2000-90
Support Software

For the LAI-2000 Plant Canopy Analyzer

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For IBM PC Compatibles

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LI-COR®

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for the LAI-2000 Plant Canopy Analyzer

Software Version 2.15
Publication No. PCA103-9204   April, 1992

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General Information

The 2000-90 diskette contains a program (C2000.EXE) that can operate on data files generated by the LAI-2000.

The files on the disk are:

PROGRAM FILE   C2000.EXE   - LAI-2000 support program.

DOCUMENTATION FILES

READ.ME	- Recent changes.
C2000.HLP	- Help file used by C2000.EXE.
2000.DAT	- Sample LAI-2000 data files for C2000 program.

The C2000 program is approximately 100K bytes in size, and runs on any IBM PC/XT/AT/PS/2 or compatible computer.

***GENERAL
INFORMATION***

C2000 is a support program for the LAI-2000 Plant Canopy Analyzer. It duplicates or extends many of the functions and calculations of the instrument. Input data consists of LAI-2000 data files (in standard, as opposed to user-defined, format) that reside in an ASCII file. Multiple data files may reside in a single DOS file. Each of these data files will be assigned a sequential ID number when they are read into the C2000 program. Use the COMM program (part #1000-90) to get data from the LAI-2000 to an ASCII file.

The C2000 program will only operate on DOS files that contain LAI-2000 data files that have been output in standard (as opposed to spreadsheet) format. Observations are required for recomputations.

When first run, the C2000 program will display the software revision number, and ask if you wish to load the extended help messages, which are found in the text file "C2000.hlp." It is recommended that you load these messages and print that file for future reference.

This program is command line driven. At each step, all of your options are listed on a line, and you choose the letter of the option you wish to perform. Usually, one of the options is Help, so typing **H** will give you additional information.

The main prompt line will read:

          [0] Read Help cLear Quit ?

The number in the [ ] is the number of LAI-2000 data files that are loaded into memory. Before any file manipulations can be performed, the LAI-2000 data files must be loaded into the computer's RAM. These are the ASCII files created using the COMM program to dump data from the LAI-2000 to the computer. Press **R** and the prompt

```
READ all LAI-2000 files from DOS source file <filename>
Enter source file
(Note: using a wildcard * or ? will get a directory)
(default = 2000.dat)
```

appears. Press **ENTER** to load the 3 sample data files contained in "2000.dat", or type in the name of the data file you wish to load.

A message appears which indicates how many LAI-2000 files were loaded into RAM, and assigns an ID# to each file. The C2000 Main Menu now appears, from which all file analysis takes place.

☞ Keep in mind that file manipulations do *not* affect the data source files; only the RAM-resident files loaded into C2000 are changed. If you wish to save files which have been operated on, use the "PRINT" command to write the file(s) to a disk file. See the "PRINT" menu for further information.

Main Menu

READ   [3] **Read** Delete Edit Compute Print Show Format Help cLear Quit ?

Press **R** to read any additional files into RAM. Subsequent Reads will *Add* LAI-2000 files into memory; no files are overwritten.

DELETE   [3] Read **Delete** Edit Compute Print Show Format Help cLear Quit ?

Press **D** to delete files from RAM. The prompt

```
DELETE files <x thru y> from memory
Enter file ID# for x,y (or S for Show info)
```

appears. If you can't remember the ID#'s of the file(s) you wish to delete, press **S** <enter> to see a list of the LAI-2000 files currently in memory. Enter x,y to delete files. In this example, entering 1,3 will delete all "2000.dat" files in memory which were loaded with the "READ" command.

CLEAR [3] **Read** Delete Edit Compute Print Show Format Help **cLear** Quit ?

Press **L** to clear the display.

EDIT Menu

Press **E** at the Main Menu to access the EDIT sub-menu. There are several options in this menu.

[3] Read Delete **Edit** Compute Print Show Format Help cLear Quit ?

☞ You can return to the Main Menu by pressing **Q**.

EDIT HEADER edit: **heaDer** Records Canopy_model Mask Help Quit ?

Header information which can be edited includes the angle vectors (ANGLES) and the Prompts and responses.

Angles edit header: **Angles** Prompts_responses Help Quit ?

Changes ANGLE values (the angles viewed by the 5 rings of the detector in the LAI-2050 Optical Sensor) to <a,b,c,d,e> in <files x thru y>. Enter the 5 new angle values and the range of file ID's in which to change this information. **NOTE:** *You should never need to edit this.*

Prompts & Responses edit header: Angles **Prompts_responses** Help Quit ?

