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# **CI - 110**

## **Digital Plant Canopy Imager Instruction Manual**



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# TABLE OF CONTENTS

Introduction .....	1-1
Using this Manual .....	1-1
The CI-110 Digital Plant Canopy Imager Features.....	1-1
Installation of the Software .....	1-1
CI-110 Installation Instructions.....	1-2
The CI-110 Application Window.....	1-3
Using a Mouse.....	1-4
Getting Help .....	1-4
Using the Help Window.....	1-5
Technical Support .....	1-5
Hardware Configurations .....	2-1
Computer Rechargeable Battery .....	2-1
External Power Supply.....	2-1
Pre-operation .....	2-1
Charging the Batteries.....	2-2
Using the Laptote™ Outdoors .....	2-2
Manipulating Images .....	3-1
Capture Images.....	3-1
Open Images.....	3-2
Scaling Images .....	3-3
Crop Images .....	3-4
Refresh Images.....	3-4
Save Images .....	3-4
Print Images .....	3-5
Measuring Images .....	4-1
Getting Started .....	4-1
Setting Measurement Options .....	4-1
Setup.....	4-1
Adjustment .....	4-6
Save Setup.....	4-7
Making Measurements .....	4-7
Do you need to Blankout an Area? .....	4-7
Defining the Areas and Objects you want to Measure.....	4-9

Refreshing an Image .....	4-9
Making Measurements .....	4-9
PAR Measurements .....	4-9
Working With Data .....	5-1
CI-110 Result Data Window .....	5-1
Moving Around the Data sheet .....	5-2
Copying a Block of Data .....	5-2
Selecting Measurement Output .....	5-2
Saving the Data Sheet .....	5-2
Theory And Applications .....	6-1
How the Data Numbers are Derived .....	6-1
Equations .....	6-2
Application Tips .....	6-3
Plant Canopy Structure .....	6-3
Plant Canopy Size .....	6-3
Foliage Size .....	6-3
Fish-eye Lens Field-of-View .....	6-3
Sky Conditions .....	6-4
Cropping an Image .....	6-4
Miscellaneous .....	7-1
Cleaning .....	7-1
Moving the Computer .....	7-1
Protecting the CI-110 .....	7-1
Storage .....	7-1
Production Test Check Sheet	
CID Hardware Warranty	

# INTRODUCTION

This chapter describes the organization of this manual and introduces you to most of the CI-110 Digital Plant Canopy Imager's features. It also covers some basics about using the CI-110, including:

- Using this manual
- The CI-110 features
- Installation of the CI-110
- Starting the application
- The main program window
- Using a mouse
- On-line help and technical support

## USING THIS MANUAL

The CI-110 Instruction Manual is designed to provide you with complete instructions on using the CI-110 to measure plant canopy fish-eye images. Refer to the Windows Help Menu in *Windows* software for questions on how to work with the computer.

## THE CI-110 DIGITAL PLANT CANOPY IMAGER FEATURES

The CI-110 Digital Plant Canopy Imager provides a means of making fast, convenient, and non-destructive plant canopy measurements. It consists of a fish-eye image capture head, a detachable probe, plant canopy analysis software, a computer carrier and a laptop computer. The image taken in the field will show up on the computer screen directly. You save the image just as you would save other files.

The CI-110 can perform the following measurements:

- Solar beam transmission coefficient (gap fraction)
- Hemispherical diffuse radiation transmission coefficient (the sky-view factor)
- Leaf Area Index (LAI)
- Mean Foliage Inclination Angle (MFIA)
- Plant canopy extinction coefficient

The CI-110 uses a digital camera with a fish-eye lens (for focusing and zooming see the Hardware Configurations chapter) to perform a detailed scan of the plant canopy. A fish-eye binarized image with high resolution is captured by simply clicking the capture button. It is not necessary to take separate measurements above and below the canopy. Image analysis is performed with the supplied software and the computer. Researchers have the flexibility to choose the number of zenith angles as well as azimuthal divisions to set a grid on the canopy fish-eye image.

## INSTALLATION OF THE SOFTWARE

*If you purchased the CI-110 with the laptop, the CI-110 program is pre-installed in the computer. If you purchased the CI-110 without the laptop, you will need to install the program with the following steps:*

---

**CI-110 INSTALLATION INSTRUCTIONS**

The CI-110 Plant Canopy Digital Imager can be installed on Windows 2000 and Windows XP computers.

1. Insert the CD into the CD drive.
2. If autorun is enabled, the Setup.exe program will automatically start. If autorun is disabled, open My Computer, select the CD drive, and double click on Setup.exe. The CI-110 exe. program will be installed in the C: \Program Files\CI-110 directory unless you tell it to do otherwise.
3. At the User Information dialog window, you are asked to type in Name, Company and Serial information.
4. Follow the on-line instructions to finish the installation.

Plug the instrument into the computer's USB port. A New Hardware Found wizard should start.

**For Windows 2000:**

Select Next.

Select Search for a suitable driver for my device (recommended).

Select only Specify a location.

Browse to the CD directory Win2000 and select OK.

Select Next.

When it asks if you want to Continue the Installation, select Yes.

Select Finish.

Do the same for the next part of the composite USB device found.

**For Windows XP:**

Select "No, not this time" when it asks to connect to Windows Update.

Select "Install from a list or specific location (Advanced).

Select "Search removable media" and "Include this location in the search" and browse to the CD directory WinXP.

The computer should find the Belkin USB VideoBus II, Video installation package and ask to Continue Anyway (software has not passed Windows Logo testing). Select Continue Anyway.

Select Finish.

The new hardware Wizard should launch again for the Belkin VideoBus II Audio. Follow the same instructions for it:

Select No, not this time.

Install from a list or specific location.

Include this location in the search: D:\WinXP (use the drive letter for your CD drive).

Continue Anyway.

Finish.

To download the latest version of the CI-110 software, go to the website:

<http://www.cid-inc.com/Software/CI-110>.

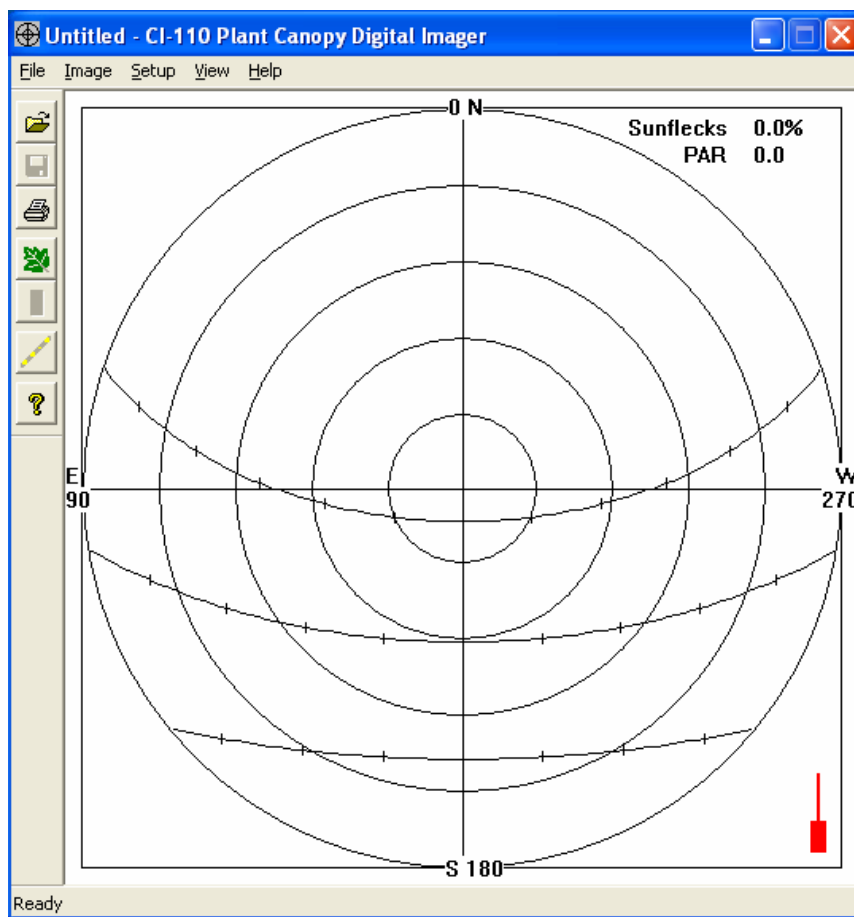


Figure 1-1. The main window of the CI-110 Program.

