

10. HOW TO OBTAIN THE DATA AND DOCUMENTATION

These data may be used with spreadsheet software (e.g., 1-2-3, EXCEL, or QUATTRO PRO) or with other database management and statistical software. The spreadsheets in this data package were saved as both 1-2-3 *.wk1 spreadsheet files and *.dat flat ASCII files. The computerized data are available on Exabyte 8-mm tapes, QIC $^{1}/_{4}$" tape cartridges, IBM DOS-compatible floppy diskettes (3.5" or 5.25"), and through CDIAC’s World Wide Web site and anonymous File Transfer Protocol (FTP) area (addresses given below). Requests for magnetic media should include any specific instructions required by the user and/or the user’s local computer system. Requests for this package should be addressed to:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6335
U.S.A.

Telephone: 423-574-3645
Fax: 423-574-2232
Email: cdiac@ornl.gov

FTP: cdiac.esd.ornl.gov
URL: http://cdiac.esd.ornl.gov

The data files may be acquired via Internet from CDIAC's anonymous FTP service as follows:

- FTP to cdiac.esd.ornl.gov (128.219.24.36).
- Enter “ftp” as the user id.
- Enter your electronic mail address as the password (e.g., fred@zulu.org).
- Change to the directory “pub/ndp061a” (i.e., use the command “cd pub/ndp061a”).
- Set ftp to get ASCII files by using the ftp “ascii” command.
- Retrieve the ASCII database documentation file by using the ftp “get ndp061a.txt” command.
- Retrieve the ASCII data files by using the ftp “mget *.dat” command.
- Retrieve the ASCII FORTRAN files by using the ftp “mget *.for” command.
- Retrieve the ASCII SAS (registered trademark of the SAS Institute, Inc., Cary, North Carolina) files by using the ftp “mget *.sas” command.
- Set ftp to get binary files by using the ftp “binary” command.
- Retrieve the binary spreadsheet files by using the ftp “mget *.wk1” command.
- Exit the system by using the ftp “quit” command.
- Contact CDIAC by phone, fax, email, or letter to order a hard copy of this documentation.

PART 2: CONTENT AND FORMAT OF DATA FILES

11. LISTING OF FILES PROVIDED

The following table lists the files on the magnetic media distributed by CDIAC along with this documentation. These files are also available through CDIAC's anonymous FTP service (cdiac.esd.ornl.gov) and World Wide Web site (http://cdiac.esd.ornl.gov) via the Internet (see Sect. 10, How to Obtain the Data and Documentation).

Table 1. List and description of the digital files

File numbe r	Name	Description	File size (kB)
1	**ndp061a.txt**	ASCII descriptive information file	90
2	**regr92.dat**	1992 height, diameter, and biomass data	5
3	**regr93.dat**	1993 height, diameter, and biomass data	5
4	**trees91.dat**	1991 biomass and nutrient data	9
5	**trees92.dat**	1992 height, diameter, and nutrient data	15
6	**trees93.dat**	1993 height, diameter, and nutrient data	262
7	**regr92.wk1**	spreadsheet file corresponding to **regr92.dat** (File 2)	14
8	**regr93.wk1**	spreadsheet file corresponding to **regr93.dat** (File 3)	16
9	**trees91.wk1**	spreadsheet file corresponding to **trees91.dat** (File 4)	27
10	**trees92.wk1**	spreadsheet file corresponding to **trees92.dat** (File 5)	35
11	**trees93.wk1**	spreadsheet file corresponding to **trees93.dat** (File 6)	400
12	**regr92.for**	FORTRAN 77 data retrieval routine to read **regr92.dat** (File 2)	1
13	**regr93.for**	FORTRAN 77 data retrieval routine to read **regr93.dat** (File 3)	1
14	**trees91.for**	FORTRAN 77 data retrieval routine to read **trees91.dat** (File 4)	1
15	**trees92.for**	FORTRAN 77 data retrieval routine to read **trees92.dat** (File 5)	2
16	**trees93.for**	FORTRAN 77 data retrieval routine to read **trees93.dat** (File 6)	3
17	**regr92.sas**	SAS data retrieval routine to read **regr92.dat** (File 2)	1
18	**regr93.sas**	SAS data retrieval routine to read **regr93.dat** (File 3)	1
19	**trees91.sas**	SAS data retrieval routine to read **trees91.dat** (File 4)	1

Table 1 (continued)

20	**trees92.sas**	SAS data retrieval routine to read **trees92.dat** (File 5)	1
21	**trees93.sas**	SAS data retrieval routine to read **trees93.dat** (File 6)	2

12. DESCRIPTION OF THE DOCUMENTATION FILE

ndp061a.txt (File 1)

This file contains a detailed description of the data base (name of the numeric data package, principal investigators, keywords, background information, experimental setup and methods, applications of the data, data limitations and restrictions, references, QA checks and data-processing activities performed by CDIAC) and how to obtain the data and documentation. A description of the formats, units, and other pertinent information about each file associated with this database is included.

13. DESCRIPTION OF THE DATA FILES

DATA FORMAT AND UNITS

The data contained in this NDP are available as both 1-2-3 spreadsheet files and flat ASCII files. SAS and FORTRAN programs designed to read each ASCII data file are also provided.

In all files, C (carbon dioxide treatment) is defined as follows:

1 = no chamber;
2 = ambient (350 microliters CO_2 per liter air);
3 = 525 microliters CO_2 per liter air;
4 = 700 microliters CO_2 per liter air.

N (nitrogen treatment) is defined as follows:

1 = unfertilized;
2 = 10 g N per square meter per year;
3 = 20 g N per square meter per year.

Each variable label consists of up to six characters, where

BM denotes biomass,

BR denotes branch,
CC denotes a concentration (mass per unit mass) of a nutrient in plant tissue,
CD denotes candle (new shoots where needles have not come out yet),
CHBR denotes open-top chamber identification label,
CR denotes coarse root [the sum of medium root plus tap root (i.e., diameter >2 mm)],
DIA denotes diameter,
FO denotes foliage
FR denotes fine root (diameter <2 mm),
HT denotes height,
LF denotes leaf (needle),
LR denotes lateral root,
MR denotes medium root (diameter from 2 mm to 1 cm),
N1 denotes first-flush needle (the first flush of needles in a given year),
N2 denotes second-flush needle (the second flush of needles in a given year),
NO denotes old needle (needles that appeared before 1993),
NS denotes senesced needle (brown needles that were about ready to fall off the tree),
REP denotes seedling replicate identification label,
RT denotes root,
ST denotes stem (includes branches in 1991 and 1992),
TB denotes trunk bottom (10 cm from the bottom of the trunk),
TM denotes trunk middle (halfway up the trunk),
TR denotes tap root,
TT denotes trunk top (the middle of the top shoot),

and where the standard chemical symbol (in all upper case) is used for elements. The general pattern for indicating nutrient concentrations (i.e., the final two letters are “CC”) is that the first two letters indicate the plant tissue, and the following one or two letters indicate the nutrient; thus, “LFMNCC” represents the measured concentration of manganese in leaf tissue.