Allows you to edit the prompts and responses which you set up when creating the LAI-2000 data files. Press **P**, and another menu appears:

```
E - Edit these prompts and remarks
S - Skip to the next file
Q - Quit and return to the main menu
```

EDIT RECORDS   edit: heaDer **Records** Canopy_model Mask Help Quit ?

Records are the observations in the LAI-2000 files. Both A (above) and B (below) records must be present to perform computations. Press **R** to view the Records sub-menu:

Add   edit record: **Add** Delete Multiply Replace eXchange Help Quit ?

Allows merging of observations between 2 LAI-2000 files. When operating the LAI-2000 in remote mode, the A and B records will need to be merged into a single file for computation. Select destination file ID#, type of record (i.e., A or B), record type to add, and the source file.

This function has two uses: first, to fix a file created by improper use of the Edit Records Replace command, or with FCT 34 and 35 in the instrument. For example, if you use the wrong source file, all records specified are replaced with erroneous records. You would have to delete all of these records from these files, and use the ADD function to replace records from the right file. Secondly, the ADD function can be used as part of a space-saving trick when operating in Remote mode. See the Edit Record eXchange command for details.

Delete   edit record: Add **Delete** Multiply Replace eXchange Help Quit ?

Removes *observations* (files are deleted from the main menu). Select by ID#, TIME, and/or Observation NUM. If you select TIME, a starting and ending time is specified; records between these times are deleted. If you select NUM, a low and high observation # is selected. Records within this range are deleted. If you select ID#, you can select a list of the ID's (A, B, ?, 1, 2) to be deleted. Any combination of these prompts can be selected, as well. For example, if you want to delete all A observations between 4:00 p.m. and 8:00 p.m., you would enter I (for ID#), followed by A, and T (for Time) followed by 16:00:00 and 20:00:00 (hh:mm:ss).

Multipy edit record: Add Delete **M**ultiply Replace eXchange Help Quit ?

Multiplies records in an observation by a constant, as when standardizing data for two different sensor calibrations, or if you use the wrong (or forget to use) calibration factor for a sensor. If you used erroneous calibration data, simply multiply the readings by the ratio of the correct cal (numerator) to the wrong cal (denominator). LAI is not affected by the cal factor; it is only needed if you want to compare rings, as when measuring sky brightness, etc. Enter ID#, record types, and multiplier.

Replace edit record: Add Delete Multiply **R**eplace eXchange Help Quit ?

This function duplicates FCTs 34 and 35 in the LAI-2000. A range of files is specified, along with the type of record to be replaced. The source file and replacement record types are then specified. For example, all "?" records in files 1 thru 3 can be replaced with "?" records from file 10. The criteria for choosing the replacement from the source file is time; the source record closest in time to the record being replaced is selected.

Exchange edit record: Add Delete Multiply Replace e**X**change Help Quit ?

This function turns "A" records into "B" records, and vice-versa. This can save space in the console which is logging below canopy readings when used in remote mode. The console logging below canopy readings (Remote Below mode) adds 2 records at each logging period; one "B" record and a ? record. The ? record is replaced with "A" records in FCT's 34 and 35 in the instrument, or with the Edit Record Replace command of this program.

To save memory space, the console logging the "B" readings can be set to Remote Above mode or 1-sensor mode (logging set to ON KEY, rather than a time interval). In this configuration, only 1 record (an "A" record) is recorded. The eXchange function can then be used to turn these "A's" into "B's", and then use the Edit Record Add function to add these "A" records from the "Above" file to the "B" records in your "Below" file. If 1-sensor mode is used, the readings can initially be "B" readings, so the eXchange function can be skipped

*EDIT CANOPY
MODEL*

edit: heaDer Records **Canopy_model** Mask Help Quit ?

The canopy model refers to the distance vector. Normally, one assumes a horizontal continuous canopy, and the distance values are 1/cos(angle). By changing the distance values, canopy structure data can be obtained from individual plants (e.g., a single fruit tree).

With an individual plant, all LAI values become FOLIAGE DENSITY in units of m^2/m^3 (assuming the distance vector is in meters). In addition, if canopy volume and drip line area are known, drip-line LAI (DLLAI) can be calculated (see User Format List).

☞ This technique for an individual plant is valid only if the leaves are small in comparison to the overall canopy size. A single tree is a valid example; don't expect the same success applying this to a single grass plant, however.

There are two options available within the Canopy_model function; an Individual canopy model, and a Continuous canopy model.

Individual Canopy

set canopy model: Continuous **Individual** Help Quit ?

For the Individual canopy, you are asked to enter the file ID#, and N, the number of X, Y coordinates for the plant crown.

