

CI-110 Plant Canopy Imager



Operation Manual

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INTRODUCTION

The CI-110's digital platform enables you to simultaneously capture wide-angle plant canopy images and estimate Leaf Area Index (LAI) and Photosynthetically Active Radiation (PAR) levels from a single canopy scan. LAI is used to characterize plant and forest canopies. This value ranges from 0-10, with 0 representing no canopy or bare ground and 10 representing a dense conifer forest canopy.



CI-110 Specifications	
Lens	Self-leveling PENTAX lens
Image Resolution	768 x 494 pixels
Interface	USB
Measuring Time	0.5 sec
Fish-Eye Lens Angle	170°
Operating Temperature	5-50°C
Probe Size	20 x 20 mm
Arm Length	400 mm
Probe and Arm Weight	0.5 kg

There are 24 PAR sensors on the CI-110, located along the top of the arm. The PAR sensors are filtered GaAsP (gallium arsenide phosphide) photodiodes. The specifications are in the following table.

PAR Sensor Specifications	
Range	0 - 2500 $\mu\text{mol}/\text{m}^2 \text{ s}$
Accuracy	5 $\mu\text{mol}/\text{m}^2 \text{ s}$
Response	400 - 700 nm

SOFTWARE INSTALLATION

The CI-110 software arrives pre-installed on a tablet computer. The CI-110 software can be installed on another computer, either for field use or to analyze images later, and the following steps should be repeated on each computer used with the CI-110 Plant Canopy Imager.

The CI-110 software features ClickOnce technology, which will automatically go and search for updates when the program is opened. If an update is available, the user will be prompted to download and install the update. ClickOnce requires an internet connection to search for updates. The software takes about 10 seconds to start-up.

The instructions for installing CI-110 Plant Canopy Analysis Software version 6.0 are the same for Windows Vista, Windows XP, Windows 7 and Windows 8. The current version of CI-110 software can be downloaded from the web at:

<http://www.cid-inc.com/support/software-downloads>

Navigate to the webpage and select the download for the “current version” of software. This should be the download link at the top of the page. Run the .exe file to install the software. Follow the prompts to download and install the software on your PC.

HARDWARE INSTALLATION

The CI-110 is supplied with the hardware and driver installed on a tablet computer. The following steps should be repeated on each computer used with the CI-110 Plant Canopy Imager. The driver is compatible with 32 and 64 bit operating systems.

The driver is installed through the CI-110 Plant Canopy Analysis software. To install the driver after downloading the software:

1. Open the CI-110 software.
2. Select the Advanced Settings Tab.
3. Select “Install Driver”.
4. Click “Next” in the Device Driver Installation Wizard.
5. Click “Finish” to complete the driver installation.

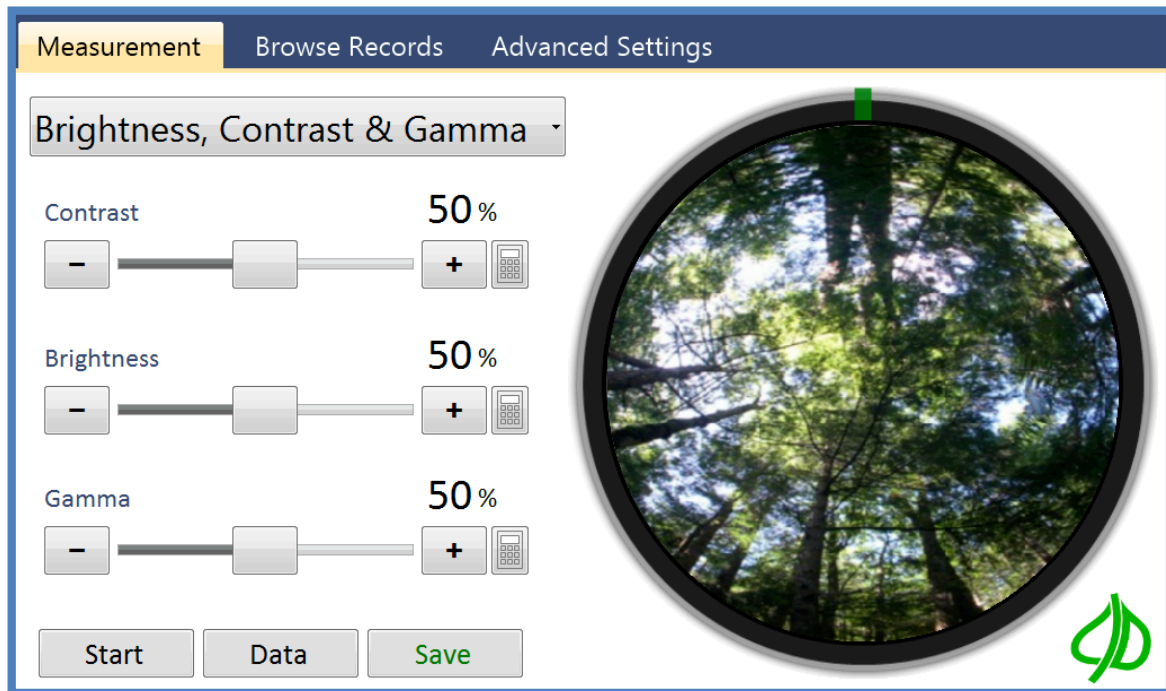
GETTING STARTED

These instructions will walk you through basic operation of the CI-110 software. The sections that follow will go into more detail on functionality and features.

Starting the Application

1. Click on the Windows **Start** button.
2. Go to **Programs** and find the **CID-Bio Science** folder.
3. Select CI-110 Plant Canopy Imager.

The dialog below will appear...



Enabling GPS

The CI-110 software will automatically record your current GPS position with measurements when the GPS device built into the handle of the CI-110 is connected. For more information, see the Location section of this manual.

1. Click the drop-down list and select **Location**.
2. The GPC on-board the CI-110 software will automatically search the system for a GPS device and automatically connect to it if satellites are available.

The CI-110 software will attempt to re-connect the GPS every time the application starts after the first connection is established. It may take 10-15 minutes to establish a connection with the right number of satellites the first time the CI-110 is used in a new location. During the time the CI-110 is allowed to search for satellites, **it should be outside or near a window for the fastest results.**

Recording your first measurement

1. Attach the CI-110 hardware via USB to the computer. The Start, Data and Save buttons will be enabled once the device is detected.
2. Click the **Start** button. This will cause the round image area on the right to be updated with a live video stream from the CI-110 device.
3. Place the CI-110 under the canopy area to measure. Be sure the camera is facing north for accurate readings (as indicated by the compass needle which turns green when aiming north).
4. Click the **Pause** button to preview your measurement. Adjust the Brightness, Contrast & Gamma, etc. as needed to increase the contrast between sky and foliage.
5. Click **Data** and **Edit** to view your measurement details and make changes.
6. Click the **Save** button. Hold the camera steady for the 1-2 second delay while the image is saving. The application will save your measurement. To review your measurement click on the Browse Records tab. After saving the app will automatically go back into live video mode.

APPLICATION FUNCTIONALITY

Below are summaries of each application tab and their purpose. The sections that follow detail application functionality are user interaction.

Measurement

This tab is used to record measurements and view their details. The data on this screen is stored with each measurement record, along with settings and other information (see *Application Output*). The options available in the drop-down list will differ if the CI-110 hardware is enabled or if an image is being edited. The options for Exposure, Color Control and PAR and Sunflecks are only seen when an image is being acquired. These options are hidden during post-measurement analysis.