## THE CI-110 SOFTWARE APPLICATION WINDOW

To start the CI-110 program, double-click the CI-110 icon or choose Program from the Start menu, then the CI-110 Digital Plant Canopy Imager program. The CI-110 program requires the Windows graphical operation system. If you are not familiar with Windows, please refer to your Windows built-in Help menu.

### Main window

The main window (Figure 1-1) is the first thing to appear when you start the CI-110

## Menu Bar

The menu titles are listed in the menu bar. The menu bar appears just below the title bar at the top of the screen. The title bar displays the image file name (if opened) followed by the program name. Menu commands, followed by ellipses (...) open dialog boxes. The dialog boxes contain options used to perform functions or to specify settings. Use the menu bar to access the CI-110's menu commands. Either click the menu you want to open or press the Alt key and the underlined character in the title of the menu you want to access. Then use the cursor arrow and the ENTER keys to select and activate menu commands

## Toolbar

The toolbar (Figure 1-2) provides quick access to the most commonly used commands of the CI-110. You can close the toolbar by unchecking the Toolbar command in the **View** menu

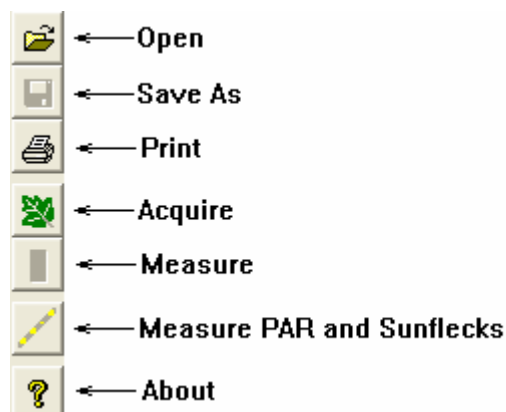


Figure 1-2. The Toolbar

## Image Window

The image window is where an image is displayed and image measurements and manipulations are performed. To learn more about working with image measurements, see the *Measuring Images* chapter.

## USING A MOUSE

Menus, commands, and dialog box options can all be chosen and selected by pointing to them with your mouse. Refer to the Windows Help menu on how to use the mouse if you are not familiar with using it.

## GETTING HELP

The CI-110's on-line help uses the standard Windows Help system. To get help, choose the **Help** menu **Content...** command, or if you need help on a specific dialog and its options, press F1 while in the dialog box, or click the dialog **Help** button.

## Using the Help Window

To view help on a specific topic, click on the underlined words, or active graphic. While in **Help**, the pointer resembles a hand when it is over a selectable help topic.

Click the **Index** button to view **Help** on a specific topic. Click the **Back** button to flip back through the help topics you have already referenced.

You may use the Windows **Help** menus to perform additional operations, such as copying and printing text from help screens.

View the Windows Help menu on **Help** for more information.

## Technical Support

If you have any questions about the CI-110 features and functions, first look in the CI-110 Instruction Manual or consult Windows Help.

If you cannot find the answer, contact your nearest technical support representative.

CID, Inc., is committed to providing our customers with high quality and timely technical support. Technical support representatives are available to U.S. and Canadian customers on a 1-800 line to answer your technical questions.

Before calling technical support, please have the following information available. It will assist the technical support representative in helping you with your problems more quickly and efficiently:

- A brief description of the problem, including the exact text or error message received and the steps taken to create it.
- Type of printer that you are using to print your files.
- The version of the CI-110 program you are running.
- The contents of the AUTOEXEC.BAT and CONFIG.SYS files.

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Address:	4845 NW Camas Meadows Drive Camas, WA 98607 USA
Phone:	800-767-0119 (U.S. and Canada) 360-833-8835
Fax:	360-833-1914
Internet:	<a href="http://www.cid-inc.com">http://www.cid-inc.com</a>
E-mail:	<a href="mailto:support@cid-inc.com">support@cid-inc.com</a> <a href="mailto:sales@cid-inc.com">sales@cid-inc.com</a>
Customer Service:	Customer service representatives are available to answer questions about specifications, pricing, and sales of all CID, Inc. products. They may also issue replacement disks.



# HARDWARE CONFIGURATIONS

This chapter discusses the CI-110 hardware configurations. The CI-110 is powered via USB Port on the computer, which is powered by the computer's rechargeable battery or by an external power supply.

## COMPUTER RECHARGEABLE BATTERY

The CI-110 laptop computer is shipped with the internal battery charged and ready to use. However, the battery may lose power during shipping, so charge it again after you receive it. The battery can last for approximately 1~2 hours of continuous use. The battery is automatically charged when the external power supply is plugged in. For more information, please see the computer's manual on recharging the battery. If you are using your own computer, it too will need to be fully charged before using the CI-110.

## EXTERNAL POWER SUPPLY

To use the external power supply, connect the computer's AC plug into a wall outlet. Most computers are designed to use 100 to 240 VAC with frequency 50 to 60 Hz.

*Caution: Avoid using AC power in wet conditions.*

## PRE-OPERATION

First, plug the handle arm into the sensor head. Then, insert the USB plug from the cable end of the handle arm into the USB port on the back (or on the side) of the computer (see figure 2-1). Open the computer lid and turn the computer on. The computer will start Windows. Refer to your computer User's Guide or computer Windows on-line **Help** for everything you need to know about your Focusing and Zooming.

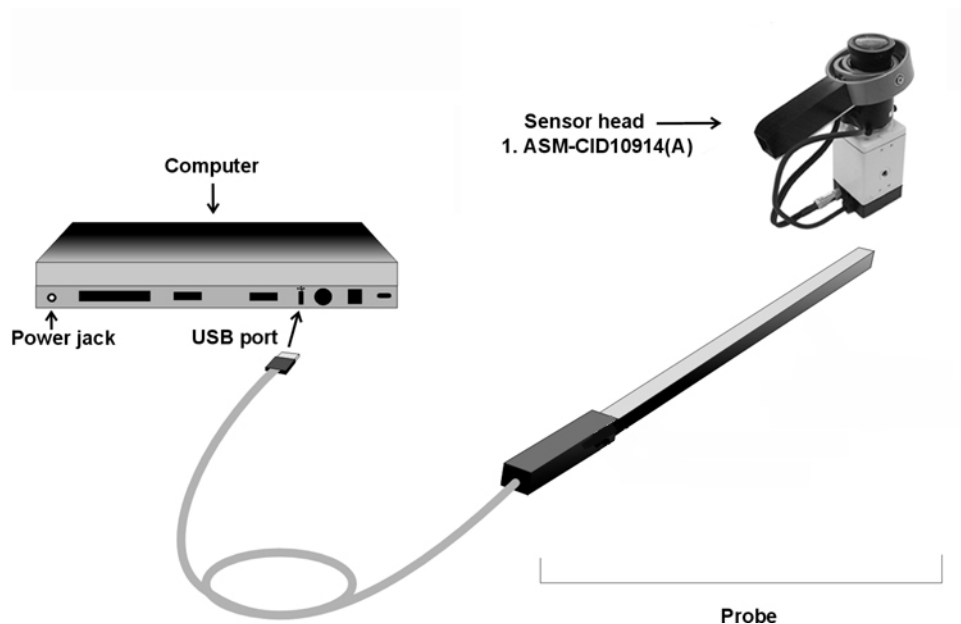


Figure 2-1. The CI-110 Digital Plant Canopy Imager configuration.

## CHARGING THE BATTERIES

Refer to your computer User's Guide or computer Windows on-line Help for how to charge and take care of the computer battery.

*It is very important that you read the chapter concerning battery.*

## USING The *Laptote* OUTDOORS

Make sure to properly secure the *laptote* to the computer before using.