FLAT ASCII DATA FILES

The following tables describe the contents and formats of the five flat ASCII files that are distributed with this data package. Missing values are represented by –9.99, with two exceptions: -9 represents missing values of REP in **trees91.dat (File 4)**, and -9.9 represents missing values of HT in **regr93.dat (File 3)**. The data files in this package do not contain any negative values other than the missing-value indicators. The following tables also indicate the column in the corresponding spreadsheet files in which each variable is found. For **trees92.dat (File 5)**, the user should note that, for the sake of consistency of format, all data in columns >35 are shown with an apparent precision of two digits to the right of the decimal (i.e., hundredths of the specified unit); for **trees93.dat (File 6)**, this applies to all data in columns >42. This should not be construed as the true precision of measurement; for many variables the user will observe only zeros to the right of the decimal (other than in the case of -9.99, the missing-value indicator).

The user is strongly urged to pay careful attention to the variable widths specified in the following tables and in the FORTRAN and SAS data retrieval programs provided with this package (*.for and *.sas, respectively). In some cases (i.e., where values occupy all the allotted six or seven spaces), adjacent values will run together, and there will be no space between adjacent values. Therefore, importing the data into a program with space or tab delimiters would produce erroneous results. It is highly recommended that the *.wk1files provided with this data package be used for spreadsheet applications.

Table 2. Contents of regr92.dat (File 2)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition
C	character	6	1	6		A	CO_2 treatment level
N	character	6	7	12		B	N treatment level
CHBR	character	6	13	18		C	Open-top chamber identification label
REP	numeric	6	19	24		D	Seedling replicate identification label
HT	numeric	6	25	30	cm	E	Seedling height
DIA	numeric	6	31	36	mm	F	Seedling diameter
LFBM	numeric	6	37	42	g	G	Leaf biomass
STBM	numeric	6	43	48	g	H	Stem biomass
CRBM	numeric	6	49	54	g	I	Coarse-root biomass
FRBM	numeric	6	55	60	g	J	Fine-root biomass

Table 3. Contents of regr93.dat (File 3)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition
C	character	6	1	6		A	CO_2 treatment level
N	character	6	7	12		B	N treatment level
CHBR	character	6	13	18		C	Open-top chamber identification label
REP	numeric	6	19	24		D	Seedling replicate identification label
HT	numeric	6	25	30	cm	E	Seedling height
DIA	numeric	6	31	36	mm	F	Seedling diameter
LFBM	numeric	6	37	42	g	G	Leaf biomass
BRBM	numeric	6	43	48	g	H	Branch biomass
STBM	numeric	6	49	54	g	I	Stem biomass
RTBM	numeric	6	55	60	g	J	Root biomass

Table 4. Contents of trees91.dat (File 4)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition
C	character	6	1	6		A	CO_2 treatment level
N	character	6	7	12		B	N treatment level
CHBR	character	6	13	18		C	Open-top chamber identification label
REP	character	6	19	24		D	Seedling replicate identification label
LFBM	numeric	6	25	30	g	E	Leaf biomass
STBM	numeric	6	31	36	g	F	Stem biomass
RTBM	numeric	6	37	42	g	G	Root biomass
LFNCC	numeric	6	43	48	%	H	Leaf N concentration
STNCC	numeric	6	49	54	%	I	Stem N concentration
RTNCC	numeric	6	55	60	%	J	Root N concentration
LFBCC	numeric	6	61	66	ppm	K	Leaf B concentration
STBCC	numeric	6	67	72	ppm	L	Stem B concentration
RTBCC	numeric	6	73	78	ppm	M	Root B concentration
LFCACC	numeric	6	79	84	%	N	Leaf Ca concentration
STCACC	numeric	6	85	90	%	O	Stem Ca concentration
RTCACC	numeric	6	91	96	%	P	Root Ca concentration
LFKCC	numeric	6	97	102	%	Q	Leaf K concentration
STKCC	numeric	6	103	108	%	R	Stem K concentration
RTKCC	numeric	6	109	114	%	S	Root K concentration
LFMGCC	numeric	6	115	120	%	T	Leaf Mg concentration
STMGCC	numeric	6	121	126	%	U	Stem Mg concentration
RTMGCC	numeric	6	127	132	%	V	Root Mg concentration
LFPCC	numeric	6	133	138	%	W	Leaf P concentration

Table 4 (continued)

STPCC	numeric	6	139	144	%	X	Stem P concentration
RTPCC	numeric	6	145	150	%	Y	Root P concentration
LFSCC	numeric	6	151	156	%	Z	Leaf S concentration
STSCC	numeric	6	157	162	%	AA	Stem S concentration
RTSCC	numeric	6	163	168	%	AB	Root S concentration

Table 5. Contents of trees92.dat (File 5)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition
C	character	7	1	7		A	CO_2 treatment level
N	character	7	8	14		B	N treatment level
CHBR	character	7	15	21		C	Open-top chamber identification label
REP	character	7	22	28		D	Seedling replicate identification label
HT	numeric	7	29	35	cm	E	Seedling height
DIA	numeric	7	36	42	mm	F	Seedling diameter
LFNCC	numeric	7	43	49	%	G	Leaf N concentration
BRNCC	numeric	7	50	56	%	H	Branch N concentration
STNCC	numeric	7	57	63	%	I	Stem N concentration
TRNCC	numeric	7	64	70	%	J	Tap-root N concentration
MRNCC	numeric	7	71	77	%	K	Medium-root N concentration
FRNCC	numeric	7	78	84	%	L	Fine-root N concentration
LFCACC	numeric	7	85	91	%	M	Leaf Ca concentration
STCACC	numeric	7	79	98	%	N	Stem Ca concentration
BRCACC	numeric	7	99	105	%	O	Branch Ca concentration
FRCACC	numeric	7	106	112	%	P	Fine-root Ca concentration
MRCACC	numeric	7	113	119	%	Q	Medium-root Ca concentration

Table 5 (continued)

TRCACC	numeric	7	120	126	%	R	Tap-root Ca concentration
LFMGCC	numeric	7	127	133	%	S	Leaf Mg concentration
STMGCC	numeric	7	134	140	%	T	Stem Mg concentration
BRMGCC	numeric	7	141	147	%	U	Branch Mg concentration
FRMGCC	numeric	7	148	154	%	V	Fine-root Mg concentration
MRMGCC	numeric	7	155	161	%	W	Medium-root Mg concentration
TRMGCC	numeric	7	162	168	%	X	Tap-root Mg concentration
LFSCC	numeric	7	169	175	%	Y	Leaf S concentration
STSCC	numeric	7	176	182	%	Z	Stem S concentration
BRSCC	numeric	7	183	189	%	AA	Branch S concentration
FRSCC	numeric	7	190	196	%	AB	Fine-root S concentration
MRSCC	numeric	7	197	203	%	AC	Medium-root S concentration
TRSCC	numeric	7	204	210	%	AD	Tap-root S concentration
LFCUCC	numeric	7	211	217	ppm	AE	Leaf Cu concentration
STCUCC	numeric	7	218	224	ppm	AF	Stem Cu concentration
BRCUCC	numeric	7	225	231	ppm	AG	Branch Cu concentration
FRCUCC	numeric	7	232	238	ppm	AH	Fine-root Cu concentration

Table 5 (continued)