Browse Records

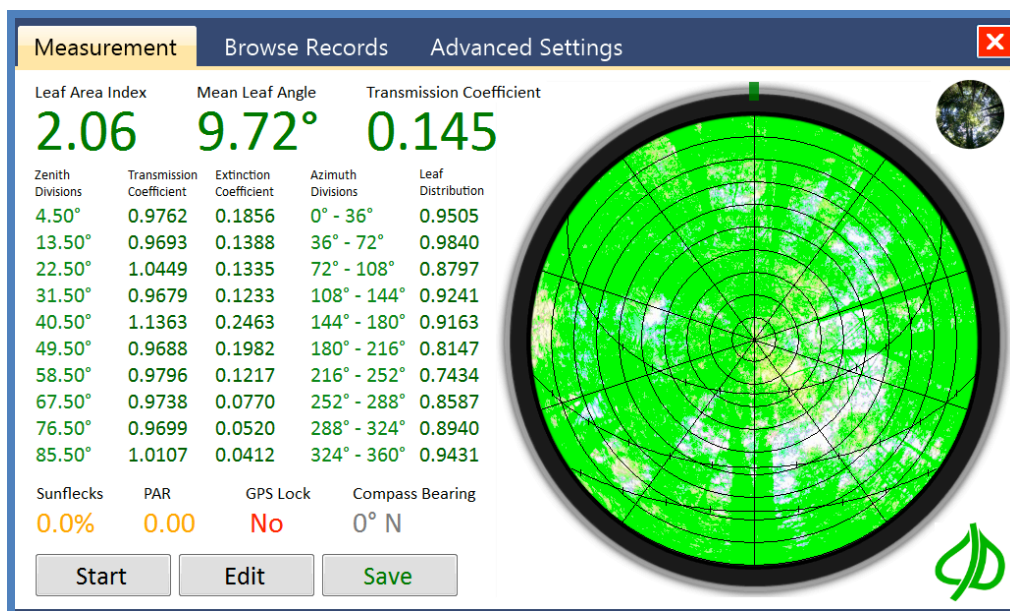
This tab is used to search, export, delete, edit and review saved records.

Advanced Settings

This tab is used to configure the application and calibrate the device.

MEASUREMENT TAB

This tab is used to record measurements and view their details. The data on this screen is stored with each measurement record, along with settings and other information (see *Application Output*).



Start/Pause button

Clicking the Start button enables a live video feed from the CI-110 device or displays a dialog to select an image file (when the CI-110 is not physically attached). Clicking the Pause button stops the video feed and changes the button text back to Start.

Data/Edit button

Clicking the Data button measures the current image and displays statistics. Clicking the Edit button displays the options to manipulate the measurement image.

Save button

This button saves the current image and measurements. The folder and format used to store measurements can be configured in the Advanced Settings tab. Review the *Application Output* section of this document for details on the data saved.

Original / Measured Image Toggle button

In the upper right corner of the screen is a tiny preview of the measured image or original camera image. Clicking on this small circle toggles the image displayed between these two.

GPS Lock

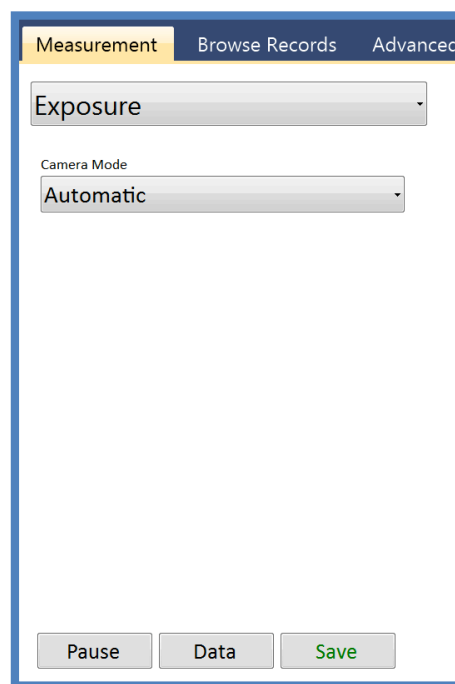
This indicates if there is a GPS satellite lock on your current position. Records saved without a GPS Lock may store the wrong GPS location, or no GPS location. The text will

toggle from a red “No” to green “Yes” when a GPS lock has been acquired. The CI-110 should be outside or near a window to get the fastest GPS lock.

Exposure

This feature is used to optimize the image exposure for accurate processing. The exposure should be adjusted so that a difference between leaf material and sky can be seen. It is recommended to always adjust the camera exposure first, before saving any images.

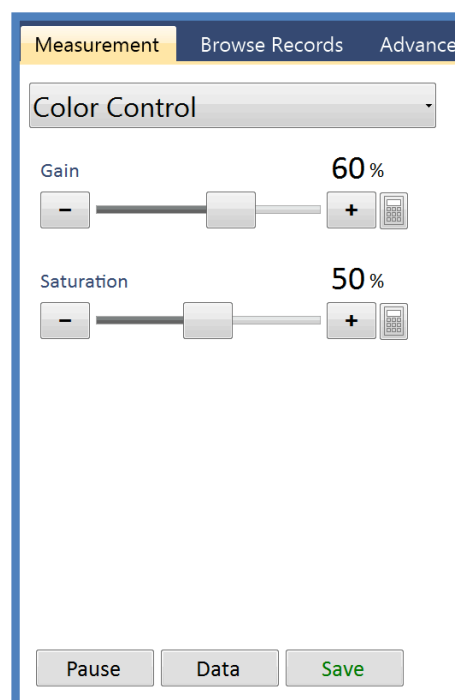
There are two modes for the camera exposure, automatic and manual. If outdoors, the automatic exposure feature should provide an accurate image for processing. If indoors or under low-light conditions, the manual exposure option allows the user to adjust the exposure and see the affect directly in the image.



Color Control

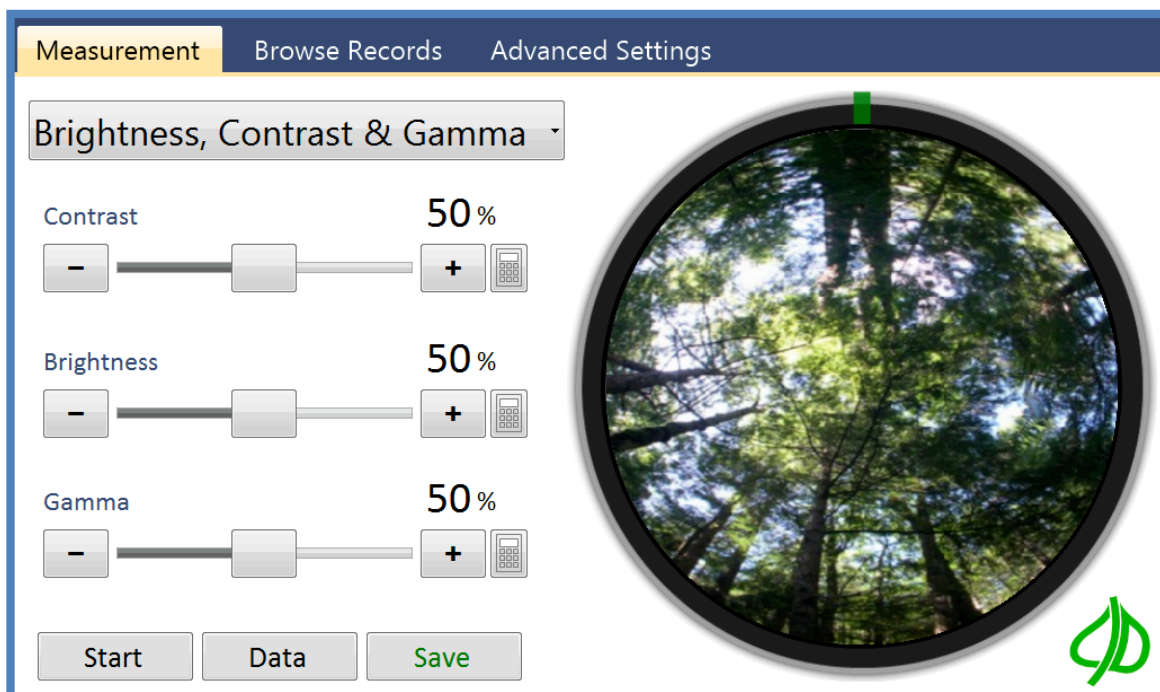
This feature is used to optimize the image colors for accurate processing. If needed, the color control gain and saturation levels can be adjusted to help render leaf elements as green and sky elements as blue.