# MANIPULATING IMAGES

CI-110 provides a number of image manipulation features designed to help you measure your image. This chapter discusses how to:

- Capture images
- Open images
- Zoom in and out on images
- Crop images
- Restore an image to the last saved version
- Save images

## CAPTURE IMAGES

If you have installed the CI-110 software into your own computer, and before you can capture your first image, you need to specify and select the capture device by choosing **File** menu **Select Source...** command. The Select Source dialog box appears (Figure 3-2). Select *USB VideoBus II Video*. Once you have selected this setting, you do not need to select it again.

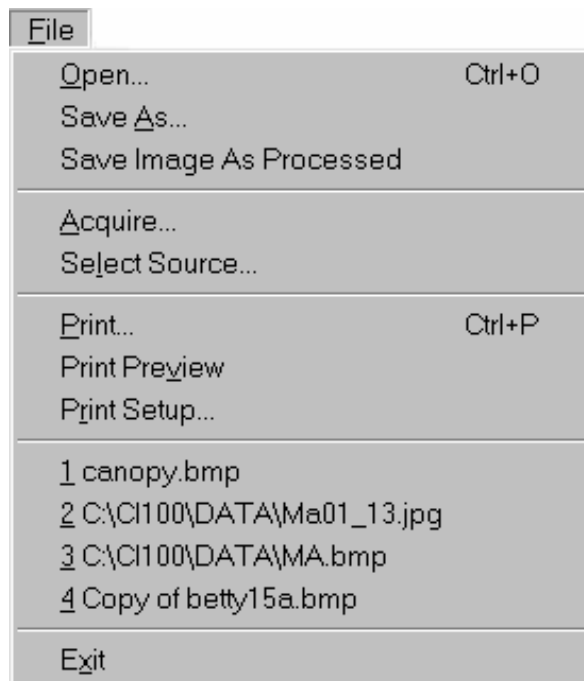


Figure 3-1. File menu.

To capture a fish-eye image, choose the **File** menu **Acquire...** command, or click on the **Acquire** icon (see *Toolbar* in Chapter 1 for illustration), the capture screen appears (Figure 3-3).

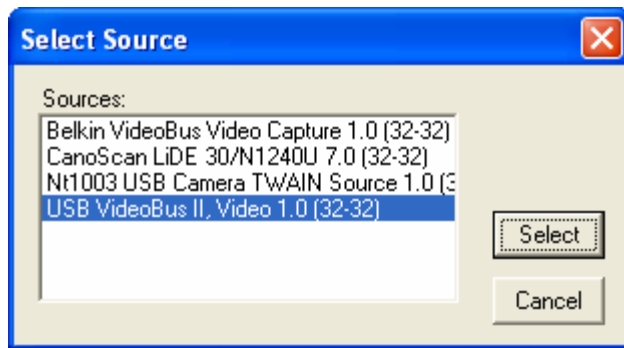


Figure 3-2. Select Source window.

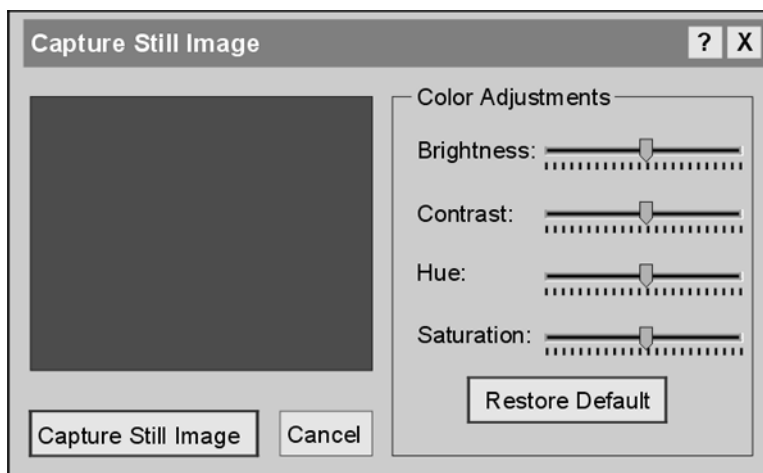


Figure 3-3. Capture screen.

Hold the CI-110 instrument below the plant canopy in a level position. The capture screen will show a live view of the plant (or forest) canopy fish-eye image. You may move the probe to find the best image (See the Application Tips section in the Theory and Applications chapter). Adjust the image if you need to by using the menu on the right side of the *Capture Still Image* window (Figure 3-3). Hold the leveled probe steady, then click on the *Capture Still Image* button on the lower left corner of the *Capture Still Image* window. After a few seconds, the capture screen disappears and the image captured is displayed in the image window of the CI-110 program. To save the image, see the *Save Images* section in this chapter).

## OPEN IMAGES

You may either open an existing fish-eye image file (in .bmp format or being converted to .bmp format), or use the CI-110 to capture your image. You may also scan a fish-eye photograph (with a TWAIN compatible scanner), save it in .bmp format and open it within the CI-110 software.

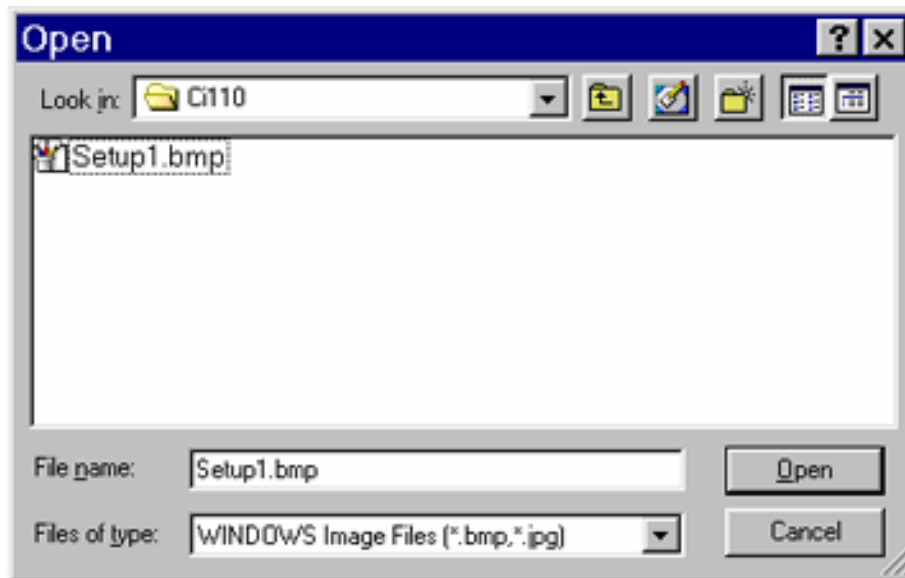


Figure 3-4. Open image file dialog box.

To open an image file:

1. Choose the **File** menu **Open...** command (Figure 3-1) or click the **Open** icon (see *Toolbar* in Chapter 1 for illustration). The **Open** image file dialog box appears (Figure 3-4).
2. From the drive and directory where the CI-110 is installed (c:\CI-110, if you accepted default installation settings), choose the data sub directory (or the sub directory where you want to save the image files), then double-click the image file name (for example: File001.bmp) or click on Open. The Open image file dialog box closes and the selected fish-eye image appears.

## SCALING IMAGES

Choose the **View** menu **View Scale** command (Figure 3-5). A number of scale choices appear. They are 1/2, 3/4, 5/6, 7/8, Full, and 3/2 scales. You may choose one of them to fit your computer's working environment.

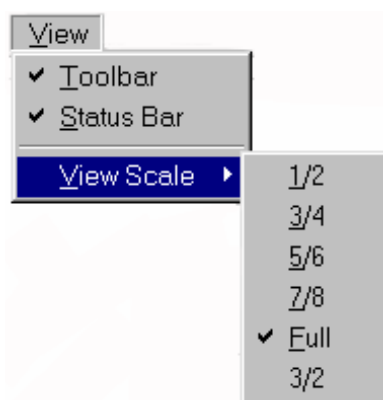


Figure 3-5. View menu

## CROP IMAGES

To crop an image so that it only includes a specified area of interest, see the Geometry Setup section of the Measurement Setup chapter for details.

## REFRESH IMAGES

Choose the **Image** menu, **Refresh** command (Figure 3-6). The green threshold color overlay on the fish-eye image will disappear. You may start over to define and measure the image.

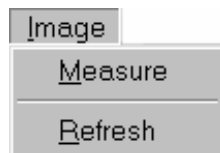


Figure 3-6.