If N>2, then you are asked to enter:

1. The X, Y coordinates for the plant outline, and
2. The height of the sensor above the ground.

If N≤2, you are asked to enter:

1. The distances from the sensor to the canopy edge at the 5 vector angles,
2. Canopy volume (needed only for DLLAI), and
3. Drip-line area (needed only for DLLAI).

When defining the canopy by X and Y coordinates, observe the following rules:

1. X is the horizontal distance from the sensor in the direction of view.
2. Y is the height of the canopy above the ground.
3. Only one side of the canopy needs to be specified (X>0).
4. The first and last coordinate pair should be at X=0. Start at the bottom center of the canopy, go out the bottom, up the side, and back to the top center. For example, with a cone-shaped tree whose bottom limb is 1 m high, lower radius is 2 m, and peak is 3 m, the coordinates would be entered as (N=3):

0	1	[at center (x=0), bottom (y=1)]
2	1	[at right edge (x=1), bottom (y=1)]
0	3	[at center (x=0), top (y=3)]

There can be as many coordinate pairs as is necessary to define the outer profile of the plant canopy. If the DIST for a given angle turns out to be 0, the MASK is adjusted to ignore that ring.

Continuous Canopy

set canopy model: **C**ontinuous Individual Help Quit ?

The Continuous canopy model function resets the distance vectors in a range of files to be 1/cos(angle). Any Individual canopy parameters that you may have entered for a file are not lost when this is done, unless the file is subsequently written to disk. These Individual canopy parameters are not saved when the canopy model indicates that they are not needed.

EDIT MASK

edit: heaDer Records Canopy_model **Mask** Help Quit ?

The computation Mask function indicates which rings are to be ignored during computations. This applies to computations done as a result of the Compute function, as well as computations done for the alternate LAI methods found in the User Format list.

COMPUTE Menu

Press **C** at the Main Menu to access the COMPUTE sub-menu.

[3] Read Delete Edit **Compute** Print Show Format cLear Help Quit ?

Any files with observations present can be computed according to a standard format, or using one of three optional computation algorithms.

COMPUTE STANDARD

Compute files: **Standard** Options Last_option Expand Help Quit ?

Using the Standard format, files are computed using the previous A readings, and bad readings (transmittance >1) are skipped. The MASK is used to determine if any rings are to be ignored.

COMPUTE OPTIONS

Compute files: Standard **Options** Last_option Expand Help Quit ?

The Options menu allows you to select a variety of computational methods, according to the following menu:

```
---------- Defining A and B -------------------------------------------
F - find above and below by comparing first A, B pair.  (default)
A - assume A records are above, and B are below.
B - assume B records are above, and A are below.


---------- Determining above readings -----------------------------
P - use previous above reading as found in the file.  (default)
I - interpolate above reading from the rest of the above readings.
C - use closest-in-time above reading.


---------- What to do with 'bad' readings ---------------------------
S - skip any record containing a transmittance >1.  (default)
T - force transmittance to 1 if it is >1.
Enter options (default = 'FPS')
```

***COMPUTE
LAST OPTION***

Compute files: Standard Options **Last_option** Expand Help Quit ?

Files are computed using the options (user-defined or default) which were used the last time computations were performed. The options used are retained as a part of each file, so a group of files can be computed all at once, each with its own options. This option string is available in user format (code p), and is included in the standard format as three lower case characters immediately following the LAI in the first line, as shown below.

FILE	DATE	TIME	PLANTS	REM	LAIait	SEL	DIFN	MTA	SEM	SMP
13	3 MAY	20:05:56	W WHEAT	MASK	2.07	0.06	0.235	65	5	15

If the 3 characters following the LAI header are blank, the standard computation is assumed (equivalent to codes 'FPS').

***COMPUTE
EXPAND***

Compute files: Standard Options Last_option **Expand** Help Quit ?

Each A/B pair of observations found in the source file(s) causes a new file to be created, having only one pair of readings. This new file has all the attributes of the source file (mask, last-compute option, canopy model, etc.).

If the source file's last-compute option included interpolation, then the above readings in the new files will be interpolated values.

PRINT Menu

Press **P** at the Main Menu to access the PRINT sub-menu.

[3] Read Delete Edit Compute **Print** Show Format cLear Help Quit ?

One or more selected files can be printed to a destination using a DOS specifier such as CON (console), LPT1 (line printer), COM1 or COM2 (the RS-232C serial ports), or to a disk file. If you are writing to a file that already exists, you are given the option of appending or overwriting the file.