Saturation describes the intensity of the color in the image. The gain will adjust the bright part of the image and is similar to the contrast control.



Brightness, Contrast & Gamma

This feature is used to optimize the image for accurate processing. These settings can be manipulated at any time. For example, measurements can be recorded outside then later optimized inside where it's easier to see the computer's display. It is recommended to adjust the brightness and contrast before saving the canopy image in order to make all plant elements green. After an image is saved, the gamma can also be adjusted.



Contrast

Controls the ratio between brighter and darker pixels in the measurement image.

Brightness

Controls the luminance of the measurement image.

Gamma

Controls the gamma correction of the measurement image. The gamma adjustment is only available after the "data/edit" button is selected.

Location

This screen is used to specify the location of the CI-110 device. Users can choose to enter Longitude and Latitude manually, or use the GPS device in the CI-110, or enter a text based tag to identify different locations. The CI-110 should be outside or near a window to get the fastest GPS lock and the GPS may not work indoors.

Longitude and Latitude

These values can be changed by clicking the keyboard icon or typing within the field.

Tags

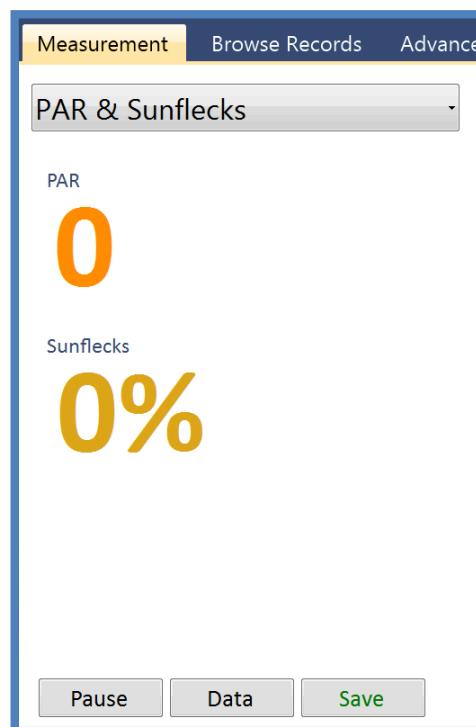
This field can be used to store text that identifies a specific location, project or other details. For example, “Project #57, Flag #101” might denote the project and measurement plot location. The tag feature is still useful even when GPS is not usable.

PAR and Sunflecks

This screen is used to view the current PAR (photosynthetically active radiation) intensity and sunflecks value. There are 24 PAR sensors positioned along the top of the CI-110 arm. The light intensity over these sensors is average together to provide the PAR value.

Sunflecks are brief periods of an increased amount of solar radiation reaching below the canopy. Sunflecks are caused by wind moving leaves in the canopy or by the sun's movement throughout the day. The fraction of the ground covered by sunflecks can be useful to researchers when determining the amount of canopy cover. The sunfleck value can also be directly related to canopy structure characteristics.

The sunfleck value is a percentage of the PAR sensors exposed to a radiation level greater than the set threshold. The default sunfleck minimum PAR is set at 300 $\mu\text{mol}/\text{m}^2\text{s}$. Adjustments to the PAR and sunfleck calibrations can be made through the Advanced Settings tab.



PAR LAI Calculation

This screen is used to change the way PAR data is recoded. Several factors are possible to adjust by the user: light above the canopy, leaf distribution factor and the solar zenith.

The “Light Above Canopy” should be set to the PAR intensity above the canopy at the time of the measurement. The PAR sensors of the CI-110 can be used to measure the PAR directly, or an estimate of the PAR above the canopy can be used. The light above the canopy ranges from 1 to 2000 $\mu\text{mol}/\text{m}^2 \text{ s}$.

The “Leaf Distribution Factor (chi)” is the distribution of leaf angles within a canopy. It ranges from 0.01 to 10. The default value for chi is 1.0. At this leaf distribution factor, the canopy angle distribution is assumed to be spherical. A vertical crop, like onions, may have a chi of less than 1 (ex: 0.7), while a strongly horizontal crop, such as strawberries, may have a chi of 3 or greater. Many plants have a range or variation for this factor, such as maize (0.7-2.5). The leaf distribution factor does not produce significant error in the LAI equation.

The “Solar Zenith” ranges from 1 to 90 degrees. The solar zenith angle is measured from directly overhead to the geometric center of the sun's disc. It is based on your current position globally and the time of day. The solar zenith angle at sunrise and sunset is 90 degrees.

Measurement Browse Records Advanced Settings

PAR LAI Calculation

Light Above Canopy 1350 PAR

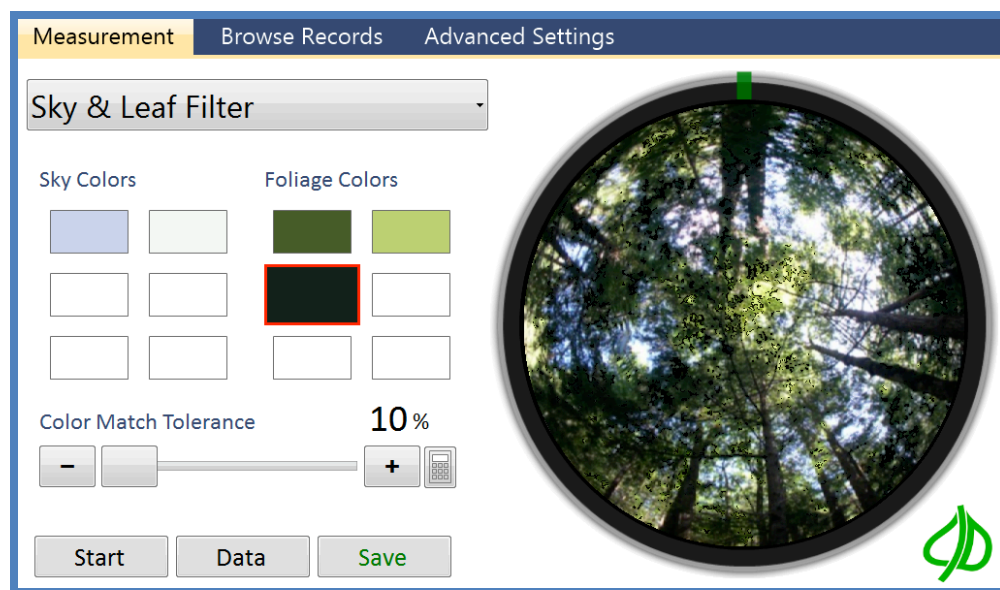
Leaf Distribution Factor 1 (Chi)