## SAVE IMAGES

Save As...

Choose the **File** menu **Save As ...** command or click the **Save As** icon (see *Toolbar* in Chapter 1 for illustration), the **Save As** dialog box (Figure 3-7) appears. Use this command to save and name the acquired image to a directory or a disk by entering a file name and path. The image file type is the BMP (.bmp) format. Once you have saved an image to an appropriate file name and file type, you may continue to save modifications to the same file name.

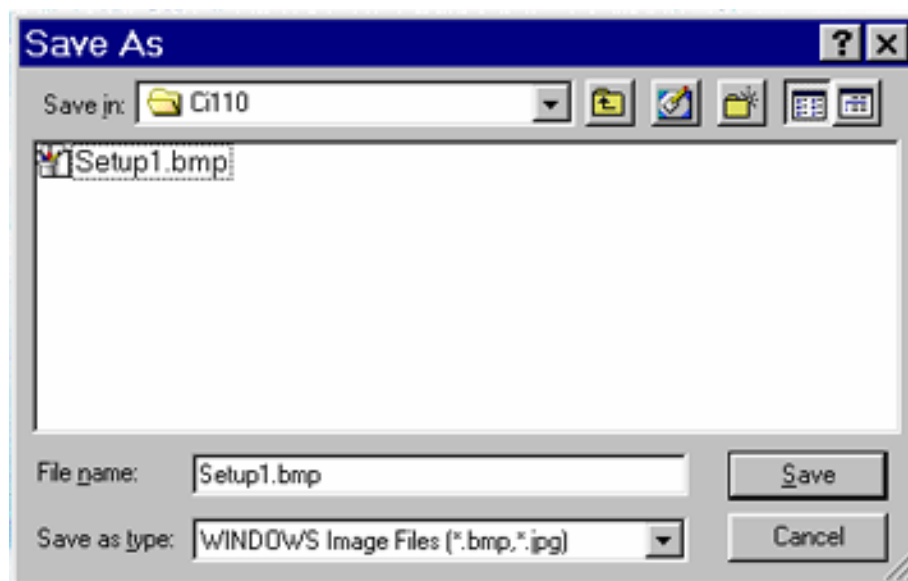


Figure 3-7. Save As dialog box.

## Save Processed Images

The **Save Processed Image** option enables you to save the image with the threshold layer as part of the image so you will have a permanent record. The procedure to do this is:

1. Click **Save Processed Image** in the **File** menu
2. Choose the **File** menu **Save As...** dialog box to name the image file

## PRINT IMAGES

To print an image from the computer screen:

1. Choose the **File** menu **Print** command or click the Print icon (see *Toolbar* in Chapter 1 for illustration) on the toolbar. The Print dialog box appears.
2. Specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options. Refer to your printer's *User's Manual* for more information.
3. Select **OK** to print the image using the specified settings.

# MEASURING IMAGES

This chapter discusses how to:

- Set measurement options
- Blank out any segment of the fish-eye image from measurements
- Set the threshold
- Setup adjustment
- Save setup

## GETTING STARTED

Getting Started assumes a basic familiarity with Windows and its terminology. If you are not familiar with Windows, refer to your Windows built-in Help menu.

## SETTING MEASUREMENT OPTIONS

Choosing **Setup** from the menu bar (Figure 4-1) provides the following three menu choices:

1. Setup,



Figure 4-1. Setup menu.

2. Adjustment, and 3. Save Setup.

## Setup

Choose the **Setup** menu (Figure 4-1) **Setup...** command. The setup dialog box (Figure 4-2) appears. There are three tabs:

1. Geometry
2. Output
3. Crop Circle

Click the appropriate option tab to setup.

## Geometry

The *Geometry* tab (Figure 4-2) enables you to control the **Number of Zenith Divisions, Number of Azimuthal Divisions, View Range, Starting Zenith Angle, Ending Zenith Angle, and Threshold Level.**



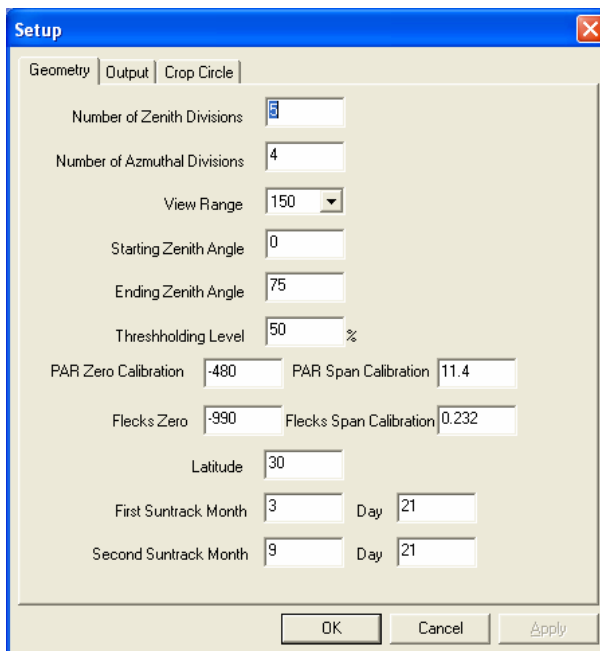


Figure 4-2. Geometry dialog box.

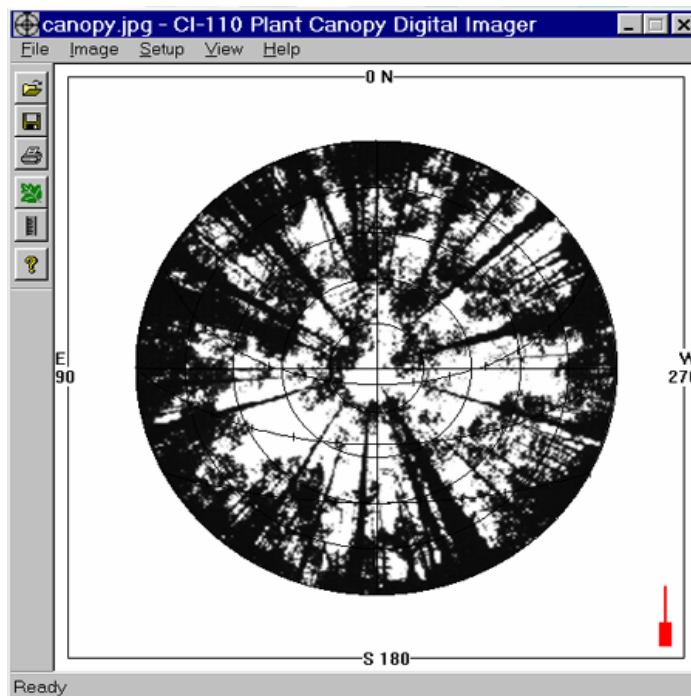


Figure 4-3. Zenith division = 4.

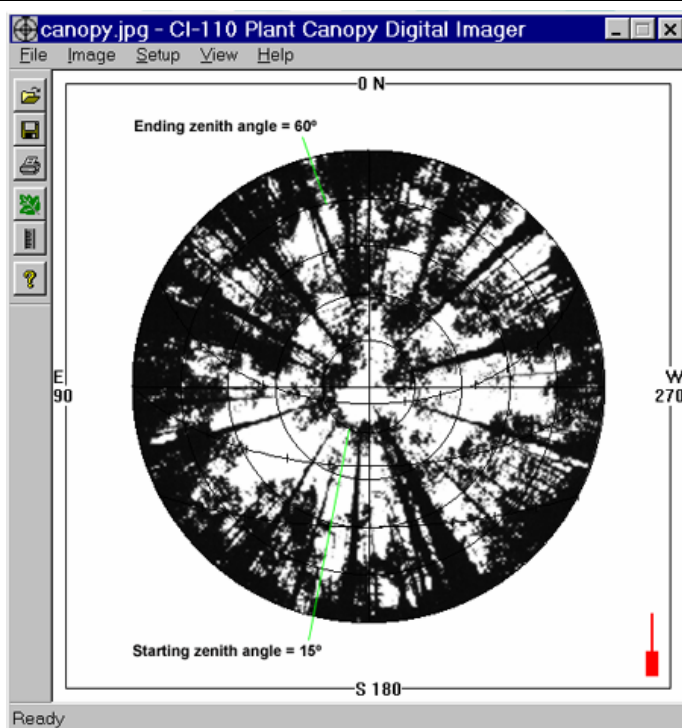


Figure 4-4. Azimuthal division = 4.