MRCUCC	numeric	7	239	245	ppm	AI	Medium-root Cu concentration
TRCUCC	numeric	7	246	252	ppm	AJ	Tap-root Cu concentration
LFMNCC	numeric	7	253	259	ppm	AK	Leaf Mn concentration
STMNCC	numeric	7	260	266	ppm	AL	Stem Mn concentration
BRMNCC	numeric	7	267	273	ppm	AM	Branch Mn concentration
FRMNCC	numeric	7	274	280	ppm	AN	Fine-root Mn concentration
MRMNCC	numeric	7	281	287	ppm	AO	Medium-root Mn concentration
TRMNCC	numeric	7	288	294	ppm	AP	Tap-root Mn concentration
LFZNCC	numeric	7	295	301	ppm	AQ	Leaf Zn concentration
STZNCC	numeric	7	302	308	ppm	AR	Stem Zn concentration
BRZNCC	numeric	7	309	315	ppm	AS	Branch Zn concentration
FRZNCC	numeric	7	316	322	ppm	AT	Fine-root Zn concentration
MRZNCC	numeric	7	323	329	ppm	AU	Medium-root Zn concentration
TRZNCC	numeric	7	330	336	ppm	AV	Tap-root Zn concentration
LFKCC	numeric	7	337	343	%	AW	Leaf K concentration
STKCC	numeric	7	344	350	%	AX	Stem K concentration
BRKCC	numeric	7	351	357	%	AY	Branch K concentration

Table 5 (continued)

FRKCC	numeric	7	358	364	%	AZ	Fine-root K concentration
MRKCC	numeric	7	365	371	%	BA	Medium-root K concentration
TRKCC	numeric	7	372	378	%	BB	Tap-root K concentration
LFPCC	numeric	7	379	385	%	BC	Leaf P concentration
STPCC	numeric	7	386	392	%	BD	Stem P concentration
BRPCC	numeric	7	393	399	%	BE	Branch P concentration
FRPCC	numeric	7	400	406	%	BF	Fine-root P concentration
MRPCC	numeric	7	407	413	%	BG	Medium-root P concentration
TRPCC	numeric	7	414	420	%	BH	Tap-root P concentration
LFBCC	numeric	7	421	427	ppm	BI	Leaf B concentration
STBCC	numeric	7	428	434	ppm	BJ	Stem B concentration
BRBCC	numeric	7	435	441	ppm	BK	Branch B concentration
FRBCC	numeric	7	442	448	ppm	BL	Fine-root B concentration
MRBCC	numeric	7	449	455	ppm	BM	Medium-root B concentration
TRBCC	numeric	7	456	462	ppm	BN	Tap-root B concentration
LFFECC	numeric	7	463	469	ppm	BO	Leaf Fe concentration
STFECC	numeric	7	470	476	ppm	BP	Stem Fe concentration

Table 5 (continued)

BRFECC	numeric	7	477	483	ppm	BQ	Branch Fe concentration
FRFECC	numeric	7	484	490	ppm	BR	Fine-root Fe concentration
MRFECC	numeric	7	491	497	ppm	BS	Medium-root Fe concentration
TRFECC	numeric	7	498	504	ppm	BT	Tap-root Fe concentration

Table 6. Contents of trees93.dat (File 6)

Variable	Variable type	Variable width	Starting column	Ending column	Units	Spreadsheet column	Definition
C	character	7	1	7		A	CO_2 treatment level
N	character	7	8	14		B	N treatment level
CHBR	character	7	15	21		C	Open-top chamber identification label
REP	character	7	22	28		D	Seedling replicate identification label
HT	numeric	7	29	35	cm	E	Seedling height
DIA	numeric	7	36	42	mm	F	Seedling diameter
N1CCC	numeric	7	43	49	%	G	First-flush needle C concentration
N1NCC	numeric	7	50	56	%	H	First-flush needle N concentration
N2CCC	numeric	7	57	63	%	I	Second-flush needle C concentration
N2NCC	numeric	7	64	70	%	J	Second-flush needle N concentration
CDCCC	numeric	7	71	77	%	K	Candle C concentration
CDNCC	numeric	7	78	84	%	L	Candle N concentration
NOCCC	numeric	7	85	91	%	M	Old-needle C concentration
NONCC	numeric	7	92	98	%	N	Old-needle N concentration
NSCCC	numeric	7	99	105	%	O	Senesced-needle C concentration
NSNCC	numeric	7	106	112	%	P	Senesced-needle N concentration
BRCCC	numeric	7	113	119	%	Q	Branch C concentration
BRNCC	numeric	7	120	126	%	R	Branch N concentration
FRCCC	numeric	7	127	133	%	S	Fine-root C concentration

Table 6 (continued)

FRNCC	numeric	7	134	140	%	T	Fine-root N concentration
TRCCC	numeric	7	141	147	%	U	Tap-root C concentration
TRNCC	numeric	7	148	154	%	V	Tap-root N concentration
LRCCC	numeric	7	155	161	%	W	Lateral-root C concentration
LRNCC	numeric	7	162	168	%	X	Lateral-root N concentration
TTCCC	numeric	7	169	175	%	Y	Trunk-top C concentration
TTNCC	numeric	7	176	182	%	Z	Trunk-top N concentration
TMCCC	numeric	7	183	189	%	AA	Trunk-middle C concentration
TMNCC	numeric	7	190	196	%	AB	Trunk-middle N concentration
TBCCC	numeric	7	197	203	%	AC	Trunk-bottom C concentration
TBNCC	numeric	7	204	210	%	AD	Trunk-bottom N concentration
NOPCC	numeric	7	211	217	%	AE	Old-needle P concentration
NOKCC	numeric	7	218	224	%	AF	Old-needle K concentration
NOSCC	numeric	7	225	231	%	AG	Old-needle S concentration
NOCACC	numeric	7	232	238	%	AH	Old-needle Ca concentration
NOMGCC	numeric	7	239	245	%	AI	Old-needle Mg concentration
NOMNCC	numeric	7	246	252	ppm	AJ	Old-needle Mn concentration

Table 6 (continued)

NOFECC	numeric	7	253	259	ppm	AK	Old-needle Fe concentration
NOCUCC	numeric	7	260	266	ppm	AL	Old-needle Cu concentration
NOBCC	numeric	7	267	273	ppm	AM	Old-needle B concentration
NOZNCC	numeric	7	274	280	ppm	AN	Old-needle Zn concentration
TRPCC	numeric	7	281	287	%	AO	Tap-root P concentration
TRKCC	numeric	7	288	294	%	AP	Tap-root K concentration
TRSCC	numeric	7	295	301	%	AQ	Tap-root S concentration
TRCACC	numeric	7	302	308	%	AR	Tap-root Ca concentration
TRMGCC	numeric	7	309	315	%	AS	Tap-root Mg concentration
TRMNCC	numeric	7	316	322	ppm	AT	Tap-root Mn concentration
TRFECC	numeric	7	323	329	ppm	AU	Tap-root Fe concentration
TRCUCC	numeric	7	330	336	ppm	AV	Tap-root Cu concentration
TRBCC	numeric	7	337	343	ppm	AW	Tap-root B concentration
TRZNCC	numeric	7	344	350	ppm	AX	Tap-root Zn concentration
LRPCC	numeric	7	351	357	%	AY	Lateral-root P concentration
LRKCC	numeric	7	358	364	%	AZ	Lateral-root K concentration
LRSCC	numeric	7	365	371	%	BA	Lateral-root S concentration

Table 6 (continued)