Solar Zenith 57 Degrees

Start Data Save

Sky & Leaf Filter

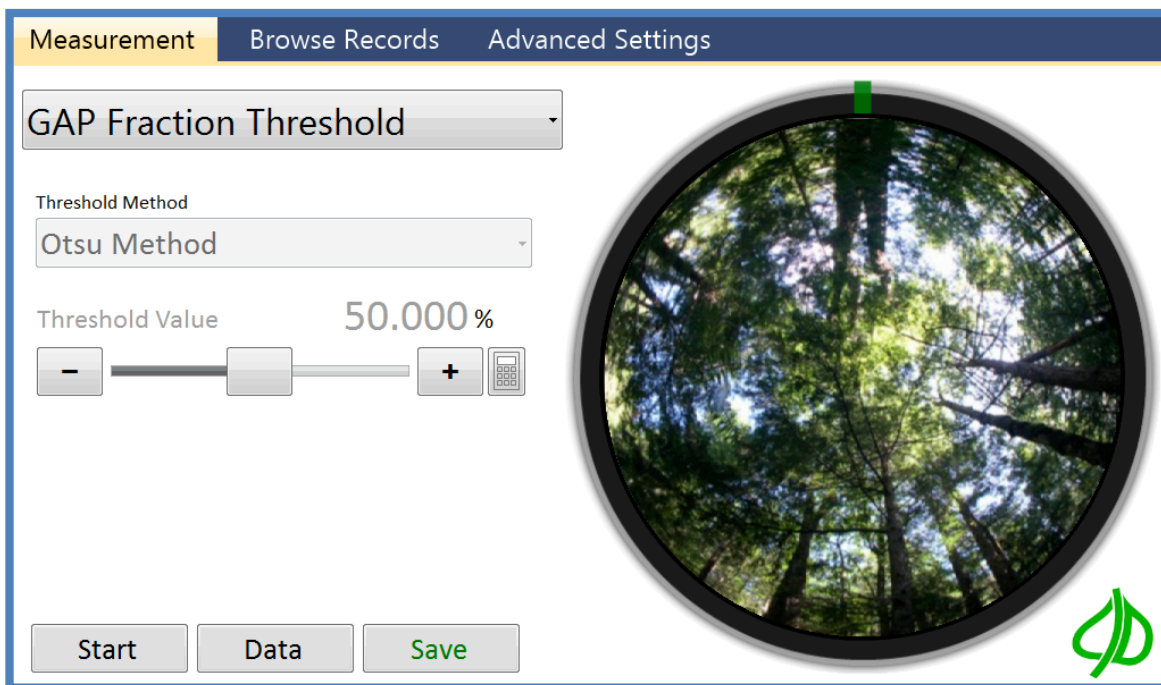
This feature allows users darken specific colors (foliage area) and lighten others (sky area). In the example below foliage colors that should be green are blurred by the sky with a blue hue. After applying the Sky & Leaf Filter the image on the right shows those areas are darkened so they will be counted as foliage instead of sky...



To use this filter click on a color square, click on the color in the image to work with and then select the "Color Match Tolerance". Increase this tolerance to include pixels with colors similar to the selected color.

Gap Fraction Threshold

Canopy gap fraction is the probability of a ray of light passing through the canopy without encountering foliage or other plant elements. TheCI-110 Plant Canopy Analysis software includes several different methods to analyze the Gap Fraction, including the Otsu method, Entropy Crossover method and manual threshold. The Entropy Crossover method is automatic, as the user is not required to input anything.



The choice of appropriate Gap Fraction method is left to the discretion of the user. It is recommended to experiment and use the threshold method that best separates canopy and sky. Most likely, very similar results will be acquired with any method used. The following research involves the comparison of several gap fraction methods:

[An Improved Estimate of Leaf Area Index Based on the Histogram Analysis of Hemispherical Photographs.](#)

Agricultural and Forest Meteorology, volume 149, pages 920-928, 2009.

Juarez, R., Riberio da Rocha, H., Silva e Figueira, A., Goulden, M., Miller, S.

Azimuth Divisions

This screen allows users to control how the measurement is separated in azimuth divisions, and select the area to be measured. Azimuth divisions can be thought of as pie slices, making up the hemispherical picture.

Number of Azimuth Divisions

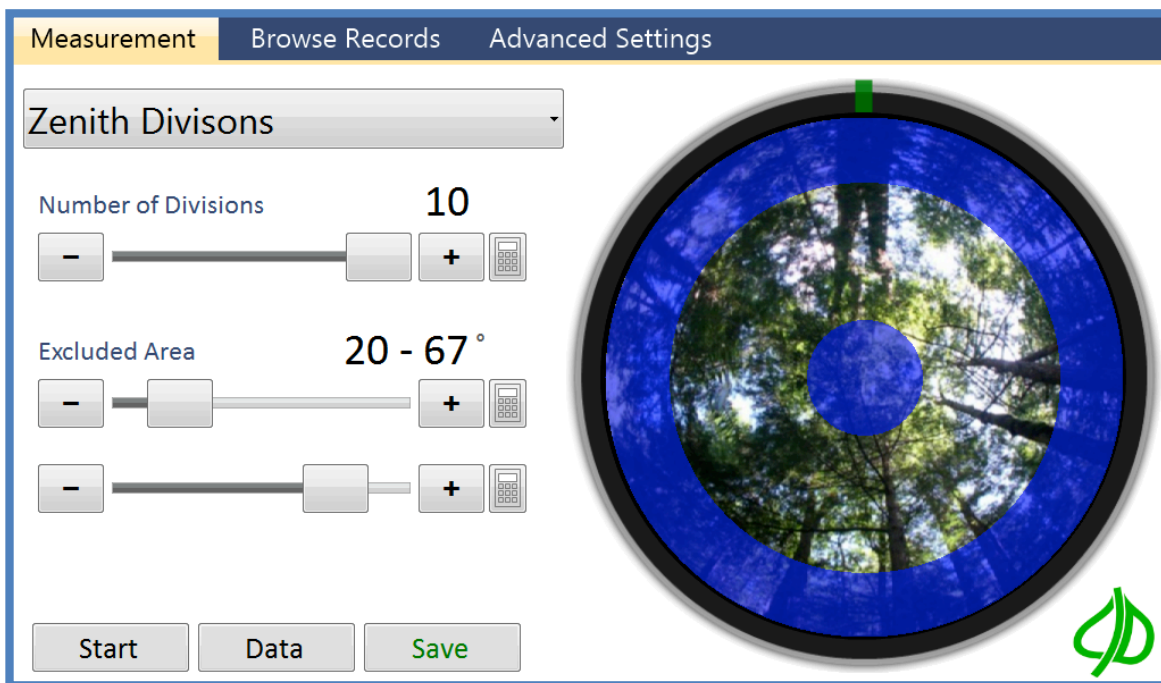
This field indicates how measurement data will be divided. Measurements can automatically be split into up to 10 azimuth divisions.

Excluded Area

These fields indicate which part of the camera image should be measured. The area masked in blue will be excluded. In addition to using the slider controls users can select using their finger by sliding a finger clockwise over the area to exclude, or counter clockwise over the area to exclude.

Zenith Divisions

This screen allows users to control how the measurement is separated in zenith divisions, and select the area to be measured. Zenith divisions are represented as rings in the



hemispherical picture.

Number of Zenith Divisions

This field indicates how measurement data will be divided. Measurements can automatically be split into up to 10 zenith divisions.

Excluded Area

These fields indicate which part of the camera image should be measured. The area masked in blue will be excluded. In addition to using the slider controls users can select using their finger by sliding a finger clockwise over the area to exclude, or counter clockwise over the area to exclude.

For more information on how azimuth and zenith divisions influence LAI estimation:

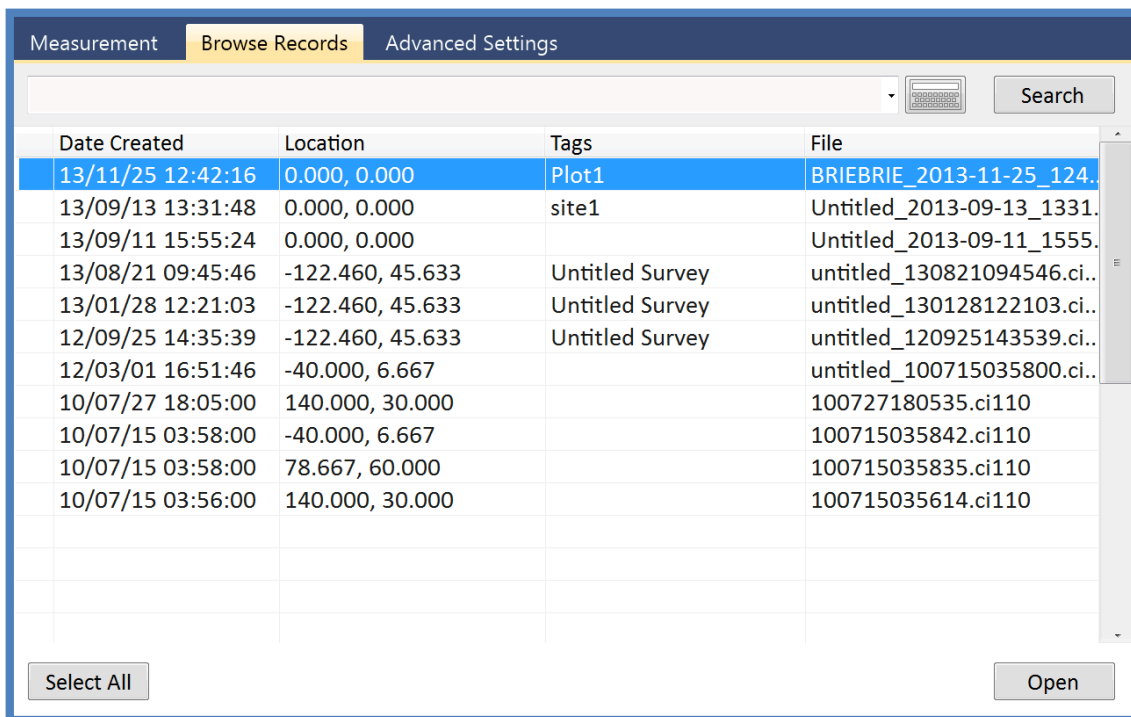
[Sampling Gap Fraction and Size for Estimating Leaf Area and Clumping Indices from Hemispherical Photographs.](#)