- ◇ **Zenith Divisions** *Zenith Division* ranges from 1 to 10. The CI-110 comes with 150° lens. An example is shown in Figure 4-3. The results of the measurements are generated for each zenith division (see Figure 5-1).
- ◇ **Azimuthal Divisions** *Azimuthal Division* ranges from 1 to 10 (An example is shown in Figure 4-4). The results of the measurements are generated for each azimuthal division (see Figure 5-1).
- ◇ **View Range** The view range is 150°.
- ◇ **Starting Zenith Angle** *Starting Zenith Angle* ranges from 0 to 75°. You may crop your fish-eye image from the inner circle by changing the starting zenith angle. Figure 4-4 demonstrates a starting zenith angle of 15°.
- ◇ **Ending Zenith Angle** *Ending Zenith Angle* ranges from 75 to 0°. You may crop your fish-eye image from the outer circle by changing the ending zenith angle. Figure 4-4 demonstrates a setup with an ending zenith angle of 60°. The CI-110 sensor is a 150° fish-eye camera. Set the ending zenith angle smaller than 75° if you do not want the outer-most ring of the image. For example: If you want to analyze a <150° fish-eye image instead of 150°, set the ending zenith angle as <75°.
- ◇ **Thresholding Level** *Thresholding Level* ranges from 0 to 100%. See the Making Measurements section later in this chapter for details.
- ◇ **PAR Zero Calibration** *PAR Zero Calibration* is done at the factory and normally is not required to be done later. The number is adjusted until the PAR reading flickers from 0 to .1 when the sensors are covered.
- ◇ **PAR Span Calibration** *PAR Span Calibration* is done at the factory and normally is not required to be done later. The calibration number is adjusted until the PAR reading matches a calibrated sensor exposed to the same sunlight
- ◇ **Flecks Zero** *Flecks Zero* is done at the factory and normally is not required to be done later. The calibration number is adjusted to give a sunflecks

- ◇ **Flecks Span Calibration** reading of zero when all the sensors are in the shade. *Flecks Span Calibration* is done at the factory and normally is not required to be done later. The calibration number is adjusted to give a sunflecks reading of 100% when all the sensors are in bright, direct sun.
- ◇ **Latitude** *Latitude* should be the approximate latitude where measurements are taken. It is used to calculate and plot the suntracks.
- ◇ **First Suntrack Month and Day** *First Suntrack Month and Day* are used to draw one of the suntracks
- ◇ **Second Suntrack Month and Day** *Second Suntrack Month and Day* are used to draw one of the suntracks. A default value near the Fall equinox puts the suntrack near the middle between the Winter suntrack and the Summer suntrack

## Output

The *Output* tab allows users to select the parameters to be measured by checking the on boxes. Click on *Output* in the Setup dialog box (Figure 4-6). The window displays the available output parameters:



Figure 4-5. Output Setup dialog box.

**LAI:** Leaf Area Index

**LD:** Leaf Distribution

**MFIA:** Mean Foliage Inclination Angles

**TR:** Transmission coefficients or gap fraction

**TD:** Transmission coefficients of diffuse radiation (The sky view factor)

**K:** Plant canopy extinction coefficient

**PAR:** See chapter on *PAR Measurements* (Page 4-9)

**SUN TRACK:** Sun tracks are plotted when turned on. These require the camera to be oriented so the handle points “North” if they are to be accurate. Go to **SETUP** to select the month and day desired for the track. The Winter and Summer sun tracks are automatically displayed.

**Crop Circle** The Crop Circle tab shows the values of the center and the radius of the image. It also enables you to set up blankout starting and ending angles. Click on Crop Circle in the Setup dialog box (Figure 4-7). The window displays the following options:

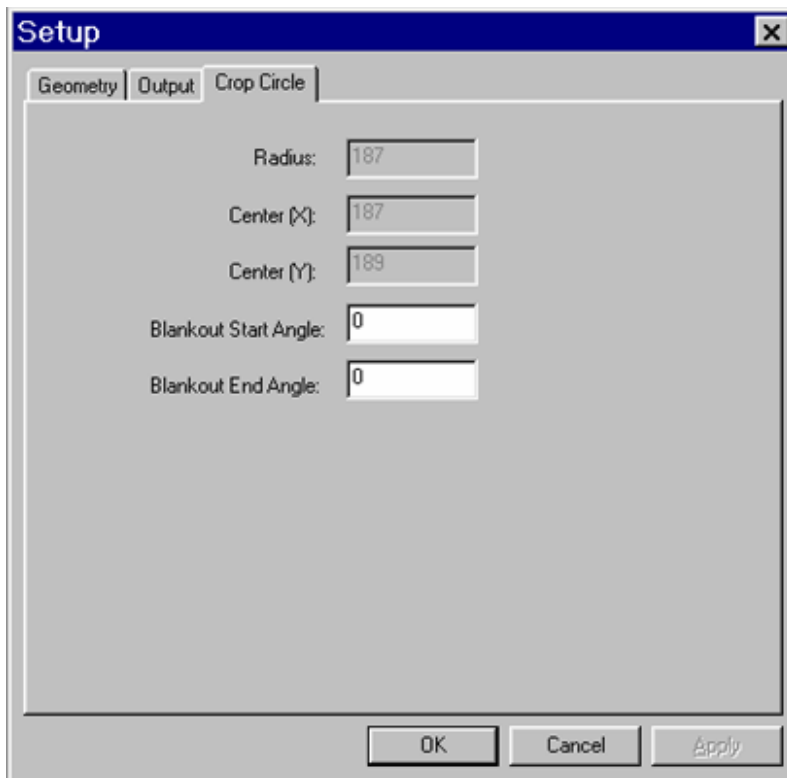


Figure 4-6. Crop Circle dialog box.

**Radius:** The crop circle's radius in pixels.

**Center (X):** The horizontal index in image coordinates of the camera view's center.

**Center (Y):** The vertical index in image coordinates of the camera view's center.

**Blankout Start Angle** and **Blankout End Angle** allow users to blank out an unwanted area from being measured, (for example, parts of the operator's body gets into the fish-eye image). Blankout Start Angle ranges from 0 to 359°. Blankout Ending Angle ranges from 1 to 360°.

## ADJUSTMENT

The Adjustment command allows you to reposition your fish-eye images. If you purchased a new CI-110 instrument, this adjustment is not needed. The manufacturer did the image adjustment. If you have the CI-100 (old model) and have upgraded to the CI-110 program, you may use the *Adjustment* feature to reposition the fish-eye images taken with the CI-100. Note that the images need to be converted to .bmp format first.

Choose **Setup** menu, **Adjustment** command to reposition the image. A warning message appears (Figure 4-7). Press *Yes* if it is necessary. Move the cursor on the edge of the image circle by moving your mouse.

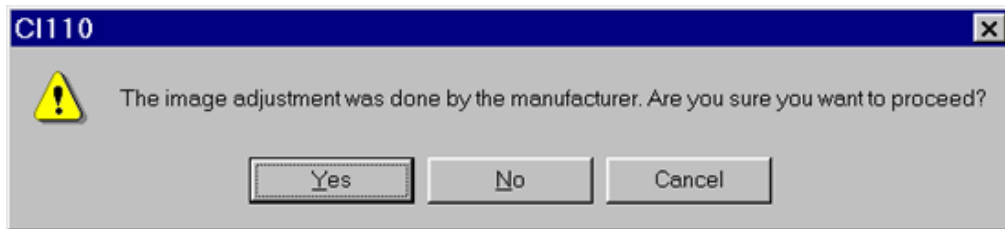


Figure 4-8. A warning message.

The cursor changes from an arrow into an arrow cross (Figure 4-9). Press the upper mouse button and drag. If the image is smaller (you will see a blank circle that is part of the frame accommodating the lens) than the outer most zenith ring, drag the arrow cross towards the center of the image while pressing the upper mouse button until the black frame is outside the outer most zenith ring. You may repeat this procedure as many times as you need to get it right.