PRINT STANDARD

print files: **Standard** std_No_obs User Help Quit ?

Files are printed in Standard format. If the file includes Individual canopy model data, it is output as well.

PRINT NO OBSERVATIONS

print files: Standard **std_No_obs** User Help Quit ?

Files are printed in Standard format for the file header(s), but any observations are suppressed.

PRINT USER

print files: Standard std_No_obs **User** Help Quit ?

Files are output using the currently defined user format, which is set using the Format User command from the Main Menu.

SHOW Menu

Press **S** at the Main Menu to access the SHOW sub-menu.

[3] Read Delete Edit Compute Print **Show** Format cLear Help Quit ?

The Show command prints file header information to the CRT about the LAI-2000 files currently in memory. The displayed information is user-defined, using the Format Show command from the main menu. The format codes are the same as the User Print format codes.

FORMAT Menu

Press **F** at the Main Menu to access the FORMAT sub-menu.

[3] Read Delete Edit Compute Print Show **Format** cLear Help Quit ?

The Format commands allow the user to define the format of the information to be printed, or for displaying on the CRT using the Show command.

USER PRINT

Formats: **User_print** Show_format Descriptions Help Quit ?

Allows the user to specify a sequence of codes for the User Format Print command. A list of the codes is displayed for you to choose from (see below).

SHOW FORMAT

Formats: User_print **Show_format** Descriptions Help Quit ?

Allows you to specify a sequence of codes which will be displayed on the CRT using the Show command. Again, a list of codes is displayed (see DESCRIPTIONS command).

DESCRIPTIONS Formats: User_print Show_format **Descriptions** Help Quit ?

☞ This option is available only if the Help file was loaded when you started the C2000 program.

Detailed information concerning any of the codes present in the list shown below can be obtained by entering the letter or number code displayed.

```
------------------------ LAI-2000 Format Codes----------------------------------
0...FILE  5      response 2      A...SEM  F      GAP( )
1...DATE TIME  6...LAI          B...SMP         G...Slope
2...prompt 1   7...SEL          C...CT#( )      H...Intercept
3...response 1 8...DIFN         D...SDU( )      I...STDERR
4...prompt 2   9...MTA          E...DST( )      J...LangLAI

------------------------ Miscellaneous Codes----------------------------------
0...#obs each   M...Mean B( )   P...Mean 2( )   m...mask( )
a...Angles( )   L...Mean A( )   N...Mean 1( )   k...Decimal Julian Day
e...extcoeff( ) p...Options     s...DIFN+sky    K...Julian (leap year)
f...extfct( )

------------------------ Constrained Least Squares Inversion --------------------
Q...LAI         R...Constraint  S...Fracs( )    T...MTA
                                                b...MU,NU of Beta Dist.

------------------------ Ellipsoidal Inversion ----------------------------------
U...LAI         V...MTA         X...X factor

------------------------ Individual Crown Analysis -------------------------------
W...Sensor ht   Y...Cpy Volume  Z...Cpy area    d...Dripline LAI
n...# XY pairs  x...coords      c...Cpy model
```

Codes Codes 0-9 and A-J reference LAI-2000 file headers, and are the same as the Spreadsheet format codes in the LAI-2000's program.

0 - shows the number of each type (A, B, ?, 1, 2) of record found in a file.

a - shows the 5 angles associated with each ring (the ANGLE vector).

e - shows 5 extinction coefficients (fraction of foliage projected toward the 5 view angles of each ring), computed by dividing contact number by LAI.

f - shows the slope and intercept of a linear fit of extinction coefficient vs. zenith angle (degrees).

M, L, P, N - prints the 5 mean values of all A, B, 1, or 2 records in the file.

p - prints the 3-character option code that was used the last time a file was computed. If this field is blank, the standard options (equivalent to 'FPS') were used.

s - computes DIFN weighted by the measured sky distribution. The normal DIFN value (code 8) assumes an isotropic sky.

m - prints the 5-digit mask value. "11111" indicates that all rings are included in the computations. "11110" means that ring 5 is excluded, etc.

k - prints the Julian day based on the date and time. This can be useful if you want to plot LAI vs time, for example. When you select this, you are asked if it is a Leap Year or not.

K - same as above, except a Leap Year is assumed.

Constrained Least Squares Parameters

An alternative method of inverting gap fraction data is that of constrained least squares. Refer to:

Norman, J.M. and G.S. Campbell, 1989. Canopy structure. In: Plant Physiological Ecology: Field Methods and Instrumentation. (eds R.W. Pearcy, J. Ehleringer, H.A. Mooney, and P.W. Rundel). Chapman and Hall, London and New York. pp. 301-325.