Canadian Journal of Forest Research, volume 40, pages 1588-1603, 2010.

Gonsamo, A., Walter, J., Pellikka, P.

BROWSE RECORDS TAB

This tab is used to browse through measurement records. Double-click on a record to select it. When a record is selected, a checkmark will appear next to the left of the record. A record can also be selected by simply clicking on the left where that checkbox



appears/disappears.

Once a record is selected, Delete, Export buttons will appear next to the Open button in the lower right. All records can be selected by clicking the "Select All" button. Files can be exported as a .csv (Microsoft Excel compatible) or .KML (Google Earth compatible).

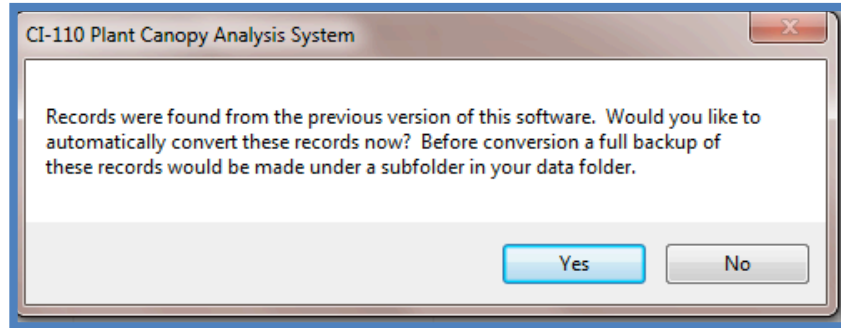
Search Keywords

This textbox can be used to filter results in the Browse Records tab. Type a value then click the Search button to only show records with that value. Click the Reset button to clear this value.

Converting Previous Records

For data files created with a previous CI-110 software version, navigate to the Browse Records Tab to convert the files to be compatible with this software version.





If records are found from a previous version of the software, you will be asked “Would you like to automatically convert these records now?” Before conversion, a full backup of these records will be made under a subfolder in your data folder. If you remove the .ci110 filename extension, the record will no longer be visible from the Browse Records tab.



ADVANCED SETTINGS TAB

This tab is used to control features in the software that are not typically changed between measurements. Details about the hardware and software version are located towards the bottom of the Advanced Settings Tab.

The Advanced Settings Tab also buttons to install the CI-110 driver, check for software updates and access the release notes.

Measurement	Browse Records	Advanced Settings
Output Folder <i>Output Folder, Measurement Filename Prefix and Image File Format.</i>		
Camera Lens Alignment <i>The lens is aligned with the camera at the factory. Re-alignment may be required if the instrument is dropped or damaged.</i>		
PAR Sensor Calibration <i>PAR sensors are calibrated by the manufacture and typically do not require re-calibration.</i>		
Compass Calibration <i>The compass is calibrated at the factory. Based on local magnetic fields re-calibration may be required.</i>		
Firmware Version v1.0.0 build 3890		
Hardware Serial Number E2D.D0.01		<input type="button" value="Install Driver..."/>
Software Version Version 6.0.1.1037		<input type="button" value="Check for updates..."/> <input type="button" value="Release Notes..."/>

Output Folder

The **Output Folder** textbox contains the path to store measurement records (see *Application Output*). Use the **Browse** button to change the output folder by browsing to your selection.

Output Filename Prefix


The **Output Filename Prefix** contains the prefix to use for new measurement records. For example, a prefix of "CI-110 Demo Survey_" would cause all new measurements to be saved as files with that prefix. This can be used to keep project data organized within the application and elsewhere.

Output Image Format

The **Output Image Format** selection specifies the image format to use for each saved image (see *Application Output*).


Measurement Browse Records **Advanced Settings**

Output Folder

C:\Users\Barry\Pictures\CI-110\  **Browse**

New measurements will be saved to the folder specified above.

Output Filename Prefix

Untitled 

The text below will be used as a prefix for new records. For example, if "Untitled" is used files will be named "Untitled_1.png", "Untitled_2.png", etc.

Image File Format

PNG (Recommended) ▾

Cancel **OK**

Application Output

By default CI-110 images and data will be stored under the Windows user's Documents folder in a subfolder called CI-110. Each measurement is saved as a .ci110 file. Within the .ci110 file, there are three separate files that can be accessed by re-naming the record in the CI-110 software. The three files are:

1. Camera Image (.png, .bmp, etc.)
2. Measurement.XML
3. Cache.dat

To open a file, double-click on the filename which will open the CI-110 software and load the data.

The screenshot shows a software window titled 'File Details'. At the top, there are three tabs: 'Measurement' (selected), 'Browse Records', and 'Advanced'. Below the tabs is a dropdown menu labeled 'File Details'. Under this menu, there are two input fields. The first is labeled 'File Name' and contains the text 'ed_2014-02-26_201842.zip'. To the right of this field is a small icon of a keyboard. The second field is labeled 'File Path' and contains the text 'C:\Users\Barry\Pictures\CI-110'. At the bottom of the window, there are three buttons: 'Start', 'Data', and 'Update'.

To view the .xml data in Version 6 of the software:

1. Re-open the .ci110 file in the software.
2. Go to "file details" on the drop down measurement menu list.
3. Change the end of the filename to .zip. It will warn that changing from .ci110 to .zip will not allow the software to search for the file when you click browse in the Browse Records tab.
4. Click "yes" on the warning.
5. Exit the software and open the .zip file. In the .zip file there is the .xml, which has the numerical data in it, as well as the .png image file.
6. Remember to change the extension back to .ci110 to be able to browse/search for the file in the CI-110 software.

The Measurement.XML file

This file contains measurement data including...

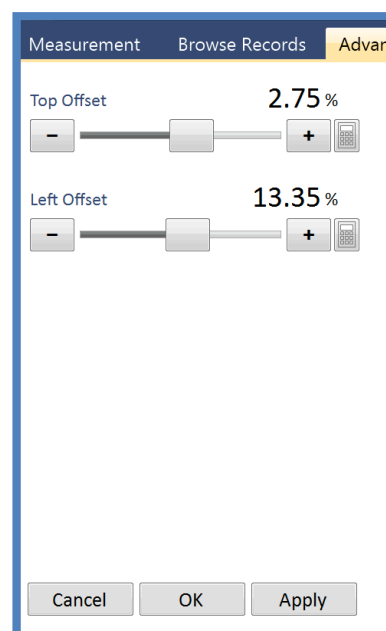
- Image file format and location
- Image threshold
- Camera settings
- Timestamp
- Compass bearing
- GPS quality, number of satellites, GPS lock indicator
- Longitude, latitude and altitude
- Location tags
- Zenith divisions, extinction coefficient, transmission coefficient
- Azimuth divisions, leaf distribution
- Image contrast, brightness, gamma
- Threshold method
- Sky and leaf filter details
- PAR
- Sunflecks
- Leaf area index
- Mean leaf angle
- Gap fraction
- Leaf distribution factor (chi)
- PAR above canopy
- Solar zenith

Camera Lens Alignment

The CI-110 hardware and tablet computer are paired together as a complete system before leaving the factory. Each system has a slightly different offset.