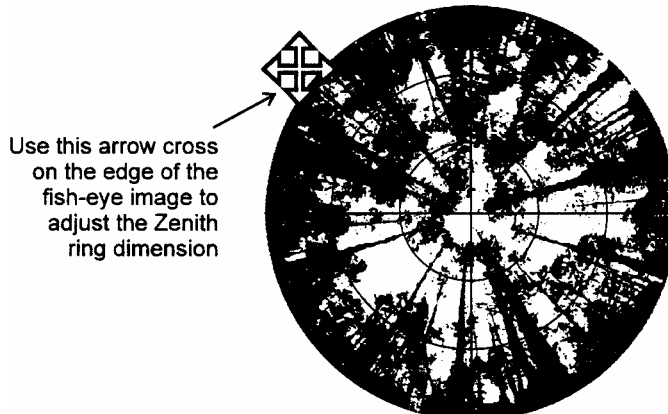


Figure 4-8. A cross arrow on the edge.

If the image is off center, you may adjust the image center. The cursor changes into a thin cross (Figure 4-9) when you move the mouse inside of the outer most zenith ring and press the upper mouse button. To adjust, keep pressing the button and moving the mouse beside the computer screen. You are able to move the image around by doing so. You may repeat the procedure as many times as you need until the entire image is centered.

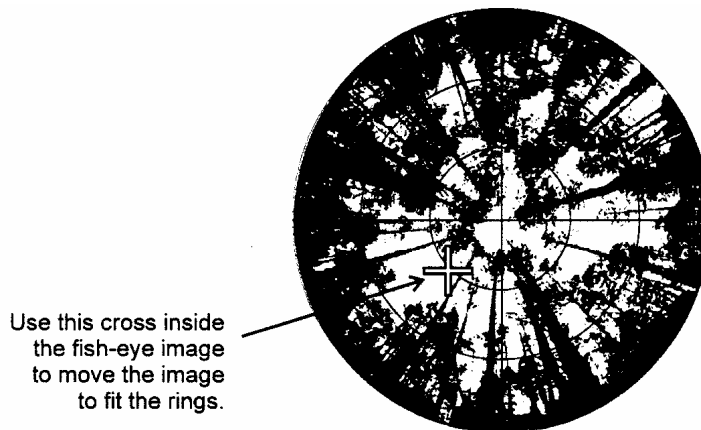


Figure 4-9. A thin cross cursor inside the image.

## SAVE SETUP

Choose **Setup** menu **Save Setup** command to save the changes you have made.

## MAKING MEASUREMENTS

Making measurements involves:

- Setting the measurement options
- Defining the areas and objects you want to measure
- Measuring

Choose the **Image** menu, (Figure 4-11) **Measure** command to open the dialog box. The Measure Setup dialog box, (Figure 4-12) is where you setup the blankout areas, change thresholds and make measurements.

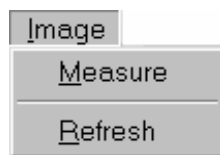


Figure 4-11. Image menu.

## Do you need to Blankout an Area?

In ordinary situations, it is not necessary to blank out an area of a fish-eye image. However, you may want to blank out an area for the following situations:

1. You, other people, or foreign objects are present in the image.

2. The sun or its strong glare in the image affects accurate thresholding (for example, foliage definition is affected).
3. Your sample field is not large enough or you are too close to the edge of the field causing part of the image to be undesirable.

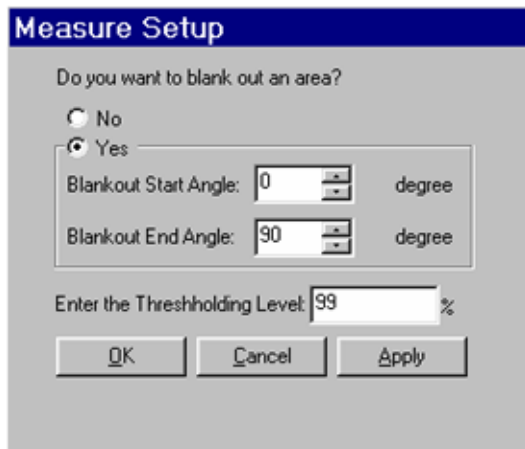


Figure 4-12. Measure Setup dialog box.

4. For some reason you only want to measure a particular part of the image.
5. Other reasons you may think of...

Click on the *Yes* button if you need to blankout an area; then enter the blankout starting and ending angles. A convenient way to do this is to move the *Measure Setup* dialog box away from the CI-110 main screen. Thus, you may see what is happening to the image. Figure 4-13 is an example of using the blankout feature.

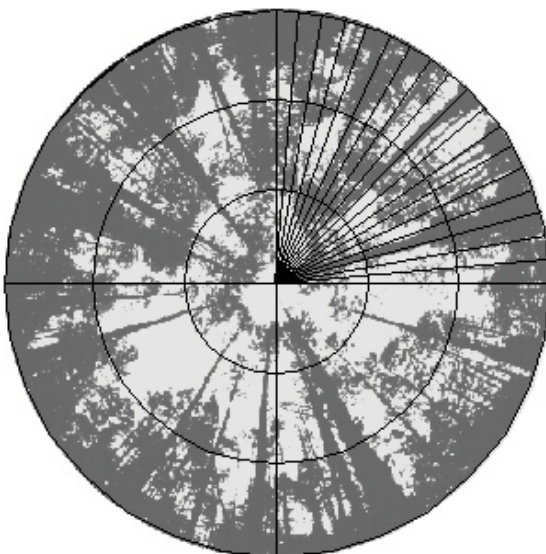


Figure 4-13. A Blankout example with 270° Blankout start angle and 359°-end angle.

## Defining the Areas and Objects you want to Measure

Thresholding an image is to set a threshold level for defining areas (for example, foliage) to measure. Threshold ranges from 1 to 100%. The higher the threshold level, the larger the area of the image it defines. The threshold level may be set and changed in the Measure Setup dialog box (see figure 4-12). Arrange the main screen and the Measure Setup box side by side, so that you may see the result of the thresholding. First, enter a threshold number, and then click on Apply. A green threshold layer will appear on the top of the image. Check whether it defines the foliage area. If not, enter another threshold number until you are satisfied.

## Refreshing an Image

If you are not satisfied with the threshold result, use the **Refresh** command in the **Image** menu (Figure 4-11) to clear the threshold overlay and start over again.

## Making Measurements

After you have completed setting the options in the Measure Setup dialog box, click **OK** to start the measurement. It only takes a few seconds for the program to finish the measurement. The Result window displays the measurement data. See the *Working With Data* chapter for details.

## PAR MEASUREMENTS

The CI-110 uses 24 photodiodes that are sensitive in the 400-700 nm photosynthetic active radiation region. The PAR measurement is the average of the measurements of the photodiodes. Sunflecks are the percent of the photodiodes that are in direct sunlight. The 24 photodiodes are on 1 cm centers in the handle of the CI-110.



# WORKING WITH DATA

This chapter describes the CI-110 data sheet window and how to:

- Move around the data sheet
- Copy a block of data
- Select measurement output
- Saving the data sheet

## CI-110 RESULT DATA WINDOW

The CI-110 Result data window (Figure 5-1) is used to display measurement results. Columns and rows organize the data sheet. Measurement results are assigned to the columns and the rows corresponding to the output parameters selected in the Output tab of the Setup dialog box (Figure 4-6).