LRCACC	numeric	7	372	378	%	BB	Lateral-root Ca concentration
LRMGCC	numeric	7	379	385	%	BC	Lateral-root Mg concentration
LRMNCC	numeric	7	386	392	ppm	BD	Lateral-root Mn concentration
LRFECC	numeric	7	393	399	ppm	BE	Lateral-root Fe concentration
LRCUCC	numeric	7	400	406	ppm	BF	Lateral-root Cu concentration
LRBCC	numeric	7	407	413	ppm	BG	Lateral-root B concentration
LRZNCC	numeric	7	414	420	ppm	BH	Lateral-root Zn concentration
FRPCC	numeric	7	421	427	%	BI	Fine-root P concentration
FRKCC	numeric	7	428	434	%	BJ	Fine-root K concentration
FRSCC	numeric	7	435	441	%	BK	Fine-root S concentration
FRCACC	numeric	7	442	448	%	BL	Fine-root Ca concentration
FRMGCC	numeric	7	449	455	%	BM	Fine-root Mg concentration
FRMNCC	numeric	7	456	462	ppm	BN	Fine-root Mn concentration
FRFECC	numeric	7	463	469	ppm	BO	Fine-root Fe concentration
FRCUCC	numeric	7	470	476	ppm	BP	Fine-root Cu concentration
FRBCC	numeric	7	477	483	ppm	BQ	Fine-root B concentration
FRZNCC	numeric	7	484	490	ppm	BR	Fine-root Zn concentration

Table 6 (continued)

BRPCC	numeric	7	491	497	%	BS	Branch P concentration
BRKCC	numeric	7	498	504	%	BT	Branch K concentration
BRSCC	numeric	7	505	511	%	BU	Branch S concentration
BRCACC	numeric	7	512	518	%	BV	Branch Ca concentration
BRMGCC	numeric	7	519	525	%	BW	Branch Mg concentration
BRMNCC	numeric	7	526	532	ppm	BX	Branch Mn concentration
BRFECC	numeric	7	533	539	ppm	BY	Branch Fe concentration
BRCUCC	numeric	7	540	546	ppm	BZ	Branch Cu concentration
BRBCC	numeric	7	547	553	ppm	CA	Branch B concentration
BRZNCC	numeric	7	554	560	ppm	CB	Branch Zn concentration
NSPCC	numeric	7	561	567	%	CC	Senesced-needle P concentration
NSKCC	numeric	7	568	574	%	CD	Senesced-needle K concentration
NSSCC	numeric	7	575	581	%	CE	Senesced-needle S concentration
NSCACC	numeric	7	582	588	%	CF	Senesced-needle Ca concentration
NSMGCC	numeric	7	589	595	%	CG	Senesced-needle Mg concentration
NSMNCC	numeric	7	596	602	ppm	CH	Senesced-needle Mn concentration
NSFECC	numeric	7	603	609	ppm	CI	Senesced-needle Fe concentration
NSCUCC	numeric	7	610	616	ppm	CJ	Senesced-needle Cu concentration
NSBCC	numeric	7	617	623	ppm	CK	Senesced-needle B concentration

Table 6 (continued)

NSZNCC	numeric	7	624	630	ppm	CL	Senesced-needle Zn concentration
TTPCC	numeric	7	631	637	%	CM	Trunk-top P concentration
TTKCC	numeric	7	638	644	%	CN	Trunk-top K concentration
TTSCC	numeric	7	645	651	%	CO	Trunk-top S concentration
TTCACC	numeric	7	652	658	%	CP	Trunk-top Ca concentration
TTMGCC	numeric	7	659	665	%	CQ	Trunk-top Mg concentration
TTMNCC	numeric	7	666	672	ppm	CR	Trunk-top Mn concentration
TTFECC	numeric	7	673	679	ppm	CS	Trunk-top Fe concentration
TTCUCC	numeric	7	680	686	ppm	CT	Trunk-top Cu concentration
TTBCC	numeric	7	687	693	ppm	CU	Trunk-top B concentration
TTZNCC	numeric	7	694	700	ppm	CV	Trunk-top Zn concentration
TMPCC	numeric	7	701	707	%	CW	Trunk-middle P concentration
TMKCC	numeric	7	708	714	%	CX	Trunk-middle K concentration
TMSCC	numeric	7	715	721	%	CY	Trunk-middle S concentration
TMCACC	numeric	7	722	728	%	CZ	Trunk-middle Ca concentration
TMMGCC	numeric	7	729	735	%	DA	Trunk-middle Mg concentration
TMMNCC	numeric	7	736	742	ppm	DB	Trunk-middle Mn concentration

Table 6 (continued)

TMFECC	numeric	7	743	749	ppm	DC	Trunk-middle Fe concentration
TMCUCC	numeric	7	750	756	ppm	DD	Trunk-middle Cu concentration
TMBCC	numeric	7	757	763	ppm	DE	Trunk-middle B concentration
TMZNCC	numeric	7	764	770	ppm	DF	Trunk-middle Zn concentration
TBPCC	numeric	7	771	777	%	DG	Trunk-bottom P concentration
TBKCC	numeric	7	778	784	%	DH	Trunk-bottom K concentration
TBSCC	numeric	7	785	791	%	DI	Trunk-bottom S concentration
TBCACC	numeric	7	792	798	%	DJ	Trunk-bottom Ca concentration
TBMGCC	numeric	7	799	805	%	DK	Trunk-bottom Mg concentration
TBMNCC	numeric	7	806	812	ppm	DL	Trunk-bottom Mn concentration
TBFECC	numeric	7	813	819	ppm	DM	Trunk-bottom Fe concentration
TBCUCC	numeric	7	820	826	ppm	DN	Trunk-bottom Cu concentration
TBBCC	numeric	7	827	833	ppm	DO	Trunk-bottom B concentration
TBZNCC	numeric	7	834	840	ppm	DP	Trunk-bottom Zn concentration
N1PCC	numeric	7	841	847	%	DQ	First-flush needle P concentration
N1KCC	numeric	7	848	854	%	DR	First-flush needle K concentration
N1SCC	numeric	7	855	861	%	DS	First-flush needle S concentration

Table 6 (continued)

N1CACC	numeric	7	862	868	%	DT	First-flush needle Ca concentration
N1MGCC	numeric	7	869	875	%	DU	First-flush needle Mg concentration
N1MNCC	numeric	7	876	882	ppm	DV	First-flush needle Mn concentration
N1FECC	numeric	7	883	889	ppm	DW	First-flush needle Fe concentration
N1CUCC	numeric	7	890	896	ppm	DX	First-flush needle Cu concentration
N1BCC	numeric	7	897	903	ppm	DY	First-flush needle B concentration
N1ZNCC	numeric	7	904	910	ppm	DZ	First-flush needle Zn concentration
N2PCC	numeric	7	911	917	%	EA	Second-flush needle P concentration
N2KCC	numeric	7	918	924	%	EB	Second-flush needle K concentration
N2SCC	numeric	7	925	931	%	EC	Second-flush needle S concentration
N2CACC	numeric	7	932	938	%	ED	Second-flush needle Ca concentration
N2MGCC	numeric	7	939	945	%	EE	Second-flush needle Mg concentration
N2MNCC	numeric	7	946	952	ppm	EF	Second-flush needle Mn concentration
N2FECC	numeric	7	953	959	ppm	EG	Second-flush needle Fe concentration
N2CUCC	numeric	7	960	966	ppm	EH	Second-flush needle Cu concentration
N2BCC	numeric	7	967	973	ppm	EI	Second-flush needle B concentration
N2ZNCC	numeric	7	974	980	ppm	EJ	Second-flush needle Zn concentration

Table 6 (continued)

CDPCC	numeric	7	981	987	%	EK	Candle P concentration
CDKCC	numeric	7	988	994	%	EL	Candle K concentration
CDSCC	numeric	7	995	1001	%	EM	Candle S concentration
CDCACC	numeric	7	1002	1008	%	EN	Candle Ca concentration
CDMGCC	numeric	7	1009	1015	%	EO	Candle Mg concentration
CDMNCC	numeric	7	1016	1022	ppm	EP	Candle Mn concentration
CDFECC	numeric	7	1023	1029	ppm	EQ	Candle Fe concentration
CDCUCC	numeric	7	1030	1036	ppm	ER	Candle Cu concentration
CDBCC	numeric	7	1037	1043	ppm	ES	Candle B concentration
CDZNCC	numeric	7	1044	1050	ppm	ET	Candle Zn concentration

1-2-3 SPREADSHEET FILES

Five 1-2-3 data files, from which the corresponding flat ASCII files described in the preceding section were generated, are also provided with this data package.

regr92.wk1 (File 7) is the spreadsheet file from which **regr92.dat** was generated. The listing that describes the contents and format of **regr92.dat** also indicates the column of **regr92.wk1** in which each variable is found.

regr93.wk1 (File 8) is the spreadsheet file from which **regr93.dat** was generated. The listing that describes the contents and format of **regr93.dat** also indicates the column of **regr93.wk1** in which each variable is found.

trees91.wk1 (File 9) is the spreadsheet file from which **trees91.dat** was generated. The listing that describes the contents and format of **trees91.dat** also indicates the column of **trees91.wk1** in which each variable is found.

trees92.wk1 (File 10) is the spreadsheet file from which **trees92.dat** was generated. The listing that describes the contents and format of **trees92.dat** also indicates the column of **trees92.wk1** in which each variable is found.

trees93.wk1 (File 11) is the spreadsheet file from which **trees93.dat** was generated. The listing that describes the contents and format of **trees93.dat** also indicates the column of **trees93.wk1** in which each variable is found.

14. LISTING OF THE FORTRAN DATA RETRIEVAL PROGRAMS

This section lists the five FORTRAN data retrieval programs provided by CDIAC with this data base. Each program is designed to read one of the five flat ASCII data files.

regr92.for (File 12)

This file is designed to read file **regr92.dat**:

```
C ***REGR92.FOR***
C FORTRAN PROGRAM TO READ THE FILE REGR92.DAT FROM NDP-061A
C
      INTEGER C, N, REP, HT
      REAL DIA, LFBM, STBM, CRBM, FRBM
      CHARACTER*6 CHBR
C
      OPEN (UNIT=1, FILE='regr92.dat')
    1 CONTINUE
      READ(1,100,END=99) C, N, CHBR, REP, HT, DIA, LFBM, STBM,
     + CRBM, FRBM
```

```
  100 FORMAT(2I6,A6,2I6,5F6.2)
C
      GO TO 1
   99 CONTINUE
      STOP
      END
```

regr93.for (File 13)

This file is designed to read file **regr93.dat**:

```
C ***REGR93.FOR***
C FORTRAN PROGRAM TO READ THE FILE REGR93.DAT FROM NDP-061A
C
      INTEGER C, N, REP
      REAL HT, DIA, LFBM, BRBM, STBM, RTBM
      CHARACTER*6 CHBR
C
      OPEN (UNIT=1, FILE='regr93.dat')
    1 CONTINUE
      READ(1,100,END=99) C, N, CHBR, REP, HT, DIA, LFBM, BRBM,
     + STBM, RTBM
  100 FORMAT(2I6,A6,I6,2F6.1,4F6.2)
C
      GO TO 1
   99 CONTINUE
      STOP
      END
```

trees91.for (File 14)

This file is designed to read file **trees91.dat**:

```
C ***TREES91.FOR***
C FORTRAN PROGRAM TO READ THE FILE TREES91.DAT FROM NDP-061A
C
      INTEGER C, N, REP, LFBCC, STBCC, RTBCC
      REAL LFBM, STBM, RTBM, LFNCC, STNCC, RTNCC, LFCACC,
     + STCACC, RTCACC, LFKCC, STKCC, RTKCC, LFMGCC, STMGCC,
     + RTMGCC, LFPCC, STPCC, RTPCC, LFSCC, STSCC, RTSCC
      CHARACTER*6 CHBR
C
      OPEN (UNIT=1, FILE='trees91.dat')
    1 CONTINUE
      READ(1,100,END=99) C, N, CHBR, REP, LFBM, STBM, RTBM, LFNCC,
     + STNCC, RTNCC, LFBCC, STBCC, RTBCC, LFCACC, STCACC, RTCACC,
     + LFKCC, STKCC, RTKCC, LFMGCC, STMGCC, RTMGCC, LFPCC, STPCC,
     + RTPCC, LFSCC, STSCC, RTSCC
C
  100 FORMAT(2I6,A6,I6,6F6.2,3I6,15F6.2)
C
      GO TO 1
```

```
   99 CONTINUE
      STOP
      END
```

trees92.for (File 15)

This file is designed to read file **trees92.dat**:

```
C ***TREES92.FOR***
C FORTRAN PROGRAM TO READ THE FILE TREES92.DAT FROM NDP-061A
C
      INTEGER C, N, REP, HT
      REAL DIA, LFNCC, BRNCC, STNCC, TRNCC, MRNCC, FRNCC,
     + LFCACC, STCACC, BRCACC, FRCACC, MRCACC, TRCACC,
     + LFMGCC, STMGCC, BRMGCC, FRMGCC, MRMGCC, TRMGCC,
     + LFSCC, STSCC, BRSCC, FRSCC, MRSCC, TRSCC,
     + LFCUCC, STCUCC, BRCUCC, FRCUCC, MRCUCC, TRCUCC,
     + LFMNCC, STMNCC, BRMNCC, FRMNCC, MRMNCC, TRMNCC,
     + LFZNCC, STZNCC, BRZNCC, FRZNCC, MRZNCC, TRZNCC,
     + LFKCC, STKCC, BRKCC, FRKCC, MRKCC, TRKCC,
     + LFPCC, STPCC, BRPCC, FRPCC, MRPCC, TRPCC,
     + LFBCC, STBCC, BRBCC, FRBCC, MRBCC, TRBCC,
     + LFFECC, STFECC, BRFECC, FRFECC, MRFECC, TRFECC
      CHARACTER*7 CHBR
C
      OPEN (UNIT=1, FILE='trees92.dat')
    1 CONTINUE
      READ(1,100,END=99) C, N, CHBR, REP, HT,
     + DIA, LFNCC, BRNCC, STNCC, TRNCC, MRNCC, FRNCC,
     + LFCACC, STCACC, BRCACC, FRCACC, MRCACC, TRCACC,
     + LFMGCC, STMGCC, BRMGCC, FRMGCC, MRMGCC, TRMGCC,
     + LFSCC, STSCC, BRSCC, FRSCC, MRSCC, TRSCC,
     + LFCUCC, STCUCC, BRCUCC, FRCUCC, MRCUCC, TRCUCC,
     + LFMNCC, STMNCC, BRMNCC, FRMNCC, MRMNCC, TRMNCC,
     + LFZNCC, STZNCC, BRZNCC, FRZNCC, MRZNCC, TRZNCC,
     + LFKCC, STKCC, BRKCC, FRKCC, MRKCC, TRKCC,
     + LFPCC, STPCC, BRPCC, FRPCC, MRPCC, TRPCC,
     + LFBCC, STBCC, BRBCC, FRBCC, MRBCC, TRBCC,
     + LFFECC, STFECC, BRFECC, FRFECC, MRFECC, TRFECC
C
  100 FORMAT(2I7,A7,2I7,67F7.2)
C
      GO TO 1
   99 CONTINUE
      STOP
      END
```

trees93.for (File 16)