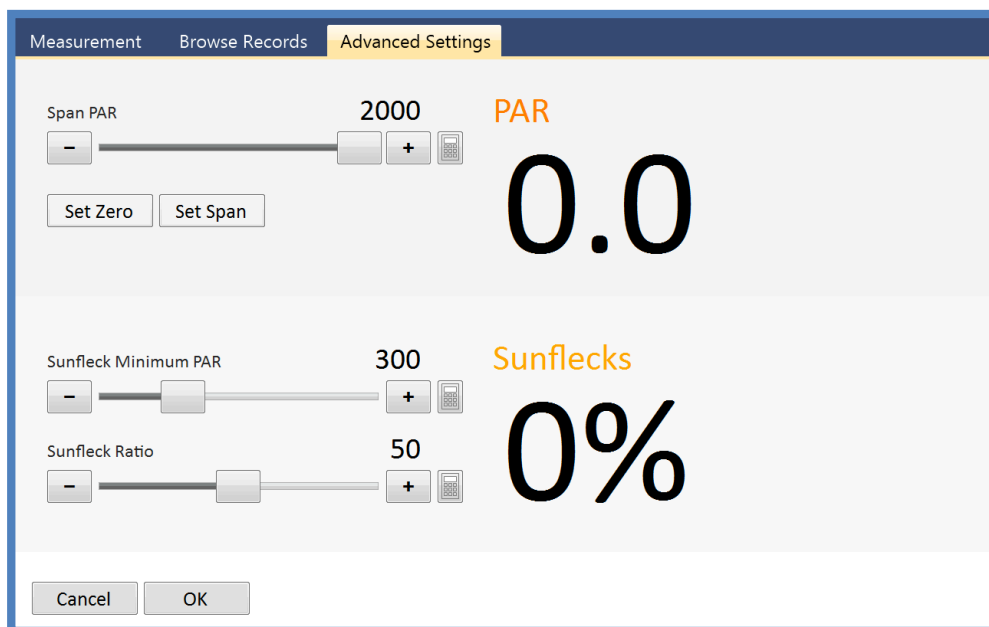
The images are automatically aligned by the software from a factory calibration of the offset. This offset is to the optical center of the fisheye camera lens.

The offset values for each CI-110 are pre-entered in the software and included on the CI-110 Product Test Check Sheet in the CI-110 User Manual.



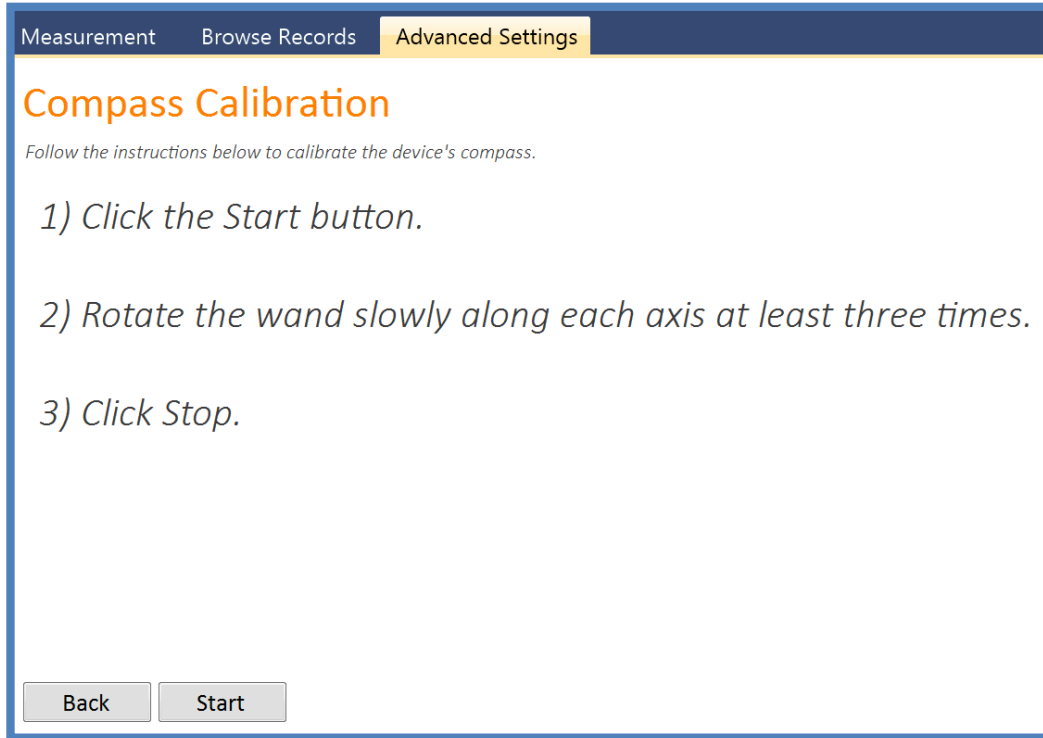
PAR Sensor Calibration

The 24 PAR sensors located along the arm of the CI-110 are calibrated at the factory. Typically, the PAR sensors do not require re-calibration. There is a warning before entering the PAR sensor calibration that this should only be performed by the manufacturer. The calibration values found at the factory for the CI-110 can be found on in the CI-110 Product Test Check Sheet at the end of the CI-110 User Manual.



Compass Calibration

The compass of the CI-110 is located in the handle. The compass should be calibrated whenever it isn't pointing north, or whenever the CI-110 is taken to a location with a different magnetic field. To calibrate the compass, follow the instructions that appear in the application. When instructed to rotate the wand (arm) along every axis, be careful to hold the CI-110 camera head securely so it does not fall off.



The screenshot shows a software interface with a dark blue header bar containing three tabs: "Measurement", "Browse Records", and "Advanced Settings". The "Advanced Settings" tab is selected and highlighted in yellow. Below the header, the title "Compass Calibration" is displayed in orange. Underneath the title, a small italicized instruction reads: "Follow the instructions below to calibrate the device's compass." A list of three numbered steps is presented in a light gray, italicized font: "1) Click the Start button.", "2) Rotate the wand slowly along each axis at least three times.", and "3) Click Stop." At the bottom of the screen, there are two gray rectangular buttons labeled "Back" and "Start".

THEORY

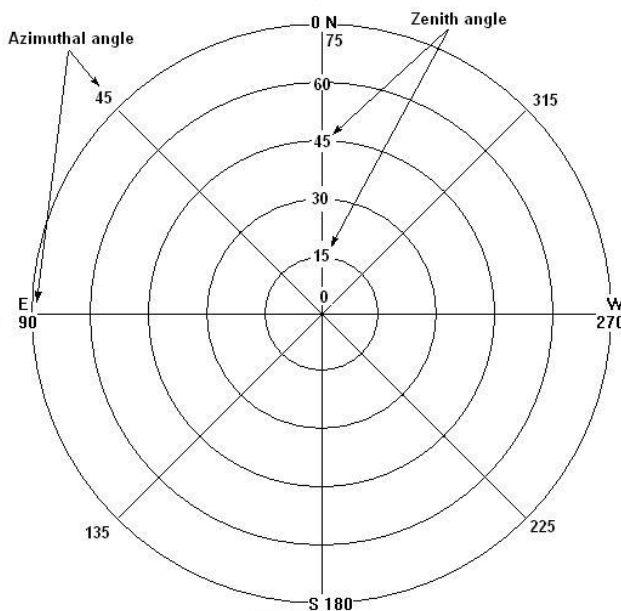
The CI-110 software calculates the solar beam transmission coefficients, or the fraction of the sky visible from beneath the plant canopy using the *Gap-Fraction Inversion Procedure* (Norman and Campbell, 1989).