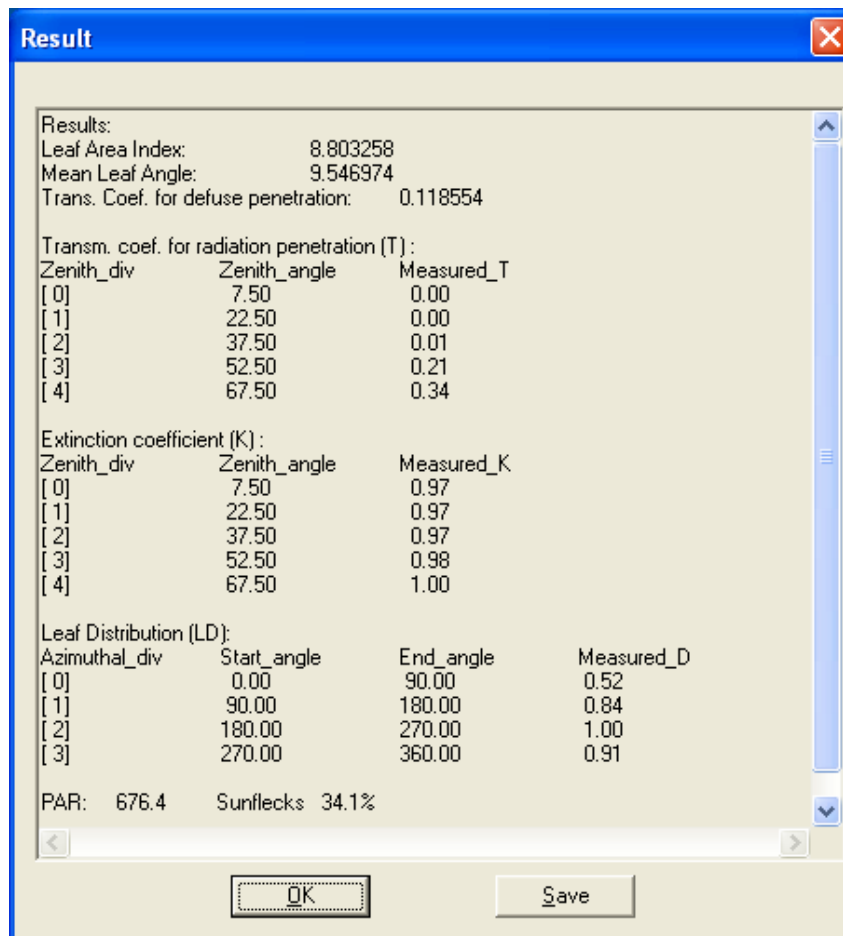


Figure 5-1. Result window.

## Moving Around the Data Sheet

You may move around the data sheet by moving the cursor with either your mouse or with the arrow keys.

Function	Keystroke
Move one column right/left	→ or ←
Move one row up/down	↑ or ↓

## Copying a Block of Data

Select a block of data you want to copy by dragging the mouse over the desired rows (or columns). Press Ctrl + C to copy the selected data to the Clipboard. The copied data can then be pasted to other Windows applications.

## Selecting Measurement Output

Choose the *Output* tab in the Setup dialog box under the **Setup** menu to select measurement output (see Figure 4-6 in the *Measuring Images* chapter).

## Saving the Data Sheet

The data sheet may be saved by clicking the **Save** button on the bottom of the Result window (see Figure 5-1). The **Save As** dialog box appears (Figure 5-2). A default filename is generated using the date and a sequential number. If you do not want to use the default name, type over it with the name you desire, and select a path, then click on **Save**. The CI-110 program will add file type .rpt automatically. The .rpt is a text format. The saved data sheet may then be opened in other (for example Lotus 1-2-3) applications in text format.

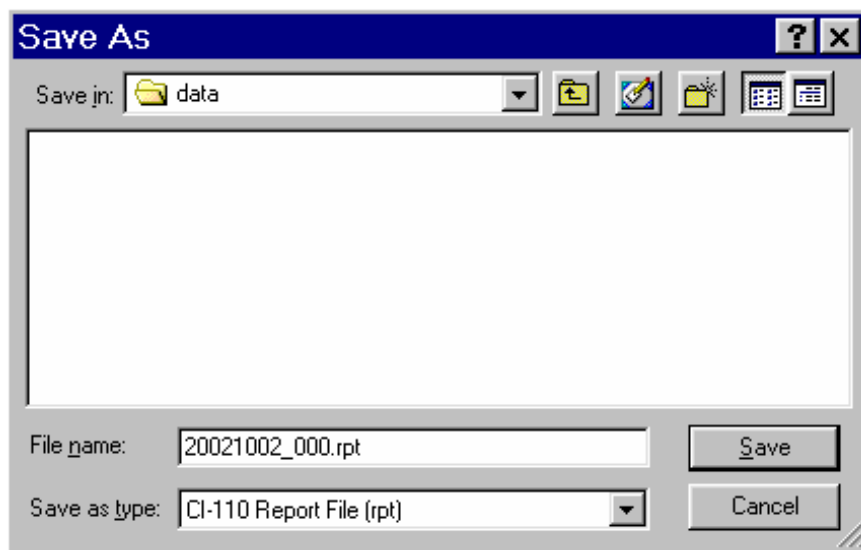


Figure5-2. Save As data sheet dialog box.

# THEORY AND APPLICATIONS

This chapter discusses the following topics:

- How data numbers are derived
- Equations
- Application tips

## HOW THE DATA NUMBERS ARE DERIVED

The CI-110 consists of a fish-eye image capturing device, plant canopy analysis software, and a computer. The software digitizes and manipulates the captured images, then calculates the solar beam transmission coefficients, or the fraction of the sky visible from beneath the plant canopy. A value between 0 and 1 is assigned; with 0 meaning no sky is visible below the plant canopy, and 1 meaning that the entire area is sky or no foliage coverage. A fraction number indicates partial foliage cover.

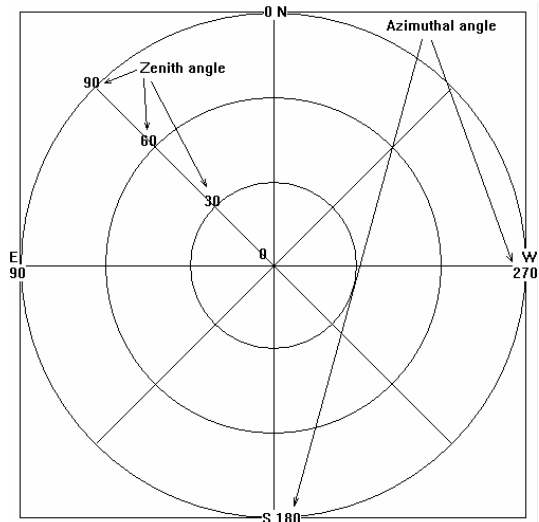


Figure 6-1. Grids for analyzing fish-eye images.

The gap-fraction inversion procedure (Norman and Campbell, 1989)\* is used. The CI-110 software first divides the image into sectors or grids (see Figure 6-1) according to user-defined number of zenith division (rings) and azimuthal division. Then, the fraction of sky (solar beam transmission coefficient) visible in each sector is analyzed by automatically tallying the sky portion of the image pixels in that sector at a fast speed. After all the sectors have been analyzed and the average solar beam transmission coefficients for each zenith division are computed, the hemispherical diffuse radiation transmission coefficient (the sky view factor), mean foliage inclination angles, and plant canopy extinction coefficients will be computed accordingly by CI-110's plant canopy analysis software.

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

## EQUATIONS

### 1 $\tau_d$ : The transmission coefficient for the diffuse radiation penetration

$$\tau_d = 2\Delta\varphi \sum_{\varphi_i=\varphi_1}^{\varphi=n} \tau_{\varphi_i} \sin\varphi_i \cos\varphi_i$$

where  $i$ : the  $i$ th zenith angle division ( $n$  is the number of divisions selected by you)

$\Delta\varphi$ : the zenith angle increment in radians

$\tau_{\varphi_i}$ : the transmission coefficient for the ray penetration (or the fraction of the sky visible) in each zenith angle area. 0 means that no sky is visible and 1 means that entire area is sky.

### 2 L: Leaf area index

$$\tau_{\varphi_i} = e^{-k_{\varphi_i} L}$$

$$K_{\varphi_i} = \frac{\sqrt{x^2 + \tan^2 \varphi_i}}{A}$$

$$K_{\varphi_i} = 1 \quad \text{for horizontal leaves } x \rightarrow \infty$$

$$K_{\varphi_i} = \frac{2 \tan \varphi_i}{\pi} \quad \text{for vertical leaves } x \rightarrow 0$$

$$K_{\varphi_i} = \frac{1}{2 \cos \varphi_i} \quad \text{for spherical leaves } x \rightarrow 1$$

where  $K$ : the extinction coefficient of the canopy

$A$ : a polynomial function:

$$A = x + 1.774 (x + 1.182)^{-0.733}$$

where  $x$  represents leaf angle distribution (Norman and Campbell, 1989).