This file is designed to read file **trees93.dat**:

```
C ***TREES93.FOR***
```

```
C FORTRAN PROGRAM TO READ THE FILE TREES93.DAT FROM NDP-061A
C
      INTEGER C, N, REP, HT
      REAL DIA, N1CCC, N1NCC, N2CCC, N2NCC, CDCCC,
     + CDNCC, NOCCC, NONCC, NSCCC, NSNCC, BRCCC,
     + BRNCC, FRCCC, FRNCC, TRCCC, TRNCC, LRCCC,
     + LRNCC, TTCCC, TTNCC, TMCCC, TMNCC, TBCCC, TBNCC, NOPCC,
     + NOKCC, NOSCC, NOCACC, NOMGCC, NOMNCC, NOFECC, NOCUCC,
     + NOBCC, NOZNCC, TRPCC, TRKCC, TRSCC, TRCACC, TRMGCC, TRMNCC,
     + TRFECC, TRCUCC, TRBCC, TRZNCC, LRPCC, LRKCC, LRSCC, LRCACC,
     + LRMGCC, LRMNCC, LRFECC, LRCUCC, LRBCC, LRZNCC, FRPCC,
     + FRKCC, FRSCC, FRCACC, FRMGCC, FRMNCC, FRFECC, FRCUCC,
     + FRBCC, FRZNCC, BRPCC, BRKCC, BRSCC, BRCACC, BRMGCC,
     + BRMNCC, BRFECC, BRCUCC, BRBCC, BRZNCC, NSPCC, NSKCC,
     + NSSCC, NSCACC, NSMGCC, NSMNCC, NSFECC, NSCUCC, NSBCC,
     + NSZNCC, TTPCC, TTKCC, TTSCC, TTCACC, TTMGCC, TTMNCC,
     + TTFECC, TTCUCC, TTBCC, TTZNCC, TMPCC, TMKCC, TMSCC,
     + TMCACC, TMMGCC, TMMNCC, TMFECC, TMCUCC, TMBCC, TMZNCC,
     + TBPCC, TBKCC, TBSCC, TBCACC, TBMGCC, TBMNCC, TBFECC, TBCUCC,
     + TBBCC, TBZNCC, N1PCC, N1KCC, N1SCC, N1CACC, N1MGCC, N1MNCC,
     + N1FECC, N1CUCC, N1BCC, N1ZNCC, N2PCC, N2KCC, N2SCC, N2CACC,
     + N2MGCC, N2MNCC, N2FECC, N2CUCC,N2BCC, N2ZNCC, CDPCC, CDKCC,
     + CDSCC, CDCACC, CDMGCC, CDMNCC, CDFECC, CDCUCC, CDBCC, CDZNCC
      CHARACTER*7 CHBR
C
      OPEN (UNIT=1, FILE='trees93.dat')
    1 CONTINUE
      READ(1,100,END=99) C, N, CHBR, REP, HT, DIA, N1CCC,
     + N1NCC, N2CCC, N2NCC, CDCCC, CDNCC, NOCCC, NONCC, NSCCC,
     + NSNCC, BRCCC, BRNCC, FRCCC, FRNCC, TRCCC, TRNCC, LRCCC,
     + LRNCC, TTCCC, TTNCC, TMCCC, TMNCC, TBCCC, TBNCC, NOPCC,
     + NOKCC, NOSCC, NOCACC, NOMGCC, NOMNCC, NOFECC, NOCUCC,
     + NOBCC, NOZNCC, TRPCC, TRKCC, TRSCC, TRCACC, TRMGCC, TRMNCC,
     + TRFECC, TRCUCC, TRBCC, TRZNCC, LRPCC, LRKCC, LRSCC, LRCACC,
     + LRMGCC, LRMNCC, LRFECC, LRCUCC, LRBCC, LRZNCC, FRPCC,
     + FRKCC, FRSCC, FRCACC, FRMGCC, FRMNCC, FRFECC, FRCUCC,
     + FRBCC, FRZNCC, BRPCC, BRKCC, BRSCC, BRCACC, BRMGCC,
     + BRMNCC, BRFECC, BRCUCC, BRBCC, BRZNCC, NSPCC, NSKCC,
     + NSSCC, NSCACC, NSMGCC, NSMNCC, NSFECC, NSCUCC, NSBCC,
     + NSZNCC, TTPCC, TTKCC, TTSCC, TTCACC, TTMGCC, TTMNCC,
     + TTFECC, TTCUCC, TTBCC, TTZNCC, TMPCC, TMKCC, TMSCC,
     + TMCACC, TMMGCC, TMMNCC, TMFECC, TMCUCC, TMBCC, TMZNCC,
     + TBPCC, TBKCC, TBSCC, TBCACC, TBMGCC, TBMNCC, TBFECC, TBCUCC,
     + TBBCC, TBZNCC, N1PCC, N1KCC, N1SCC, N1CACC, N1MGCC, N1MNCC,
     + N1FECC, N1CUCC, N1BCC, N1ZNCC, N2PCC, N2KCC, N2SCC, N2CACC,
     + N2MGCC, N2MNCC, N2FECC, N2CUCC,N2BCC, N2ZNCC, CDPCC, CDKCC,
     + CDSCC, CDCACC, CDMGCC, CDMNCC, CDFECC, CDCUCC, CDBCC, CDZNCC
C
  100 FORMAT(2I7,A7,2I7,F7.1,144F7.2)
C
      GO TO 1
   99 CONTINUE
      STOP
      END
```

15. LISTING OF THE SAS DATA RETRIEVAL PROGRAMS

This section lists the five SAS data retrieval programs provided by CDIAC with this data base. Each program is designed to read one of the five flat ASCII data files.

regr92.sas (File 17)

This file is designed to read file **regr92.dat**:

```
*REGR92.SAS - SAS PROGRAM TO READ REGR92.DAT FROM NDP-061A;

DATA REGR92;
INFILE 'regr92.dat';
INPUT C 1-6 N 7-12 @13 CHBR $CHAR6. REP 19-24 HT 25-30 DIA 31-36
LFBM 37-42 STBM 43-48 CRBM 49-54 FRBM 55-60;
RUN;
```

regr93.sas (File 18)

This file is designed to read file **regr93.dat**:

```
*REGR93.SAS - SAS PROGRAM TO READ REGR93.DAT FROM NDP-061A;

DATA REGR93;
INFILE 'regr93.dat';
INPUT C 1-6 N 7-12 @13 CHBR $CHAR6. REP 19-24 HT 25-30 DIA 31-36
LFBM 37-42 BRBM 43-48 STBM 49-54 RTBM 55-60;
RUN;
```

trees91.sas (File 19)

This file is designed to read file **trees91.dat**:

```
*TREES91.SAS - SAS PROGRAM TO READ TREES91.DAT FROM NDP-061A;

DATA TREES91;
INFILE 'trees91.dat';
INPUT C 1-6 N 7-12 @13 CHBR $CHAR6. REP 19-24 LFBM 25-30
STBM 31-36 RTBM 37-42 LFNCC 43-48 STNCC 49-54 RTNCC 55-60
LFBCC 61-66 STBCC 67-72 RTBCC 73-78 LFCACC 79-84 STCACC 85-90
RTCACC 91-96 LFKCC 97-102 STKCC 103-108 RTKCC 109-114
LFMGCC 115-120 STMGCC 121-126 RTMGCC 127-132 LFPCC 133-138
STPCC  139-144 RTPCC 145-150 LFSCC 151-156 STSCC 157-162
RTSCC 163-168;
RUN;
```

trees92.sas (File 20)

This file is designed to read file **trees92.dat**:

```
*TREES92.SAS - SAS PROGRAM TO READ TREES92.DAT FROM NDP-061A;

DATA TREES92;
INFILE 'trees92.dat' lrecl=504;
INPUT C 1-7 N 8-14 @15 CHBR $CHAR7. REP 22-28 HT 29-35
DIA 36-42 LFNCC 43-49 BRNCC 50-56 STNCC 57-63 TRNCC 64-70
MRNCC 71-77 FRNCC 78-84 LFCACC 85-91 STCACC 92-98
BRCACC 99-105 FRCACC 106-112 MRCACC 113-119 TRCACC 120-126
LFMGCC 127-133 STMGCC 134-140 BRMGCC 141-147 FRMGCC 148-154
MRMGCC 155-161 TRMGCC 162-168 LFSCC 169-175 STSCC 176-182
BRSCC 183-189 FRSCC 190-196 MRSCC 197-203 TRSCC 204-210
LFCUCC 211-217 STCUCC 218-224 BRCUCC 225-231 FRCUCC 232-238
MRCUCC 239-245 TRCUCC 246-252 LFMNCC 253-259 STMNCC 260-266
BRMNCC 267-273 FRMNCC 274-280 MRMNCC 281-287 TRMNCC 288-294
LFZNCC 295-301 STZNCC 302-308 BRZNCC 309-315 FRZNCC 316-322
MRZNCC 323-329 TRZNCC 330-336 LFKCC 337-343 STKCC 344-350
BRKCC 351-357 FRKCC 358-364 MRKCC 365-371 TRKCC 372-378
LFPCC 379-385 STPCC 386-392 BRPCC 393-399 FRPCC 400-406
MRPCC 407-413 TRPCC 414-420 LFBCC 421-427 STBCC 428-434
BRBCC 435-441 FRBCC 442-448 MRBCC 449-455 TRBCC 456-462
LFFECC 463-469 STFECC 470-476 BRFECC 477-483 FRFECC 484-490
MRFECC 491-497 TRFECC 498-504;
RUN;
```

trees93.sas (File 21)

This file is designed to read file **trees93.dat**:

```
*TREES93.SAS - SAS PROGRAM TO READ TREES93.DAT FROM NDP-061A;

DATA TREES93;
INFILE 'trees93.dat' lrecl=1050;
INPUT C 1-7 N 8-14 @15 CHBR $CHAR7. REP 22-28 HT 29-35
DIA 36-42 N1CCC 43-49 N1NCC 50-56 N2CCC 57-63 N2NCC 64-70
CDCCC 71-77 CDNCC 78-84 NOCCC 85-91 NONCC 92-98
NSCCC 99-105 NSNCC 106-112 BRCCC 113-119 BRNCC 120-126
FRCCC 127-133 FRNCC 134-140 TRCCC 141-147 TRNCC 148-154
LRCCC 155-161 LRNCC 162-168 TTCCC 169-175
TTNCC 176-182 TMCCC 183-189 TMNCC 190-196 TBCCC 197-203
TBNCC 204-210 NOPCC 211-217 NOKCC 218-224 NOSCC 225-231
NOCACC 232-238 NOMGCC 239-245 NOMNCC 246-252 NOFECC 253-259
NOCUCC 260-266 NOBCC 267-273 NOZNCC 274-280 TRPCC 281-287
TRKCC 288-294 TRSCC 295-301 TRCACC 302-308 TRMGCC 309-315
TRMNCC 316-322 TRFECC 323-329 TRCUCC 330-336 TRBCC 337-343
TRZNCC 344-350 LRPCC 351-357 LRKCC 358-364 LRSCC 365-371
LRCACC 372-378 LRMGCC 379-385 LRMNCC 386-392 LRFECC 393-399
LRCUCC 400-406 LRBCC 407-413 LRZNCC 414-420 FRPCC 421-427
FRKCC 428-434 FRSCC 435-441 FRCACC 442-448 FRMGCC 449-455
FRMNCC 456-462 FRFECC 463-469 FRCUCC 470-476 FRBCC 477-483
FRZNCC 484-490 BRPCC 491-497 BRKCC 498-504 BRSCC 505-511
```

```
BRCACC 512-518 BRMGCC 519-525 BRMNCC 526-532 BRFECC 533-539
BRCUCC 540-546 BRBCC 547-553 BRZNCC 554-560 NSPCC 561-567
NSKCC 568-574 NSSCC 575-581 NSCACC 582-588 NSMGCC 589-595
NSMNCC 596-602 NSFECC 603-609 NSCUCC 610-616 NSBCC 617-623
NSZNCC 624-630 TTPCC 631-637 TTKCC 638-644 TTSCC 645-651
TTCACC 652-658 TTMGCC 659-665 TTMNCC 666-672 TTFECC 673-679
TTCUCC 680-686 TTBCC 687-693 TTZNCC 694-700 TMPCC 701-707
TMKCC 708-714 TMSCC 715-721 TMCACC 722-728 TMMGCC 729-735
TMMNCC 736-742 TMFECC 743-749 TMCUCC 750-756 TMBCC 757-763
TMZNCC 764-770 TBPCC 771-777 TBKCC 778-784 TBSCC 785-791
TBCACC 792-798 TBMGCC 799-805 TBMNCC 806-812 TBFECC 813-819
TBCUCC 820-826 TBBCC 827-833 TBZNCC 834-840 N1PCC 841-847
N1KCC 848-854 N1SCC 855-861 N1CACC 862-868 N1MGCC 869-875
N1MNCC 876-882 N1FECC 883-889 N1CUCC 890-896 N1BCC 897-903
N1ZNCC 904-910 N2PCC 911-917 N2KCC 918-924 N2SCC 925-931
N2CACC 932-938 N2MGCC 939-945 N2MNCC 946-952 N2FECC 953-959
N2CUCC 960-966 N2BCC 967-973 N2ZNCC 974-980 CDPCC 981-987
CDKCC 988-994 CDSCC 995-1001 CDCACC 1002-1008 CDMGCC 1009-1015
CDMNCC 1016-1022 CDFECC 1023-1029 CDCUCC 1030-1036
CDBCC 1037-1043 CDZNCC 1044-1050;
RUN;
```

16. PARTIAL LISTINGS OF THE FLAT ASCII DATA FILES

This section provides a sample listing of the first and last two data records in the five flat ASCII data files provided with this data base. Sample listing for **regr92.dat**:

First two data records:

```
1      1   CL6     3    38 20.38 16.13 15.00 15.65  3.15
1      1   CL6    17    29 14.42 12.66 25.18 -9.99 -9.99
```

Last two data records:

```
4      3    D4     4    33 19.92 65.00 56.91 -9.99 -9.99
4      3    D4    15    43 23.99 41.42 51.87 -9.99 -9.99
```

Sample listing for **regr93.dat**:

First two data records:

```
1      1   CL6     7  52.4  27.8116.10 50.00 61.60 63.38
1      1   CL6     8  52.5  14.6 45.90 12.50 37.34 -9.99
```

Last two data records:

```
4      3    D4    11  53.1  39.4367.77 82.80208.85 -9.99
4      3    D4    21  53.5  40.4284.20 77.50318.40135.81
```

Sample listing for **trees91.dat**:

First two data records:

```
     1     1   CL6     1  0.43  0.13  0.29  1.84  0.40  0.96    39    18    41
0.26  0.16  0.16  0.88  1.19  0.62  0.11  0.13  0.06  0.23  0.31  0.17  0.13
0.17  0.14
     1     1   CL7     1  0.40  0.15  0.25  1.82  0.37  0.95    36    26    35
0.28  0.20  0.17  0.93  1.34  0.49  0.10  0.18  0.06  0.22  0.22  0.13  0.22
0.28  0.13
```

Last two data records:

```
     4     3    C6    -9  1.07  0.45  0.59  1.15  0.61  0.69    33    21    21
0.30  0.24  0.16  0.82  1.19  0.39  0.09  0.17  0.07  0.24  0.31  0.13  0.11
0.18  0.11
     4     3    D4    -9  1.22  0.33  0.89  1.15  0.54  0.51    42    21    17
0.24  0.18  0.13  0.77  1.16  0.46  0.09  0.12  0.06  0.22  0.25  0.14  0.13
0.17  0.11
```

Sample listing for **trees92a.dat**:

First two data records:

```
      1      1    CL6      3     38  20.38   2.25  -9.99   0.38   0.27   0.38
0.65   0.34   0.16  -9.99   0.33   0.22   0.19   0.14   0.10  -9.99   0.06
0.05   0.06   0.21   0.13  -9.99   0.04   0.03   0.05   3.60   4.50  -9.99
3.00   2.20   1.60 400.00 201.00  -9.99  63.00  55.00  77.00  77.00  64.00
-9.99  33.00  61.00  17.00   0.91   0.67  -9.99   0.06   0.04   0.13   0.24
0.11  -9.99   0.05   0.03   0.04  33.00  11.00  -9.99  19.00  11.00   9.00
472.00 623.00  -9.99 618.00 462.00 365.00
      1      1    CL7      3     39  14.15   1.59  -9.99   0.29   0.34   0.28
0.51   0.50   0.14  -9.99   0.36   0.21   0.24   0.13   0.10  -9.99   0.07
0.05   0.07   0.19   0.12  -9.99   0.04   0.03   0.04   8.70   3.60  -9.99
2.80   2.00   3.10 414.00 176.00  -9.99  76.00  56.00  83.00 111.00  62.00
-9.99  23.00  19.00  19.00   0.77   0.70  -9.99   0.06   0.07   0.09   0.15
0.12  -9.99   0.04   0.03   0.04  38.00  22.00  -9.99  14.00   8.00  14.00
581.00 250.00  -9.99 756.00 353.00 354.00
```

Last two data records:

```
      4      3     C6      3     31  21.20   1.40  -9.99   0.55   0.28   0.31
0.41   0.39   0.17  -9.99   0.33   0.20   0.23   0.12   0.12  -9.99   0.07
0.05   0.07   0.08   0.11  -9.99   0.04   0.02   0.04   2.40   2.50  -9.99
3.50   2.10   2.80 397.00 255.00  -9.99  89.00  64.00  88.00  61.00  46.00
-9.99  17.00  10.00   8.00   0.63   0.64  -9.99   0.03   0.03   0.09   0.13
0.21  -9.99   0.05   0.03   0.04  35.00  38.00  -9.99  15.00   8.00  11.00
401.00 436.00  -9.99 700.00 367.00 297.00
```

```
      4      3     D4      3     41  20.56   1.36   0.58   0.16   0.33   0.33
0.47   0.28   0.07   0.33   0.19   0.10   0.17   0.13   0.09   0.15   0.05
0.04   0.06   0.08   0.05   0.06   0.04   0.02   0.04   4.20   8.80   5.30
2.20   3.50   1.90 280.00 116.00 271.00  79.00  56.00  94.00  66.00  29.00
58.00  21.00  13.00  14.00   0.62   0.40   0.63   0.07   0.08   0.16   0.12
0.05   0.10   0.04   0.03   0.04  27.00   8.00  14.00  11.00   7.00  11.00
286.00  43.00  11.00 499.00 251.00 239.00
```

Sample listing for **trees93.dat**:

First two data records:

```
      1      1    CL6      1     93   34.8  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99
      1      1    CL6      2     95   33.8  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99
```

Last two data records:

```
      4      3     D4     19     97   41.8  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
```

```
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99
      4      3     D4     21    114   40.0  38.69   1.06  -9.99  -9.99  49.87
1.11  49.66   1.36  -9.99  -9.99  49.37   0.66  45.81   0.58  48.24   0.15
47.84   0.31  48.11   0.58  47.94   0.21  47.87   0.18   0.12   0.46   0.14
0.35   0.20 105.20 395.40   3.00  25.00  38.00   0.03   0.19   0.05   0.08
0.06  53.40 139.20   5.00   8.00  15.00   0.07   0.29   0.08   0.14   0.09
80.00 404.00   4.00   7.00  16.00   0.11   0.25   0.10   0.25   0.10
99.001173.00  14.00  23.00  14.00  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99
-9.99  -9.99  -9.99   0.17   0.75   0.08   0.20   0.23 111.00  69.00  10.00
15.00  36.00   0.11   0.58   0.06   0.10   0.11  89.00  56.00   6.00  14.00
31.00   0.06   0.37   0.05   0.10   0.08  70.00  31.00   4.00  12.00  22.00
0.15   0.57   0.12   0.32   0.20 160.00 121.00   5.00  29.00  45.00  -9.99
-9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99  -9.99   0.22   0.67
0.11   0.13   0.13 110.00
```

APPENDIX A: REPRINT OF PERTINENT LITERATURE

Johnson, D. W., J. T. Ball, and R. F. Walker. 1997. Effects of CO_2 and nitrogen fertilization on vegetation and soil nutrient content in juvenile ponderosa pine. *Plant and Soil* 190:29–40.

Walker, R. F., D. R. Geisinger, D. W. Johnson, and J. T. Ball. 1997. Elevated atmospheric CO_2 and soil N fertility effects on growth, mycorrhizal colonization, and xylem water potential of juvenile ponderosa pine in a field soil. *Plant and Soil* 195:25–36.