Images of plant canopy are broken down into zenith and azimuth divisions. The fraction of sky (solar beam transmission coefficient) visible in each division is analyzed by tallying the sky portion of the image pixels.

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.

When the divisions have been analyzed, the average solar beam transmission coefficients, hemispherical diffuse radiation transmission coefficient (the sky view factor), mean foliage inclination angles, and plant canopy extinction coefficients are computed.

The key equations involved in this process are as follows...



1 τ_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

τ_{φ} : 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 α : 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

TECHNICAL SUPPORT

If you have a question about the CI-110, first look in the CI-110 Operation Manual. There is also online support available for the CI-110 at <http://cid-inc.com/support>. If you cannot find the answer, you can contact a Technical Support Representative located in your country. CID Bio-Science, Inc. is committed to provide customers with high quality, timely technical support. Technical support representatives are to answer your technical questions by phone or by e-mail at support@cid-inc.com.

CID Bio-Science, Inc.'s contact information:

CID Bio-Science, Inc.
1554 NE 3rd Ave
Camas, WA 98607 USA

Phone: 800-767-0119 (U.S. and Canada)
360-833-8835
Fax: 360-833-1914

Internet: <http://www.cid-inc.com>
E-mail: support@cid-inc.com

Customer Service

Customer Service Representatives answer questions about specifications and pricing, and sell all of the CID Bio-Science, Inc. products. Customers sometimes find that they need CID Bio-Science, Inc. to upgrade, recalibrate or repair their system. In order for CID Bio-Science, Inc. to offer these services, the customer must first contact us and obtain a Return Merchandise Authorization (RMA) number. Please contact a customer service representative for specific instructions when returning a product.

Frequently Asked Questions

If there are any questions about the CI-110, please check the Frequently Asked Questions below, as well as the CID Bio-Science support webpage and forum at <http://cid-inc.com/support>.

1. Where do I download the most current version of CI-110 software?
 - a. The latest version of software and the driver can be downloaded at <http://cid-inc.com/support/software-downloads>. Click the most recent version of CI-110 software to start the download. If prompted that the publisher is not verified, click Run or Install to continue the setup. Next, install the driver according to the Instruction Manual.
 - b. Make sure to completely erase the old version of software and the driver before downloading the new version. To do this, go to Add or Remove Programs in your computer's Control Panel. Uninstall the "Plant Canopy Analysis System" software and the CI-110 driver (USB TV Device Driver).
2. Where do I find a CI-110 driver?
 - a. The CI-110 driver is compatible with 32 or 64 bit systems. You can install the driver by going to the Advanced Settings tab, clicking on "Install Driver..." and following the Installation Wizard prompts. Alternatively, you can download the CI-110 driver at: <http://www.cid-inc.com/Software/CI-110/V6Driver.zip>. Instructions to install the driver can be found in the Hardware Installation section of the CI-110 User Manual.
3. Why won't the GPS lock or find a location?
 - a. The GPS can take up to 15 minutes to locate satellites and establish longitude, latitude and altitude parameters. This time should be shorter after the initial connection. The GPS typically needs to be outdoors to connect to satellites.
4. What is the accuracy of the CI-110 GPS?
 - ◆ Position: 5m CEP without SA
 - ◆ Velocity: 0.1m/sec, without SA
 - ◆ Time: +/- 50ns synchronized to GPS time
 - a. CEP is Circular Error Probability. CEP is defined as the radius of a circle centered on the true value that contains 50% of the actual GPS measurements. So a receiver with 1 meter CEP accuracy will be within one meter of the true measurement 50% of the time. The other 50% of the time the measurement will be in error by more than one meter.
5. Where are the PAR sensors located?
 - a. The PAR sensors are located along the top of the wand/arm that the camera connects to.

6. How do I tell when the CI-110 is facing north?
 - a. The tick or arrow-tip on the outside of the image will change from red to green when the CI-110 camera and wand are pointed north. North or green is at the 12 o'clock position on the image.
7. What is the difference between the CI-110 and the CI-120?
 - a. The CI-110 lens probe and the accompanying software that calculates Leaf Area Index was designed to measure forest canopies. The CI-120 compact lens probe was designed later to measure in rice paddies and wetland conditions where the CI-110 lens probe could not get low enough to take the image. The current CI-110 has even lower clearance than previously, so the CI-120 is no longer offered.
 - b. The self-leveling feature of the CI-110 is a very significant advantage when measuring tree canopies. The CI-110 lens probe has a 170° viewing angle.
8. Can I use the CI-110 to study the canopy of grapes?
 - a. Unfortunately, due to their irregular canopy shape, the gap fraction method for calculating the Light Area Index of canopies of grapes grown on vertical trellises cannot be accurately measured. So the instrument cannot be recommended for the study of vertically growing grapes.
9. What types of canopies is the 110 used for?
 - a. For types of canopies that work well with the CI-110, please refer to the list of published research (<http://www.cid-inc.com/resources>). The CI-110 has been used to effectively measure the LAI of forests, rice, pastureland, sub-Mediterranean grasslands, winter wheat, *Quercus* species, *Shpaeralcea* and *Shepherdia* species, *Amaranthus powellii*, *Erythroxylum coca*, *Olea europaea*, and *Cypripedium flavum*, among others.
10. Why do past images appear darker in software version 5.3 and later software versions?
 - a. Software version 5.3.1 includes a fix to a bug that prevented the software from properly controlling the camera exposure. Images taken with previous versions of software may appear darker when opened in version 5.3.1 or later. After properly adjusting the exposure, the image should appear correctly.
11. What are the improvements with the new CI-110 Spring 2013?
 - a. New and improved camera and filter.

- b. New and improved GPS.
- c. Updated software with many bug fixes.

12. How do I access the CI-110 log file if an error occurs?

- a. To access the Log Files:
 - 1) Start the CI-110 software.
 - 2) Press Control+Escape at the same time or Cnt + Alt + Delete (this launches the Task Manager). Or, right-click or click and hold on the the task bar (the bar that has the system tray/notification area and the start menu button at the bottom of the screen). Select "Start Task Manager" from the list.
 - 3) From the Task Manager, click on the Processes tab.
 - 4) Right click on CID.CI110.exe and select Open File Location (this launches the file browser)
 - 5) You should see several ApplicationLog and ErrorLog files.

13. How do I calibrate the Sol Tab tablet touch screen?

- a. To calibrate the Sol Tab tablet daylight visible touch screen:
 - 1. Go to "Start" and "Control Panel"
 - 2. Go to "Hardware and Sound"
 - 3. Under "Tablet PC Settings," choose "Calibrate the screen for pen or touch input"
 - 4. Click the "calibrate" button.
 - 5. Follow the instructions to touch the screen and choose to save the calibration data.

14. Which Gap Fraction Method should I use?

- a. For more information on Gap Fraction Methods please refer to the article by Juarez et al.:
[An Improved Estimate of Leaf Area Index Based on the Histogram Analysis of Hemispherical Photographs.](#)
Agricultural and Forest Meteorology, volume 149, pages 920-928, 2009.
Juarez, R., Riberio da Rocha, H., Silva e Figueira, A., Goulden, M., Miller, S.

15. Why is the image so dark?

- a. The CI-110 camera was modified to use a blue lens, the contrast and other parameters have been adjusted for optimum accuracy. Indoor lights are not usually strong enough to show anything other than a dark or black image.

16. Which side is up on the stick and camera?

- a. The bottom of the camera mount has a cable attached to it and the stick has opaque white plastic on the top. Both should have labels indicating TOP.