### 3 $\alpha$ : The mean foliage inclination angle of the canopy

$$\alpha = \tan^{-1} x \quad (0^\circ \leq \alpha \leq 90^\circ)$$

$$x = \frac{b}{a}$$

where  $b$ : the horizontal projection of the foliage

$a$ : the vertical projection of the foliage

---

**APPLICATION TIPS****Plant Canopy Structure**

The CI-110 applies the gap-fraction computation method, which assumes random leaf distribution. A non-uniformly distributed canopy with obvious gaps will lead to over-estimations of the solar beam transmission, thus, leading to underestimation of LAI. In circumstances that do not satisfy the assumption, distinct sampling techniques should be used.

The CI-110 software allows you to manipulate the captured fish-eye image by giving you an option to block the areas that have large gaps in the canopy, thus, reducing the size of the image. Take several reduced sized image measurements. Then, by using the average values of the measurements, you may achieve a better estimation of the solar beam transmission, and therefore achieve a reliable estimation of LAI. The number of images needed for averaging depends on the canopy structure and its distribution. In row crop canopies, a measurement technique is to take four evenly spaced readings along a diagonal transect that runs between two rows, and to do several transects to prevent the same few plants from dominating the entire set of readings. It is best not to excessively weigh the “in row” or “between row” situations.

**Plant Canopy Size**

Prior to taking measurement with the CI-110, it is necessary to observe the canopy size. If the plot is too small, the fish-eye lens' field-of-view will extend beyond the edge of the foliage being measured, and LAI will be underestimated. The reverse is true when measurements are taken in a plot surrounded by a denser canopy. The suggested minimum plot radius from the fish-eye lens is approximately 3 times the plot height. The exception to the suggested minimum plot radius is in dense plant canopies, less distance may be required because the fish-eye may not be able to see to the edge of the canopies.

Several techniques may be used if measuring a less than minimum size requirement: 1) Select a blankout area (see Blankout Area in the Measurements chapter), so the image captured excludes any surrounding foliage, or other extraneous areas. 2) Manipulate the starting angle to reduce the field-view.

**Foliage Size**

In comparison to the area of view of each zenith division (ring), the leaves are assumed to be small. With this assumption, the distance from the fish-eye lens to the leaf at an angle of 30° from zenith should be at least four times the leaf width.

**Fish-eye Lens  
Field-of-View**

Use the Blankout Area function the CI-110 software offers to block out undesired areas from the fish-eye lens' field-of-view, such as the operator, a neighboring plot, or large gapped canopy areas.

### Sky Conditions

The optimal sky conditions for measurements are under an evenly cloudy sky, early morning, or late afternoon, when the amount of scattered radiation is low. Under sunny sky conditions, the fish-eye lens should be shaded to minimize underestimation of LAI and overestimation of solar beam radiation and diffuse radiation. Measurements may be taken under various sky conditions and later manipulated using the CI-110 software to achieve the best results.

### Cropping an Image

The proper way to crop an image is by setting the starting zenith angle and ending zenith angle (see page 4-2 and 4-3). In many cases, the outer-most ring of the canopy image has certain unwanted objects. It's important to crop the ring to ensure an accurate estimate. To do so, set the ending zenith angle as  $75^\circ$ ,  $70^\circ$  or an angle to make sure you get rid of the unwanted objects. When you change the angle less than  $90^\circ$ , the outer image ring will be out of the zenith ring definition. Therefore, the left-out ring of the image will not be included in the calculation. You can set the ending zenith ring exactly where you want it.

The same goes with starting zenith angle. If there is a big opening in the center of a fish-eye image, you should crop the inner ring area by resetting starting zenith angle.

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# MISCELLANEOUS

## CLEANING

To keep your CI-110 and computer clean, wipe the exterior case and LCD with a slightly damp cloth. A mild detergent may be used if necessary. Do not use solvents of any kind. Clean the fish-eye lens with a soft non-abrasive cloth, using a small amount of commercial lens cleaning fluid if necessary.

***WARNING: Keep liquid, including cleaning fluid, out of the computer's keyboard, speaker grill and other openings. Never spray cleaner directly on the computer. Never use harsh or caustic chemical products to clean the computer.***

## MOVING THE COMPUTER

Before moving the computer, even just across the room:

- Make sure all disk/CD activity has ended (the disk/CD light is off).
- Remove the disk/CD from the drive, and disconnect the PC Card FDD.
- Shut down Windows and turn the computer off.
- Disconnect the power cord.
- Close all port covers.

***Note: Do not pick up the computer by the display panel, or by the back (where the ports are located).***

For long trips, transport the CI-110 and the computer in the carrying case/bag.

## PROTECTING THE CI-110

The CI-110 comes with optical parts and/or a computer. It should be stored and cared for in the same manner as you would any other optical and computer equipment.

Place the computer on a flat surface.

To keep your computer in prime operating condition, make sure your work area is free from:

- Dust and moisture.
- Liquids and corrosive chemicals.
- Equipment that generates a strong electromagnetic field, such as stereo speakers (other than the speakers you have connected to the computer) or speakerphones.
- Rapid changes in temperature and/or humidity and sources of temperature changes, such as air conditioner vents or heating ducts.
- Extreme heat, cold, or humidity.
- Protect the camera by avoiding direct sunlight.

## STORAGE

- Store the CI-110 and the computer in the carrying case that it came in.





## CI-110 PRODUCTION TEST CHECK SHEET

<b>SENSOR HEAD HANDLE SERIAL NUMBER:</b>
<b>SENSOR HEAD SERIAL NUMBER:</b>
<b>RMA NUMBER:</b>
<b>CI-110 SOFTWARE VERSION:</b>
<b>COMPUTER MODEL / SERIAL NUMBER:</b>
<b>WINDOWS VERSION:</b>

<b>CI-110 SOFTWARE OPTION 1</b>	INSTALLED:	
	VERIFIED:	
	CUSTOM CONFIG. FILE PRESENT:	
<b>CI-110 SOFTWARE OPTION 2</b>	CUSTOM CONFIG. FILE GENERATED AND SAVED ON THE CD:	
	VERIFIED:	
<b>PAR CALIBRATION</b>	PAR ZERO CAL:	
	PAR SPAN CAL:	
	FLECKS ZERO CAL:	
	FLECKS SPAN CAL:	
	TESTING DATE:	
<b>ENVIRONMENTAL TESTING</b>	TESTING DATE:	
<b>IMAGE CAPTURE AND ADJUSTMENT FUNCTIONS</b>	FOCUSED IMAGE:	
	CENTERED IMAGE:	

CI-110 DIGITAL PLANT CANOPY IMAGE TEST DATE: \_\_\_\_\_

NOTES: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

# CID Hardware Warranty

## Important: Please read

Seller's Warranty and Liability: Seller warrants new equipment of its own manufacturing against defective workmanship and materials for a period of one year, of a single shift operation, from date of receipt of equipment - ***the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause is not to be considered a defect.*** Any defect must be called to the attention of CID, Inc., Camas, Washington, USA, in writing, within 90 days after receipt of the unit.

Seller's liability for defective parts is limited to the repair or replacement of any part of the instrument without charge, if CID, Inc.'s examination discloses that part to have been defective in material or workmanship, and in no event shall exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. No equipment may be repaired or altered by anyone not authorized by CID, Inc.

Material and equipment covered hereby, which is not manufactured by Seller, is to be covered only by the warranty of its manufacturer. Seller shall not be liable to the Buyer for loss, damage, or injury to persons (including death), or to property or things, whatsoever, including, but without limitation, products processed by the use of the equipment; or for damages of any kind or nature (including, but without limitation, loss of anticipated profits), occasioned by or arising out of installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The purchaser is to pack, ship, or deliver the instrument to CID, Inc., in Camas, Washington, USA, within 30 days after CID, Inc. has received written notice of the defect at the customer's expense. No other arrangements may be made unless otherwise approved in writing by CID, Inc.

The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory, or otherwise (***including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose***), not expressly set forth herein.