Perry, S.G., A.B. Fraser, D.W. Thomson, and J.M. Norman, 1988. Indirect sensing of plant canopy structure with simple radiation measurements. Agric. and For. Meteor. (42) 255-278.

Q - LAI (or foliage density) by method of constrained least squares.

R - the smallest constraint that yields all positive area fractions.

S - foliage angle distribution. The angle classes are 9, 27, 45, 63, and 81 degrees (90 divided evenly into 5 rings). If one or more rings are thrown out (masked), there will be fewer angle classes. For example, if there are four classes, they will be at 11, 34, 56, and 79 degrees (5 will be printed, but the 5th one will be -1, signifying that it is missing).

T - Mean Tip Angle based on the distribution (S).

b - Mu, Nu of Beta distribution (Goel and Strebel, 1984, Agron. J. (76) 800-802).

<u>Beta Distribution</u>

A two-parameter method of describing leaf angle distribution is the beta distribution. To compute this, area fractions in leaf angle classes must be known, and that is done as part of the constrained least squares inversion, provided in codes Q, R, S, and T. For more information on the beta distribution, refer to:

Goel, N.S. and D.E. Strebel, 1984. Simple beta distribution of leaf orientation in vegetation canopies. Agron. J. (76) 800-802.

<u>Ellipsoidal Inversion</u>

Another method of inverting gap fraction data is to use an ellipsoidal-based description of leaf angle distribution. Refer to:

Norman, J.M. and G.S. Campbell, 1989. Canopy structure. In: Plant Physiological Ecology: Field Methods and Instrumentation. (eds R.W. Pearcy, J. Ehleringer, H.A. Mooney, and P.W. Rundel). Chapman and Hall, London and New York. pp. 301-325.

Campbell, G.S., 1986. Extinction coefficients for radiation in plant canopies calculated using an ellipsoidal inclination angle distribution. Ag. For. Meteorol. (36) 317-321.

U - LAI (or foliage density) obtained from the ellipsoidal distribution method.

V - Mean Tip Angle obtained from the ellipsoidal method.

X - the ratio of horizontal to vertical radii of an ellipsoid whose surface area fractions describe the foliage angle distributions in the canopy.

Individual Canopy Analysis

These parameters are relevant only if the file's DIST vector has been changed to describe an isolated canopy, rather than a continuous canopy. See the Edit Canopy Individual command for a detailed description of this function.

c - canopy model, either HORIZ or ISOL.

n - the number of X,Y coordinates used to describe the outline of the canopy.

x - the actual X,Y coordinates (if you include this in a format, put it last, since it will potentially leave a "ragged" right edge.

d - drip-line LAI. This is foliage density times volume divided by drip line area. Recall that foliage density is in the LAI value (Code 6 or Q or U) for an individual canopy.

Z - the drip line area, either calculated from the X,Y coordinates and sensor height information (the canopy below the sensor is ignored), or entered by the user.

Y - canopy volume above the sensor, either calculated from the X,Y coordinates, or entered by the user.

W - sensor height.

Individual canopy files printed in Standard format appear as shown below.

```
FILE  DATE     TIME      TREE  REM    LAI   SEL   DIFN   MTA  SEM  SMP
   5  13 SEP  09:48:02      5  MAC24  2.70  0.63  0.115   60   2    4

ANGLES  7.000  23.00  38.00  53.00  68.00
CNTCT#  1.155  1.236  1.266  1.174  1.491
STDDEV  0.185  0.294  0.300  0.280  1.156
DISTS   3.082  2.625  2.522  1.665  0.942
GAPS    0.028  0.039  0.041  0.142  0.245

SNRHGT  VOLUME  AREA  DLLAI  NPTS
  0.50   14.60  8.87   4.45     8

     X       Y
  0.00    0.53
  0.76    0.61
  1.22    1.22
  1.52    1.83
  1.68    2.44
  0.91    3.05
  0.31    3.66
  0.00    4.04

A  1  09:48:16  2.907  3.959  3.789  3.330  2.409
B  2  09:48:30  0.077  0.261  0.351  0.517  1.910
A  3  09:48:47  2.857  3.857  3.620  3.177  2.732
B  4  09:48:58  0.093  0.073  0.108  0.896  1.777
A  5  09:49:11  3.238  4.466  4.252  3.873  3.383
B  6  09:49:22  0.199  0.079  0.059  0.455  0.358
A  7  09:49:38  4.748  5.422  5.252  4.579  3.460
B  8  09:49:55  0.059  0.565  0.387  0.359  0.230
```

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