17. The handle on the stick get warm, is this normal?
- Yes, this is normal. The power to run the PAR sensors and camera run through the handle of the stick. This generates the heat in the handle.
18. The image seems to be centered incorrectly. How do I center the image?
- Go to the Advanced Settings tab and change the Top and Left offsets to the values in the Product Test Check Sheet page of this manual.
19. How do I focus the image?
- The lens of the CI-110 can be twisted to bring the canopy image into focus.
20. How much storage does the tablet computer have?
- The Sol Tab computer has 32GB of storage capacity.
 - The Acer tablet computer also has 32GB of storage capacity.
21. How does adjusting brightness affect LAI?
- The effect of adjusting the brightness depends on whether it is done during image acquisition or afterwards, during image processing. If you have already taken the image and are now processing it afterwards, the following relationship is expected: LAI will decrease with increasing brightness.
 - This is because plant elements, such as back-lit leaves or light green leaves, will be washed-out in the photo and will appear as sky to the software. Increased brightness= more sky = decreased LAI. To counter-act this, re-assign "Foliage" and "Sky" colors in the Sky and Leaf Filter option after setting the desired brightness.
 - It is recommended to:
 - Adjust the brightness so the image appears properly exposed.
 - Go to the Threshold menu and choose a method.
 - Adjust the slider until all the plant elements appear green.
 - Press the Data button.
 - Go back and adjust the brightness/contrast until all the plant elements are green.
 - Keep tweaking the settings until you have grouped all the plant elements together and separated the sky or background.

22. How do I analyze images on a different computer?
- Download and install the CI-110 Plant Canopy Analysis software on the computer. Then, transfer the .ci110 files to the computer. Create a folder in your pictures to be able to use the search function in Browse Records. Double-clicking on the .ci110 file will open the software with the file loaded.
23. What type of external battery will work with the tablet computer?
- The battery life of the CI-110 is directly related to the tablet that operates the instrument. Currently, the battery life for using the CI-110 and Acer Iconia W3 tablet is around 4 hours. This is with the CI-110 software open and running the entire time on the tablet. Battery life can be lengthened by closing the software, dimming or turning off the display or putting the tablet to sleep between measurements.
 - If extra battery life is needed, there are lots of universal batteries (normally marketed for laptops) that could be used. Essentially, these are bricks with a wire that plugs into the tablet where the AC adapter normally would go. Using a universal battery in conjunction with the CI-110 and tablet could extend the battery life by several hours, or allow for additional "battery"
 - USB battery devices generally do not work with the tablet and a true laptop external battery should be used.
24. How far from the canopy does the CI-110 camera lens need to be?
- The distance from the CI-110 lens to the leaf at an angle of 30° from zenith should be at least four times the leaf width.
25. What should I do if the sunflecks always read 100%, even though some of the PAR sensors are covered?
- In the Advanced Settings tab, go to "Par Sensor Calibration" and hit "Yes" to proceed.
 - While testing indoors, where PAR is 12.5, change the Sunfleck Minimum PAR to 10.
 - Sunflecks value will now respond as expected when some sensors are covered.
 - The default value is 300.

Troubleshooting and Tips

This section of the document outlines suggestions or tips to resolve issues using the CI-110 software.

Canopy Gaps

The CI-110 employs the gap fraction computation method and assumes random leaf distribution. A non-uniformly distributed canopy with gaps will cause over-estimations of the solar beam transmission and under-estimations of LAI.

In circumstances that do not satisfy the assumption use the Zenith and Azimuth selections to exclude large canopy gaps, and make multiple measurements then average your results. The number of measurements needed for averaging depends on the canopy structure and its distribution.

Canopy Size

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.

If you must measure a small plot adjust the Zenith and Azimuth selections to exclude everything beyond your plot.

Distance from Canopy

The distance from the CI-110 lens to the leaf at an angle of 30° from zenith should be at **least four times the leaf width.**

Sky Conditions

The optimal sky conditions for measurements are under even cloud coverage during early morning or late afternoon (when the amount of scattered radiation is low). Under sunny sky conditions the lens should be shaded to minimize to prevent underestimation of LAI and overestimation of solar beam radiation and diffuse radiation.

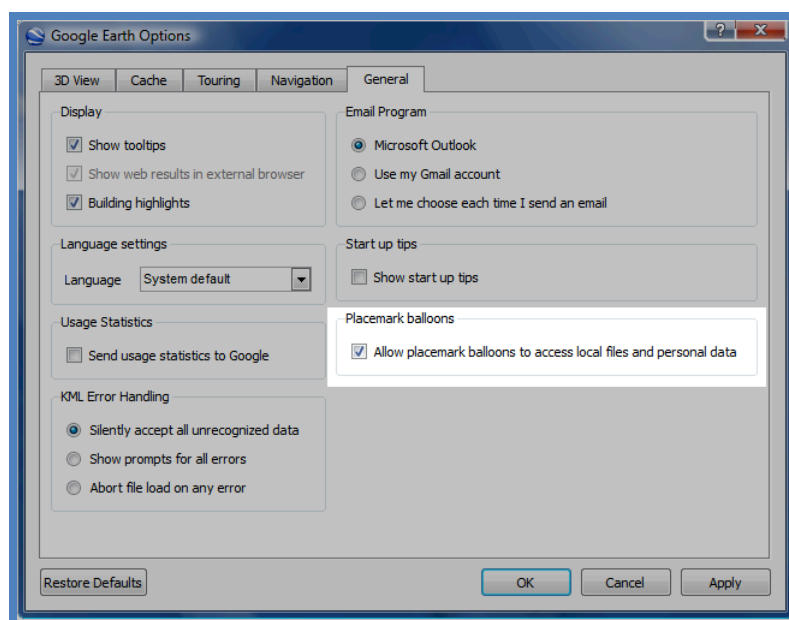
Row Crops

One 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.

Google Earth displays icons instead of CI-110 images.

Google Earth is commonly used to read the KML files exported from the CI-110 application's Browse Records tab. By default Google Earth does not allow you to load KML files from your local drives. To resolve this issue follow the instructions below...

1. Start Google Earth
2. Click the **Tools** menu at the top of the screen.
3. Click **Options**.
4. Click the **General** tab.
5. Check "Allow placemark balloons to access local files and personal data".



6. Click **OK**.
7. Reload your KML file, or exit Google Earth and restart it from the CI-110 application.

CID BIO-SCIENCE, INC. 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 Bio-Science, 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 Bio-Science, 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 Bio-Science, 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 Bio-Science, Inc., in Camas, Washington, USA, within 30 days after CID Bio-Science, 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 Bio-Science, 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.



CI-110 Product Test Check Sheet

Serial Number:	
Testing Function	Final
PAR Sensor Calibration	PAR Zero Calibration:
	PAR Span Calibration:
	Sunflecks Zero Calibration:
	Sunflecks Span Calibration:
Compass, Lens & Camera Settings	Top Offset:
	Left Offset:
CI-110 Plant Canopy Image Test Date:	
Comments	

WARRANTY REGISTRATION CARD



1554 NE 3rd Ave, Camas, WA 98607, USA

Phone: (360) 833-8835 Fax: (360) 833-1914 e-mail: sales@cid-inc.com Web: www.cid-inc.com

PRODUCT REGISTRATION CARD

Please complete and return this form to CID within 30 days to
validate your Warranty on Parts and Labor.

Registration Information:

Your Name: _____ Title: _____

Company/University: _____

Address: _____

City: _____ State: _____ Zip: _____

Country: _____ Email: _____

Phone: _____ Fax: _____

CID Serial Number(s): _____

Purchase Date: _____ Purchase Price: _____

FOLD ON DOTTED LINE

Your opinions will help improve our service. Please answer the following questions.

1. What was the basis of your product selection?

☐ Representative Recommendation

☐ Product Features

☐ Technical Specifications

☐ Warranty

☐ Other _____

☐ Price

☐ Product Design

☐ Brand Name

☐ Service

2. What other competing brands did you consider? _____

3. Where did you first learn of this product?

☐ Advertisement in _____

☐ Friend/Colleague

☐ Other _____

☐ Representative

☐ Exhibit

4. Who selected this product?

☐ I did

☐ University Department

☐ Other _____

☐ Research Group

☐ Purchasing

5. Comments/Suggestions:
